Quality Characteristics of Australian Chickpeas (*Cicer arietinum* L.) for Food Usage

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Declaration

I, Lakshmi Iyer, hereby declare that this submission entitled, 'Quality Characteristics of Australian Chickpeas (*Cicer arietinum* L.) for Food Usage' is my own work and that, to the best of my knowledge and belief, contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma to the university or other institute of higher learning, except where due acknowledgment is made in the text.

Lakshmi Iyer

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List of Publications, Oral and Poster Presentations

1 Black R G, Singh U and Iyer L (1995) Functional and nutritional properties of cereal-legume composite flours. Poster paper presented at the 45th RACI Conference, 10-14th September Adelaide.

2 Iyer L and Singh U (1997) Functional properties of wheat and chickpea composite flours. Food Australia 49(1) 27-31.
This paper was presented as a poster paper at the 29th AIFST Conference, 5-8th May 1996 Gold Coast.

3 Singh U and Iyer L (1997) Dehulling chickpea (*Cicer arietinum* L.): Comparison of laboratory mills, different pretreatments and genotypes. Submitted to the J Food Sci. Techn.

4 Iyer L,C Jarvis and N Azudin (1996) Pilot scale manufacture of value added pulse products for niche markets. (Oral presentation) Proc. 46th RACI Conference, Ed. C W Wrigley p 325-329.

5 Iyer L and C Jarvis (1996) Dehulling efficiency of pulses. (Poster paper) In the Proc. 46th RACI Conference, Ed. C W Wrigley p 334-339.

6 Iyer L and C Jarvis (1997) Utilising pulse hull in pan bread production. Paper presentation (Oral) at the 47th RACI Conference, 14-18th September Perth.

7 P M Burridge, R G Black, Iyer L, G Lonergan and D S Petterson (1997) A collaborative study on laboratory scale equipment used to estimate pulse dehulling efficiency and splitting quality for Australian breeding programs. Poster paper presented at the 47th RACI Conference, 14-18th September Perth.

8 Iyer L, C Jarvis, J B Brouwer and R G Black (1997) Products for markets. Poster paper presented at the IFLC III Conference, 22-26th September Adelaide.

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List of Abbreviations (In alphabetical order)

AFISC	Australian Food Industry Science Centre
AGT	Academy of Grain Technology
AIFST	Australian Institute of Food Science and Technology
AWB	Australian Wheat Board
-CHO	Total carbohydrates
CFTRI	Central Food Technological Research Institute, Mysore, India
DAV	Department of Agriculture, Victoria
Energy (NR)	Energy (non-ruminants)
Energy (R)	Energy (ruminants)
GRDC	Grains Research and Development Corporation
HTC	Hard-to-cook phenomenon
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics, Patencheru, India
IFLC III	International Food Legume Conference III
IN	Instant Noodle
kGy	KiloGray
NPN	Non-Protein Nitrogen
NSW	New South Wales
QLD	Queensland
RACI	Royal Australian Chemical Institute
SA	South Australia
SDN	Steamed and Dried Noodle
TDF	Total Dietary Fibre
TLC	The Lentil Company
UNSW	University of New South Wales
VIC	Victoria
VIDA	Victorian Institute for Dryland Agriculture
WA	Western Australia

Abstract

Australia is emerging as a significant producer and a major exporter of chickpeas. There is, however, little data on quality of Australian chickpea or on the use of chickpea in new food formulations for the western world. Physical properties, chemical composition and nutritional qualities of four major commercially traded *desi* varieties, two *kabuli* varieties and some new releases collected from the important growing sites of Australia were evaluated over four harvests to study effect of location, season and genotype. The composition of these varieties were compared with advanced breeding lines grown in experimental plots over two seasons. Proximate composition of *desi dhal* (dry, dehusked split cotyledon) was measured and compared to whole seed.

As pulses are processed before consumption, varietal differences and effect of location on processing properties were examined. The soaking and sprouting properties of commercially released varieties were studied and a rapid, objective test was developed using deformation in the texture analyser to evaluate cooking quality of *desi* and *kabuli* seeds. A laboratory sized mill was designed and custom built to mimic dehulling conditions in the Indian subcontinent (largest importer of *desi* chickpea) and dehulling efficiency of *desi* varieties were evaluated. The effect of conditioning the seed prior to dehulling was also studied.

The functional properties of wheat:chickpea composite flours were examined to predict their behaviour in food formulations. IN and SDN were successfully made by substituting wheat flour with 5, 10, 15 and 20% *besan* (flour from *desi dhal*) and pan bread with added fibre was manufactured by utilising hull form *kabuli* chickpea.
The study has identified appropriate varieties for specific end uses.

Overall, the study has shown that the Australian chickpea industry can move away from trading a raw undifferentiated commodity to a value-added product.

Introduction

1 Introduction

The global success of agriculture since World War II has largely been due to the availability of high yielding, disease resistant crops and cheap, abundant energy that facilitated the use of fertilisers, pesticides, irrigation and mechanisation. However, the increase in the fertiliser nitrogen cost in developing countries has had a strong inhibitory effect on further development. Under these conditions, food legumes (hence referred to as *pulses*) and biological nitrogen fixation associated with these crops take on added importance (FAO 1982). Pulses are also increasing in importance in Australia as an alternate crop to wheat due to agro-economic benefits and Australia is emerging as a significant producer and a major exporter of pulses to the Indian subcontinent and Middle East. The largest pulse crop produced in Australia is lupins, followed by field peas, chickpeas, faba beans and lentils (Meyers Strategy Report 1993).

The use of pulses as stockfeed is being researched with increased enthusiasm due to substantial growth in the domestic intensive pig and poultry industries. The dairy and aquaculture industries are also changing to a predominantly pulse based ration. The Australian pulse industry has been a major beneficiary since the demise of the European field pea market for stock feed.

Pulses are an integral part of the human diet in many developing countries. The use of pulses as a major food source in the Indian subcontinent dates back to 2000 BC and there is biblical reference to the virtues of pulses in the Old Testament (Book of Daniel). They are also a regular part of the diet in Central Asia, the Mediterranean, South America and some African nations. Pulses are a good source of plant protein and are cheaper than animal protein. As a general rule, pulses are high in dietary fibre and low in fat. Pulses are a good source of the essential amino acid, lysine, but are deficient in sulphur containing amino acids, methionine, cystine and tryptophan (Singh and Jambunathan 1982). On the other hand, cereals contain lower amounts of protein and are deficient in lysine, but have adequate amounts of the sulphur amino acids (Eggum and Beames 1983). It is often emphasised that pulse proteins are the natural supplements to the cereal proteins in producing an overall essential amino acid balance and together are considered a good solution to combat the world protein-calorie malnutrition problem. Pulses are known to contain several anti-nutritional factors such

as trypsin inhibitors, chymotrypsin inhibitors, lectins, phytates, polyphenols, flatulence factors, and lesser amounts of lathyrogens, goitrogens, and saponins depending on the type of pulse (Chavan *et al* 1989). Available evidence and ancient processing methods such as dehulling, roasting, soaking & cooking, fermentation and germination often cause considerable reduction and in some cases eliminate these anti-nutritional factors (Jaya and Venkataraman 1980a, Rao and Deosthale 1982).

Chickpea (*Cicer arietinum* L.) is the fifth most important pulse of the world on the basis of production after soybean, peanut, beans and peas (Kelley and Rao 1997). India is the major producer with nearly 80% of the total world production but is also a growing importer. Turkey, Pakistan, Australia, Mexico, Burma, and Ethiopia are the other important producers of chickpea. While the chemical composition and processing properties of chickpeas grown in the Indian subcontinent, Turkey, South America, and Chile are documented (Jambunathan and Singh 1978, Sotelo *et al* 1987), the Australian pulse industry is relatively young and there is a need to study the crop profile in detail. Export markets are becoming more discerning and the provision of suitable technical information about the crop is essential to foster trade.

This project aims at systematically studying the chemical composition, physical and functional properties, and overall quality of the commercially released varieties of *desi* and *kabuli* chickpea produced from various sites in Australia over four seasons. The chemical composition and processing qualities of advanced breeding lines of *desi* and *kabuli* cultivars were also evaluated in order to compare between existing varieties and near releases. The information is required (a) for breeders to provide them with technical data on the quality of new lines and (b) to better market Australian chickpeas in the Indian subcontinent.

Hydration capacity and the rate of germination of whole seeds of selected varieties were studied as these are important processing properties. Pulses in general, and chickpea in particular, are notorious for their hard-to-cook (HTC) phenomenon. This property of pulses is probably the single most important reason for their unpopularity in the Western world where convenience is a very important attribute in foods. There was a need to develop an objective test to measure cookability in seeds and rank the Australian chickpea varieties. About 50% of *desi* chickpea is processed to produce

(dehulled, split cotyledons), so it was necessary to study the composition of the splits. Dehulling the whole seed is dependent on a host of factors inherent to the seed and type of pre-treatment. Dehulling efficiencies under different pre-treatment were compared in a laboratory sized mill that was designed to mimic the milling conditions in the Indian subcontinent.

As composite flours of food crops are assuming significance in view of their increasing utilisation in various food formulations, functional properties of wheat and chickpea flours was investigated. New chickpea based products were developed by modifying traditional wheat based recipes to include chickpea flour/hull to target the health conscious, the elderly and the growing vegetarian population in the Western world.

Literature Review

2 Literature Review

2.1 Pulse Production in Australia

The value of Australian pulse production grew from AU$ 74 million in 1984/85 to AU$ 320 million in 1991/92, a rise of 330 percent. The production of pulses in Australia increased from 238,000 tonnes in 1982/83 to 1.8 million tonnes in 1993/94, with an annual growth rate of 25% (Meyers Strategy Group 1993). The total production is set to double to more than four million tonnes, valued at over AU$ 1 billion by 2005 (Pulse 1996). Reasons for this growth include:

- low, often fluctuating, prices for traditional cereal crops (eg. AU$ 170/tonne for wheat, 1992/93 and AU$ 270/tonne, 1995/96 season) (AWB 1996);
- relatively higher prices for pulses (AU$ 369/tonne for chickpea, AU$ 305/tonne for field pea, (average prices over 5 seasons from 1989/90 to 1993/94) (AWB 1996);
- intensification of producers' cropping regimes to improve cash-flow;
- greater farmer awareness of the rotational benefits of pulses;
- need to maintain a sustainable farming system (Walsgott 1989) and
- to compete in primarily unsubsidised markets (Meyers Strategy Group 1993).

Due to variations in climatic conditions, a range of species are produced and there is significant regionalisation in the production of particular pulses. In Western Australia, lupins is the predominant pulse, but recently production of lentils, faba beans, and chickpeas is increasing. The southern Australian grain belt produces a wide range of winter pulses such as field pea, faba beans, lupins and chickpeas while in the northern grain belt, chickpeas are the dominant crop. The northern region also has a significant summer pulse industry which includes mung beans, navy beans, cowpeas, and pigeon peas; emerging minor crops include culinary beans, lab lab beans and adzuki beans. Tables 2.1 and 2.2 illustrate the area sown to pulses and production in Australia from 1990/91 to 1993/94, respectively.

Table 2.1. Area sown to pulses in Australia ('000 hectares)

Crop	1990/91	1991/92	1992/93	1993/94
Lupins	793	934	939	941
Fields peas	318	423	372	389
Chick peas	167	211	145	140
Faba beans	44	58	82	81
Mung beans	24	28	32	34
Navy beans	9	4	6	7
Total	1388	1658	1573	1592

ABARE 1993

Table 2.2. Australian production of pulses ('000 tonnes)

Crop	1990/91	1991/92	1992/93	1993/94
Lupins	758	1038	987	957
Fields peas	318	463	421	432
Chick peas	196	221	172	162
Faba beans	53	64	99	97
Mung beans	14	18	15	19
Navy beans	9	4	4	4
Total	1348	1808	1679	1671

ABARE 1993

2.2 Domestic Consumption and Export of Chickpea

Among the pulses, chickpea is the third most important crop, contributing about 14% of the world production of pulses and occupying about 15% of the world area under pulses (Von Oppen and Rao 1978). Chickpea is second to dry beans (*Phaseolus vulgaris*) in cultivated area and third in production to dry beans and dry peas (Singh *et al* 1991). Chickpea is mainly produced and consumed in Asia, the Middle East, South America, and some Mediterranean countries. Australia is emerging as a major producer and a significant exporter of chickpea.

Until recently, most pulses grown in Australia were used as stock feed, but with improved market access and increased profitability in the human food industry, grower confidence is gradually increasing to diversify trading opportunities. Domestic food consumption of pulses is small (less than 1%), however, in recent years the swing towards health foods has seen pulses gain popularity as a high fibre, low fat, non-animal protein food.

India is a major target for the export of chickpeas for human consumption. Australia, the world's second largest exporter of chickpeas after Turkey, exported about 100,000 tonnes of chickpeas in 1992/93 and it is estimated that exports will rise by 200% by the year 2000, which translates to approximately AU$ 75 million at 1994 prices (P Wilson, Personal Communication AWB 1994).

Eighty percent of the world chickpea production is of the *desi* type (types of chickpea to be discussed in Section 2.3). The trend in Australia is similar and more than 90% is exported for human consumption with the remainder being used as stock feed domestically. Ready-to-use convenience packs of processed (precooked) *desi* chickpea are being recently produced in Australia for food use (Hogan 1996). This operation, however, is relatively small and the product is still gaining acceptance.

Demand for the large seeded *kabuli* type is far greater and is more popular in both domestic and export markets. The returns to growers for the bold *kabuli* seeds is also higher (~AU$ 80-100 in a stable conservative market) than its *desi* counterpart (~AU$ 190-200, 1995 prices) but, agronomically *kabuli* seeds are more susceptible to fungal damage during the maturation stage thus making it a higher risk crop. *Kabuli* chickpea is domestically consumed in salads, casseroles, stews, and is the main ingredient in

humus (Greek style dip), *felafel* (burger from Middle East) and curries from the Indian subcontinent.

2.3 Classification and Seed Structure

The chickpea, (*Cicer arietinum* L.) is also known as Bengal gram, boot, *chola, chole*, garbanzo bean, gram, hommes and pois chiche (Duke 1981, Janoria *et al* 1984) and is in the family Fabaceae. The genus *Cicer* comprises 39 known species (van der Maesen 1975). Based on seed colour and geographic distribution, chickpea is grouped into two types: *'desi'* (Indian origin) and *'kabuli'* (Mediterranean and Middle Eastern origin). The seeds of *desi* cultivars have a pronounced angularity and strongly ridged surface with a prominent wrinkle at the beak. They are darker and usually smaller than the *kabuli* cultivars and can be brown, light brown, fawn, yellow, orange, black or green. Commercially traded varieties of *desi* chickpea in Australia are brown to dark brown. Small seeds of the *desi* cultivar are often used as animal feed.

Kabuli cultivars have larger seeds with a white to cream coloured smooth seed coat and are used almost exclusively for cooking as whole seeds. Although the seeds of *kabuli* cultivars are bigger than *desi* seeds, the average seed coat weight is higher in the *desi* type (14%) compared with 6% in *kabuli* type (Saini and Knights 1984) but, in both types there is good adherence of the seed coat to the cotyledon (Knights 1980).
The Australian chickpea industry is currently reviewing the release of some pale brown, semi bold *desi* chickpea that can be consumed whole (like the *kabuli*) or processed to yield splits and flour. Black and green coloured *desi* chickpea that are popular in parts of India and Africa are still quite foreign to Australia.

2.4 Chemical Composition

The chemical composition of chickpea seed has been reported quite extensively (Esh *et al* 1959, Jambunathan and Singh 1978, Sotelo *et al* 1987). However, it must be highlighted that the data is representative of samples grown in the Indian subcontinent, Europe and Mexico. The chemical profile of the Australian chickpea crop is not yet fully understood.
Lal *et al* (1963) studied the distribution of nutrients in *kabuli* and *desi* cultivars of chickpea and reported that *kabuli* cultivars had higher protein, fat and iron content.

However, work conducted by Singh *et al* (1981) indicated no significant difference in the levels of protein, soluble sugars, starch, fat, and ash between *desi* and *kabuli* types. According to this study, the distinguishing feature between the two seed types were weight of the seed coat and the fibre content.

Rossi *et al* (1984) reported that *desi* and *kabuli* samples had identical protein and ash contents. *Kabuli* seeds had significantly higher fat and nitrogen-free extract and lower crude fibre content than *desi* cultivars. The difference in crude fibre content was attributed to the smaller size of the desi type and thus a higher percentage of hull and fibre. The cotyledon contains, on average, 96% of the protein, 94% of the fat, 81% of the ash, 88% of the carbohydrate, 94% of the phosphorus, and 70% of the iron of the whole seed (Esh *et al* 1959). The seed coat contains most of the non-digestible carbohydrate and a relatively higher proportion of calcium. Table 2.3 gives the relative distribution of nutrients (per 100 g) in different parts of chickpea seeds.

2.4.1 Proteins

2.4.1.1 Protein Content

The crude protein content of chickpea seeds ranges from 12.6 to 30.5%, (Gowda *et al* 1990) with an average of 21.5%, and that of *dhal* (dry, split cotyledons) ranges from 20.5 to 30.5%, with an average of 25.5% (Rao and Rao 1974, Singh *et al* 1983). Protein content and its stability in the chickpea are influenced not only by genetic makeup, but also due to environmental factors such as location, soil type, irrigation, and level of fertilisation (Dahiya *et al* 1982), although the extent to which these factors influence protein content is not fully understood. However, it has been shown that location (site) had the greatest influence on seed protein content and the effects due to cultivars (genotype) were significant, but of a lower magnitude (Singh *et al* 1983). The variability in protein content of a given chickpea genotype has been a matter of concern to chickpea breeders involved in breeding for higher protein. Chickpea seeds contain significant non protein nitrogen which is positively correlated with the total seed nitrogen (Khanvilkar and Desai 1981, Singh and Jambunathan 1981a). Seed coat nitrogen is mostly comprised of non protein nitrogen components. Thus, any large variation in protein content can only be due to a significant increase or decrease in non protein nitrogen.

Table 2.3. Relative distribution of nutrients (per 100 g) in different parts of chickpea seeds

Nutrient	Seed Coat	Cotyledon	Embryo	Whole Seed
Proportion	14.5	84.0	1.5	100.0
Protein (g)	3.0	25.0	37.0	22.0
(N x 6.25)	(2)	(95.5)	(2.5)	
Fat (g)	0.2	5.0	13.0	4.5
	(0.6)	(94)	(5)	
Ash (g)	2.8	2.6	5.0	2.7
	(15)	(81)	(3)	
Crude fibre (g)	48.0	1.2		8.0
	(87)	(13)		
Carbo-	46.0	66.0	42.0	63.0
hydrate (g)	(11)	(88)	(1)	
Phosphorus	24.0	290.0	740.0	260.0
(mg)				
	(1.5)	(94.0)	(4.5)	
Iron (mg)	8.0	5.5	11.0	6.0
	(20)	(77)	(3)	
Calcium (mg)	1000.0	70.0	110.0	200.0
	(72)	(29)	(0.8)	

Note: Figures in parenthesis indicate percent relative distribution of nutrients. n~100 cultivars.

(Esh *et al* 1959)

2.4.1.2 Amino Acid Composition

The quality of a food protein is generally estimated by comparing its essential amino acid composition with a standard reference protein. According to Rao and Subramaniam (1970), tryptophan is the first limiting amino acid in chickpea while FAO (1970) reported that both tryptophan and valine were equally limiting and Eggum and Beames (1983) claim methionine to be the most limiting. The wild chickpea, C. *reticulatum*, containing high levels of sulphur amino acids can be useful

in breeding to improve the protein quality of chickpea. Jambunathan and Singh (1981) reported that in chickpea, methionine was positively and significantly correlated with cystine. They also observed that there were no significant differences in amino acid composition between *desi* and *kabuli* cultivars. Singh *et al* (1981) observed no noticeable differences in the concentration of sulphur containing amino acids between *desi* and *kabuli* cultivars. Other workers (Kaul and Gassi 1971, Sharma and Goswami 1971) have, however, reported genetic variations in the methionine content of chickpea cultivars. Rossi *et al* (1984) found the levels of leucine and lysine to differ significantly between *desi* and *kabuli* cultivars.

Amino acid composition of the embryo is nutritionally better than that of the cotyledon, as it contains higher amounts of lysine, sulphur amino acids, threonine and valine (Singh and Jambunathan 1982). The levels of other amino acids of the embryo are similar to the cotyledon. Since the cotyledon is a major component of chickpea seed and the embryo is usually removed during commercial *dhal* milling, (see section 2.8) the genetic or environmental manipulation in cotyledon protein is essential to improve the quality of chickpea protein.

2.4.1.3 Fractionation and Characterisation of Protein

Singh and Jambunathan (1982a) fractionated the storage proteins of chickpea seed into albumin (water soluble), globulin (salt soluble), prolamine (alcohol soluble), glutelin (acid/alkali soluble) and residual proteins. The albumin fraction from chickpea cotyledon had the highest concentration of sulphur amino acids, methionine and cystine. They found the globulin to be most deficient in methionine and cystine, while the albumin and glutelin contained higher amounts of these amino acids. Hence, the globulin fraction is mainly responsible for the poor nutritive value of chickpea protein for human and other monogastric animals (Millerd 1975).

Singh *et al* (1981a) found that the percentage of salt soluble proteins decreased with maturation of the seed. The electrophoretic pattern revealed that deposition of seed storage protein in cotyledons occurred 14 days after flowering. Most of the biochemical activity occurred between 14 and 28 days after flowering. Tawde and Cama (1962) have optimised conditions for electrophoretic separation of the protein fractions using Sephadex gel filtration, sedimentation analysis and SDS-PAGE techniques. It has been reported that different varieties of chickpea show differences in

banding patterns obtained by acrylamide gel electrophoresis (Rao and Rao 1974), however, Singh *et al* (1981a) concluded that there was no significant difference in the electrophoretic patterns of *desi* and *kabuli* cultivars.

2.4.1.4 Protein Quality

Biological evaluation of seed protein is essential because chemical analyses (chemical score) do not always reveal how much of a protein is biologically available and utilised due to the presence of certain proteins (especially in pulses) that can inhibit proteolytic activity of digestive enzymes. These protease inhibitors are believed to be largely responsible for the poor digestibility of pulse proteins which have been inadequately cooked (Sathe *et al* 1984). It is well documented that nutritive value and protein digestibility of pulses are very poor unless subjected to cooking or some other form of moist heat treatment (Liener 1976). Chickpea (especially *kabuli* types) is low in polyphenols and most of the protease inhibitory activity can be easily destroyed by normal cooking procedures. However, it is still unclear as to why completely denatured pulse proteins are incompletely attacked by digestive enzymes and thus are unable to fulfill their full nutritional potential. It is postulated that the structure of denatured pulse proteins might limit their susceptibility to enzymatic attack. However, Nene *et al* (1975) report a considerable enhancement in proteolytic digestion when some pulses are irradiated at a dose strength of 1 Mrad. This is attributed to the degradation of pulse protein making it more susceptible to enzyme action, largely by pepsin rather than trypsin, and the presence of trypsin inhibitor masking trypsin action. Degree of pulse digestibility ranges from 93% for lentils to 59% in faba bean with the digestibility of chickpea ranging from 76-90%. The variations in the reported values indicate the genetic diversity in protein quality in the chickpea cultivars (Sumathi and Pattabiraman 1976). Jambunathan and Singh (1981) have reported higher digestibility values for yellow (*kabuli*) chickpeas but, Rossi *et al* (1984) reported the *in vitro* protein digestibility to be higher in the black (*desi*) seeds. Rossi *et al* (1984) suggested that the discrepancy could be due to different methods employed to estimate protein digestibility. Chickpea cultivars exhibited higher TD (True Digestibility), BV (Biological value) and NPU (Net Protein Utilisation) than cowpea and mung beans, (Khan *et al* 1979) and higher NPU than soybean, faba bean, pigeon pea and black gram (Chandrashekharappa 1979). The range for BV, PER (Protein Efficiency Ratio), TD,

and NPU values reported for chickpea is presented in Table 2.4. There is currently considerable debate on the validity of comparing and ranking biological score of plant protein with that of casein which is derived from milk. Debate also continues over the best analytical method to estimate protein quality as most of the methods involve nitrogen balance studies using a laboratory animal.

It has been shown that polyphenols in beans decrease protein digestibility in animals and man, probably by making protein partially unavailable or by inhibiting digestive enzymes (Bressani *et al* 1988). It is unclear at this stage whether the decreased protein digestibility followed by occasional stomach disorders in humans is due to a rapid discharge of proteins from the intestine or a resistance to hydrolysis of protein by the gastrointestinal enzymes (Bressani and Elais 1974). The role of various major globulins in the low protein digestibility of chickpea proteins needs further investigation.

Table 2.4 Protein quality of chickpea

Parameter	Range
Biological Value	52.0-85.0
Protein Efficiency Ratio	1.2-2.64
Digestibility Coefficient	76.0-92.8
Net Protein Utilisation	87.0-92.0

Esh *et al* (1959), Khan *et al* (1979), Pushpamma (1975), Chandrashekharappa (1979)

2.4.2 Carbohydrates

Chickpea seeds contain 52.4-70.9% total carbohydrate of which the major proportion is starch (Shobhana *et al* 1976, Agarwal and Bhattacharya 1980, Hardinge *et al* 1965, Iyengar and Kulkarni 1977). Sotelo *et al* (1987) showed that the Mexican varieties of chickpea contained 57.3-63.3% total carbohydrate, which is a narrower range than reported for samples of Indian origin. This is probably because only the *kabuli* cultivar was studied. The remaining carbohydrates of chickpea seeds are mostly sugars (reducing and non-reducing) and dietary fibre. (Rao and Belvady 1978).

The carbohydrate content of foods is rarely determined by direct estimation, but is mostly calculated 'by difference', after analysis for moisture, protein, fat, fibre and ash.

Until recently dietary fibre was measured as crude fibre which is usually determined by sequential extraction using ether, acid and alkali. It is now established that this procedure results in gross underestimation of the true dietary fibre content, since varying amounts of hemicellulose and pectins are lost. This suggests that the calorific value of such foods have been overestimated in the past. (see section 2.4.2.4). Plant cell wall polysaccharides, which constitute dietary fibre, are also known as 'unavailable carbohydrate'. When unavailable carbohydrate is expressed as a proportion of the total carbohydrate, pulses have considerably higher amounts (23.9-36.7%) than cereals (9.8-21.4%) with the exception of pearl millet (24.6%). Among the pulses, chickpea had the highest unavailable carbohydrate content (25.6%) (Kamath and Belvady 1980).

2.4.2.1 Starch

The starch content in whole chickpea seed ranges from 37.2-50.8% (Sosulski *et al* 1982, Aman 1979, Singh *et al* 1982). The accumulation of starch in the chickpea seed is accompanied by a decline in the pod wall during the early stages of development (Singh and Jambunathan 1982). The seed starch content increases up to 28 days after flowering and then shows a slight decrease during maturation.

Dehusked splits or *dhal* contains 55.3-58.1% starch, but there is no appreciable difference in the starch content of *desi* and *kabuli dhal* (Jambunathan and Singh 1978). The starch content of *desi* and *kabuli* whole seed samples exhibit greater differences with the mean starch values for *desi* whole seeds being 4-5 percentage units lower than the *kabuli* whole seeds (Jambunathan and Singh 1978). In a later study Singh *et al* (1991) observed no large differences in the starch content of eight newly developed and two commonly grown chickpea cultivars.

The amylose content of chickpea starch ranges from 31.8 to 45.8% of the total starch, the remainder being amylopectin (Lineback and Ke 1975). The variation in amylose content has been ascribed to differences in genetic make up and more importantly, the method of estimation. Detailed methods of preparation and the properties of legume starches have been reported by Schoch and Maywald (1968). There is a degree of controversy about the method employed to quantify pulse starches. Some researchers have employed the colorimetric method of McCready and Hassid (1943), others have used the iodine affinity method (Lineback and Ke 1975) and more recently the spectrophotometric absorbance method of Gibson *et al* (1996). The contention is

primarily because of the difference in structure and properties of cereal and pulse starches and the adoption of the method standarised for cereal starch to pulse starch. Chickpea starch exhibits restricted swelling patterns when pasted in water over the temperature range of 65 °C-100 °C, and produces stabilised Brabender hot-paste viscosities with an iodine affinity value of 6.08%. These properties are attributed to the linear fraction (amylose) in starch (Schoch and Maywald 1968). The cooking qualities of peas and beans are probably influenced by the pasting characteristics of their starchy component (Nielsen and Gleason 1945).

The physico-chemical properties of starch depend upon the amylose and amylopectin levels which has a direct impact on its application in the food industry. According to Modi and Kulkarni (1975), the amylose constituent of starch is responsible for the ability of starch to gel in the presence of sugar and other appropriate ingredients. Much work is needed in the area of chemically modifying pulse starches in order to improve their functional properties and use in the food industry. It is postulated that the presence of structural and/or compositional components may play a greater role than starch in regulating some quality traits in canned bean (Srisuma *et al* 1994). All these aspects of Australian pea and bean varieties are largely unknown.

2.4.2.2 Sugars

The non-reducing sugar component comprises mostly of the total sugars which range from 4.8-9.3% (Rao and Belvady 1978). The carbohydrate composition of chickpea seed (including sugars and dietary fibre) is tabulated in Table 2.5.

Kabuli cultivars are reported to contain slightly higher amounts of soluble sugars (6.1%) than the *desi* types (5.4%) (Jambunathan and Singh 1978). This was confirmed by Rossi *et al* (1984), but the mean values they reported are higher, being; 8.3% and 7.7% for *kabuli* and *desi* types respectively. The mean level of sucrose was 35% higher in *kabuli* (6.2 g/100 g) than in *desi* types (4.0 g/100 g) (Saini and Knights 1984). The level of the raffinose series of oligosaccharides was on average, 3% higher in *kabuli* than in the *desi* type. Values ranging from 6.7-8.4% have been reported by Schweizer *et al* (1978). Chickpea seeds contain higher amounts of raffinose (0.45%), and manninotriose (2.33%) than cowpeas, lentils, faba bean and mung beans. (Sosulski *et al* 1982).

Table 2.5 Carbohydrate composition of chickpea seed

Constituent	g/100 g
Total Carbohydrate	50.6-70.9
Starch	37.2-50.8
Amylose (% of total)	31.8-45.8
Total Sugars	4.8-9.3
Reducing sugars	0.1
Sucrose	0.7-2.9
Raffinose	trace-3.0
Verbascose	trace-4.5
Stachyose	0.5-6.5
Manninotriose	1.6-3.1
Dietary Fibre	19.9-22.7
Cellulose	7.1-9.7
Hemicellulose	3.5-8.7

Rao and Belvady (1978), Jambunathan and Singh (1978), Sosulski *et al* (1982)

Several workers have reported high levels of stachyose, up to 26.7% of the total soluble sugars in chickpea.

It is unclear at this stage which oligosaccharides contribute to or trigger flatulence and whether their action is synergistic. The enzymes invertase and α–galactosidase are required for complete hydrolysis of these oligosaccharides in the human gut. Since the human gastrointestinal tract does not possess α–galactosidase, these oligosaccharides are believed to cause flatulence in human and monogastric animals, which is characterised by the production of high amounts of hydrogen, carbon dioxide and small amounts of methane gas (Anderson *et al* 1979, Reddy *et al* 1980). It is the presence of these sugars in chickpea seeds that causes a major constraint in its full utilisation as human food especially in the Western world. Enzymatic processes using exogenous sources of α–galactosidases to hydrolyse the sugars have been developed by several groups (Sugimoto and Van Buren 1970, Delente *et al* 1974), but so far they have not been successful either in hydrolytic efficiency, final product acceptability, cost, and/or effectiveness in reducing flatulence.

2.4.2.4 Dietary Fibre

Dietary fibre plays an important role in human nutrition and health. Fibre in foods reduce the irritation in the hind gut by acting as a diluent to the products of digestion. Clinical evidence suggesting an inverse relation between dietary fibre intake and cancer, especially colon cancer has been well documented (Burkitt 1978). A diet containing at least 37 g dietary fibre per day may be protective against chronic diseases in Western societies (Kromhout *et al* 1982). Fibre also causes faecal bulking and alleviates constipation. Most importantly to obese persons, fibre in food does not contribute to dietary calories. Pulses are considered to be a good source of dietary fibre and have been successfully used in the dietary treatment of diabetes, hypertension, hypercholesterol and some types of cancer (McIntosh and Wong 1996).

The dietary fibre content in chickpea ranges from 7.1-13.5% of which cellulose and hemicellulose are the major components (Cristofaro *et al* 1974). The dietary fibre concentration is directly related to the seed coat content and large variations in seed coat content of chickpea cultivars have been reported (Singh *et al* 1980, Singh 1984a). The white seeded chickpea cultivars are preferred because of the low amount and thickness of seed coat, suggesting that cultivars with reduced seed coat thickness would improve the utilisation of nutrients (Koinov *et al* 1976). The seed coat thickness and content are significantly higher in *desi* than *kabuli* types and this information can be used to distinguish between the two cultivars (Jambunathan and Singh 1978, Singh *et al* 1981b). The concentration of crude fibre (CF), acid detergent fibre (ADF), neutral detergent fibre (NDF) and dietary fibre (DF) were significantly higher in the seed of *desi* cultivars than in those of *kabuli* cultivars and these values are presented in Table 2.6. The *dhal* CF and ADF composition were similar for both types of chickpea indicating that the fibre constituents in whole seeds are determined mainly by the husk. Singh (1984a) suggests that in terms of calorific value and utilisation of nutrients from *dhal* and whole seed, *kabuli* cultivars are superior to *desi* types as the latter contains higher amounts of cellulose and hemicellulose.

Vidal-Valverde and Frias (1991) studied the effects of different cooking processes on NDF, ADF, cellulose, and lignin content of pulses. They found a decrease in all components of dietary fibre for chickpeas and the decrease was more pronounced in pressure cooked samples compared to those from normal cooking procedures.

Table 2.6. Cellulose, hemicellulose, lignin and pectic compositions (per 100 g) of whole seeds of *desi* and *kabuli* chickpea cultivars

Constituent	Type	Range	Mean
Cellulose (g) (CF)	*Desi*	7.1-9.7	9.0
	Kabuli	2.6-4.7	3.2
Hemicellulose (g)	*Desi*	3.5-8.7	5.8
(NDF-ADF)	*Kabuli*	4.0-7.3	5.5
Lignin (g)	*Desi*	2.2-5.9	3.7
(ADF-CF)	*Kabuli*	1.1-2.1	1.7
Pectic substances(g)	*Desi*	1.5-3.8	3.0
(DF-NDF)	*Kabuli*	2.4-4.1	3.3

Singh (1984a)

Despite the many virtues of high fibre content in foods, it influences the bioavailability and modifies the environment in the colon (Ali *et al* 1981). According to Singh *et al* (1983), dietary fibre of various pulses decreases the lipid and cholesterol levels in plasma, heart and liver of young rats. As the level of unavailable carbohydrate increases, the digestibility of pulses in humans decreases. The chickpea seed coat fibre shows maximum hyocholesterolemic effect followed by black gram and green gram (Kritchovsky and Story 1974, Soni *et al* 1982, Macintosh and Wong 1996).

The cooking process that makes pulses digestible has the effect of decreasing the amount of dietary fibre components on a wet weight basis. However, the content of the fibre compounds remains relatively high and contributes considerably to the amount of fibre in the diet (Vidal-Valverde and Frias 1991). This data would be useful where dehydrated cooked legume meals are used as food supplements (Marero *et al* 1988).

2.4.2.5 Digestibility of Carbohydrates

In vitro starch digestibility of meal samples indicated no significant difference between *desi* and *kabuli* types, however the mean values of digestibility of isolated starches of *kabuli* types was higher than those of *desi* types (Singh *et al* 1982). *In vitro* starch digestibility values of *desi* and *kabuli* cultivars are presented in Table 2.7.

Table 2.7 *In vitro* starch digestibility of *desi* and *kabuli* cultivars

Cultivar	*/g meal	*/g meal starch	*/isolated starch
***Desi*-Range**	39.8-50.5	85.4-99.5	108.3-123.0
Mean ± SE	45.2 ± 2.0	89.7 ± 4.6	114.7 ± 5.4
***Kabuli*-Range**	40.5-51.7	86.6-100.2	120.4-148.5
Mean ± SE	47.1 ± 2.3	91.5 ± 5.1	135.0 ± 5.7

* = mg maltose released. Starch digestibility was measured using pancreatic amylase and the results expressed as mg maltose released per gram meal and mg maltose released per gram meal starch (Singh *et al* 1982).

The digestibility of isolated starch was higher than that of the meal starch. There appears to be no relationship between the digestibility of meal starch and isolated starch of chickpea. Perhaps, some interfering substances are present in meal samples and in higher concentration in *desi* than in *kabuli*. Singh *et al* (1982) found no relationship between the *in vitro* starch digestibility and the stachyose and raffinose contents of chickpea.

The concentration of unavailable carbohydrate is highest in chickpea (Kamath and Belavady 1980) and consequently it has the lowest carbohydrate digestibility among the commonly consumed Indian pulses when studied by *in vitro* method (Rao 1969). Shurpalekar *et al* (1973) reported that the flatus-inducing capacity of pulses was correlated with the digestibility of the carbohydrates. As a result, green gram which has the most digestible carbohydrate, produces the least amount of flatus, whilst chickpea and red gram produce the highest amount of flatus.

Khader and Rao (1981) reported that attempts to increase the rate of digestion of carbohydrates alone is not sufficient to reduce the flatulence activity of pulses. *In vitro* and *in vivo* studies conducted by El Faki *et al* (1983) indicate that apart from oligosaccharides, starch and hemicelluloses contribute substantially to the total flatulence effect of chickpea, cow pea and horse gram. They suggest the removal of oligosaccharides and hemicelluloses by preliminary water soaking, followed by precipitation of protein would produce a significantly non-flatulent product. According to Kon *et al* (1971), blending raw beans before cooking improves the

digestibility of starch. Long chains of the amylose molecule have been implicated with reduced digestibility, which may cause flatulence (Rao 1976). Legume starches are known to influence the utilisation of amino acids and proteins from other sources in the diet.

Significantly less growth was observed in rats fed with chickpea starch compared with starches from black gram and green gram (Geervani and Theophilus 1980). This was attributed to a greater *in vivo* digestibility of Phaseolus starch than chickpea starch. Geervani and Theophilus (1980) also showed that the availability of lysine and methionine for rats fed on a casein based diet but containing chickpea starch was lower than for rats fed corn, black gram, and mung bean starches. This was attributed to delayed or incomplete digestion of protein as a result of starch. Effects of processing on flatus factors are discussed in Section 2.5.3.

2.4.3 Lipids

The total lipid content in chickpea ranges from 3.1-6.9%. Differences in the fat content of *desi* (4.9%) and *kabuli* cultivars (5.4%) have been reported (Jambunathan and Singh 1978). Triglycerides are the major components of neutral lipids, whereas lecithin is the major component of polar lipids (Ghiradi *et al* 1974). Linoleic and oleic acids are the major unsaturated fatty acids which constitute 67% while saturated fatty acids make up about 10%. Palmitic acid is the principal saturated fatty acid (Table 2.8). The total unsaturated fatty acids content in chickpea (67%) is higher than in lentils (62%), lima beans (55%), and field beans (15%) but is lower than kidney beans (86%), black gram (76%), and green gram (73%) (from Salunkhe *et al* 1982).

Unsaturated fatty acids of pulses can lower cholesterol level in serum, liver (Devi and Kurup 1972) and the eye (Benolken *et al* 1973). The lipid and proteins of chickpea lowered serum cholesterol in rats and these findings indicate that the hypocholesteroemic effect of chickpea in rats is due to the combined effect of dietary fibre, lipids and protein (Murthy and Urs 1985). Minerals such as iron (Fe^{+2}, Fe^{+3}), copper, manganese, and nickel are known to catalyse the autoxidation of lipids during storage which in turn induces protein polymerisation (Tai *et al* 1974).

Table 2.8. Fatty acid composition of chickpea lipids

Fatty acids	%
Saturated fatty acids	10.4
Palmitic acid (16:0)	9.2
Stearic acid (18:0)	1.2
Unsaturated fatty acids	67.1
Oleic acid (18:1)	21.8
Linoleic acid (18:2)	43.3
Linolenic acid (18:3)	2.0

from Salunkhe *et al* 1982

The production of free radicals (a byproduct of oxidation) damages proteins, enzymes and amino acids, induces non-enzymatic browning, affects the functional properties of proteins, and brings about undesirable organoleptic changes which reduces customer acceptance (Roubal and Tappel 1966). Fritz (1976) reported that amylose is primarily responsible for the formation of complexes between lipids and carbohydrates. The presence of appreciable amounts of polyunsaturated fatty acids, although nutritionally advantageous, may cause lipid oxidation by interacting with proteins, amino acids, starch, vitamins and minerals during storage and can affect processing and the quality of end product. These unfavourable interactions also reduce bioavailability of the nutrients. These problems are accentuated in the dry split dehulled cotyledon (*dhal*) and in the resultant flour. Dehulling accelerates the rancidity process suggesting that perhaps one function of the seed coat is to maintain the edible quality of the seed (Kulkarni 1988a). However, the problem of lipid oxidation is not as severe as in field pea and soybeans where shelf life is dramatically reduced due to rancidity.

2.4.4 Minerals

Pulses are good sources of dietary minerals. Mineral composition of chickpea seeds and *dhal,* recommended dietary intakes (RDI) and amount present are tabulated in Table 2.9. It has been demonstrated that chickpea is rich in magnesium (48% of RDI) and iron (49% of RDI) and the *dhal* is rich in phosphorus (44% of RDI) and also a

good source of zinc (24% of RDI) and potassium (23% of RDI) (Jambunathan and Singh 1981).

Table 2.9 Mineral composition of chickpea seeds and *dhal* (mg/100 g) and RDI (mg)

Mineral	Seed/*dhal*	Range	RDI*[+]	% of RDI[#]
Phosphorus	Whole seed	244-458	1000	35
(P)	*Dhal*	265-615		44
Calcium	Whole seed	93-259	800	22
(Ca)	*Dhal*	23-166		12
Magnesium	Whole seed	92-168	270	48
(Mg)	*Dhal*	89-146		44
Iron	Whole seed	3-11	12-16	49
(Fe)	*Dhal*	4.5-7.4		43
Copper	Whole seed	0.6-2.1	**	
(Cu)	*Dhal*	0.6-1.7		
Zinc (Zn)	Whole seed	1.5-4.2	12	24
Sodium (Na)	Whole seed	10-150	920-2300	5
Potassium (K)	Whole seed	692-1028	1950-5460	23

Cowan *et al* (1967), Meiners *et al* (1976), Rockland *et al* (1979), Rao and Deosthale (1981), Jambunathan and Singh (1981). *RDI given in the table is for adult males, [+] NHMRC (1991), [#] the median value was used for calculations. (n varies for different minerals as data are a collection of several references) ** No RDI for Cu in Australia.

The mean values of potassium, copper, magnesium, iron and phosphorus of *desi* and *kabuli* whole seed and *dhal* samples showed no significant differences. Mean values of calcium for *desi* whole seed was significantly higher than in the *kabuli* and the mean value for zinc in *kabuli* was significantly higher than in *desi* as is shown in Table 2.10. In a later study by Singh *et al* (1991) on newly developed chickpea cultivars, calcium content was noticeably higher in *desi* than in *kabuli* cultivars, but no definite trend was observed for magnesium, iron, copper, and zinc. However, in the *dhal,* the mean values of calcium (57 mg/100 g) and manganese (1.89 mg/100 g) were significantly

higher in *kabuli* (Sankar Rao and Deosthale 1981, Jambunathan and Singh 1981). Jambunathan and Singh (1981) examined the mineral and trace element composition of the seed coats of *desi* and *kabuli* and reported significant differences in calcium, zinc, copper, iron and manganese content. Calcium was the predominant mineral of chickpea seed coats and accounted for ~65% of the total calcium in the whole seed.

As calcium is concentrated in seed coat the consumption of whole seed would be nutritionally desirable for calcium deficiency. Jambunathan and Singh (1981) reported that location had only a small effect on the mineral content of the seed. Data on the mineral content of Australian chickpea and *dhal* is lacking.

Due to the reasonably high potassium content in chickpea seeds, there may be some benefit for hypertensive patients suffering from excessive loss of potassium through body fluids to include chickpeas as part of their diet. The iron availability is highest in chickpea compared to other pulses (Cowan *et al* 1967).

Iron absorption in the gut increases when consumed with ascorbic acid, so it is recommended that lemon juice or citrus fruits be consumed during or immediately after a meal rich in iron (Radd 1996). Dry seeds are generally good sources of iron, but germinated peas and beans contain less iron than dry seeds on a 100 g wet weight basis owing to increased water content (Chen *et al* 1975). However, the availability of iron is increased in germinated seeds (Singh and Banerjee 1953). The Mg, Ca, K and P contents of germinated peas and beans are between those of seeds and sprouts (Fordham *et al* 1975). The desired dietary components (proteins, complex polysaccharides) and the anti-nutritional factors such as phytic acid, polyphenols can interact with minerals altering their bioavailability (O'Dell 1969). The phytate ion complexes with di- and trivalent cations (Zn^{++}, Ca^{++}, Mg^{++}, Fe^{++} and Fe^{+++}) to form insoluble compounds which cannot be easily absorbed by the animal gastrointestinal tract (Maddaiah *et al* 1964, Oberleas *et al* 1966).

Table 2.10 Mineral and trace element composition (mg/100 g) of *desi* and *kabuli* cultivars grown in North India

		Wholeseed		*Dhal*	
Element	**Seed type**	**Range**	**Mean**	**Range**	**Mean**
Phosphorus	*Desi*	261-458	325	266-555	397
	Kabuli	282-398	336	352-565	422
Potassium	*Desi*	1006-1159	1074	884-1120	966
	Kabuli	1005-1184	1128	887-1057	982
Calcium	*Desi*	140-259	191*	32.4-65.4	45*
	Kabuli	125-178	155*	45.1-66.1	57*
Magnesium	*Desi*	128-168	142	89-140	114
	Kabuli	129-151	140	115-139	126
Zinc	*Desi*	1.5-2.9	1.96*	1.9-2.6	2.24
	Kabuli	2.0-3.1	2.49	2.1-3.3	2.67
Copper	*Desi*	0.6-1.3	0.85	0.6-1.7	0.85
	Kabuli	0.8-1.2	0.96	0.7-1.1	0.91
Iron	*Desi*	3.0-9.8	7.26	4.9-6.5	5.73
	Kabuli	5.9-7.3	6.66	5.1-6.2	5.59

Jambunathan and Singh (1981), n = 7 *desi* cultivars and 8 *kabuli* cultivars, * = significant at $p < 0.05$.

2.4.5 Vitamins

There is limited information available on the vitamin composition of chickpea. Some of the available data along with RDI and percent of RDI present in chickpea is shown in Table 2.11.

Chickpea seeds are a good source of thiamin, pyridoxine, and folic acid (B group vitamins) (>40% of RDI). Chickpea seeds contain relatively low levels of ascorbic acid and a highly significant negative correlation was observed between the mineral content and the ascorbic acid content (Chandra and Arora 1968). There is no significant difference in the vitamin content of whole seed and *dhal* (Gopalan *et al* 1977).

Table 2.11 Range of vitamin content of chickpea seeds

Vitamin	Range (mg/100 g)	RDI*+ (mg)	% of RDI #
Thiamin	0.28-0.40	0.8	43
Riboflavin	0.15-0.30	1.2	12
Pyridoxin	0.55	0.9-1.4	48
Ascorbic acid	2.2-6.0	30	14
Niacin	1.6-2.9	13	17
Carotene	0.12	750 (μg)	16
Folic acid	0.15	200 (μg)	75

Gupta and Das (1959), Lakshmiah and Ramasastri (1969), Aliya and Geervani (1981).

* RDI quoted is for adults, + NHMRC (1991), # used the median value for calculations, n varies for different vitamins.

The rapid synthesis of provitamin A, B-complex vitamins and vitamin C in germinating seeds has been investigated by Chen *et al* (1975). Tocopherol content ranged from 117-662 μg/100 g and carotene content ranged from 1.1-5.6 μg/100 g in germinated seeds which was lower than in dry seeds (24-2300 μg/100 g, 1.8-37.4 μg/100 g, respectively). Banerjee *et al* (1955) reported that the contents of niacin, pyridoxine, pantothenic acid, inositol, biotin and vitamin K increased in some pulses after germination. Ascorbic acid content in germinated seeds (14.8-32.9 mg/100 g) was much higher than that of the dry seeds (1.0-5.2 mg/100 g) (Fordham *et al* 1975). The reduced form comprised about 1/3-1/2 of the total ascorbic acid.

Information on the bioavailability of vitamins and their interaction with other nutrients of chickpea is limited. The nondigestible polysaccharides and lignin are known to reduce the availability of B6 vitamins possibly by physical entrapment, binding by ionic, or other adsorptive process or alterations in the viscosity of the intestinal contents (Gregory and Kirk 1981).

Processing causes considerable losses to the B vitamins ranging from 2-86% depending on the pulse, the ingredient make up and type of process (Pushpamma and Geervani 1981). Losses are greater in products subjected to high temperature and longer cooking time. Some of the losses can be avoided by increasing consumer

awareness such as cooking whole seeds or dhal in just sufficient water or not discarding surplus cooking liquor because it contains the leached water-soluble vitamins. Lin *et al* (1975) have examined the effects of sequential soaking, blanching and thermal processing on folic acid retention in canned garbanzo beans. They found that the retention of total and free folic acid in the canned beans was 70% and 73%, respectively, of that present in the original seed (3.47 μg/g total folic acid on dry matter basis).

2.5 Antinutritional Factors (ANF)

Pulses are known to contain several antinutritional factors (ANF) such as trypsin inhibitors, chymotrypsin inhibitors (Chavan and Hejgaard 1981), lectins (Contreras and Tagle 1974), phytates, polyphenols (Rao and Deosthale 1982), flatulence factors (Jaya *et al* 1975) and minor ANF such as lathyrogens, goitrogens, and saponins (Fenwick and Oakenfull 1983) depending on the type of pulse. Chickpea seeds, not unlike other pulses, contain a variety of chemical substances known to cause digestive disturbances when ingested. As a result, the nutritive value and protein digestibility of chickpea is poor unless the seeds are cooked which destroys the protease inhibitors and other heat labile compounds or decorticated (Singh and Jambunathan 1981). Of the various ANF, protease inhibitors, amylase inhibitors, oligosaccharides (mainly trisaccharides) and polyphenols of chickpea are the most important. Table 2.12 shows the levels of various ANF and some toxic substances present in chickpea. Information on ANF content in the Australian chickpea crop is limited.

2.5.1 Protease Inhibitors

Trypsin inhibitor activity was observed to be in decreasing order for soybean, field bean, faba bean, pea, lentil, and chickpea (Gallardo *et al* 1974) and for black gram, kidney bean, red gram, mung bean and chickpea (Pak and Barja 1974). The chymotrypsin inhibitor activity in chickpea was found to be higher than in cowpea, pigeonpea, broad bean and lentil (Chavan and Hejgaard 1981). Considerable variation has been observed in the levels of protease inhibitors of chickpea genotypes (Chavan and Kadam 1989). Trypsin inhibitor activity was higher in both *kabuli* and *desi* seeds of chickpea than chymotrypsin inhibitor activity (Singh and Jambunathan 1981b).

Trypsin inhibitor activity was about 70% higher in *desi* seed as compared to *kabuli* seed but only 25% higher in *desi* as compared with *kabuli dhal*. As observed for trypsin inhibitor, the chymotrypsin units inhibited (CUI/mg protein) were higher in the case of *desi* cultivars (34 units) compared to *kabuli* seeds (23 units).

Table 2.12 ANF and toxic substances of chickpea seed

ANF/toxic substance	Range	Mean
Protease inhibitors (Units/mg)		
Trypsin	6.7-14.6	10.8
Chymotrypsin	5.7-9.4	7.1
Amylase inhibitor (Units/g)	0-15.0	8.7
Oligosaccharides (g/100 g)		
Stachyose	1.06-3.40	1.50
Raffinose	0.50-1.90	1.01
Verbascose	traces-4.5	1.33
Polyphenols		
Total phenols	1.55-1.70	3.03
Tannins	traces	
Phytic acid (mg/100 g)	2.8	2.8
Phytohemagglutinins	traces	
Cyanogens	traces	
Mycotoxins (on storing)	traces-35 ppm	18

Williams and Singh (1987)

Saini and Weder (1992) have examined trypsin and chymotrypsin inhibitor activities of *desi* and *kabuli* varieties grown in Australia. They also reported the *desi* type to have a higher mean inhibitory activity than the *kabuli* type, but there was no significant

difference in inhibitor activity for any of the enzymes (bovine, porcine and human trypsin and chymotrypsin) examined. Among the *desi* types, Barwon exhibited inhibition of all six enzymes and SP1.563 had lowest inhibition among the *kabuli* types.

The chymotrypsin inhibitor of chickpea was found to be more heat resistant than trypsin inhibitor but both were completely destroyed when subjected to boiling or extended periods of heating (Belitz and Weder 1990). Protein denaturation by heat has been reported to improve digestibility, but excessive heating reduces the nutritive value of protein, possibly by promoting amino cross-linkage of protein chains (Shemer and Perkins 1975).

Trypsin inhibitors contain no tryptophan (Liener 1979) but are a rich source of cystine (30-40% of total cystine content) which is readily available for growth after heat treatment (Kakade *et al* 1969). As pulses are always consumed after some form of processing, breeders are looking at the possibility of increasing levels of trypsin inhibitors as a means of increasing S amino acid content and therefore improving the nutrient quality of pulses (de Lumen 1990, Deshpande and Damodaran 1990). According to Deshpande (1992), the whole issue of nutritional concern over protease inhibitor intake from pulses has been exaggerated and misinterpreted by basing most studies on 'raw' seeds &/or 'purified inhibitor' in animal models. Deshpande (1992) is adamant that attempts to extend the rationale of those findings to human nutrition is incorrect.

Rajalakshmi and Vanaja (1967) reported that fermentation reduced antitryptic activity. Jaya *et al* (1975) attributed an increase in PER to the destruction of trypsin inhibitors as a result of germination.

2.5.2 Amylase Inhibitors

The nutritional significance of α-amylase inhibitors in pulses has received attention only in recent years. Pancreatic amylase inhibitor is present in most pulses but appears to be lower in chickpea than in other important food pulses (Jaffe *et al* 1973). Mean values indicated slightly higher inhibitory activity in *desi* (9.0 Units inhibited/g meal for pancreatic amylase) than *kabuli* cultivars, (7.4 Units inhibited/g meal for pancreatic

amylase) though clear cut differences were not observed between the cultivars. The amylase inhibitors were completely inactivated when extracts were boiled for 10 minutes (Singh *et al* 1982). Since chickpeas are usually consumed after boiling, the amylase inhibitors may not be of practical importance except in the case of unheated chickpea meal wherein some inhibition of starch digestion may be expected.

2.5.3 Flatulence Factors

Pulses are notorious inducers of flatulence in humans when consumed in large quantities. It is generally recognised that bacterial fermentation of food residues remaining after digestion and assimilation of available nutrients is the source of intestinal gases causing gastrointestinal distress, diarrhoea, and/or a bloated sensation. The galactose containing oligosaccharides, such as raffinose, stachyose and verbascose are responsible for flatulence caused by pulses (Rackis 1975, Olson *et al* 1975). Chickpea is known to produce more flatus than other pulses because of the higher content of oligosaccharides (Jaya and Vankataraman 1979, 1981). Stachyose and raffinose contents are higher in *desi* seeds than in *kabuli* seeds. When *desi* and *kabuli* were considered together, stachyose accounted for 27% and raffinose for 10% of the total soluble sugars (Singh *et al* 1982). The difference in flatus effect between whole seed and *dhal* is only about 10% and can be explained on the basis of dilution with husk fraction present in whole seed (El Faki *et al* 1983).

It is well documented that processing ameliorates the flatus problem to varying degrees in different pulses. Fermentation is more effective in reducing flatulence (Rajalakshmi and Vanaja 1967) than cooking, germination, puffing, and alcohol extraction. Jaya and Venkataraman (1979) reported a decrease in flatus factors in germinated chickpea. However, Shurpalekar and co-workers (1973) observed that germinated or cooked chickpea did not greatly alter the flatus inducing capacity as compared to the raw form.

The rate of disappearance of the flatus causing agents is slower in chickpea when compared with other pulses (Aman 1979). Cooking appeared to increase the oligosaccharide content of all pulses and the increase was proportionately higher in chickpea (Rao and Belvady 1978). The amount of these sugars was reduced on cooking when the cooking water was discarded (Iyengar and Kulkarni 1977). El Faki

et al (1983) suggest that starch and hemicellulose also contribute towards chickpea flatulence. Olson *et al* (1975) conclude that α–galactoside-free bean residue and protein-rich fractions also have a stimulating and perhaps a synergistic effect on flatulence in rats.

The flatulence-inducing oligosaccharides accumulate in developing seeds mainly toward the later stages of seed maturation (Singh and Jambunathan 1982b). Consumption of green chickpea (immature) should therefore cause less flatulence. Owing to the vast differences in oligosaccharide content among the chickpea cultivars and their implication in human nutrition, attempts should be made to screen and select cultivars having lower levels of oligosaccharides without drastically affecting the commercial cultivation of the crop. Developing 'designer chickpeas' with zero flatus factors has been discussed as the only solution to the flatus problem, but it may prove to be an expensive academic exercise, because these oligosaccharides are known to play a very important defence role in preventing fungal attack during seed maturation (Hedley 1996).

2.5.4 Polyphenols (Tannins) and other Compounds

Phenolic compounds are ubiquitous in the plant kingdom and are food components exclusively of vegetable origin. Condensed tannins are the predominant class of polyphenols that occur widely in food grains and pulses (Salunkhe *et al* 1990). There is no evidence that they have a nutritional role in our diet. These compounds provide a defence mechanism against premature germination (Hulse 1975), against bacterial, viral, and fungal attack analogous to the immune system of animals (Deshpande *et al* 1986), against being eaten by insects; and finally being eaten by herbivores with the mechanism of protein precipitating properties (Barry 1989). There is much debate on the appropriate chemical method to estimate this class of compounds that contain closely related derivatives of phenols (Deshpande *et al* 1986).

In vitro and *in vivo* studies indicate that tannins decrease protein (enzyme and non-enzyme) digestibility either by inactivating digestive enzymes or by reducing the susceptibility of the substrate proteins after forming complexes with tannins. Tannins are also reported to reduce the bioavailability of vitamins and minerals (Salunkhe *et al*

1982, Reddy *et al* 1985). According to Singh and Jambunathan (1981b) polyphenolic compounds exhibited a highly significant negative correlation with *in vitro* protein digestibility and a significant positive correlation with protease inhibitor activities (trypsin and chymotrypsin) in chickpea. The mean value of polyphenolic compounds (mg/g meal) in *desi* seed (4.7 mg/g) was more than twice the amount present in *desi dhal* (2.1 mg/g), while a comparison of the mean values between *kabuli* seed (2.1 mg/g) and *dhal* (1.8 mg/g) showed no such difference. This observation could be related to the variability in the seed coat percentages in *desi* and *kabuli* cultivars.

No detectable amount of tannins was observed when 10 genotypes of chickpeas, differing in seed colour and originating from different countries were analysed (Price *et al* 1980). Singh (1984b), however, reported that polyphenolic compounds of cultivars with a dark testa showed more digestive inhibitory activity than those with a light testa and claimed these phenolic compounds are responsible for the variability in seed coat colour (Singh 1984b). In a later study on quality of pigeon pea, Singh (1993) concluded that most of the polyphenols (80-90%) were concentrated in the seed coat which explains the high polyphenolic levels in whole seed. Chang *et al* (1994) reported a similar finding in cowpeas. Singh (1984b) also concluded that the polyphenols in chickpeas may or may not be tannins and observed no relationship between tannins and total phenolic compounds.

Paredes-Lopez and Harry (1989) reported 100% loss of tannins in soybeans during tempe production which is a fermented product. Polyphenolic losses in fermented legume batters ranged from 26-52% depending on the duration and temperature of the process (Yadav and Khetarpaul 1994). Contrary to these results, Goyal (1991) and Grewal (1992) reported an increase in the polyphenolic content of some pulse-based fermented products. Dehulling eliminates more than 90% of the tannins in soybeans (Reddy and Pierson 1994), 96% of the tannins in cowpeas (Ogun *et al* 1989, Chang *et al* 1994) and significant levels of tannin is eliminated in chickpea because of their predominance in the seed coat (Singh 1984b). Cooking decreases tannin content by 60% (when the cooking water is discarded) and 24 hour germination reduces tannin levels by 59% in chickpea (Rao and Deosthale 1982). Tannin content is further reduced (75%) when 24 hour germinated chickpea seeds are cooked.

2.5.5 Phytic Acid

Phytate is a naturally occurring organic substance (myo-inositol hexakis dihydrogen phosphate) with chelating properties that forms strong complexes with some nutrient mineral cations such as calcium, copper, zinc, and iron thereby reducing their bioavailability (Erdman 1979). Phytic acid is present in discrete regions of cereals, pulses, some roots and tubers where it accounts for 78 to 85% of the total phosphorus depending on cultivar and species (Reddy *et al* 1989a, Chitra *et al* 1995). Phytates also affect the solubility, functionality and digestibility of proteins by forming complexes. They also interact with enzymes such as trypsin, pepsin, α-amylase and β-galactosidase, resulting in a decrease of activity (Reddy *et al* 1989a).

Phytic acid content in chickpea was reported to be in the range of 2.01-2.97 mg/g (Manan *et al* 1985), 3.43 mg/g (Hussain *et al* 1989) and 7.48-8.00 mg/g (Duhan *et al* 1989). However, Chitra *et al* (1995) have reported a value of 9.6 mg/g and showed a significant negative correlation between phytic acid and *in vitro* protein digestibility. Phytic acid was significantly and positively correlated with protein content but the magnitude of correlation was low in chickpea. The mean phytic acid content in *dhal* was reported to be 3.1 mg/g and this significant reduction suggests accumulation of phytate mainly in the hull of chickpea (Hussain *et al* 1989). Roasting and autoclaving significantly reduced the phytic acid levels in chickpea seed and *dhal* which is in agreement with the findings of Khan *et al* (1986) in roasted wheat. A study by Duhan *et al* (1989) reports a significant reduction in phytic acid levels in sprouted chickpea (28-34%), cooked pre-soaked chickpea (20-26%) and 7-11% in cooked unsoaked chickpea. This suggests that soaking plays an important role in lowering phytic acid content in chickpea.

Reddy *et al* (1986) have reported a 58 and 97% reduction in phytate level in *khaman* and *dhokla,* respectively, which are two popular chickpea flour based fermented Indian foods. Rajalakshmi and Vanaja (1967) reported a decrease in phytate of 35% in *khaman.* Grewal (1992) and Gupta *et al* (1992) have shown that buttermilk fermentation significantly reduced the levels of phytic acid in cereals and pulses, blends of which have an important place in the Indian diet. Germinated soybeans in tempe

preparation and fermentation increases amount of phytate hydrolysed by the action of phytase (Supramo and Markakis 1987). Gad *et al* (1982) observed a decrease in phytic acid content in steeped and sprouted chickpea. Belavady and Banerjee (1953) demonstrated that, during germination, the phytic phosphorus diminished and the water-soluble phosphorus increased.

According to Ogun *et al* (1989), phytic acid levels in cowpeas were not affected by dehulling, cold soaking, hot soaking, and cooking during the preparation of two popular Nigerian foods. However, Gustafsson and Sandberg (1995) concluded that soaking for 17 hours at pH 7.0 and 55 °C caused a 98% reduction in phytate content in brown beans.

2.5.6 Other Factors

Other ANF in chickpea include phytohaemagglutinins, saponins and mycotoxins. The phytohaemagglutinins (or lectins) interact with glycoproteins on the surface of red blood cells causing agglutination. They impair the ability of cells to absorb nutrients from the gastrointestinal tract, thus causing serious growth retardation and even death in extreme cases (Liener 1979, Jaffe 1980). Chickpea produces a certain amount of agglutinating activity in cow erythrocytes (Contreras and Tagle 1974, Pak and Bajra 1974), which contradicts earlier observations that no haemagglutination factor was present in chickpea (Honavar *et al* 1962, Liener 1976). Lectins are heat labile and the greatest reduction of agglutination was obtained with moist heat at 100 °C (Liener 1979). Residual lectin activity in the batter after fermentation during the production of some Indian pulse based foods can be eliminated during the final steaming (Rao 1978). Ayyagari *et al* (1989) did not observe any lectin activity in fermented Indian foods such as *dosa* or *dhokla.*

A wide variety of plants and tubers are potentially toxic because they contain cyanogenic glycosides which on acid or enzymatic hydrolysis yield hydrocyanic acid (HCN) that is a potent respiratory inhibitor. Chickpea seeds contain traces of glycosides, well below the permitted toxicity range (Pak and Bajra 1974). Traditional processing methods dramatically reduce the levels of the glycosides (Reddy and Pierson 1994).

The exact mechanism of saponin action is not fully known. Cheeke (1976) reported that saponins may cause growth inhibition. They seem to lower plasma cholesterol levels in several mammalian species and are important in human diets to reduce the risk of coronary heart disease (Oakenfull 1981). The saponin content of chickpea seed is 56 g/kg (dry matter) and is not destroyed by processing or cooking (Fenwick and Oakenfull 1983). The saponin content of *felafel* (prepared from chickpea) was 21 g/kg (dry matter). The same workers obtained a 56% reduction in saponins of soybean tempe fermented with *Rhizopus oligosporus.*

Several workers consider mycotoxins as non-nutritive factors but it must be noted that they are not naturally occurring substances and it is a wet harvest and/or incorrect storage conditions that promote the growth of fungi which synthesises the mycotoxins. Bottalico *et al* (1979) detected mycotoxins in chickpea using thin layer chromatography techniques. The level of aflatoxin contamination, especially B1, increased when chickpea was stored in hessian bags for six months (Nahdi *et al* 1982). *Desi* and *kabuli* seeds showed no large differences in the surface microflora (Deo and Gupta 1980).

2.6 Storage

Over 90% of the total postharvest losses in quantity and quality occur during storage (Salunkhe *et al* 1985). The major losses can be classified as physical (moisture), chemical (autoxidation and hydrolytic degradation of lipids) and biological (grain respiration and infestation by insects, moulds, and rodents).

2.6.1 Losses in Cooking and Milling Quality

Laboratory studies on chickpea storage for 6 months recorded over 55% weight loss (Gupta *et al* 1981). The weight loss has a direct effect on the quantitative and qualitative losses during *dhal* milling (Chitre *et al* 1955). The nutritive value of whole seed is indirectly influenced by hardening of the seed coat when stored for long periods at a high temperature. High temperature, high moisture content, and long storage times decrease the protein quality due to Maillard reaction (Varriano-Marston and De-Omana 1979) and contribute to impaired cookability in several beans (Burr *et al* 1968). The latter is also referred to as hard-to-cook (HTC) phenomenon which is a major

constraint associated with the preparation of pulse based foods for human consumption. The mechanism of HTC is not yet fully understood. Factors that have been implicated in the hardening phenomenon are an increase in the bound protein content of seed coat and aleurone layer and changes to pectins and calcium ions, resulting in loss of water uptake capacity of cotyledons (Bressani 1983). In addition to reducing the palatability and excessive use of fuel, HTC decreases the nutritional quality of pulses (Tuan and Phillips 1991, 1992).

2.6.2 Losses in Nutritional Quality

Decreases in the protein quality of chickpeas stored for long periods are attributed to change in the levels of essential amino acids. Storage for over 12 months caused the majority of the storage proteins to be coagulated or denatured, decreased their water solubility and reduced the amount of available lysine (Ben Gera and Zimmermann 1972, Liu 1997). The reduction in lysine content was in part due to blocking of the ε–NH_2 group of lysine by fat fractions. Reddy and Pushpamma (1986) reported a 10-30% loss of lysine, methionine and tryptophan in chickpea, as well as decreases in net protein ratio and digestibility. Trypsin inhibitors in chickpea are more resistant to loss on storage, a fact which might contribute to poor protein digestibility.

Arya (1981) reported no change in flavour or taste for chickpea *dhal* or flour when stored up to 52 weeks below 11% moisture, but on storage at 14% moisture mould growth and a musty odour occurred after 8 weeks. The musty odour was due to degradation of the free and bound lipids and possibly due to production of low molecular weight unstable compounds. The study also indicated that the proportion of phospholipids in bound lipids decreased, while neutral lipids increased during storage at the higher moisture level.

Heat treatment prior to storage influences the nutritive value of chickpeas. Lipids in heat processed chickpea flours are more stable to oxidative changes than raw flour probably due to the partial inactivation of lipases during the heat treatment (Kowsalya and Urs 1979). Heat treatment also retarded the subsequent oxidation of unsaturated fatty acids, which is a beneficial step in storage quality.

According to Shehnaz and Theophilus (1975), storage of chickpea in bags produced greater loss of thiamin than when stored in bottles, but the trend was reversed for riboflavin probably due to its light sensitivity. Previous studies, however, concluded that high storage temperatures reduce the content of all the B group vitamins (Chitre *et al* 1955, Pingale *et al* 1956). Pingale *et al* (1956) measured thiamin content only and assumed it to be an index of the changes to other vitamins; thiamin content reduced from 432 mg/100 g to 392 mg/100 g in 6 months of storage. Vallidevi *et al* (1972) have reported an average loss of 10% in thiamin, riboflavin and nicotinic acid contents of chickpea *dhal* when stored for one year under ambient conditions.

2.6.3 Losses Due to Infestation

Chickpea stored improperly is subject to attack by insects and moulds causing irreversible physical and chemical damage to the grain. The pulse beetle (*Bruchus chinensis*) is the most common storage insect in chickpea (Gupta *et al* 1981). According to Yannai and Zimmermann (1970), cultivar differences also exist in the susceptibility of chickpea to pulse beetle attack. This insect inflicted more rapid deterioration of *kabuli* chickpea than of *desi* types. In fact, *desi* types are more resistant to fungal and insect attack both during seed maturation and storage. This could be attributed to their darker seed coat which has higher levels of tannins (J B Brouwer, Personal Communication VIDA 1994).

Shehnaz and Theophilus (1975) and Gupta *et al* (1981) report that insect infestation causes a decrease in the weight-volume ratio, 55% loss in seed weight, an increase in kernel damage, a 3% increase in moisture and a decrease in viability. Chemical and nutritive changes in chickpea during storage caused by the attack of pulse beetle have been the subject of several investigations (Vallidevi *et al* 1972, Wadnerkar *et al* 1978). Insect infestation doubled the protein and ash content and reduced the starch levels when compared with the control sample. The increase in protein and ash contents may be due to the consumption of endosperm (high in carbohydrates and low in proteins and ash) by the insects (Shehnaz and Theophilus 1975). The endosperm damaged by infestation facilitates the autoxidation of the fat present in the chickpea with a corresponding increase in free fatty acids. Infestation lowered the PER of chickpea *dhal* (Parpia 1973) probably because of deficiencies in essential amino acids or the

presence of deleterious metabolites like uric acid (Bressani 1983). A marked decrease (24%) in the tryptophan content of infested chickpea seed has been reported (Shehnaz and Theophilus 1975). The colour of *dhal* produced from insect infested chickpea was similar to control but developed a bitter taste on cooking due to the accumulation of insect excreta.

2.6.4 Losses Due to Fungal Attack

Generally, pulses do not support the growth of toxigenic fungi and the production of mycotoxins (Webley *et al* 1997), however, chickpea seeds have been reported to carry a microflora of 'field' and 'storage' fungi (Ahmad and Singh 1991). Toxigenic strains of *Aspergillus flavus*, *A. niger*, *A. nidulans*, *A. ochraceus* and *Penicillium* species grow vigorously and initiate grain spoilage and aflatoxin elaboration. The shift in mycoflora spectrum was more rapid in seeds stored in jute bags than those stored in metal bins (Ahmad and Singh 1991) and when the storage period exceeded 6 months (Deo and Gupta 1980). Aflatoxin B_1 was found to be the most prevalent toxin as a result of storing mouldy chickpeas (Ahmad and Singh 1991).

In early 1993, *kabuli* chickpea from the Wimmera region of VIC were infested with a white fungus, predominantly *Botrytis cinerea* which is not known to be toxigenic. The chickpeas were considered safe for human consumption after a series of tests showed that a wide range of mycotoxins including aflatoxin, ochratoxin and trichothecenes were not present (AGT and Department of Agriculture, VIC 1993).

2.6.5 Control of Losses

Physical treatments such as regular sun drying (58 °C for 10 minutes) is the cheapest, simplest and most effective method to keep stored chickpea free from insect infestation. Several types of oil (*neem*, garlic and mustard) and other inert particles such as sand, wood and ash have been successfully used in the small scale storage of pulses (Quadri and Rao 1979, Amonkar and Bannerjee 1971). The effectiveness of traditional methods such as the those mentioned above on a commercial scale needs to be further investigated. Rough seed coats (Schalk 1973) and protease inhibitors (Applebaum *et al* 1964) are known to offer resistance against insects in pulses.

Ionising radiations as a method to control infestation of stored pulses has been successfully attempted (Roy and Prasad 1993). A dose of 1 kGy of gamma radiation completely killed adult pulse beetle (*Callosobruchus chinensis* Linn) in Bengal gram within a week, but the dose of 0.5 kGy required two weeks to achieve the same level of mortality. A dose of 1 kGy is the preferred dose for the control of weevils during storage up to 6 months. Pyrethrum, carbamate insecticides and fumigants (carbon disulphide, phosphine) are lethal to insects, degrade to non toxic residues and are safe to use. However, improving the design of storage bins at an affordable cost will be the most effective method to maintain quality of stored grain (D Webley, Personal Communication AWB 1994). The improved bin design should be used at all points where large quantities of crop is stored and should enable rapid heat dissemination that will occur due to respiration.

2.7 Processing and Utilisation

Chickpea seeds are processed into a variety of products by a combination of one or more processes before consumption. The processes can be classified as:

- (a) **wet**; which includes soaking, cooking, sprouting (germination), fermenting, canning and wet grinding the whole seed or splits and
- (b) **dry**; which involves dehusking/dehulling *desi* chickpea to obtain *dhal* and milling of *dhal* to produce flour, referred to as *besan*. The *dhal* and the flour are further processed domestically to produce a range of foods or processed industrially into weaning foods, extruded products or baked goods.

In India, about 75% of chickpea is consumed in the form of *dhal* or *besan*, and the remaining 25% as whole seed (Jambunathan and Singh 1989). Developing green (immature) chickpeas harvested 10-15 days before maturity are consumed as snacks or vegetables with the major meal of the day. Green chickpeas have less starch and protein and more sugars than mature chickpeas and they are easily digested even when eaten raw (Pushpamma and Geervani 1987). Some important chickpea based foods that are made from one or more processes from around the world are listed in Table 2.13.

Table 2.13 Some important food preparations of chickpea from around the world

Food	Component	Process	Country
Dhal	Decorticated dry split cotyledons	Soaking, cooking	India, Bangladesh, Nepal, Pakistan
Chhole	Whole seed	Soaking, cooking	Afghanistan, Bangladesh, India, Iran, Pakistan
Pakoda	*Besan*	Frying	Indian subcontinent
Unleavened bread	*Besan*	Mixing dough, cooking	Ethiopia, India, Syria, Pakistan
Kiyit injera	Whole seed	Fermentation	Ethiopia
Snack	Whole seed	Roasting at high temperature.	Afghanistan, Ethiopia, India, Iraq, Iran, and Nepal
Homos-biteheneh	Whole seed	Soaking, boiling, grinding	Egypt, Jordon, Lebanon, Syria, Tunisia, and Turkey
Tempe	*dhal*	Fermentation	Canada, USA
Lablebi	Whole seed	Soaking, boiling	Jordan, Tunisia, Turkey
Dhokla	*Besan*	Fermentation	India
Salad	Whole seed	Soaking, boiling	Australia, Canada, Mexico, Spain, USA
Green immature seeds	Whole green seed	Roasted/blanched	Ethiopia, India, Iran, Nepal, Pakistan, Sudan

Jambunathan and Singh (1989)

2.7.1 Soaking

Soaking precedes cooking for most whole seeds and is measured as the extent to which the seeds absorb water. It is represented as hydration capacity (HC) and is

expressed as the percentage increase over the fresh weight. Some workers insist that the water absorption calculations should correct for solids lost during soaking (Jackson and Varriano-Marston 1981). Soaking of beans has been credited with the removal of toxic substances contained in the raw seeds (Kakade and Evans 1966, Liener 1962) and promotion of trypsin inhibitor inactivation during cooking (Bressani 1973).

2.7.1.2 Soaking: Water Absorption and Mechanism

Singh *et al* (1991) observed no differences in water absorption for the two chickpea genotypes. Studies conducted in Australia among the *desi* types indicated that Dooen exhibited the lowest rate of hydration and attained maximum absorption after 16 hours, compared with 8-10 hours recorded for Amethyst (Saini and Knights 1992). According to Saini and Knights (1992), water absorption at the end of 16 hours was highest for Semsen (102%) followed by Amethyst (99%), Dooen and Tyson (96%). Barwon recorded the lowest water absorption at the end of 16 hours (94%). According to the same workers, for *kabuli* cultivars, the hydration maximum was reached after 8 hours of soaking, although the initial hydration rates were relatively lower than for the *desi* type. After 16 hours hydration, the overall water absorption was higher for *kabuli* than for *desi* types, and perhaps reflects the difference in seed size. It thus appears that the seed size has an influence on the HC only when soaked for prolonged period. This suggests that the mechanism of water imbibition is not directly related to seed size.

Legesse and Powell (1996) studied the rate of water imbibition in chickpea at different stages of maturation and observed that cultivars with unpigmented seed coats when mature imbibed rapidly at all stages of maturation, although the overall water uptake was less in mature seeds. The rate of water uptake decreased markedly once pigmentation of the seed coat developed during maturation. The decrease in water uptake was attributed to the increased adherence of the seed coat to the cotyledons with little change in seed coat permeability during maturation of the pigmented (*desi*) cultivar. Autoradiaographic studies by several workers (Jackson and Varriano-Marston 1980, Moss 1977) have demonstrated that diffusion in the solid endosperm is the main mechanism that controls the rate of absorption in seeds regardless of the

mode of entry of the moisture. The rate of penetration of water is thus affected by seed size, seed hardness, and the permeability of the seed coat. Permeability of the seed coat is apparently affected more by environmental factors than by genetics and is influenced by the chemical make up of the testa-pericarp, including tannins and lignin, and by the pattern of development and dehydration of the seed coat during maturation (Williams and Singh 1987).

Increased cooking times for stored beans have been related to the development of 'hardshell', a condition, defined by Bourne (1967) whereby seeds fail to absorb water within a reasonable soaking time. However, Burr *et al* (1968) suggested that water imbibition rate was not related to cooking time. (Discussed in 2.6.1). They found hard-to-cook (HTC) beans imbibed water as quickly as normal beans and Molina *et al* (1972, 1976) confirmed those findings. Jackson and Varriano-Marston (1981) also observed no change in water absorption for fresh and stored beans, provided corrections were made for solids lost during soaking. Seeds with the highest rates of hydration are likely to be those with the shortest cooking time (Williams *et al* 1983). Silva *et al* (1981) found no significant differences in maximum water uptake in black beans among distilled water, tap water and sodium bicarbonate solutions. Soaking temperatures (10, 22, 35 °C) also had no significant effect upon maximum water absorption, although a slightly higher total water uptake was observed at 35 °C. Kon (1979) found that soaking at elevated temperature (up to 90 °C) increased the rate of water absorption in white beans. Short soaking times also reduce microbial growth that is likely to occur over long soaking periods (Hoff and Nelson 1966). There is little information reported in the literature on the optimum soaking conditions for chickpea.

2.7.1.3 Soaking Losses

Soaking of chickpea seeds for 6 hours significantly decreased the quantity of available carbohydrate, total soluble sugars, reducing sugars, non-reducing sugars and starch. When the soaking time was increased to 12 hours, the extent of decrease in all these carbohydrates was more pronounced (Jodd *et al* 1986). The losses increased when the soak medium contained sodium bicarbonate. The reduction in the level of carbohydrates occurs mainly because of their solubility in water and sodium bicarbonate solution. No data describing appropriate soak time and temperature

conditions for chickpea is available, but information on other pulses, for example, Californian white beans suggests chickpea should have similar hydration properties. Losses of total solids, N compounds, total sugars, oligosaccharides, calcium, magnesium, and three water soluble vitamins (thiamin, riboflavin and niacin) were measured in Californian small white beans and found to be very small at soaking temperatures up to 50 °C. A three to four fold increase in losses were observed when temperature of soak solution was raised to 60 °C.

Soak time and cooking time is significantly reduced if the soak solution contains a combination of salts. Soaking seeds in a combination of different salts, sodium bicarbonate, or sodium chloride solutions at controlled pH has a positive influence on cooking time, but had a detrimental effect on quality (Chavan *et al* 1983, Singh and Rao 1995).

2.7.2 Cooking

Cooking produces a tender, edible product, develops the aroma and inactivates antinutritional factors in pulses (Rao and Deosthale 1982). A considerable amount of chickpea produced in the world is consumed in the form of whole seed (Williams and Singh 1987) and it appears that *kabuli* type types are preferred in terms of cooking time and general acceptability. Cooking time is a highly heritable characteristic in that if genotypes differing widely in cooking time are grown at different locations, the differences between genotypes persist (Williams and Singh 1987). Despite this observation, a significant interaction between location and cooking time has been identified. It has been defined in various ways; as the time required for 50%, 90%, (Saini and Knights 1992) up to 100% of the seeds to become soft (cooked). Cooking time is defined as the time taken from the beginning of the test to when the seeds are ready to eat which means that at least 90% of them are soft enough to masticate without having to chew (Williams and Singh 1987). According to Williams *et al* (1983) cooking time is defined as the time from commencement of boiling until 90-100% of the seeds are cooked, as determined by visual determination of the degree of gelatinisation and also softness of the seed as determined by pressure of the thumb and finger.

2.7.2.1 Cooking: Principle and Mechanism

Cooking of pulses involves gelatinisation of the starch and disorientation of the cellular matrix of the seed to the extent that it becomes soft enough to disintegrate readily in the mouth. In the chickpea, it can be followed by colour change of the white starch-containing cotyledon to a clear amber colour which develops during gelatinisation of the starch. The time taken to cook is affected by the permeability of the seedcoat and the cotyledon to hot water, the physical hardness of the seed, the chemical composition of the cell walls (all of which affect the rate of penetration), the physical size of the seed which governs the distance water must penetrate in order to reach all parts of the seed, the type of water used in cooking and by altitude of cooking location (Silva *et al* 1981). Since size has such a profound effect on cooking time, all agronomic factors that influence seed size will indirectly affect cooking time. The high positive correlation between size and cooking time, however, disappeared when *kabuli* chickpea seeds were soaked prior to cooking. The cooking time of large seeded *kabuli* chickpeas was reduced to a greater degree than that of the small seeded genotypes, and the mean cooking time of large seeds, after soaking (46 $\pm$ 9.7 minutes) was less than that of small-seeded genotypes (60 $\pm$ 4.7 minutes) (Singh *et al* 1988). This can be attributed to differences in testa/pericarp since there is a strong negative relationship between seed size and the thickness of the testa/pericarp in *kabuli* chickpea (unpublished study ICARDA).

Cooking times of unsoaked black beans increased 4.5 times at higher altitudes compared to soaked seeds at sea level (Silva *et al* 1981). There is no reported study evaluating the effect of altitudes on cooking times of chickpea. Soaking in salt combination solution (2.5% sodium chloride, 1% sodium tripolyphosphate, 0.75% sodium bicarbonate and 0.25% sodium carbonate) decreased cooking time to less than 2 hours (Varriano-Marston and De Omana 1979). Cooking time is also affected by the nutrient level of the growing environment, including water, nitrogen, phosphorus and other minerals, by the level of amylose content of starches, by storage conditions and duration of storage, and finally the pre-treatments that precede cooking. Extensive overcooking of pulses can result in decreased nutritive value, thus optimal soaking/cooking regimes should be followed (Molina *et al* 1975).

2.7.2.2 Cooking Time *Desi* v/s *Kabuli*

Singh *et al* (1987) reported a range of 50 to 237 minutes for the cooking time of whole *kabuli* types. They did not determine cooking times of whole *desi* types because they are generally decorticated and split before consumption. Singh *et al* (1991) found that whole d*esi* seeds required considerably more time, although some *desi* genotypes cooked as fast as *kabuli*, possibly because of their small seed size. Williams *et al* (1983) reported a positive and significant correlation between seed size and cooking time for chickpeas which was substantiated by Singh *et al* (1988). Another group of workers (Singh *et al* 1991), however, reported that two gentoypes with similar seed size had different cooking times. Contrary to the above finding of Singh *et al* (1991), Saini and Knights (1992) reported cooking time for *desi* types to be in the range of 75-90 minutes as compared to 70-110 minutes recorded for *kabuli* types. An evaluation of the cooking times of three Australian grown *desi* cultivars (Barwon, Semsen, and Tyson) grown over three seasons revealed no differences in the cooking and soaking characteristics, with the exception of Semsen which showed lower HC and slightly longer cooking time. They also found that protein content was positively and significantly correlated with the cooking time of whole seed and *dhal*. Interestingly, a positive significant correlation has been observed between the cooking time of *dhal* and whole seed (Jambunathan and Singh 1989). The cooking properties of *dhal* from *kabuli* is not an issue because *kabuli* seeds are seldom processed to produce splits.

Several studies have proved beyond doubt that soaking chickpea seeds and splits in water significantly reduces subsequent cooking time and a further decrease in cooking time was observed when seeds were soaked in sodium bicarbonate or weak salt solutions (Williams and Singh 1987, Singh *et al* 1988, Saini and Knights 1992). It must be highlighted that soaking pulse seeds is a routine household practice in regions where pulses make a staple component of the diet with a view to minimising fuel costs. In fact, the observed reduction in cooking time due to soaking eliminated differences between cultivars, suggesting that the factors contributing towards cooking time were affected to different degrees by soaking. This, combined with the influence of growing environment upon cooking times, leads to the conclusion that cooking time is probably

less important in a chickpea breeding program than was originally believed (Williams and Singh 1987).

2.7.2.3 Roasting and Puffing

Puffed chickpea seeds are a popular high protein, low fat, cheap snack in India. Roasting and puffing are ancient methods of processing pulses and have not been modernised or automated, although some degree of mechanisation has occurred recently. Graded seeds are heated in a pan to about 80 °C, cooled overnight, and sprinkled with fresh or salt water. The moistened grain is then toasted with heated sand in a shallow pan at high temperatures (200 to 500 °C) for 1-2 minutes during which time the puffing occurs. The roasted and puffed chickpea is then gently rubbed against a coarse surface, or beaten in bags to break the husk which is removed by winnowing (Kurien 1984). Puffed chickpeas show a 20-40% increase in bulk volume compared to puffed cereals (Kurien 1985).

The low expansion in volume of puffed chickpea is attributed to the properties of starch and starch-protein interactions. Amylose content of chickpea starches and the ratio of amylose to amylopectin can influence the degree of puffing (M Wootton, Personal Communication UNSW 1995). Reports obtained from the sub-continent suggest that Australian *desi* chickpea varieties currently sold to that market have inferior puffing characteristics compared to the local produce (N Malleshi Personal Communication, CFTRI 1994). Puffing qualities of chickpea can be enhanced by the use of hardening agents such as calcium phosphate, egg white, and calcium and sodium caseinate (Kurien *et al* 1972). The husk content was found to have a direct correlation with the puffing ability of chickpea. Puffed chickpea of optimal quality was obtained when chickpea cultivars with 16% husk content were used.

Roasting and puffing decrease the level of free lipids by 15-18% and increased level of bound lipids (Chandrashekhar *et al* 1983). Puffing resulted in the retardation of oxidation of unsaturated fatty acids, but roasting alone did not produce such a beneficial effect. Roasted chickpea, however, was found to reduce the blood cholesterol level to a greater extent than raw chickpeas in rats (Chandrashekhar *et al* 1983). Prolonged cooking results in destruction and racemisation of amino acids,

changes in the protein structure and often reduces protein digestibility (Sathe *et al* 1981).

2.7.2.4 Effect of Cooking on Nutritive Quality of Chickpea

Pressure cooking (domestic) or autoclaving (laboratory) are modifications of the conventional cooking procedure that are used to reduce cooking time of pulses and produce a more nutritive product (Silva *et al* 1981). The protein quality of chickpea is improved to a greater extent by moist heat treatment than by dry heat (Kowsalya and Urs 1980, Chandrasekhar *et al* 1983), however, Attia *et al* (1994) report a significant decrease in protein content of chickpea seeds after such cooking. According to El-Faki *et al* (1984), boiling and pressure cooking did not improve the *in vitro* protein digestibility, however, Rao *et al* (1964) observed that pressure cooking for 15 minutes improved the PER of raw chickpeas from 1.3 to 2.4. As a result of heat treatment, lysine and methionine undergo considerable nutritional damage (Sathe *et al* 1982). Pressure cooked and boiled chickpea splits exhibited the largest reduction in the content of water soluble vitamins as compared to chickpeas that were processed by other cooking methods such as roasting, puffing, extrusion cooking, parching and soaking followed by frying. Studies recommend roasting of chickpeas for no longer than 10 minutes at 120 °C in order to retain its nutritive value (Rao 1974). The roasting of chickpeas at higher temperatures decreased available lysine by 12-15% and decreased protein digestibility. Roasting at 100 to 110 °C for 5 minutes and autoclaving for 20 minutes produced comparable protein quality in chickpea (Usha *et al* 1972).

The effects of cooking method on the amino acid and vitamin contents of chickpea are presented in Table 2.14 and the effect on mineral content of chickpea due to cooking is given in Table 2.15.

Table 2.14 shows greater than 50% reduction in the cystine content of boiled and parched whole chickpea seed compared to the raw whole seed. The losses in cystine content, however, were of a lesser magnitude in boiled, pressure cooked or roasted *dhal* compared to raw *dhal*. Riboflavin levels in boiled and parched whole seed was halved compared to the level in whole seed.

Table 2.14 Effects of cooking method on the amino acid and vitamin contents of chickpea

Cooking Method	Amino acids (g/16 gN)			Vitamins (mg/100 g)		
	Methionine	Cystine	Lysine	Thiamin	Riboflavin	Niacin
Whole seed						
Raw	1.1	1.3	6.20	0.40	0.30	2.90
Boiled	1.05	0.63	6.30	0.42	0.10	2.90
Parched	1.08	0.50	6.20	0.39	0.14	3.00
Dhal						
Raw	1.34	0.68	6.84	0.50	0.23	3.10
Boiled	1.03	0.53	6.40	0.21	0.06	2.30
Pressure cooked	1.04	0.50	6.46	0.19	0.05	2.40
Roasted	1.00	0.62	6.26	0.36	0.07	2.70

Geervani and Theophilus (1980)

Table 2.15 Effect of cooking on the mineral content of chickpeas

Minerals (mg/100 g)	Raw seed	Cooked seed	Cooking fluids
Calcium	103.1	55.6	20.3
Phosphorus	354.0	190.0	75.0
Magnesium	91.7	47.1	42.8
Iron	5.8	3.3	2.4
Copper	0.9	0.5	0.2
Manganese	1.7	1.0	0.2
Potassium	692.3	325.8	372.8
Zinc	2.9	1.7	0.6
Sodium	12.7	8.0	7.4

Meiners *et al* (1976)

The levels of thiamin, riboflavin and niacin were significantly reduced in heat processed *dhal* compared to raw *dhal,* with riboflavin levels being the most affected (Table 2.14). Table 2.15 shows cooking causes a significant leaching of minerals into the cooking fluids. The mineral content of the cooking fluid, especially with respect to magnesium, potassium and sodium, was as much as the cooked chickpea seed suggesting that cooking fluids should not be discarded while preparing pulse based meals, in order to minimise nutritional losses. Attia *et al* (1994) have reported significant reduction in the total ash content in the cooked seed, especially in potassium and calcium contents. These results follow the same trend as the previous findings of Meiners *et al* (1976). The minerals in cooked seeds exhibited a 0.3 to 0.5% decrease from that of raw seeds (Meiners *et al* 1976). Copper values reported in Table 2.15 were in good agreement with data from Walker and Hyomwitz (1972) on US grown samples, but were considerably lower than data from India by Roychowdhury (1962), who found 4.9 mg/100 g of raw chickpeas. Mieners *et al* (1976) report that their data were in reasonably good agreement with other North American data, but differed markedly with data from other countries such as India, Brazil and Lebanon. There is no data base on the mineral content of Australian chickpea for a comparative study with crops from other parts of the world.

When cooking followed soaking, the extent of carbohydrate loss was quite significant (Jodd *et al* 1986). This is because the solubility of sugars that are hydrated during the soaking process increases in boiling water (during cooking). Cooking increased the raffinose content from 1.6% in the raw seed to 2.7%, the verbascose plus stachyose content from 0.5 to 0.7% and sucrose levels increased from 0.7 to 2.6%. When cooking water was discarded, the levels of these oligosaccharides decreased by 45 to 80% in chickpeas (Iyengar and Kulkarni 1977). However, Rao and Belvady (1980) report a significant increase in level of oligosaccharide content. The anomaly in findings is because of the inclusion of cooking water in the analyses by the latter workers. Cooking improves the *in vitro* digestibility of carbohydrates in chickpeas (El Faki *et al* 1984). Significant and large increases in neutral detergent fibre, acid detergent fibre and cellulose was observed in cooked seeds (Vidal-Valverde and Frias 1991, Attia *et al* 1994).

2.7.2.5 Unconventional Cooking Procedures

Researchers are continuously investigating newer methods that would facilitate pulses to cook rapidly. Availability of such method(s) may increase consumption of pulses in the western world. It is also important that these procedures retain the nutritional properties of pulses. Unconventional cooking techniques will become popular only if they are simple and offer economic benefits.

2.7.2.5.1 Vacuum Infiltration

A vacuum infiltration method to prepare quick-cooking dry beans was proposed by Rockland and Metzler (1967). The method consists of (a) loosening seed coats by vacuum infiltration in a solution containing sodium salts, (b) soaking the beans in the same salt solutions, (c) rinsing, and (d) drying. The resultant product cooks in 15 minutes or less. Rockland and Jones (1974) indicate that this process does not greatly affect the structure and appearance of the beans when compared with untreated samples. The technology can be applied to chickpeas as well, however, the method has failed to make an impression in the pulse processing industry.

2.7.2.5.2 Enzyme Treatment

Pectinase treatment caused a remarkable decrease in the cooking time of pigeon peas as compared to other enzyme treatments such as papain, phytase, amylase (Singh and Rao 1995). The mode of action is the degradation of pectic substances, thereby reducing their ability to complex with divalent metal ions such as calcium and magnesium (Muller 1967). This may facilitate cell wall dissolution during the cooking process causing a reduction in cooking time (Paredes-Lopez *et al* 1991). The general acceptability for the pectinase-treated samples was good (Singh and Rao 1995). Most of the research utilising enzymes is restricted to pulses that are notorious for their prolonged cooking time and the effect of phytase on the cooking time and acceptability of chickpea has not been addressed.

2.7.2.5 3 Micronisation

Micronisation is a cooking process that uses a band of infra red energy in the range of 1.8-3.4 microns which penetrates whole seeds (pulses or grains) and rapidly increases internal temperature. This is achieved due to the vibration of the molecules at a frequency of 80-170 megacycles/second. A temperature of 90 °C can be achieved in 50 seconds, thus making it an appropriate technology for pulses which are notorious for prolonged cooking times. The technology has been successfully used for cooking grains for multi grain bread, rice and peas (FRI 1994). Recently micronising radiations have been used to lower the level of trypsin inhibitors in soybeans and reduce surface microflora, especially xerophilic moulds.

Sarantinos and Black (1996) reported that micronised chickpea seeds displayed poor cooking quality and postulate that it is due to seed hardening which largely affects the testa. They reported no change in the oligosaccharide, sugar, or starch contents and oil absorption capacity in the flour obtained from micronised chickpeas, but the sample exhibited substantially reduced water absorption. Despite some of the physico-chemical changes associated with the process, they claim micronised chickpeas may have some potential food uses, especially in extruded products.

2.7.2.6 Objective Methods to Measure Cookability of Pulses

There are several reviews in the literature about cooking time or cookability measurement and their associated subjectivity with pulses (Muller 1967, Iyer *et al* 1980). Traditionally, soaked seeds are cooked in boiling water for extended periods (60-90 minutes, depending on the pulse) in an open pan or cooked for 10-15 minutes under pressure. Some researchers have cooked unsoaked seeds which increases the cooking time dramatically making the procedure time consuming, labour intensive (Singh *et al* 1988), operator dependent and poorly reproducible. In fact, Singh *et al* (1988) suggest eliminating the laborious cooking test and use seed weight as an adequate predictor of cooking time for selection purposes.

As cooking quality is an integral part of pulse breeding programs many researchers have tried to measure the time required to soften the seed when boiled in the presence

of water. Two of the most popular equipments used to estimate cooking time or degree of doneness are the Mattson cooker and texture analyser, respectively.

2.7.2.6.1 Mattson Cooker

Burr *et al* (1968) and Kon (1968) used the Mattson type experimental device (Mattson 1946) for measuring cooking times for different varieties of beans. The device consists of a frame holding 100 saddles each of which contain one presoaked bean. A vertical plunger weighing 100 g and terminating at its lower end in a 1.6 mm diameter stainless steel rod rested on each bean. The cooker is then placed into a 2 L beaker containing 1.4 L of boiling water. At the end of each minute of cooking the number of beans penetrated by the plunger was recorded. Cooking time, taken as the time required to cook 50% of the sample (Morris 1963), is recorded from the point of contact between cooker and boiling water. Jackson and Varriano-Marston (1981) used a modified version of Mattson device for cooking 25 seeds at a time and a piercing rod of 82 g.

Saini and Knights (1992) used such an experimental cooker and reported cooking times ranging from 52-76 minutes for the *desi* types, as compared to 62-81 minutes for the *kabuli* types and concluded that the method of cooking has a marked influence on the cooking times of chickpeas. The cooking times reported are lower than those recorded for the same samples by the traditional method probably because the plunger is more sensitive than the finger and thumb.

A major limitation of the Mattson cooker is that it requires uninterrupted attention of the operator to observe the penetration of plungers into the seeds as cooking progresses and often the rods have to be guided into the seed giving false results. Procedures for statistical comparison of data corresponding to different treatments are also not established. Molina *et al* (1976) puncture-tested cooked beans in a locally built penetration-type device, equipped with a digital readout registering the electromagnetic force applied to the sample. Chhinnan (1985) adapted the Mattson cooking device with appropriate electronic circuitry and mechanical modifications for automatic monitoring of movement of plungers penetrating the seeds while they are cooked and named the prototype device 'electronic bean/cowpea cookability device'

EBcoCD. The performance of the device was reported to be satisfactory and adaptable to other pulses.

2.7.2 6.2 Texture Analyser

Objective techniques reported in the literature measure the force required to puncture, extrude, or deform individual beans or bulk of beans using texture analysers (Binder and Rockland 1964, Voisey and Larmond 1971, Sefa-Dedeh *et al* 1978). Silva *et al* (1981) used the puncture test developed by Bourne (1972) to evaluate the textural quality of black bean and they expressed the results as the average maximum force in grams required to puncture a bean.

The Instron puncture test was highly correlated with sensory texture measurements, showing that a puncture force of 150 g distinguishes 'eating-soft' cooked black beans from undercooked (175 g) and overcooked (125 g) samples (Silva *et al* 1981). The multipurpose shear press has been used to estimate the quality (cooking rates) of processed lima beans (Binder and Rockland 1964). The texture of cooked lentils was measured with a Kramer shear press fitted with a ring and a thin multiblade shear compression cell. The maximum force required to shear the sample was expressed as kg/g and used as an index of cooking quality of the lentils (Bhatty *et al* 1983). No reports are published on the adaptation of such objective tests to predict the cookability of chickpea.

2.7.3 Germination (Sprouting)

With increased emphasis on the nutritive value of foods, sprouts are gaining popularity because of their so-called 'natural' status (Fordham *et al* 1975). Germination is a simple, safe, inexpensive, and nutritionally positive method of processing chickpeas before consumption (Jaya and Venkataraman 1980a). The time required to sprout is generally short, the production yield is high and the process does not require soil or sunlight (Chen *et al* 1975).

Chickpea seeds are germinated by soaking in water for four hours followed by holding in moist cloth in darkness at room temperature (25 to 27 °C) for 24 to 72 hours (Venkataraman and Jaya 1975). Paper towels are often used as a medium for

sprouting in laboratory conditions, however, quality of sprouts needs to be monitored because of possible mould growth.

Germination tests in Australia have mainly been restricted to determining seed quality and vigour and not on producing sprouts as an end product, with the exception of mung beans. Germination procedures recommended by the ISTA (International Seed Testing Authority) are followed in Australian laboratories. Seeds are germinated in a controlled environment (incubator) set at 20 °C for 16 hours in the dark followed by 30 °C for 8 hours with a light source (A Williams, Personal Communication AGT 1995).

2.7.3.1 Changes Associated with Germination

During germination the seeds undergo pronounced metabolic changes (Koller *et al* 1962). A substantial amount of protein and carbohydrate is enzymatically hydrolysed to amino acids and sugars, respectively, and Chen *et al* (1975) reported the rapid synthesis of provitamin A, B-complex vitamins and vitamin C in germinating seeds.

Sprouting has been reported to alter the chemical composition, protein quality, and cooking characteristics of chickpeas (Azhar *et al* 1972, Ganeshkumar *et al* 1978) with protein, fat, carbohydrate, dietary fibre and ash contents decreasing with increasing germination period. Table 2.16 shows the changes in chemical composition of germinated chickpea. As the period of germination increased levels of most parameters decreased in the germinating seed. This is because the nutrients are being used to provide nourishment to the sprout. There was no net synthesis of amino acid during germination but the proportion of some of the essential amino acids were altered. *In vitro* protein digestibility increased with enzyme incubation time and was higher for germinated chickpea. This has been attributed to the modification and degradation of storage proteins. According to Venkataraman *et al* (1976) there was no improvement in the BV, digestibility coefficient and NPU of chickpea as a result of germination although Chattopadhyay and Banerjee (1953) did report an increase in BV in chickpea proteins.

Carbohydrates are the principal substrates that undergo major qualitative and quantitative changes during early stages of germination (Jaya and Venkataraman 1980b). Total sugars, reducing sugars, and non-reducing sugars in chickpea decrease during the first 24 hours of germination (Jodd *et al* 1986). This is attributed to the sugars being utilised for the production of energy needed for various processes occurring in germinating seeds.

Table 2.16. Chemical composition (g) per 100 germinated *desi* chickpea seeds

Tests	0 hour	24 hour	48 hours	72 hours
Weight (dry)	12.7	12.3	11.2	11.0
Total Carbohydrate	8.6	8.4	7.6	7.5
Protein	2.6	2.6	2.5	2.5
Fat	0.7	0.6	0.5	0.4
Dietary Fibre	0.5	0.5	0.4	0.4
Ash	0.4	0.3	0.3	0.3
Calcium (mg)	25.3	24.4	22.1	22.2
Phosphorus (mg)	39.9	39.2	35.7	35.4
Iron (mg)	1.8	1.2	1.1	1.1
Oligosaccharides(%)				
Verbascose+stachyose	1.1	0.6	0.3	0.1
Raffinose	2.4	1.1	0.6	0.3

Jaya and Venkataraman (1980a), n = 1

Total carbohydrate concentration decreased during 96 hours of germination in chickpea (Jaya and Venkataraman 1981). During germination, starches are hydrolysed by hydrolytic enzymes which degrade amylose and amylopectin by successive removal

of low-molecular weight compounds from the non-reducing chain ends releasing maltose (Swain and Dekko 1966).

Starches from germinated chickpea have improved swelling power and solubility but their intrinsic viscosity is low. These starch effects enhance the nutritional value of germinated pulses (Jaya 1978) by increasing digestibility. Germination up to 48 hours improved the *in vitro* carbohydrate digestibility while 96 hours germination did not have any additional effect. Digestibility was better when chickpea was treated with β-amylase than when treated with α-amylase (Jaya and Venkataraman 1980b). Since there is a decrease in carbohydrates, the calorific value of germinated seeds on a dry weight basis is lower than that of raw seeds (Chen *et al* 1975).

Information on effect of germination on flatus factors in pulses is controversial. Shurpalekar *et al* (1973) reported a decrease in flatulence in chickpea and Jaya and Venkataraman (1980a) also observed that the oligosaccharide content decreased with germination (Table 2.16). Rao and Belavady (1978) report a significant reduction in the raffinose family oligosaccharide content of chickpea on germination. However, germination increased gastrointestinal flatus in chickpea diets at 72 hours of germination in rats as compared to green gram diets (Venkataraman and Jaya 1975). Jodd *et al* (1985, 1986) recommend 24 hour germination as a reasonably good treatment for reduction of flatus factors as well as avoiding excess losses of the available carbohydrates. Germinated chickpea is more effective in lowering serum cholesterol than the ungerminated chickpea (Jaya and Venkataraman 1979). The authors, however, were unable to explain their observation and suggest that the effect could be due to a combination of factors. They recommend studying the effect of different fractions of ungerminated and germinated chickpea seed on the cholesterol levels of rats and identifying the fractions that may be responsible for the hypocholesterolemic effect.

Studies conducted by Kylen and Rolland (1975) on a range of sprouts report an increase in the riboflavin and niacin contents. Fordham *et al* (1975) report that sprouts alone may be a significant source of B-group vitamins. Cooking time of chickpea was drastically reduced by germination (Deep *et al* 1978). The phytin, free pectin and

calcium contents were reduced on germination, while magnesium content was relatively unaltered. Since any one of the parameters viz., phytates, calcium, magnesium and free pectin contents cannot individually account for the cooking pattern in pulses, Muller (1967) suggested the cumulative effect of these as PCMP number in a mathematical formula. The concept of PCMP number as applied to unsprouted and sprouted pulses was valid for chickpeas. Germinated chickpea requiring prolonged cooking time had higher PCMP number (11.06) while the shortening of cooking time in germinated chickpea was directly correlated with a lowering of PCMP number (7.25) (Ganeshkumar *et al* 1978).

2.7.4 Canning

Immature green chickpeas in cans or as a long life dehydrated product is gaining popularity in the Indian sub-continent. Immature green seeds are rich in proteins, total sugars, minerals and vitamins (Ramanathan and Bhatia 1970). Blanching of seeds followed by canning results in loss of the original colour (Siddappa 1959). However, preliminary soaking of seeds in sulphite solution helped in the retention of the green colour in the immature seeds and the colour of mature seeds (Luh *et al* 1978). Similarly, soaking in sodium sulphite and addition of 300 ppm EDTA in the canning brine improved the colour retention in canned chickpeas without affecting the chemical composition (Daoud *et al* 1977). Thiamin losses increased at higher concentrations of sulphite in the soak solutions but riboflavin and niacin were largely retained during soaking prior to canning (Luh *et al* 1978). Vitamin B6 retention in the canned product was affected by the use of sodium sulphite in the soaking water as a bleaching agent. White (1970) stated that pulse consumption might be increased through development of spicy, quick cooking or ready-prepared dishes with built-in appeal. Loss of nutrients during processing, and consumer acceptance are the major obstacles in popularising canned products. Chickpea varieties most suited to canning need to be identified and further investigations are essential to standardise the processing conditions on commercial scale.

2.8 Milling

Dehulling of pulses has been one of the traditional, labour intensive and inefficient operations practised domestically in Asian and African villages (Kurien and Parpia 1968). Dehulling involves loosening of the husk, either by wet or dry methods, removing the seed coat mechanically and splitting the cotyledons (Kurien *et al* 1972). Dehulling enhances appearance and texture, reduces the cooking time, lowers the level of ANF, reduces the fibre content, improves protein quality, increases palatability and digestibility of pulses (Singh 1995). The dehulling process and consequently *dhal* yield is influenced by agronomic practices, genotypes, pre-treatments, husk content, shape and size of the pulse, type of machinery used, moisture content, hardness, chemical nature and hydration level of the gums (Singh and Jambunathan 1981, Ramakrishnan and Kurien 1983, Reichart *et al* 1984). *Dhal* yields are continually being improved by better processing techniques and the availability of more suitable genotypes (Saxena *et al* 1993, Williams *et al* 1993). There is, however, an urgent need to standardise the procedure and machinery used in the mills to reduce milling losses that have been reported to be over 10% (Kulkarni 1986, 1988a). Dehulling methods can be broadly classified into two categories (a) Traditional methods of dehulling and (b) Modern methods of dehulling.

2.8.1 Traditional Methods of Dehulling

Traditional methods of dehulling pulses include small scale domestic processing and large operations in commercial *dhal* mills in urban areas. Mortar and pestle were the dehulling tools commonly used in India (Singh 1995) and are still being used in Africa (Dovlo *et al* 1976). The process is slow, inefficient and laborious (Singh *et al* 1992b). The *chakki* or quern is the basic unit for dehulling in the village system and is an improvement on the old method. It consists of two grinding stones; a stationary lower stone and a rotating upper stone; which are 30-40 cm in diameter and 4-6 cm in thickness (Singh *et al* 1992b).

Pre-treatment of pulses before milling show a large degree of regional variation ranging from soaking, boiling, sun drying, storing and oil treatment (Singh 1995). Pre-treated seeds are steadily fed through a central hole in the upper stone which is gently

and continuously rotated manually until the material is processed. The gap between the stones is adjusted by a wooden structure supported at the bottom of the *chakki* depending on the seed size and the quality of *dhal* produced. The processed material is collected and separated into *dhal*, brokens, powder and husk fractions by winnowing. The undehusked whole seed is reworked and dehusked whole seed called *gota* in India constitutes a small proportion of the range of dehulling products which is milled to produce *besan*. Parpia (1973) reported that the average *dhal* yield from household and traditional commercial dehulling methods varied from 68 to 75%, which was 10 to 17% less than the theoretical average value of 85%.

An emery-coated roller is often used in large scale commercial *dhal* mills (Kurien 1981). The emery-coating is carborundum; (silicon carbide) which is widely used for its abrasive or refractory action. A roller machine is often used to dehusk and split most pulses in a dry method of processing (Kurien 1984, Singh and Jambunathan 1990). In a roller mill, the extent of dehusking depends on roller speed and diameter of roller, length of roller (resident time), abrasion force, abrasion pressure and clearance between roller and lower sieve. A disc sheller is used for wet processing methods and works on the principle of attrition, which removes the husk and splits the cotyledons simultaneously (Kurien 1981). A cone polisher or a 'buffing machine' is used to complete the dehusking. This process inevitably results in scouring losses. Losses with respect to *dhal* quality and yield are high by this method, especially when seeds are not size graded.

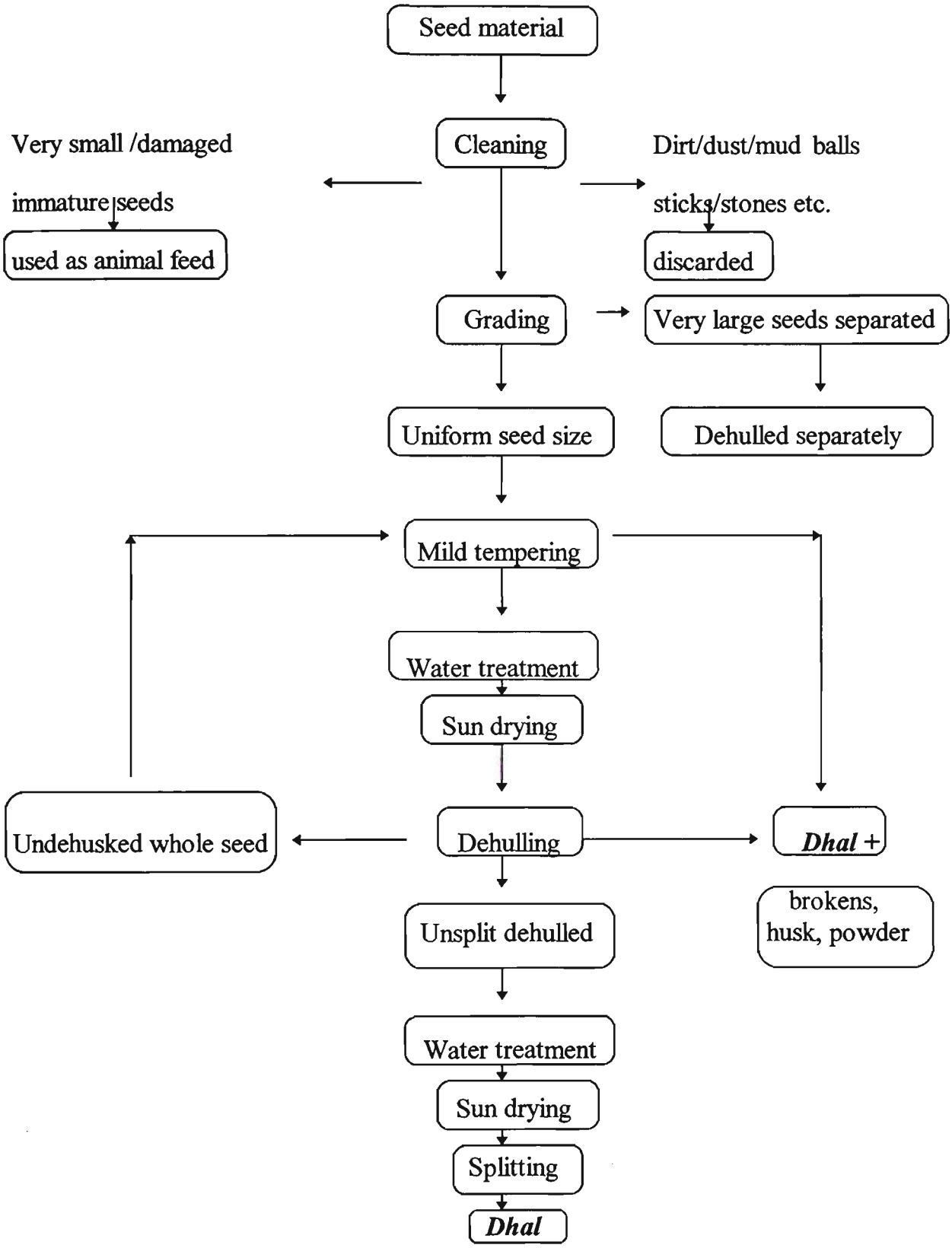
The dehulling process is region specific in the Indian subcontinent and to a large extent depends on the type of pulse. Although the sequence of operations such as premilling treatment, dehusking, conditioning and splitting are the same, variations exist in the duration and number of passes per step. As a general rule, winter pulses eg., chickpeas, field peas, lentils are relatively easy to mill and the summer pulses eg., pigeon pea, mung bean and black gram are difficult to mill. In the 'difficult to mill' pulses it is postulated that a layer of gums and non-starch polysaccharides cements the seed coat to the outer layers of the endosperm (Kurien 1977, Kulkarni 1991). Seeds are tempered after being size graded by passing through a roller. The tempering

process scratches the seed coat/testa and enhances their oil/water absorbing efficiency. Pulses are dehusked in a roller mill and different fractions are separated and collected. Sun-drying, carried out in drying yards or roof tops, of tempered whole seed and *dhal* can last from 1-5 days depending on weather conditions, thickness of layer and type of pulse (Kulkarni 1989). To improve the visual appearance of *dhal,* it is often polished using a water/vegetable oil mixture or natural dyes (Kulkarni 1988b). The quality of *dhal* deteriorates rapidly under improper storage conditions and if the water/oil mixture is not dried completely it causes rancidity. Natarajan and Shankar (1980) reported *dhal* yields of 70% in commercial *dhal* mills. A flow diagram indicating the various steps involved in chickpea (*chana*) *dhal* manufacture is shown in Figure.2.1.

2.8.2 Modern Methods of Dehulling

A new technology and machinery for dehulling pulses was developed at the CFTRI, Mysore, India, where loosening of the husk was achieved by an incipient toasting of the grain in a current of hot air, followed by tempering, when the seed coat is loosened (Kurien 1981, 1987). The process is independent of weather conditions, is less labour intensive and eliminates the use of oil. However, the technique has not been adopted by commercial *dhal* millers because of its high operating costs and no increase in yield as was originally proposed (Kulkarni 1991). With respect to modern mills, attrition type dehullers and roller mills are particularly suitable for dehulling and splitting pulses with a loose seed coat (Reichert *et al* 1984), whereas abrasive type dehullers are more suitable for dehulling pulses with a more tightly adhering seed coat (Reichert and Young 1976). Reichert *et al* (1984) developed an intermediate sized batch-dehuller capable of processing 2-8 kg of cereals and pulses. Dehulling is by abrasion from abrasive wheels (25 cm diameter) mounted on a horizontal shaft. The tangential abrasive dehulling device (TADD) has been used to study dehulling quality of the 'difficult to mill' pulses such as cowpea, mung bean and pigeon pea (Ehiwe and Reichert 1987, Singh *et al* 1992b).

Figure 2.1 Flowchart for dehulling chickpea-Procedure followed in Indian *dhal* mills



Singh (1995)

2.8.3 Dehulling Pre-Treatments

Wet pre-treatment involves water soaking followed by sun drying. This method facilitates good dehusking and splitting qualities but it adversely affects the cooking quality of the splits (Kurien and Parpia 1968). Soaking in water for up to 12 hours is not uncommon. Several workers have reported the use of chemicals such as 5% sodium bicarbonate (Reddy 1981), vinegar, sodium hydroxide and ammonia, as alternatives to vegetable oil with increases in *dhal* yields (Krishnamurthy *et al* 1972). Saxena *et al* (1981) recommended the use of sodium bicarbonate not only to loosen the husk but to also reduce the cooking time of *dhal.*

Dry pre-treatments involve oil/water application (not soaking) on pulses followed by sun drying. Losses due to breakage and powdering is high but the *dhal* produced has a reduced cooking time.

2.8.4 Seed Characteristics That Affect Dehulling

Major seed characteristics that affect dehulling efficiency are seed coat, seed size and grain hardness and seed shape. As these attributes are typical to certain varieties, selection of appropriate variety for dehulling is important. Final dehulling quality will depend on the interaction of pre-treatments of dehulling and the seed characteristics.

2.8.4.1 Seed Coat

The mean seed coat content ranges from 4.9% (*kabuli,* 19 cultivars) to 14.2% (*desi,* 21 cultivars) indicating a large variability which would significantly affect *dhal* yields (Kumar and Singh 1989). Theoretical yield of splits is determined by manually separating the seed coat content from the seed mass and is generally higher than that obtained by mechanical methods. As cell arrangements of seed coats are very different in pulses, seed morphology and anatomy has some effect on dehulling characteristics. In *kabuli* chickpeas, the outermost layer (epidermis) develops into a uniseriate palisade layer without thickening of the cell wall, whereas in *desi* chickpeas it develops into a multiseriate palisade layer which later becomes thick walled scleroids. This probably explains the ease with which *desi* varieties dehull as compared to *kabuli*. The gums and non-starch polysaccharides present in the interspace between the husk and

cotyledon have been implicated in the adherence of husk to the cotyledons, thereby making the dehulling operation difficult (Ramakrishnaiah and Kurien 1983). Measuring dehulling efficiency of *kabuli* type chickpea is only of academic interest because they are mostly eaten as whole seeds. In a later study, however, Singh (1995) reports that *dhal* yield of *kabuli* varieties are generally higher ranging from 90 to 94% compared to *desi* varieties (71-87%). This is probably because of their lower seed coat content. These findings suggest that ease of dehulling is not necessarily related to *dhal* yield.

2.8.4.2 Seed Size and Grain Hardness

Seed size has a major impact on the efficiency of dehulling and splitting of cotyledons (Singh *et al* 1992b). In order to maximise *dhal* yield, seeds are always size-graded before dehulling. Seed size is a varietal characteristic which can be strongly influenced by growing season and location of pulses (Erskine *et al* 1985, Williams and Singh 1987). Dehulling efficiency is negatively and significantly correlated with seed size in mung bean and cowpea (Ehiwe and Reichert 1987), implying that larger grains would decrease *dhal* yield. However, Kurien and Parpia (1968) concluded that 'bold-grained' varieties of pulses, especially chickpea, possess better milling quality and had improved *dhal* yields compared with small pulses. Size graded (uniform) and semi bold seeds are most suited to dehulling. The presence of too many small seeds increases inefficiency because re-work is high although losses due to chipping are high when there are too many large seeds (Singh and Jambunathan 1981).

Grain hardness also showed a negative correlation with *dhal* yield for pigeon pea (Singh *et al* 1992b). It has been shown that greater than 75% of the variability in dehulling efficiency or *dhal* yield could be accounted for by grain hardness and resistance to splitting of the grain into individual cotyledons (Reichert *et al* 1984). Data on effect of hardness of *desi* chickpea on *dhal* yield is lacking.

2.8.4.3 Seed Shape

Seed shape is a varietal characteristic in pulses (Erskine *et al* 1985) and is generally not affected by growing environment. Round spherical seeds are preferred for dehulling as

losses are low (Singh and Jambunathan 1990). The dehulling of angular flat seeds results in a greater loss of seed mass and reduced *dhal* yields (Williams *et al* 1993).

2.8.5 Dehulling Losses

Theoretical *dhal* yield should equal weight of whole seed minus weight of seed coat but this never occurs in practice. Measurable amounts of germ and cotyledon are removed during the operation (Aykroyd and Doughty 1964) which depends on dehulling method and seed characteristics (Matanhelia 1994) causing considerable qualitative and quantitative losses. Table 2.17 summarises survey data on dehulling losses in terms of powder, brokens and husk fractions during *chana dhal* production in a large and small scale processing units. According to the survey, highest *dhal* yield was reported from large scale processing units and maximum losses in terms of brokens and powder was obtained when a quern (small scale processing) was used.

Table 2.17 Dehulling losses (%) during *chana dhal* production in large and small scale processing units

Component	**Large scale processing***		**Small scale processing****	
	Range	**Mean**	**Range**	**Mean**
Chana dhal	75-85	80.0	50-80	70.8
Brokens	1-5	2.6	5-20	8.6
Powder	5-10	6.7	7-20	7.0
Husk	8-14	11.8	10-20	13.5

Singh and Jambunathan (1981b), * = 20 responses, ** = 60 responses

2.8.5.1 Effect of Dehulling on Nutrient Losses

Most common methods of dehulling remove the germ along with the husk and thereby incurs substantial losses of vitamins, minerals and proteins. As the outer layers of the cotyledons are scarified, there is considerable loss of nutrients when chickpea was dehulled for 4 minutes (Singh *et al* 1992a). This study also reported that dehulling of chickpea did not affect the protein quality in terms of amino acid composition. The effect of dehulling on the chemical constituents of *dhal* and powder fractions of chickpea are shown in Table 2.18. Protein, soluble sugars (not shown in table) and ash contents decreased and only starch content increased in *dhal* fractions as the dehulling time increased. These results indicate that dehulling causes substantial losses of macronutrients present in the outer layers of the cotyledon. After 2 to 4 minutes of dehulling, calcium, iron, zinc and manganese (not shown in table) contents were nearly two times higher in the powder fraction. Seven to 12% losses in the form of powder fraction by traditional dehulling methods is comparable to 2-4 minutes of dehulling in the Singh *et al* (1992a) study.

Table 2.18 Effect of dehulling on the chemical constituents (g/100 g) of *dhal* and powder fractions of chickpea

Dehulling	***Dhal***				**Powder**			
time (min)	Protein	Starch	Calcium	Iron	Protein	Starch	Calcium	Iron
0	18.6	56.2	43.0	5.7				
2	18.0	57.8	39.5	5.0	23.6	48.0	85.0	12.0
4	17.5	57.8	38.0	4.8	21.8	50.3	65.5	10.5
8	17.5	58.0	36.5	4.3	19.8	52.0	45.0	8.5
12	16.4	60.8	35.0	3.8	18.9	55.4	45.0	7.0

(Singh *et al* 1992a)

This suggests that calcium and iron losses would range from 10 to 25% depending on the dehulling method. Singh *et al* (1992a) conclude that the mineral content is higher in the outer layers of chickpea cotyledon and would be lost during dehulling. Thus, to reduce nutrient losses during dehulling, contact time of the seed with the abrasive rollers is an important factor to be considered.

2.8.5.2 Effect of Dehulling on Cooking Time of *Dhal*

Pulses are processed to improve texture, culinary properties, appearance and palatability. In addition to reducing the fibre content, dehulling improves appearance, texture, cooking qualities and taste (Kurien *et al* 1972). The cooking time of *dhal* is influenced by dehulling method (Singh 1987). It is not the mechanical action of the roller machines or disc shellers that influence the cooking time, but the pre-treatments given to pulse before dehulling (ICRISAT 1981). Soaking the seeds in water and subsequent sun or oven drying increased the cooking time of pulses (Paredes-Lopez *et al* 1991). *Dhal* obtained from untreated seeds had a lower cooking time. Genotypes also play an important role in influencing the cooking time of *dhal* due to pre-treatments because interactions between genotypes and pre-treatments are significant (Singh 1995).

2.9 Composition of *Dhal*

At appropriate sections in the text, reference has been made to the composition of *dhal* obtained from chickpea. Table 2.19 gives the mean values of important constituents for *dhal* from *desi* and *kabuli* cultivars. *Dhal* from *desi* cultivars has a slightly higher protein content than *kabuli dhal*. Mean protein values of *desi dhal* samples are about 4 units higher in comparison to whole seed mean protein values (22.2 g/100 g), while the mean protein difference between *kabuli* whole seed (23.2 g/100 g) and *dhal* samples is less than 2 units (Jambunathan and Singh 1978). The protein content in *desi dhal* range from 20.6 to 30.5 g/100 g and from 22.1 to 27.8 g/100 g in *kabuli dhal* on a moisture free basis. Starch values of *desi* and *kabuli dhal* samples does not show any appreciable difference while the ash content of *desi dhal* is slightly lower than *kabuli dhal*.

Table 2.19 Mean value (g/100 g) of selected constituents for *dhal* from *desi* and *kabuli* cultivars

Constituent (g/100 g)	*Desi dhal**	*Kabuli dhal***
Protein	26.4	24.5
Starch	55.4	55.8
Sugars	4.9	5.3
Fibre	1.1	1.1
Fat	5.3	5.7
Ash	2.8	3.1

Jambunathan and Singh (1978), *= 8 *desi* cultivars, **= 7 *kabuli* cultivars

2.10 Production of Flour (*Besan*)

In the Indian subcontinent *dhal* is ground under dry conditions to yield a fine flour called *besan*. It can be ground under wet conditions in combination with cereals and millets to produce a batter or dough for steaming, frying or baking. The *dhal* is sun dried for a few hours prior to grinding in a single pass with a plate mill or burr mill. Two passes are required to produce fine flour at an optimum *dhal* moisture content of 5-10% (Kurien 1985). The eating quality and texture of many of the food products depends on flour composition, degree of fineness of flour, relative proportion of particles of different mesh grades and cooking conditions (Kurien *et al* 1972). Traditional Indian snacks made from *besan (sev, ghatia)* provide a distinctive flavour and unique texture and are gaining popularity in the western world. They offer exciting alternatives to other conventional snack foods in the market today (Midson 1996).

The relative distribution of nutrients between flour fractions has shown that proteins are found in higher quantities in the fine fractions of the flour, while the coarse fractions usually contain more starch. Minerals and other extractives are uniformly distributed in the flour fractions (Shuvisitkul 1976).

2.11 Functional Properties

Functionality can be defined as the set of properties of a protein or flavour ingredient(s) that contribute to the desired colour, flavour, texture and nutritive value of a food (Black *et al* 1995). The functional characteristics of composite flours are provided not only by the proteins but also by the complex carbohydrates including pectins and hemicellulose components of the grain. The supplementation of cereals with high protein pulses enhances the nutritive value of the diets utilising such blends. (Black *et al* 1995). Functional properties of each grain type is modified in blends.

The complementary or synergistic nutritional effect of pulse protein and cereal protein is well documented (Eggum and Beames 1983) and several efforts have been made to process the two types of grain into forms in which nutrients are more readily available and optimally utilised. There are many examples of traditional foods being successfully prepared using fortified flours or composite flours in order to improve functional properties of raw materials, nutritive value and/or taste of final product. Chickpea supplementation up to 11% improved the nutritional quality of traditional Central Asian breads (Makhudov 1980). Fernandez and Berry (1989) examined the rheological and sensory characteristics of bread made from wheat and germinating chickpea and found it to be of acceptable quality. Wheat flour blended with about 30% chickpea flour is used to prepare unleavened flat bread (*missi roti*) in the Indian sub-continent to improve its nutritive value (Khan 1987). Hernandez and Sotelo (1984) supplemented wheat flour with up to 20% chickpea flour in cookie production. Valencia *et al* (1988) prepared infant feeding formulas with chickpea in combination with rice while Livingstone *et al* (1992) developed weaning foods with chickpea and malted wheat. Soybean, mung bean, cowpea and French bean are other pulses that are commonly used in the preparation of composite flours with the level of fortification depending on regional preferences, processing conditions and desired taste.

There have been numerous studies conducted separately on the functional properties of cereals and pulses. Sosulski *et al* (1976) compared of various functional properties of 10 pulses and observed considerable differences among different species. The authors reported that chickpea showed good whippability and foam stability. Whippability and foam stability are essential properties in an egg white extender for whipped toppings, chiffon mixes and confections. Slurries of high starch chickpea flours gave high peak

and cold viscosities in the viscoamylograph curve. Sathe *et al* (1982) evaluated certain functional properties of winged bean concentrate and concluded that it had lower tannins, trypsin, chymotrypsin and α-amylase inhibitory activities compared to bean flour. The literature, however, reports only few studies conducted on chickpea composite flours and interactions of their principal constituents. Deshpande *et al* (1983) studied the functional properties of wheat-bean composite flours and noted that the water and oil absorption, foaming capacity and stability, and emulsifying activity and stability increased with increasing levels of bean flours in the blends.

2.11.1 Nitrogen Solubility Index (NSI)

Nitrogen solubility index (NSI) of cereals and pulses is very important as it reflects the intrinsic properties of protein including their digestibility and dispensability in various food formulations. Pulses help in improving the NSI values of composite flours, indicating interactions between functional groups of proteins of cereals and pulses (Singh and Singh 1991).

2.11.2 Emulsification Capacity

Emulsification capacity influences stability during product storage. Emulsification stability can be greatly increased when highly cohesive films are formed by the absorption of rigid globular protein molecules that are more resistant to mechanical deformation eg., lysozymes (Graham and Phillips 1980). The high emulsion stability of pulse protein concentrates could be attributed to the globular structure of their proteins while cereal proteins have poor emulsion stability because they are linear. Emulsion capacity of cereal flours are generally lower than those of pulse flours and was confirmed by Iyer and Singh (1997). The emulsification capacity of chickpea flours was 2-3 times higher than those of wheat flours and *desi* chickpea flours that contained the highest protein also showed the highest emulsification capacity.

2.11.3 Water Absorption, Swelling Power, Hot Paste Viscosity and Gelling Ability

Water absorption, swelling power and hot paste viscosity are the inherent properties of starch molecules of cereals and pulses. When an aqueous suspension of starch granules is heated, the starches hydrate causing them to swell and eventually a paste is formed (Reddy *et al* 1989b). However, these characteristics differ remarkably between cereals and pulses. Pulse starches undergo a single stage swelling whereas cereal

starches follow a two stage swelling pattern (Lai and Variano Marston 1979). The viscoamylographic properties of cereal starches are associated with break-down and set-back values when measured in a viscoamylogram. In the case of pulses, constant viscosities are observed during heating at higher temperatures and it appears to increase the viscosity of composite flours. Fernandez and Berry (1989) reported that the viscosity contributed by starch in wheat flour increased when it was fortified with chickpea flour. The gelling ability of cereal and pulse flours appears to be a function of the nature and type of protein and starch.

2.12 Pulse Based Food Products -Value Adding

In the past two decades, considerable interest has been generated in fortifying wheat flour with high protein, high lysine material (especially pulse and oilseed flours, protein concentrates and isolates) primarily to increase the protein content, improve essential amino acid balance and enhance the functional properties of the composite flours (Qarooni 1996). This appears to be occurring even in countries where protein deficiency is not an issue.

Among the baked goods, bread made from composite flour is the most exhaustively studied product. Irrespective of the source, nonglutenous protein adjuncts exert a volume-depressing effect on bread when used at the relatively high levels necessary to accomplish the desired amount of fortification (Pomeranz 1970). The pulse component of the composite flour changes the absorption, mixing tolerance and other physical properties of doughs (Matthews *et al* 1970). Only small amounts of pulse flour (5-15%) or isolates (15-25%) are found to give acceptable volume in the finished products (D'Appolonia 1977). Singh *et al* (1993) reported that biscuits with greater than 15% substitution with chickpea were tough, difficult to break and required higher compression force. Sensory evaluation scores showed that 15% substitution level was optimum. Egyptian breads made with flour substituted with varying levels of chickpea flour and the effect of supplementation on protein quality were evaluated by Shehata and Fryer (1970). Physical properties of the dough were not affected by substitution with chickpea flour, however, feed consumption, weight gain and PER of rats fed 20% chickpea flour diets were significantly higher than that of rats fed at reduced levels of fortification. Supplementation with chickpea and soybean flour enhanced the nutritive

value of white Arabic bread and showed a high level of acceptability up to 20% fortification (Hallab *et al* 1974).

Noodles and spaghetti prepared from hard red spring wheat flour fortified with 33% pea flour improved protein quality and quantity (Nielsen *et al* 1980). The authors observed that noodle dough handling characteristics deteriorated as the level of fortification increased. They also observed that addition of pea flour reduced the cooking time for noodles but cooking losses were greater. Pea products gave the pasta a yellow colour that was generally considered desirable. Precooking the pea products improved the flavour of the fortified spaghetti. Jeffers *et al* (1979) noticed that texture and yield of *udon* (white Japanese noodles) were only slightly affected by the presence of a fortifier (pulse flours like yellow peas or soybeans) and the overall quality of the fortified noodles decreased with increasing levels of fortifier compared to control noodles made from all-wheat flour. Their results indicated that for good quality udon, the level of pulse flour supplementation should be no higher than 5-10%, depending on the individual pulse. The use of mung bean starch in the manufacture of mung bean noodles is well known but more recently field pea starches are being used for the same due to the high prices for mung bean (P McEvoy, Personal Communication AWB 1996). Hung and Nithianandan (1993) prepared unsalted white noodles fortified with lupin flour, chickpea flour and flour mixture (50:50 of both pulse flours) and found that they compared favourably with those made from wheat flours. Wheat flour was fortified with flour from cultivars Opal and Kaniva (*kabuli* chickpea) at 15 and 20% substitution levels resulting in a 10-19% increase in protein content and 3-5 times increase in fibre content in the noodles. The extrusion force for all fortified products were higher than the control indicating the firmness of cooked noodles increased with the level of substitution. A general relationship of higher firmness and high protein content in spaghetti has been demonstrated by Matsuo *et al* (1972). Singh and Seetha (1993) evaluated the oil absorption and sensory properties of a snack food (*sev*) made from commonly consumed pulse flours. They found that the score on general acceptability was highest for *sev* made from chickpea and the oil absorption of the product was only higher than green gram.

2.13 Conclusion

In the literature there are numerous reviews and references to pulses in general and chickpea in particular covering various aspects of production, composition, properties and food uses. However, most of the work has been done overseas and there is very little data about Australian chickpea. A 'compare and contrast' study of commercially traded varieties and advanced breeding lines of Australian chickpea is necessary to evaluate its quality, characteristics and possible end uses.

Materials and Methods

3 Materials and Methods

3.1 Collection of Samples of Commercially Traded Varieties

Desi and *kabuli* samples were collected over three harvests (1991/92, 92/93 and 93/94) from the major chickpea growing regions by the Wheat Quality Officers of the AWB in each State and private grain traders in NSW and QLD. Samples from WA were received during the later stages of the study which coincided with that State's increased commercial chickpea production. Typically, QLD samples were from the Darling Downs region, NSW samples from Moree, VIC from the Wimmera, SA from Kapunda and Balaklava and WA from Geraldton. Approximately 2 kg of pure varietal sample along with information on production site was collected soon after harvest in calico bags and despatched to the laboratory. As most of the samples were only farmer dressed they were manually cleaned at the laboratory to remove sticks, stones, foreign materials, brokens, infected, damaged and immature seeds and splits. Lighter materials were removed by aspiration. Cleaned samples were stored in labelled plastic jars at 15 °C.

3.1.2 Problems Encountered During Sample Collection

As commercially traded samples were sourced from around Australia; only a minimal degree of process control could be enforced. Due to a deregulated pulse market in Australia, many traders apart from the AWB, are involved which made coordinating the sample collection process extremely difficult. Fluctuating pulse prices in recent years in the international market conveys mixed signals to the farming community about which pulse to grow. Drought and/or unseasonal rain affect the quality and yield of pulses. All these factors had a direct influence on the number of samples collected during each year of the study and hence have a bearing on the interpretation of results.

3.2 Samples of Advanced Breeding Lines

Fifty three advanced breeding lines of *desi* chickpea grown in experimental plots were received from 5 States (QLD, NSW, VIC, SA and WA) in 1994/95 and 52 *desi* lines were received in 1995/96 from the Victorian Department of Dryland Agriculture (VIDA), in Horsham, VIC, as part of a joint GRDC part-funded project (DAV 273A).

Twenty one advanced breeding lines of *kabuli* chickpea grown in experimental plots were also received during each harvest from all States, except WA. These samples were cleaned and stored in labeled plastic jars at 15 °C before being processed for further analysis. The break up of advanced breeding lines of *desi* and *kabuli* genotypes received by State and season are given in Tables 3.1 and 3.2, respectively.

Table 3.1 Advanced breeding lines of *desi* genotypes received from different States of Australia in 1994/95 and 1995/96

1994/95			1995/96		
State	**Variety**	**Samples**	**State**	**Variety**	**Samples**
QLD	Amethyst	1	**QLD**	Amethyst	2
	Norwin	3		Barwon	2
NSW	Amethyst	1	**NSW**	Amethyst	1
	Norwin	2		Barwon	1
				Dooen	1
VIC	Norwin	2	**VIC**	Amethyst	1
	Desi	11		Dooen	1
	Black *desi*, tan *desi*	14		T2000	2
	light *desi*, brown *desi*			T1000	12
				T8000	14
	Desavic	3			
	Dooen	1			
	Tyson	2		Tyson	1
	T1239	3		T1239	3
	T1414	2		T1414	3
	T1587	2		T1587	2
SA	Amethyst	1	**SA**	Amethyst	1
	Norwin	1		Barwon	1
	Semsen	1		Dooen	2
WA	Dooen	1	**WA**	Barwon	1
	Semsen	1			
	Tyson	1		Tyson	1
Total		53			52

Despite attempts to obtain the same genotype over two seasons in the same location there were instances when the entire range of tests could not be conducted because insufficient sample was received due to unfavourable growing conditions. The samples were thus grouped according to genotype and not according to origin sites. The germplasm for the advanced Dooen line was sourced from Russia. T1239 (germplasm from Iran), T1414 and T1587 (near East collection) were advanced lines with specific

agronomic differences and hence monitored separately over the duration of the study. The T1000 (advance breeding material from Australia), T2000 (germplasm was either from Iran or Mexico) and T8000 (where one parent was either Amethyst, Norwin or Barwon) series included similar succession lines and as no specific line had shown any degree of agronomic potential they were grouped together.

Table 3.2 Advanced breeding lines of *kabuli* genotypes received from different States of Australia in 1994/95 and 1995/96

1994/95			1995/96		
State	**Variety**	**Samples**	**State**	**Variety**	**Samples**
QLD	Garnet	2	**QLD**	G846-3-6	1
NSW	Garnet	2	**NSW**	Mission	1
	L550	1		Narayen	2
	Narayen	1			
	UC5	1			
VIC	Kaniva	4	**VIC**	Kaniva	2
	T1000 (Iran)	8		T1000 (Iran)	8
	Garnet	1		T1000 (Russia)	5
				Garnet	1
				UC5	1
SA	Mission	1			
Total		21			21

Like the advanced breeding lines of *desi* cultivars, *kabuli* cultivars were grouped according to their genotypes. G846-3-6 was classified as Garnet because one parent used for fertilisation was Garnet. Accession lines of a Kaniva type of chickpea obtained from Iran and Russia were grown in VIC and similarly treated. Germplasm of L550 was from India while that of UC5 and Mission were from the USA.

3.3 Physical Analyses

Physical analyses conducted include the non-destructive tests on seed weight and colour of clean whole seeds. The weight of 100 seeds was measured in duplicate.

Colour was measured using a Minolta Chroma Meter (CR 310, Osaka) with a 8 mm viewing head. Colour is expressed as L* (0 = blackness, 100 = whiteness), a* (60 to -60), ($+^{ve}$ = degree of redness, $-^{ve}$ = degree of greenness) and b* (60 to -60); ($+^{ve}$ = degree of yellowness, $-^{ve}$ = degree of blueness) values. The final values for colour were the mean of 9 readings per sample.

3.4 Sample Preparation for Chemical Analyses

Approximately 200 g each of clean sample was ground in a Falling Number mill 3100 (Perten Instruments, Huddinge, Sweden) to pass through a 0.5 mm sieve. The ground material was stored at room temperature in plastic sample jars. A laboratory proto-type roller mill was used to dehull the whole *desi* seeds to produce *dhal* (details of the mill are given in section 3.5.4.2). *Dhal* was ground like the whole seeds and the flour was used for chemical analyses. All analyses were carried out in duplicate.

3.4.1 Moisture

An air-oven method was used to determine the moisture content of the ground seed. An accurately weighed sample (3 g) was dried at 130 °C for 1 hour (Clayson, Auckland) and cooled before weighing to constant weight. The percent loss in weight was determined (945.15, AOAC 1990a).

3.4.2 Ash

The ash content of ground sample was measured by incinerating 3 g of sample in a crucible at 590 °C (Carbolite muffle furnace, Melbourne) for 15 hours. The crucible was cooled in a desiccator to room temperature and then weighed to obtain the ash content (923.03, AOAC 1990b)

3.4.3 Total Protein and Non Protein Nitrogen (NPN)

Total protein was estimated on 0.5 g of ground seed by the Kjeldahl method which consisted of initial digestion with sulphuric acid followed by steam distillation in the presence of excess alkali and then titrating the dissolved ammonia against acid. A factor of 6.25 was used to obtain total protein (920.53, AOAC 1990c). NPN in a 5 g sample was extracted using 10% trichloroacetic acid and the nitrogen content in the filtrate was estimated by Kjeldahl method (Singh *et al* 1981).

3.4.4 Total Fat

Total fat in the ground seed (2 g) was measured using a modified AOAC method (922.06) (1990d). Flour was defatted using equal volumes of n-hexane and diethyl ether and the dissolved fat was weighed after the organic solvents had been evaporated to dryness in a rotary evaporator.

3.4.5 Total Dietary Fibre (TDF)

TDF was measured by the modified AOAC method (985.29) (1990e) using the Fibretec equipment (Tecator, Lund) and a combination of enzymatic and gravimetric methods. A ground sample (1 g) was gelatinised with diluted (1⟶10), heat stable α-amylase (Termamyl 120L, AXN 04056, Novo Nordisk, Bagsraerd, Denmark) and then enzymatically digested with protease (P-5380, Sigma Chemical, St. Louis) and amyloglucosidase (A-9268, Sigma Chemical, St. Louis) to remove protein and starch, respectively. The residue was filtered and washed with ethanol and acetone, dried and weighed. Half the sample was analysed for protein and the other was analysed for ash content. TDF is the weight of the residue less the weight of residual protein and ash.

3.4.6 Available Carbohydrate

The available carbohydrate was calculated by difference, i.e., available carbohydrate = 100 - {g moisture + g ash + g protein + g fat + g TDF}.

3.4.7 Available Energy

Available energy (kJ/100 g) from chickpea seeds was calculated using Atwater factors adapted from Paul and Southgate (1978) by substituting values in the following formula: (g protein x 17) + (g fat x 37) + (g available carbohydrates x 17.6) = Energy intake for non-ruminants. For ruminant energy; the amount of TDF is multiplied by 17.6 and added to the other components.

3.4.8 Thiamin (B_1)

Thiamin was estimated by the AOAC fluorometric method (942.23) (1990f). The method involves autoclaving a sample (2 g) to release the vitamin from the sample followed by enzyme (clarase 10,000 units; Solvay Biosciences, Melbourne) hydrolysis. The hydrolysed sample was filtered and purified using the sodium form of a cation exchange resin (Bio-rex 70 Resin, Bio-Rad Laboratories, California). The thiamin in the eluate was oxidised to thiochrome with potassium ferricyanide and the fluorescence

was measured with a digital fluorometer at 365 nm (excitation) and 435 nm (emission) (Model 450, Sequoia-Turner, California).

3.4.9 Riboflavin (B_2)

Riboflavin was analysed by the AOAC (970.65) (1990g) fluorometric method. A sample (2 g) was autoclaved in a weak acid followed by pH precipitation of protein. The riboflavin in the filtrate was liberated after chemical reduction with hydrogen peroxide and the fluorescence measured with a digital fluorometer at 440 nm (excitation) and 565 nm (emission) (Model 450, Sequoia-Turner, California).

3.4.10 Tannins

Tannins in freshly ground seed (5 g) was measured by extracting overnight in excess acidified methanol. Freshly prepared acidified vanillin reagent was added to an aliquot of the extract and the absorbence was read spectrophotometrically against a catechin standard at 500 nm (Hitachi, model 100-60, Tokyo) (Burns 1971).

3.4.11 Trace Minerals and Elemental Phosphorus

The levels of sodium, potassium, calcium, magnesium, zinc, iron, copper and phosphorus were determined by ICP-MS (Ion Couple Photometry - Mass Spectrometry) for whole seed (1 g) and ICP-AES (Ion Couple Photometry - Atomic Emission Spectroscopy) for *dhal* (1 g) after digestion with nitric and perchloric acids (McQuaker *et al* 1979).

3.5 Properties of Whole Seeds

Rate of water uptake (soaking), germination capacity (sprouting), cooking tests and dehulling efficiency of seeds were the processing properties that were evaluated.

3.5.1 Soaking

The method of Saini and Knight (1992) was used to study the soaking characteristics of chickpea seeds. Distilled water (100 mL) at ambient temperature (22 °C) was added to 20 g of whole seed placed in a 250 mL measuring cylinder. The exact volume of seeds plus water was noted before transferring the contents to a beaker. At pre-determined intervals, seeds were drained and their surface dried by blotting with a paper towel. The seeds were re-weighed and the increase in water taken as the amount of water absorbed. Hydration capacity (HC) was calculated as the increase in weight per unit mass and expressed as a percentage of fresh weight.

The soaked seeds, were re-immersed in 100 mL of distilled water. The new volume of seeds plus water was noted again. Swelling capacity (SC) was defined as the increase in seed volume after hydration, expressed as a percentage of initial volume.

3.5.2 Sprouting

Sprouting capacity was determined using a modified version of the International Seed Testing Authority method (ISTA 1993). Fifty seeds were accurately weighed and soaked for 4 hours at ambient temperature in 50 mL distilled water. The seeds were then evenly distributed on a double, damp filter paper and securely tied with elastic bands before wrapping in a plastic bag. The bag was placed in a 30 °C - 20 °C cycle humidity oven (Brandon Refrigeration, Melbourne) and the number of sprouted seeds counted after 24, 48 and 72 hours.

3.5.3 Objective Texture Assessment

Owing to the high degree of operator dependence and limited repeatability of the traditional thumb and finger test, an objective ranking test was developed using a Lloyd texture meter (model no. LRX, Manchester). Chickpea seeds were pre-soaked and pressure cooked under rigid conditions before evaluating texture.

3.5.3.1 Cooking Protocol

Selected genotypes of *desi* and *kabuli* seeds (30 g) were soaked for varying times (0, 6, 8 and 16 hours) in salt solutions (100 mL) of different concentrations (0, 1 and 2%). The 1% (w/v) salt solution was made up of 0.5% (w/v) sodium chloride and 0.5% (w/v) sodium bicarbonate and the 2% (w/v) salt solution was made up of 1.0% (w/v) sodium chloride and 1.0% (w/v) sodium bicarbonate.

At the end of the soak time, seeds were drained and wrapped in a paper towel to prevent drying. Tap water (300 mL) was placed at the bottom of a domestic pressure cooker (Prestige 5 L, Mumbai, India). Soaked and drained seeds (50 g) were placed on an aluminium foil previously folded to form a weigh boat; and 10 mL of distilled water was added to each. The weigh boats were arranged in 'cake tins' (2 per cake tin, accessories available with cooker) which were stacked and placed inside the cooker. The pressure cooker was covered, making sure the sealing gasket was in position and placed on a medium burner in a gas stove on 'high'. In approximately 5 minutes (when steam was emitted from the nozzle), the 'weight' was inserted and the timer switched on. The pressure cooker was heated on 'high' for 5 minutes and on

'low' for 10 minutes. At the end of 10 minutes, the pressure cooker was immersed in a sink containing cold water to prevent cooking due to latent heat. As soon as it was safe to open the cooker (in about 5 minutes) the samples were removed and kept covered to prevent skinning. Texture measurements were recorded immediately.

3.5.3.2 Texture Measurement

A perspex cylindrical sample holder (diameter 5.2 cm, height 13.6 cm) and a stainless steel flat disc (diameter 4.2 cm, thickness 1.2 cm) with a clean fit that served as a probe, were specially constructed to evaluate degree of 'cookedness' or 'doneness'. Cooked seeds (5 g) were placed at the bottom of the cylinder. The probe, with a constant crosshead speed of 100 mm/min was attached to a 500 N load cell and adjusted (zeroed) just above the layer of cooked seeds before the test commenced. As the test progressed, the seeds were deformed to form a film, the diameter of which was measured. The extent of deformation was taken to indicate the tenderness of the cooked chickpea and was proportional to the degree of 'doneness'. Figure 3.1a shows the 'zero' setting of the texture analyser and Figure 3.1b depicts the 'end of test'.

3.5.4 Dehulling

In order to test the milling capabilities of commercial Australian *desi* varieties, a laboratory sized roller mill was designed based on experience and information collected from the literature and manufactured under instruction by Suraj International, Melbourne. The working of this mill, to be referred to as the AGT mill, was similar to that of a small *dhal* mill commonly used in the Indian sub-continent. Dehulling efficiencies were compared on conditioned and non-conditioned samples and the performance of the AGT mill was compared with the Satake (Satake Engineering, Tokyo) and ICARDA mills (ICARDA, Aleppo, Syria).

3.5.4.1 Preconditioning Treatments

The bulk sample of a genotype was divided into three sub-samples which were treated as replicates for all determinations. The three pre-treatments investigated were soaking in: water, 1% (w/v) sodium chloride and 1% (w/v) sodium bicarbonate. Seed samples were soaked in twice the amount of water or salt solutions for 10 minutes. Excess liquid was drained and seeds were dried overnight in an air oven at 60 °C. The pre-conditioned seeds were stored in plastic bags until they were dehulled.

Figure 3.1a Texture meter is 'zeroed' prior to deformation.
The flat probe is lined with the top of the cooked chickpea seeds.

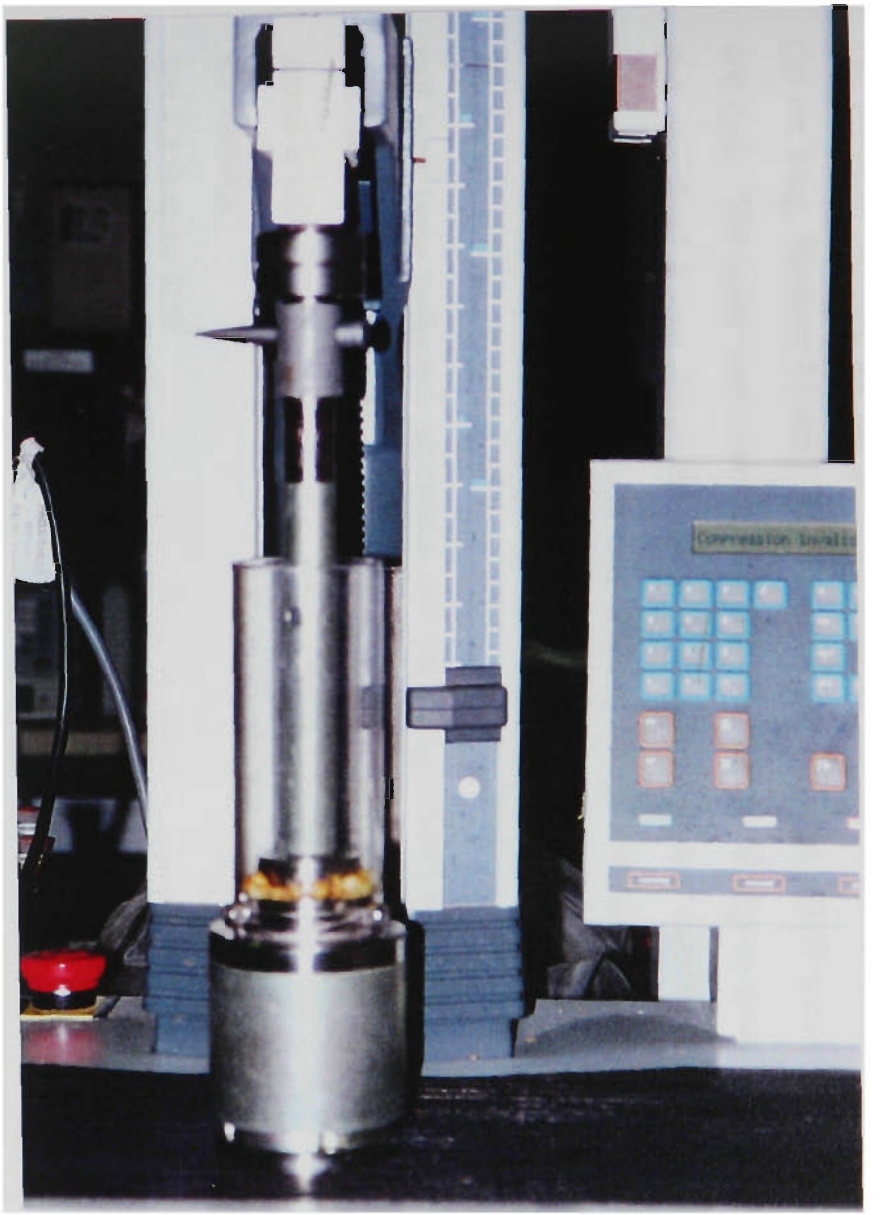


Figure 3.1b Depicts the end of the test. The cooked seeds are deformed and the deformation is computed in mm.

3.5.4.2 AGT Mill

The abrasion required for the dehulling process was provided by carborundum rollers (30 cm long, diameter 15 cm). The rollers were driven by a 3HP motor at a speed of 460 rpm. The roller was covered with a perforated metal screen (pore size = 4 mm) that was fixed 6 mm above the roller at the feed end and tapered to 5 mm at the product end. About 50 g sample was dehulled for 60 seconds, the optimum time for the 50 g sample. The AGT mill can be used in a batch or semi continuous capacity. All fractions from dehulling such as *dhal*, powder, brokens, undehusked whole seed and husk were collected, separated and their proportions calculated as described in section 3.5.4.5. Figure 3.2 shows a schematic diagram of the AGT mill. Figure 3.3a shows a side view of the prototype while Figure 3.3b shows the mill being dismantled for cleaning.

3.5.4.3 Satake Mill

The Satake grain testing mill TMO5 (Satake Engineering, Tokyo) was used at the Australian Food Industry Science Centre (AFISC), Werribee, Melbourne. The mill was fitted with an abrasive wheel, mesh grade-40. It had a thickness of 2.5 cm, diameter 15.5 cm and was driven by 1HP motor. About 30 g of sample was dehulled for 10 seconds, the optimum for the sample size. All fractions from the dehulling process were collected separately and weighed as shown in 3.5.4.5.

3.5.4.4 ICARDA Mill

The International Centre for Agricultural Research in Dry Areas (ICARDA), (Aleppo, Syria), has developed a small mill consisting of lower (rotating) and upper (stationary) carborundum discs based on the design of a stone *chakki* (quern) but with opposite moving parts (Singh and Rao 1995). The size of the carborundum disc was 17 cm in thickness and 1.8 cm diameter. The bottom disc was slightly concaved to accommodate the sample and was most suited to study the dehulling quality of lentils (Erskine *et al* 1991). The dehulling efficiency of the mill was evaluated at VIDA. About 50 g chickpea was dehulled for 20 seconds, the optimum time for the sample. All fractions from the dehulling process were collected separately and weighed as shown in 3.5.4.5.

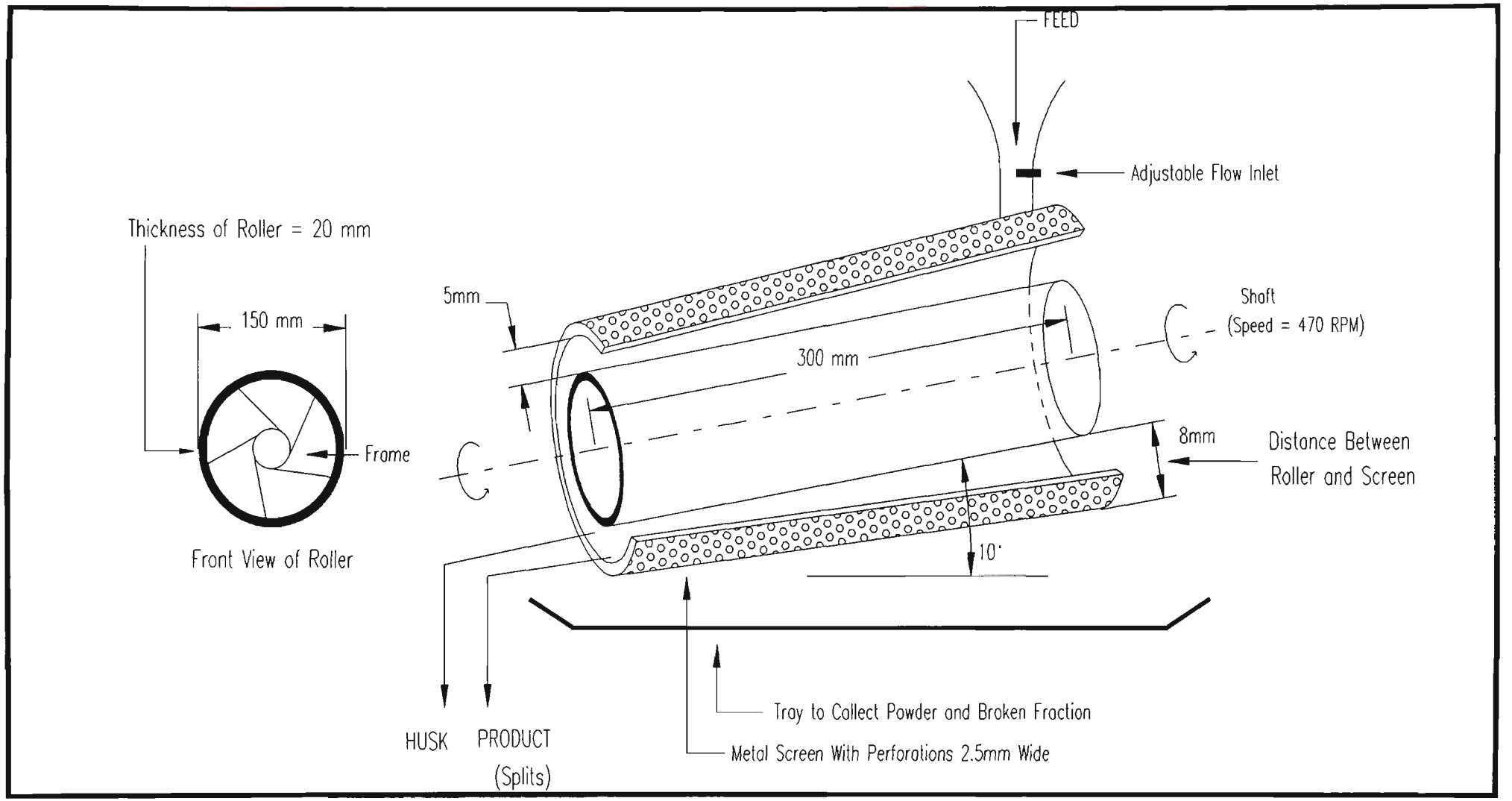


Figure 3.2 Schematic diagram of the AGT mill

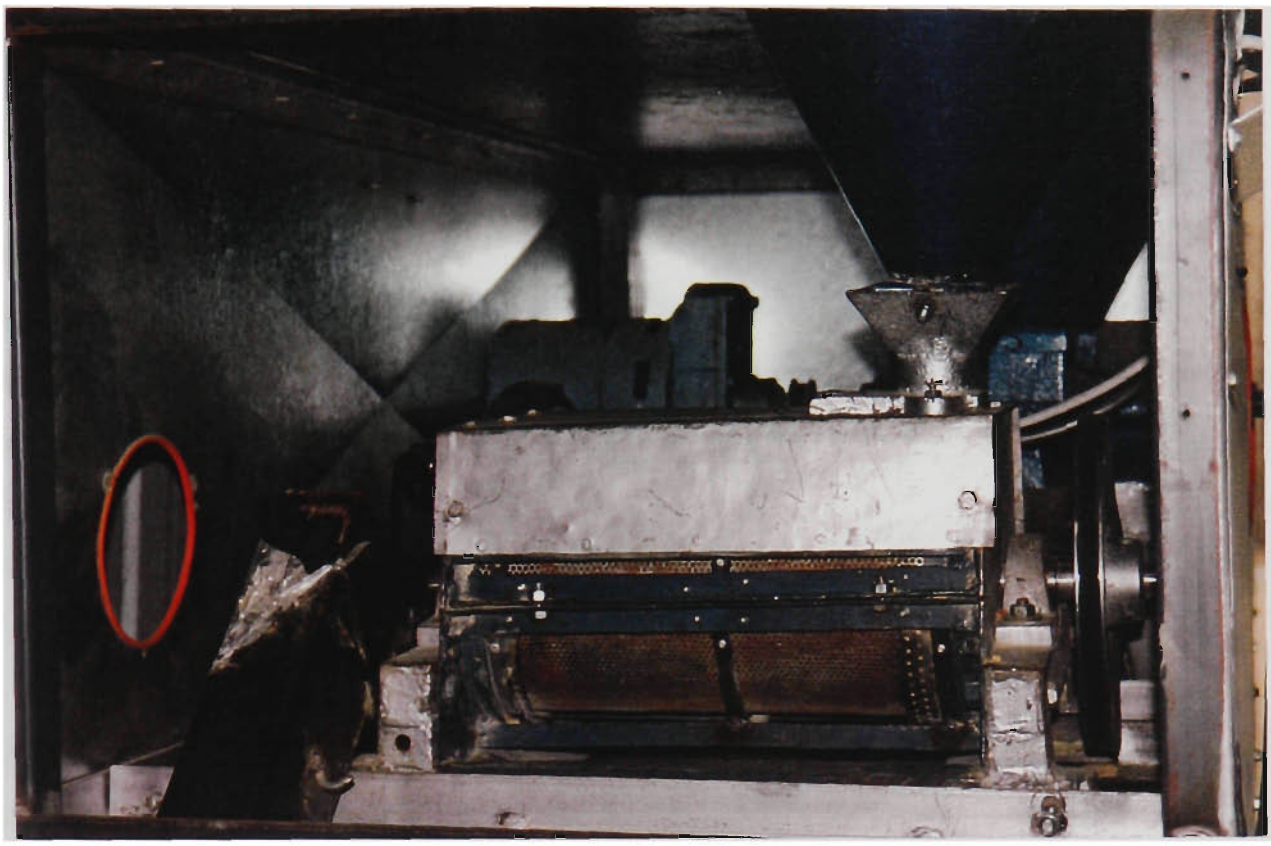


Figure 3.3a Side view of the AGT mill

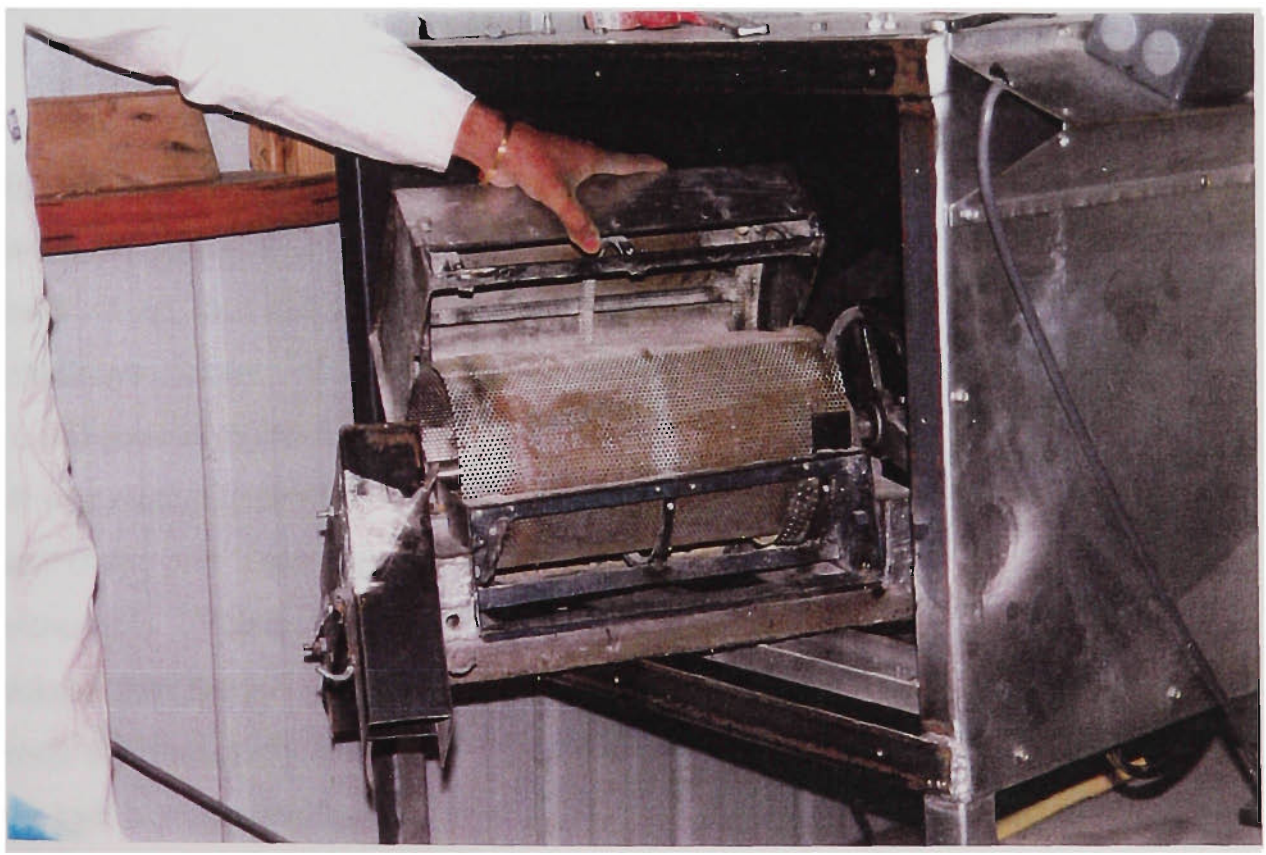


Figure 3.3b Mill being dismantled for cleaning

3.5.4.5 Separation of Fractions and Calculation of Dehulling Efficiency (DE)

Fractions obtained during dehulling were: splits (*dhal*) (D), which were retained on a 10-mesh sieve; husk (H), which was retained on a 10-mesh sieve and removed by aspiration; brokens (B), which were retained on a 30-mesh sieve; powder (P), which passed through 30-mesh sieve; whole seeds were retained on a 10-mesh sieve and manually separated.

The dehusked splits and whole seeds are together classified as *dhal*. The dehusked whole, referred to as '*gota*' in India, constituted about 4-5% of the total dehusked material regardless of the dehulling method employed and hence were combined with splits.

W_1	-	initial weight of the sample
W_2	-	weight of undehusked seed
D	-	weight of *dhal* ($D = W_1 - W_2 + H + B + P$)
Dhal yield % =		$D / W_1 X 100$
Husk %	=	$H / (W_1 . W_2) X 100$
Brokens %	=	$B / (W_1 . W_2) X 100$
Powder %	=	$P / (W_1 . W_2) X 100$
Recovery %	=	$(W_2 + D + H + P + B) / W_1 \times 100$, where W_2, D, H, P, B and W_1 represent weights of the fractions.

3.6 Functional Properties

The functional properties of wheat:chickpea composite flour were studied on a limited number of *desi* and *kabuli* cultivars. Sound samples of Amethyst (*desi*) and Garnet (*kabuli*) from SA and VIC, respectively, were decorticated in the AGT mill and ground to a fine powder in the Falling Number mill 3100 using a 0.5 mm screen. Hard and soft wheat samples were sourced from the AWB regional offices in QLD and VIC, respectively, and milled to 78% extraction in a Buhler laboratory mill (Uzwil, Switzerland). Wheat flour from each type of wheat was thoroughly mixed with chickpea flour from both the cultivars in the following ratios 90:10, 70:30 and 50:50 (w/w). Moisture, protein and fat were determined in duplicate on the different types of flour and the corresponding composite flours.

3.6.1 Water and Oil Absorption

The method described by del Rossario and Flores (1981) was used for the determination of water and oil absorption with minor modifications. A 1 g sample (either control or composite flour) was mixed with 10 mL distilled water or 15 mL refined peanut oil for 30 minutes; and the contents allowed to stand in a 30 ^{0}C water bath for 30 minutes. It was then centrifuged at 3,000 rpm for 20 minutes and the volume of supernatant recorded. Results are expressed as g absorbed/g sample.

3.6.2 Emulsification Capacity

Determination of emulsification capacity was carried out according to Singh and Singh (1991) with minor modifications. A 1 g sample was mixed with 50 mL distilled water in a beaker for 2 minutes with continuous high speed magnetic stirring. After complete dispersion, refined peanut oil was added from a burette to the beaker which was constantly stirred until the emulsion separated into two layers. Emulsification capacity is expressed as grams of oil per gram of sample or per gram of protein before phase separation occurred.

3.6.3 Flour Solubility and Swelling Power

For solubility measurement, 250 mg of flour was added to 15 mL distilled water in a centrifuge tube. The contents were thoroughly mixed using a vortex mixer, heated in a block heater at 65 °C and 95 °C for 30 minutes with occasional stirring then centrifuged at 4,500 rpm for 15 minutes. The supernatant (5 mL) was dried in a petri dish and the soluble solids content calculated as the percentage of flour soluble in water. The swelling power (capacity) was determined by weighing the precipitate and calculating the increase in weight of the precipitate.

3.6.4 Nitrogen Solubility Index (NSI)

The nitrogen solubility index (NSI) was determined at pH 6.0 and pH 7.0 according to the AACC method 46-23 (1983) with minor modifications. To a 1 g sample in a 50 mL centrifuge tube, 10 mL of buffers (pH adjusted distilled water using 0.01N sodium hydroxide) at pH 6.0 and pH 7.0 was added. The tubes were mixed in a vortex mixer for uniform sample dispersal before being shaken in a mechanical shaker for 30 minutes at medium speed. The tubes were then centrifuged at 4,500 rpm for 20 minutes. The supernatant was transferred to digestion tubes and dried before protein estimation by

the Kjeldahl method. NSI was calculated as the ratio of the nitrogen soluble in solution to total nitrogen in the sample.

3.6.5 Gelation Capacity

The gelation capacity was determined according to the method of del Rosario and Flores (1981). A sample suspension containing 8-12% (w/v) flour in 0.5% increments was prepared in 10 mL distilled water. The test tube was heated for 1 hour in boiling water, rapidly cooled under running cold tap water, and refrigerated at 5 °C for 3 hours. The least gelation concentration was determined as that concentration at which the sample did not collapse or slip from an inverted test tube.

3.6.6 Gel Consistency

Distilled water (10 mL) was added to a finely ground sample (0.5 g) in a beaker. The suspension was boiled for 20 minutes in a sand bath maintained at 120 °C. After boiling, the material was transferred to a petri dish (10 mm) and cooled to room temperature (25 °C). The contents were further cooled in a refrigerator at 5 °C for 1 hour. The gel thus formed was transferred to a smooth glass surface by inverting the petri dish. The petri dish was slowly removed and the diameter of the gel that spread on the glass was measured in mm.

3.6.7 Hot Paste Viscosity

Hot paste viscosity values were obtained with a Brabender viscoamylograph (Model Viscograph E, Duisburg, Germany) using 12% flour concentration according to Singh and Singh (1991). The temperature of homogenous slurries of wheat:chickpea composite flours was gradually increased from 30 °C (1.5 °C/minute) to 96 °C and held at that temperature for 15 minutes before being cooled to 30 °C in 44 minutes. The peak viscosity, breakdown and setback were calculated from the resulting graph which continually records changes to gel properties.

3.7 Production of Value Added Products

Instant (IN) and steamed & dried noodles (SDN) and pan bread were produced in the laboratory with some products obtained during the dehulling process.

3.7.1 Sample Preparation for Noodle Production

Australian standard white-noodle (ASW-N) grade wheat from the 1994/95 season from Fremantle, WA that was milled in a Buhler laboratory mill (Uzwil, Switzerland)

to 60% extraction rate was used as the wheat source. *Besan* was bought from the local Indian grocery store in Werribee. About 1 kg of *besan* was roasted in a heavy bottomed iron wok over a medium gas flame for 7 minutes at 105 °C. Wheat flour was mixed uniformly with both unroasted *besan* (hence referred to as raw) and roasted *besan* that had been cooled to room temperature in the following ratios 95:5, 90;10, 85:15 and 80:20 (w/w) and used for noodle production. Colour, protein and total fat were estimated on all the flours and products. Colour was measured objectively using a Minolta Chroma Meter with a 8 mm viewing head. A factor of 5.7 was used to calculate the protein content from nitrogen values. Water activity was measured with a Novasina Thermoconstanter TH200 (Switzerland) calibrated against crystalline potassium chloride. Water activity (a_w) was measured on all flours and products by placing a homogeneous sample (ground noodles) in the sample holder with the lid covered for 20 minutes before recording the reading.

3.7.2 Noodle Production

IN and SDN were produced by mixing 100 parts of flour in a Hobart mixer ('A' series, London) with a paddle beater at low speed for 1 minute with 34 parts of water containing 1 part of sodium chloride and 0.2 parts of a mixture of potassium carbonate and sodium carbonate in the ratio 6:4. This alkaline salt solution is referred to as *lye* or *kansui* in South East Asia. The mixing was repeated at medium speed for a further 4 minutes until a crumbly dough was formed. The dough was sheeted between 7 pairs of sheeting rolls, the first 3 of which were wavy, mimicking a kneading action and the last 3 were smooth steel rollers. There was a 15% reduction in the gap between the rollers coupled with an average 15% increase in speed of the rollers. The dough sheet was then cut with a pair of cutting rolls and conveyed to a steam bath via a conveyor belt. The differentials on the conveyor belt were set higher than the speed of the cutting rollers which resulted in wavy noodles strands. The noodle strands were steamed for 2 minutes and cut to produce noodle blocks each weighing 45 g. The noodle blocks were dried in hot air at 100 °C for 1 hour to produce steamed and dried noodles (SDN) or fried in palm oil at 150 °C for 90 seconds to yield instant noodles (IN). Thiamin and riboflavin levels were estimated on selected samples of SDN.

3.7.2.1 Sensory Evaluation of Noodles

Sensory evaluation was conducted by two expert panelists using a 5 point hedonic scale to evaluate colour (extremely yellow to extremely white), strength (extremely strong to extremely weak), firmness (extremely firm to extremely soft), chewiness (extremely chewy to extremely tender) and flavour (extremely wheaty to extremely beany) of noodles. Noodles made from 100% ASW-N grade flour was used as control. A copy of the sensory evaluation form is attached in Appendix I.

3.7.3 Pan Bread Production

Pan bread was produced at the William Angliss College, Melbourne, by the rapid dough method. Clean, sound samples of cultivars Garnet and Kaniva (*kabuli* chickpea) from Horsham, VIC were conditioned in water (as described in section 3.5.4.1) and dehulled in the AGT mill. The husk was separated from the splits by aspiration and pulverised in a domestic coffee grinder before grinding in a Falling Number mill 3100 fitted with a 0.5 mm screen. Protein, TDF and fat content in the baker's flour and hull were measured. A factor of 5.7 was used to calculate the protein content from nitrogen values for baker's flour and a factor of 6.25 was used to calculate the protein content from nitrogen values of hull. Control bread was produced using the formulation: baker's flour 100%, salt 2%, improver 1%, yeast 4% and water 60%. All dry ingredients were mixed at medium speed in a 10 kg Hobart mixer ('A' series, London) with a hook for 1 minute before the addition of water. The dough was mixed for 5-7 minutes at medium speed to produce a smooth dough which was divided into 4 equal portions. Ground husk, equivalent of 1%, 2% and 5% was added to the dough pieces and the fourth piece was treated as the control. Each of the dough pieces except the control, was mixed again for 1-2 minutes after the addition of 2%, 4% and 10% more water to the 1%, 2% and 5% hull supplemented breads, respectively. Bulk fermentation of the doughs were conducted for 20 minutes. Dough was scaled to yield 4 x 100 g dough pieces and rested for 12 minutes (intermediate proofing) at 26 °C. Dough pieces were moulded and placed in pup tins for final proofing of 60 minutes at 36 °C. Dough in the pup tins were baked for 18 minutes at 240 °C.

3.7.3.1 Evaluation of Bread

Moisture, protein, ash, TDF and fat were estimated on all the bread samples. A factor of 5.7 was used to calculate the protein content from nitrogen values for all breads. Carbohydrate and energy levels of all bread types was calculated using the formula in section 3.4.6 and Atwater factors adapted from Paul and Southgate (1978), respectively. Breads were evaluated 24 hours after production by two panelists for; loaf volume (visually and by rape seed displacement) (0-25), general appearance (0-25), crumb colour (0-20) (visually), crumb texture (0-20) and aroma (0-10) and the total score (0-100) was compared against that obtained for control. A copy of the evaluation form is attached in Appendix II. Crust and crumb colour were also measured objectively using a Minolta Chroma Meter with a 50 mm viewing head.

3.8 Statistical Analysis

MANOVA (multiple analysis of variance) was conducted for soaking and objective texture analysis using the Statistical Package for Scientists and Students System (SPSS 1985) and statistical tests for compositional studies, dehulling ability, functional properties and value-added products were conducted using the statistical software Minitab (1991). Standard error (SE) of the mean was determined and reported for all estimations (Snedecor and Cochran 1967).

Results and Discussion

4 Results and Discussion

4.1 Physical Properties and Chemical Composition of Chickpea Seed

4.1.1 Physical Properties and Chemical Composition of Commercially Traded Chickpea Seed

Data on physical properties and chemical composition of the major commercially traded *desi* and *kabuli* chickpea varieties from the pulse producing States of Australia were compiled over four seasons (1991-1995).

4.1.1.1 Samples Analysed

A total of 129 *desi* and 12 *kabuli* samples were received between 1991/92 and 1994/95. The ratio of *desi* to *kabuli* reflects the relatively small production of *kabuli*. Table 4.1.1 lists the *desi* varieties received from different States annually.

Table 4.1.1 Sample receival of *desi* varieties on a Statewide basis between 1991/92 and 1994/95

Yr	1991/92				1992/93					1993/94				1994/95			
	Q	N	V	S	Q	N	V	S	W	Q	N	V	W	Q	V	S	W
A	1	8	9	1	5	4	-	1	1	5	1	4	1	1	-	4	-
B	-	-	-	-	-	1	-	-	-	-	1	-	-	2	1	-	-
D	-	-	3	3	-	1	11	1	1	-	-	5	-	-	4	3	-
S	1	1	3	3	1	1	2	-	-	-	-	1	-	-	-	3	-
T	-	-	1	1	1	1	4	-	-	-	-	2	9	1	2	2	5
No					-	-	-	-	-	-	-	-	-	1	-	-	-
129	2	9	16	8	7	8	17	2	2	5	2	12	10	5	7	12	5

Q, N, V, S and W = QLD, NSW, VIC, SA and WA, respectively

A, B, D, S, T, No = Amethyst, Barwon, Dooen, Semsen, Tyson and Norwin, respectively

A poor harvest due to drought, as in 1993/94, resulted in a 20% decrease in the number of samples received during that season. The small number of samples (29) received in the following year was due to a reduction in the area sown to chickpea in North East Australia. The number of samples received from NSW decreased during

the period of the study suggesting that chickpea is probably being replaced by other pulses in the rotational program.

The number of *desi* samples from VIC was the highest each season as it is the largest producer of chickpea (~60%) in Australia (P King, Personal Communication Revell Seeds 1997). The increase in the number of samples received from WA over the 4 years of the study is evidence that the State is emerging as a significant producer of chickpea, especially Tyson.

There was a steady decrease in the number of Semsen samples received, with a marginal recovery in 1994/95, and a decline in Amethyst production, both of which could be due to the availability of alternate higher yielding varieties. Although only a small number of samples of newer varieties such has Barwon and Norwin from NSW and QLD were received, their composition was analysed in order to highlight differences with established varieties.

A total of 12 *kabuli* samples were received in the first three seasons; 4 Kaniva from VIC in 1992/93 and in 1993/94 and 1 in 1994/95. One Garnet sample was received in the first two years of the study from VIC and NSW and 1 Opal was received from NSW in 1993/94. The Garnet and Opal samples were grouped together for statistical analyses and comparisons were made with Kaniva.

4.1.1.2 Effect of Season on Properties and Composition of Amethyst, Dooen, Semsen and Tyson Cultivars

Seasonal changes were monitored only on the major varieties and selected attributes of *desi* chickpea.

4.1.1.2.1 Physical Properties

Figure 4.1.1 shows the effect of season on weight of 100 seeds (g) and colour (L* whiteness, a* redness and b* yellowness) of Amethyst, Dooen, Semsen and Tyson. Data on weight of 100 seeds was not collected in 1991/92. The colour measurements were made with the Minolta Chroma Meter with a large viewing head (50 mm) which was not consistent with successive years and hence results are not reported. Table 4.1.2 gives the effect of variety on physical properties of *desi* seeds between 1992 and 1995. (The level of significant differences can be seen from the tables). The weight of 100 seeds of the different varieties was within a narrow range for each variety in all seasons. There was, however, a significant decrease in the weight of Tyson in 1993/94

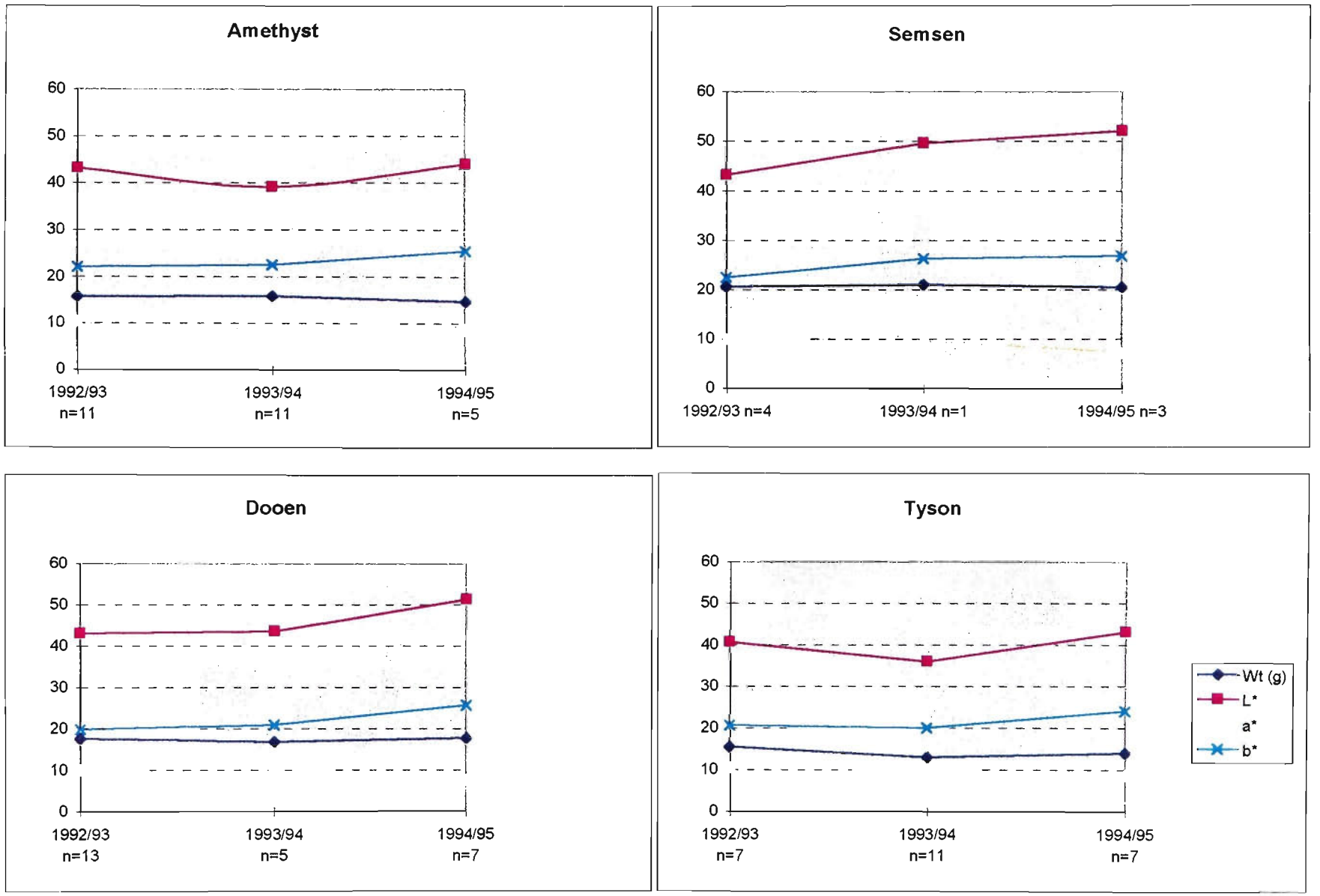


Figure 4.1.1 Effect of season on weight of 100 seeds (g) and colour of Amethyst, Dooen, Semsen and Tyson whole seeds
L* = whiteness, a* = redness, b* = yellowness

Table 4.1.2 Effect of variety on physical properties of *desi* seeds between 1992 and 1995

1992/93	No. of samples	Weight (g)	L*	a*	b*
Amethyst	11	15.6**a** ± 0.3	43.0 ± 1.5	10.5 ± 0.4	21.9 ± 1.1
Dooen	13	17.4**b** ± 0.5	42.9 ± 0.4	10.1 ± 0.3	19.6 ± 0.4
Semsen	4	20.6**c** ± 1.0	43.1 ± 1.3	10.1 ± 0.5	22.4 ± 0.6
Tyson	7	15.4**a** ± 0.8	40.5 ± 0.9	10.6 ± 0.3	20.5 ± 0.4
F value	35‡	10.7**	1.1	0.6	2.6
1993/94					
Amethyst	11	15.7**a** ± 0.6	39.0**ab** ± 1.5	11.4 ± 0.5	22.3**a** ± 0.5
Dooen	5	16.8**a** ± 1.2	43.4**a** ± 2.1	10.8 ± 0.4	20.7**ab** ± 0.7
Semsen	1	21.0	49.5	9.4	26.2
Tyson	11	12.9**b** ± 0.2	35.9**b** ± 0.8	10.1 ± 0.2	19.9**b** ± 0.5
F value	28‡	11.0**	6.0**	2.9	5.9**
1994/95					
Amethyst	5	14.6**a** ± 0.2	43.8**a** ± 1.0	8.8 ± 0.5	25.3 ± 1.0
Dooen	7	17.7**b** ± 0.4	51.2**b** ± 0.9	7.7 ± 0.2	25.5 ± 0.6
Semsen	3	20.5**b** ± 1.2	51.9**b** ± 0.8	7.3 ± 0.2	26.7 ± 0.9
Tyson	7	13.9**a** ± 0.8	42.9**a** ± 1.5	8.8 ± 0.6	23.9 ± 0.8
F value	22‡	12.4**	10.7**	1.7	1.6

L* = whiteness, a* = redness, b* = yellowness

‡ Total number of samples received

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

compared to the other seasons. This was probably because of 'improper grain filling' during growth resulting in small shriveled grains and/or due to the fact that most of the Tyson was from WA which tend to have smaller seeds (as discussed in section 4.1.1.3.1). Semsen was significantly larger and Tyson was significantly smaller in all seasons with Amethyst and Dooen having an intermediate seed size.

The L* value (brightness/whiteness) of Dooen and Semsen from 1994/95 was significantly higher i.e. samples were paler, than the corresponding samples from previous years. The L* value of Tyson from 1993/94 was significantly lower than other Tyson samples; a lower L* value indicates darker samples and the darkness is probably compounded by a smaller grain size. The L* values of Tyson from 1993/94 and Amethyst and Tyson in 1994/95 were significantly lower than the other varieties.

The a* value (redness) in 1994/95 of Amethyst, Dooen, Semsen and Tyson were significantly lower than the a* value of corresponding samples from previous years. The reason for the lower a* value is not known. The lower a* value was, however, complemented by a significant increase in b* value of Semsen, Dooen and Tyson from the 1994/95 season. The b* value of Amethyst from 1993/94 was significantly higher than the other varieties.

4.1.1.2.2 Proximate Composition

Figure 4.1.2 and Table 4.1.3 gives the effect of season on proximate composition of the 4 important varieties. The ash content was not plotted as only limited samples from each season were analysed and results showed no significant variation between seasons and varieties.

In 1993/94, the carbohydrate content of Tyson was significantly lower and TDF content was significantly higher than that of Amethyst and Dooen. There was a significant decrease in total carbohydrate content of Amethyst, Tyson and Semsen from the 1994/95 harvest compared to corresponding samples from previous years. The decrease in carbohydrate content was accompanied by a significant increase in TDF of Amethyst, Tyson, Semsen and Dooen in 1994/95. There was a significant increase in fat content for Amethyst, Semsen, Dooen and Tyson in 1994/95. The fat content showed a steady increase in all varieties till 1992/93, then increased again in 1994/95. Consequently, the gross energy for ruminants (ER kJ/100 g) was

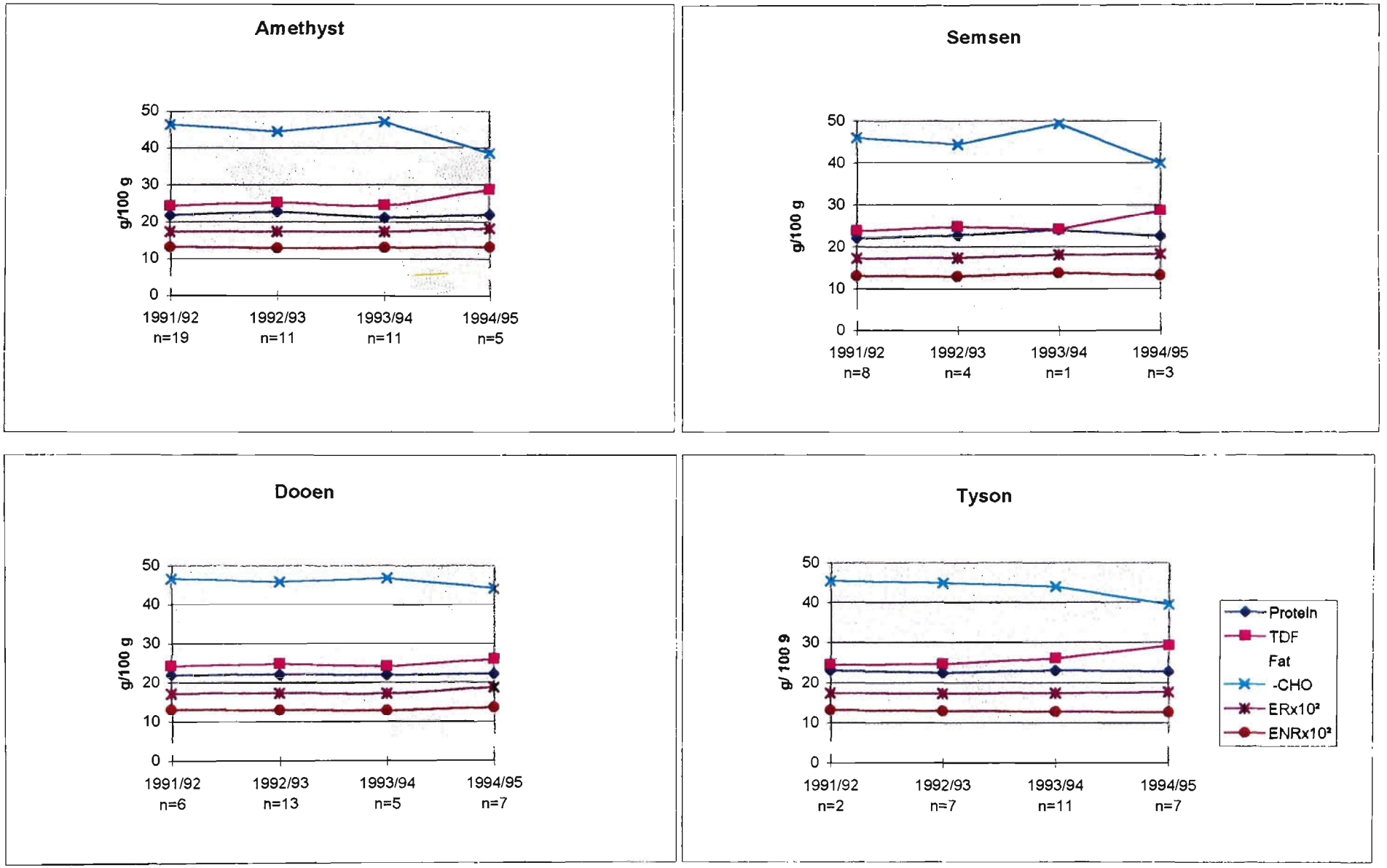


Figure 4.1.2 Effect of season on proximate composition of Amethyst, Dooen, Semsen and Tyson whole seeds
ENRx10^2 Energy non-ruminants, ERx10^2 Energy ruminants.

Table 4.1.3 Effect of variety on mean proximate composition (g/100 g) on dry weight basis of *desi* cultivars between 1991 and 1995

1991/92	No. of samples	Protein(Nx6.25) (g)	Ash† (g)	TDF (g)	Fat (g)	-CHO (g)	Energy (NR) (kJ)	Energy (R) (kJ)
Amethyst	19	21.7 ± 0.4	2.8 ± 0.1	24.2 ± 0.3	3.9 ± 0.1	46.2 ± 0.6	1315 ± 4	1730 ± 4
Dooen	6	21.9 ± 0.1	2.8 ± 0.1	24.1 ± 0.1	3.3 ± 0.2	46.5 ± 0.2	1300 ± 5	1715 ± 6
Semsen	8	22.0 ± 0.6	2.9 ± 0.1	23.7 ± 0.4	3.9 ± 0.2	45.9 ± 1.1	1310 ± 8	1720 ± 3
Tyson	2	23.0 ± 1.1	2.9 ± 0.2	24.4 ± 0.4	4.0 ± 0.3	45.2 ± 1.0	1320 ± 15	1740 ± 23
F value	35‡	0.4	0.1	0.6	1.8	0.2	1.1	2.9
1992/93								
Amethyst	11	22.7 ± 0.7	3.3 ± 0.1	25.1 ± 0.3	5.2 ± 0.1	43.7 ± 0.6	1285 ± 7	1725 ± 3
Dooen	13	22.0 ± 0.2	2.9 ± 0.1	24.6 ± 0.3	4.8 ± 0.1	45.6 ± 0.3	1285 ± 18	1720 ± 3
Semsen	4	22.7 ± 0.4	3.0 ± 0.1	24.6 ± 1.0	5.3 ± 0.2	44.3 ± 0.9	1295 ± 14	1730 ± 4
Tyson	7	22.4 ± 0.6	3.1 ± 0.1	24.5 ± 0.3	5.3 ± 0.4	44.6 ± 0.8	1295 ± 10	1725 ± 7
F value	35‡	0.5	1.6	0.6	1.5	2.3	0.7	0.4
1993/94								
Amethyst	11	21.0**a** ± 0.6	2.9 ± 0.1	24.4**a** ± 0.4	5.2**a** ± 0.1	47.0**a** ± 0.8	1305 ± 14	1735 ± 15
Dooen	5	21.9**ab** ± 0.4	2.7 ± 0.1	24.0**a** ± 0.6	4.7**b** ± 0.1	46.6**a** ± 0.8	1280 ± 19	1715 ± 15
Semsen	1	23.9	3	24	4.9	49.2	13.8	18
Tyson	11	23.0**b** ± 0.2	2.9 ± 0.1	26.0**b** ± 0.1	5.0**ab** ± 0	43.7**b** ± 0.5	1280 ± 7	1735 ± 5
F value	28‡	5.7**	0.6	8.0**	6.6**	7.2**	1.6	0.8
1994/95								
Amethyst	5	21.9 ± 0.9	3.0 ± 0.1	28.5**ab** ± 1.1	6.2 ± 0.3	38.4 ± 2.9	1315 ± 21	1820 ± 4
Dooen	7	22.1 ± 0.5	2.9 ± 0.1	25.8**a** ± 0.7	5.4 ± 0.2	44.1 ± 1.3	1355 ± 13	1870 ± 55
Semsen	3	22.5 ± 0.4	3.0 ± 0.1	28.5**ab** ± 0.4	6.1 ± 0	39.8 ± 0.5	1315 ± 6	1815 ± 2
Tyson	7	22.8 ± 0.6	2.9 ± 0.1	29.2**b** ± 0.7	5.9 ± 0.3	39.2 ± 2.2	1270 ± 24	1770 ± 12
F value	22‡	0.3	0.7	2.9*	1.3	2.1	1.8	0.6

† analyses conducted on limited number of samples

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

‡ Total number of samples received

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

significantly higher for all varieties. The energy value for non-ruminants was not affected by variety or season while that for ruminants was not affected by variety.

4.1.1.2.3 Trace Mineral Content

The effect of season on the trace mineral content of the 4 varieties is presented in Figure 4.1.3 and Table 4.1.4. In 1992/93, Tyson had a significantly higher sodium content and in 1993/94 Amethyst had a significantly lower sodium content than the other varieties. There was a significant increase in the sodium levels of Semsen and Dooen from 1994/95 than in previous years. The potassium level of Amethyst in 1992/93 was significantly lower than Semsen. Semsen and Tyson of 1992/93 had significantly reduced levels of phosphorus in comparison to later years. The calcium content of Amethyst, Semsen and Dooen showed a significant decrease in 1993/94 and a significant increase in the following year in comparison with 1992/93. Dooen had significantly lower calcium content than the other varieties in 1992/93 and 1994/95. The magnesium content of Tyson in 1993/94 was significantly lower than Amethyst.

The zinc content of Tyson was significantly lower than Amethyst and Dooen in 1993/94. The levels of zinc in Dooen and Tyson recorded a significant increase in 1994/95 whereas the iron content of Amethyst and Tyson had a significant increase in the same year. Copper levels in Tyson were significantly lower than that for Amethyst from 1992/93.

4.1.1.3 Effect of Season on Properties and Composition of Chickpea from Different States

4.1.1.3.1 Physical Properties

Tables 4.1.5 and 4.1.6 show the seasonal effect on the weight of 100 seeds and colour of whole *desi* seeds from different States and the effect of State (site) on physical properties of *desi* cultivars between 1992 and 1995, respectively.

Desi seeds from WA in 1994/95 were significantly smaller than those from QLD in 1994/95. The weight of 100 seeds was significantly lower in WA compared to QLD in 1993/94 and 1994/95. This observation is to be expected because the small seeded Tyson (which was significantly smaller than seeds from other varieties) was received from WA.

The L* and b* values were significantly different between all States in all seasons. The L* value of *desi* from QLD was significantly lower, while that of VIC, SA and WA

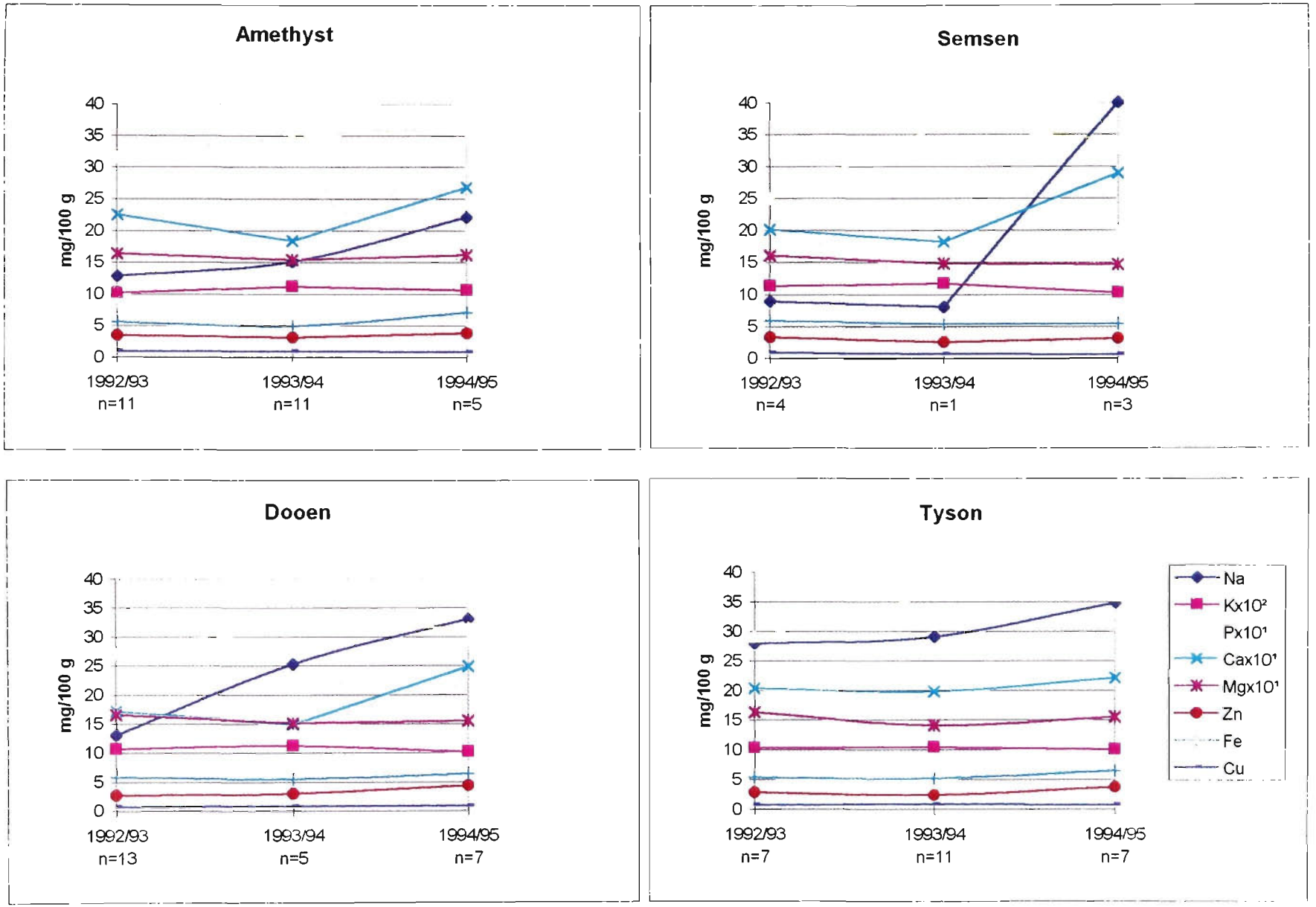


Figure 4.1.3 Effect of season on trace mineral content of Amethyst, Dooen, Semsen and Tyson whole seeds
K represented as 10^2, P, Ca and Mg represented as 10^1

Table 4.1.4 Effect of variety on mean trace mineral content (mg/100 g) on dry weight basis of *desi* cultivars between 1992 and 1995

1992/93	No. of samples	Sodium (mg)	Potassium (mg)	Phosphorus† (mg)	Calcium (mg)	Magnesium (mg)	Zinc (mg)	Iron (mg)
Amethyst	11	12.9**ab** ± 2.7	1011**a** ± 28	316 ± 30	224**a** ± 9	163 ± 3	3.5 ± 0.3	5.5 ± 0.2
Dooen	13	19.2**ab** ± 2.0	1066**ab** ± 12	271 ± 17	171**b** ± 4	165 ± 2	2.7 ± 0.3	5.8 ± 0.2
Semsen	4	8.8**b** ± 1.0	1126**b** ± 29	250 ± 7	200**ab** ± 8	160 ± 2	3.3 ± 0.2	5.8 ± 0.2
Tyson	7	27.8**a** ± 7.4	1030**ab** ± 23	290 ± 18	202**ab** ± 11	163 ± 5	2.8 ± 0.2	5.3 ± 0.2
F value	35‡	3.7*	3.4*	1.7	9.9**	0.2	1.9	1.2
1993/94								
Amethyst	11	15.0**a** ± 1.9	1112 ± 33	347 ± 30	183**a** ± 8	153**a** ± 4	3.1**a** ± 0.1	4.9 ± 0.2
Dooen	5	25.2**b** ± 1.8	1116 ± 26	319 ± 22	148**b** ± 8	151**ab** ± 3	3.0**a** ± 0.2	5.4 ± 0.2
Semsen	1	8.0	1166	366.0	181.0	148.0	2.5	5.3
Tyson	11	28.9**b** ± 2.2	1036 ± 10	362 ± 10	197**a** ± 2.8	141**b** ± 2	2.4**b** ± 0.1	5.1 ± 0.3
F value	28‡	13.3**	3.3	0.7	13.1**	4.5**	9.4**	0.9
1994/95								
Amethyst	5	22.0 ± 3.5	1057 ± 39	364 ± 18	267 ± 17	161 ± 6	3.8 ± 0.5	7.0 ± 1.0
Dooen	7	33.0 ± 4.8	1013 ± 14	314 ± 47	247 ± 7	154 ± 2	4.3 ± 0.3	6.3 ± 0.5
Semsen	3	40.0 ± 7.0	1020 ± 36	339 ± 17	288 ± 16	146 ± 4	3.1 ± 0.5	5.3 ± 0.3
Tyson	7	34.7 ± 8.3	1002 ± 25	360 ± 16	220 ± 28	155 ± 4	3.7 ± 0.3	6.4 ± 0.5
F value	22‡	0.7	0.7	0.6	1.2	1.2	1.2	0.7

† analyses conducted on limited number of samples

‡ Total number of samples received

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Table 4.1.5 Effect of season on physical properties of *desi* cultivars from different States

QLD	No. of samples	Weight (g)	L*	a*	b*
1992/93	7	16.7 ± 1.1	45.0**a** ± 0.9	10.7**a** ± 0.4	23.1 ± 1.3
1993/94	5	16.6 ± 0.8	41.6**a** ± 1.9	11.7**a** ± 0.8	23.7 ± 0.4
1994/95	4	20.1 ± 2.6	35.0**b** ± 1.1	8.0**b** ± 0.4	20.5 ± 0.8
F value	16‡	1.6	13.9**	8.8**	2.1
NSW					
1992/93	8	17.3 ± 0.7	42.2**a** ± 1.0	10.8 ± 0.5	21.3 ± 0.8
1993/94	2	15.0 ± 0.8	32.5**b** ± 3.1	12.2 ± 1.8	19.4 ± 0.1
F value	10‡	2	17.6**	0.2	1.2
VIC					
1992/93	17	17.0 ± 0.5	42.1**a** ± 0.6	10.0**a** ± 0.2	19.9**a** ± 0.4
1993/94	12	15.7 ± 0.9	41.3**a** ± 1.5	10.6**a** ± 0.3	21.4**a** ± 0.5
1994/95	7	18.0 ± 1.2	48.6**b** ± 2.0	7.8**b** ± 0.6	24.5**b** ± 0.7
F value	36‡	1.8	7.8**	16.8**	16.8**
SA					
1992/93	2	16.1 ± 2.5	36.8**a** ± 5.6	9.9**a** ± 0.2	18.8**a** ± 0.5
1994/95	12	16.5 ± 0.9	47.3**b** ± 1.3	7.9**b** ± 0.2	26.2**b** ± 0.5
F value	14‡	0	8.8*	10.1**	33.0**
WA					
1992/93	2	13.9 ± 1.6	42.4**a** ± 0.6	10.7 ± 0.4	21.8**ab** ± 1.5
1993/94	10	13.4 ± 0.5	35.7**b** ± 0.8	10.5 ± 0.5	20.0**a** ± 0.6
1994/95	5	13.5 ± 0.6	45.6**a** ± 1.7	10.2 ± 0.5	24.4**b** ± 0.9
F value	17‡	0.1	21.2**	0.1	9.0**

L* = whiteness, a* = redness, b* = yellowness

‡ Total number of samples received

Values presented are Mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Table 4.1.6 Effect of State (site) on physical properties of *desi* cultivars between 1991and 1995

1992/93	No. of samples	Weight (g)	L*	a*	b*
QLD	7	16.7 ± 1.1	45.0**a** ± 0.9	10.7 ± 0.4	23.1**a** ± 1.3
NSW	8	17.3 ± 0.7	42.2**a** ± 1.0	10.8 ± 0.5	21.3**ab** ± 0.8
VIC	17	17.0 ± 0.5	42.1**a** ± 0.6	10.0 ± 0.2	19.9**b** ± 0.4
SA	2	16.1 ± 2.5	36.8**b** ± 5.6	9.9 ± 0.2	18.8**ab** ± 0.5
WA	2	13.9 ± 1.6	42.4**ab** ± 0.6	10.7 ± 0.4	21.8**ab** ± 1.5
F value	36‡	1.0	3.6*	1.1	3.1*
1993/94					
QLD	5	16.6 ± 0.8	41.6**a** ± 1.9	11.7 ± 0.8	23.7**a** ± 0.4
NSW	2	15.0 ± 0.8	32.5**b** ± 3.1	12.2 ± 1.8	19.4**b** ± 0.1
VIC	12	15.7 ± 0.9	41.3**a** ± 1.5	10.6 ± 0.3	21.4**b** ± 0.5
WA	10	13.4 ± 0.5	35.7**b** ± 0.8	10.5 ± 0.5	20.0**b** ± 0.6
F value	29‡	2.5	5.4**	1.5	6.3**
1994/95					
QLD	4	20.1**a** ± 2.6	35.0**a** ± 1.1	8.0**a** ± 0.4	20.5**a** ± 0.8
VIC	7	18.0**ab** ± 1.2	48.6**b** ± 2.0	7.8**a** ± 0.6	24.5**b** ± 0.7
SA	12	16.5**ab** ± 0.9	47.3**b** ± 1.3	7.9**a** ± 0.2	26.2**b** ± 0.5
WA	5	13.5**b** ± 0.6	45.6**b** ± 1.7	10.2**b** ± 0.5	24.4**b** ± 0.9
F value	28‡	3.4*	9.8**	5.8**	10.0**

L* = whiteness, a* = redness, b* = yellowness

‡ Total number of samples received

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

was significantly higher in 1994/95 than in previous years. In 1992/93, the L* value of SA was significantly lower than QLD, NSW and VIC and the b* value of VIC was significantly lower than QLD. In 1993/94 samples from WA and NSW had significantly lower L* and b* values whereas in 1994/95, QLD samples had the lowest values for brightness and yellowness. The a* values of QLD and VIC samples were significantly lower in the same year compared to previous years. In 1994/95 the a* values of WA was significantly higher than that for QLD, VIC and SA. NSW samples of 1993/94 showed a significant decrease in L* value compared to the samples from 1992/93. According to these results, changes in brightness (L* value) and redness (a* value) of samples do not seem to be correlated.

Like the L* value, the b* value showed a significant increase in VIC and WA seeds in 1994/95 compared to preceding years, probably suggesting a positive correlation between brightness and yellowness. The L* and b* values showed a significant increase and the a* value showed a significant decrease in SA samples from 1994/95 compared to those from 1992/93. The relation if any, between the L*, a* and b* values is difficult to evaluate because of the lack of uniformity in colour of the seed.

4.1.1.3.2 Proximate Composition

The effect of season on mean proximate composition of *desi* samples from different States is shown in Table 4.1.7 and the effect of State (site) on mean proximate composition of *desi* cultivars between 1991 and 1995 is given in Table 4.1.8.

The TDF content of samples from QLD, SA and WA in 1994/95 were significantly higher than samples from earlier years. As a result, the energy value for ruminants was also significantly higher in QLD, SA and WA samples of 1994/95. The energy value for ruminants for *desi* from VIC in 1994/95 was also significantly higher than in previous years. The fat content of VIC (1991/92 and 1993/94) and WA (1993/94) samples were significantly lower than samples from other States, while the fat content of VIC, SA and WA samples from 1994/95 were significantly higher than in previous years. Total carbohydrate content of samples in 1993/94 from QLD was significantly higher than samples from the following year while the carbohydrate content of WA samples was significantly lower in 1994/95 compared to previous years. The carbohydrate content of WA in 1993/94 was significantly lower than in all other States. Total carbohydrate content of QLD, VIC and WA from 1994/95 was significantly

Table 4.1.7 Effect of season on mean proximate composition (g/100 g) on dry weight basis of *desi* cultivars from different States

QLD	No. of samples	Protein(Nx6.25) (g)	Ash† (g)	TDF (g)	Fat (g)	-CHO (g)	Energy (NR) (kJ)	Energy (R) (kJ)
1991/92	2	22.0 ± 2.0	3.2 ± 0.2	25.2a ± 1.4	4.7 ± 0.3	44.0ab ± 2.4	1310 ± 5	1745ab ± 28
1992/93	7	23.2 ± 1.1	3.2 ± 0.2	24.6a ± 0.5	5.0 ± 0.2	44.0ab ± 1.0	1290 ± 8	1720a ± 4
1993/94	5	20.0 ± 1.4	3.3 ± 0.1	23.4ab ± 0.2	5.4 ± 0.3	48.1a ± 0.6	1280 ± 5	1715ab ± 0
1994/95	4	23.4 ± 1.0	2.9 ± 0.1	28.9b ± 1.7	5.6 ± 0.3	38.4b ± 2.8	1300 ± 34	1805b ± 4
F value	18‡	0.9	1.8	6.9**	1.9	5.0*	0.7	3.5*
NSW								
1991/92	9	21.9 ± 0.6	2.7a ± 0.1	23.5 ± 0.3	4.2a ± 0.2	46.0 ± 0.8	1320a ± 3.9	1730 ± 4
1992/93	8	22.8 ± 0.3	2.9ab ± 0.1	24.0 ± 0.4	5.1b ± 0.2	45.1 ± 0.5	1290b ± 11	1725 ± 4
1993/94	2	20.0 ± 1.4	3.3b ± 0.1	24.7 ± 0.2	5.3b ± 0.3	46.4 ± 0.6	1280ab ± 5	1715 ± 0
F value	19‡	3.2	11.1*	1.8	8.1**	0.7	5.2*	1.4
VIC								
1991/92	16	21.3 ± 0.4	2.9 ± 0.1	24.2 ± 0.3	3.4a ± 0.2	47.0a ± 0.5	1315a ± 5	1730a ± 4
1992/93	17	21.8 ± 0.1	3.1 ± 0.1	24.8 ± 0.3	5.2bc ± 0.2	45.3b ± 0.4	1290b ± 6	1725a ± 3
1993/94	12	22.0 ± 0.5	2.8 ± 0.1	24.8 ± 0.4	4.9b ± 0.1	46.2ab ± 0.6	1290b ± 11	1735a ± 11
1994/95	7	22.7 ± 0.4	2.9 ± 0.1	25.5 ± 0.7	5.9c ± 0.3	43.4c ± 0.8	1365c ± 10	1870b ± 55
F value	52‡	2.1	1.2	1.8	28.3**	6.3**	15.0**	13.5**
SA								
1991/92	8	22.8ab ± 0.3	3.0ab ± 0.1	24.2a ± 0.2	3.6a ± 0.2	45.0 ± 0.7	1300 ± 5	1715a ± 3
1992/93	2	24.0a ± 0.1	3.3b ± 0.2	25.4a ± 1.8	4.8ab ± 0.1	42.6 ± 1.9	1310 ± 27	1715a ± 0
1994/95	12	21.4b ± 0.4	2.9a ± 0	28.7b ± 0.6	6.0b ± 0.2	39.2 ± 1.9	1310 ± 14	1815b ± 6
F value	22‡	5.2*	3.8*	19.0**	28.4**	3.0	0.8	110.6**
WA								
1992/93	2	22.5 ± 1.4	2.9 ± 0	25.8a ± 0.2	5.3ab ± 0.3	43.4a ± 0.9	1275 ± 5	1730a ± 8
1993/94	10	22.7 ± 0.3	3.0 ± 0.1	25.9a ± 0.2	5.0a ± 0	43.8a ± 0.5	1280 ± 8	1730a ± 5
1994/95	5	23.5 ± 0.5	3.0 ± 0.1	28.6b ± 0.4	5.7b ± 0.1	38.8b ± 1.3	1320 ± 30	1825b ± 25
F value	17‡	1.3	1.2	24.3**	18.1**	11.0**	2.3	22.6**

† analyses conducted on limited number of samples

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

‡ Total number of samples received

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

Table 4.1.8 Effect of State (site) on mean proximate composition (g/100 g) on dry weight basis of *desi* cultivars between 1991 and 1995

1991/92	No. of samples	Protein(Nx6.25) (g)	Ash† (g)	TDF (g)	Fat (g)	-CHO (g)	Energy (NR) (kJ)	Energy (R) (kJ)
QLD	2	22.0 ± 2.0	3.2a ± 0.2	25.2 ± 1.4	4.7a ± 0.3	44.0 ± 2.4	1310ab ± 5	1745a ± 28
NSW	9	21.9 ± 0.6	2.7b ± 0.1	23.5 ± 0.3	4.2a ± 0.2	46.0 ± 0.8	1320a ± 3.9	1730ab ± 4
VIC	16	21.3 ± 0.4	2.9ab ± 0.1	24.2 ± 0.3	3.4b ± 0.2	47.0 ± 0.5	1315ab ± 5	1730ab ± 4
SA	8	22.8 ± 0.3	3.0a ± 0.1	24.2 ± 0.2	3.6ab ± 0.2	45.0 ± 0.7	1300b ± 5	1715b ± 3
F value	35‡	1.6	4.9**	1.9	3.8*	2.2	3.3*	3.8*
1992/93								
QLD	7	23.2 ± 1.1	3.2 ± 0.2	24.6 ± 0.5	5.0 ± 0.2	44.0 ± 1.0	1290 ± 8	1720 ± 4
NSW	8	22.8 ± 0.3	2.9 ± 0.1	24.0 ± 0.4	5.1 ± 0.2	45.1 ± 0.5	1290 ± 11	1725 ± 4
VIC	17	21.8 ± 0.1	3.1 ± 0.1	24.8 ± 0.3	5.2 ± 0.2	45.3 ± 0.4	1290 ± 6	1725 ± 3
SA	2	24.0 ± 0.1	3.3 ± 0.2	25.4 ± 1.8	4.8 ± 0.1	42.6 ± 1.9	1310 ± 27	1715 ± 0
WA	2	22.5 ± 1.4	2.9 ± 0	25.8 ± 0.2	5.3 ± 0.3	43.4 ± 0.9	1275 ± 5	1730 ± 8
F value	35‡	1.9	1.4	1.3	0.3	1.7	0.4	0.5
1993/94								
QLD	5	20.0 ± 1.4	3.3 ± 0.1	23.4a ± 0.2	5.4a ± 0.3	48.1a ± 0.6	1330 ± 5	1715 ± 0
NSW	2	20.0 ± 1.4	3.3 ± 0.1	24.7ab ± 0.2	5.3ab ± 0.3	46.4ab ± 0.6	1280 ± 5	1715 ± 0
VIC	12	22.0 ± 0.5	2.8 ± 0.1	24.8ab ± 0.4	4.9b ± 0.1	46.2a ± 0.6	1290 ± 11	1735 ± 11
WA	10	22.7 ± 0.3	3.0 ± 0.1	25.9b ± 0.2	5.0b ± 0	43.8b ± 0.5	1280 ± 8	1730 ± 5
F value	29‡	2.5	3.6	6.1**	3.6*	4.6*	1.7	0.2
1994/95								
QLD	4	23.4ab ± 1.0	2.9 ± 0.1	28.9ab ± 1.7	5.6 ± 0.3	38.4 ± 2.8	1300 ± 34	1805 ± 4
VIC	7	22.7ab ± 0.4	2.9 ± 0.1	25.5a ± 0.7	5.9 ± 0.3	43.4 ± 0.8	1365 ± 10	1870 ± 55
SA	12	21.4a ± 0.4	2.9 ± 0	28.7b ± 0.6	6.0 ± 0.2	39.2 ± 1.9	1310 ± 14	1815 ± 6
WA	5	23.5b ± 0.5	3.0 ± 0.1	28.6ab ± 0.4	5.7 ± 0.1	38.8 ± 1.3	1320 ± 30	1825 ± 25
F value	28‡	4.0*	0.1	4.0*	0.5	1.2	2.7	1.0

† analyses conducted on limited number of samples

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

‡ Total number of samples received

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

lower than other samples from those States in previous years. The energy for non-ruminants was significantly lower in NSW in 1992/93 and VIC in 1992/93 and 1993/94 compared to other years. SA samples from 1991/92 had the lowest energy value for ruminants and non-ruminants compared to the other States.

4.1.1.3.3 Trace Mineral Content

Table 4.1.9 shows the effect of season on the trace mineral content of samples from different States and Table 4.1.10 gives the effect of State (site) on trace mineral levels between 1992 and 1995.

Sodium content of WA samples was significantly higher than all other States in 1992/93 and 1994/95. The potassium content of NSW samples from 1993/94 was significantly higher than its 1992/93 samples while the potassium content of VIC in 1994/95 was significantly lower than in previous years. NSW samples from 1993/94 also had significantly higher potassium levels compared to samples from other States in that season. Phosphorus content in NSW, VIC and WA in 1992/93 was significantly lower than in later years. The phosphorus content of NSW in 1992/93 and that of QLD in 1993/94 were significantly lower compared to the other States. The calcium content of VIC samples from 1994/95 was significantly higher than previous samples from that State whereas calcium levels in WA *desi* chickpea was significantly higher in 1992/93. VIC had the lowest calcium content in 1992/93 and 1993/94, while WA had the lowest calcium content in 1994/95. Samples of QLD, VIC and WA from 1993/94 had significantly lower magnesium levels compared to other years and NSW samples from 1993/94 had the highest magnesium level compared to the other States. NSW samples recorded significantly lower zinc levels in 1992/93, while VIC and WA recorded a significantly lower zinc contents in 1993/94 compared to other years. The iron content of QLD and VIC in 1994/95 was significantly higher than in previous years. The iron content of NSW in 1992/93 and of QLD in 1994/95 were the lowest among all the States in the respective seasons. The copper content of VIC in 1993/94 was significantly higher than in other seasons.

4.1.1.4 Comparison of *Desi* Chickpea Varieties - Composition

Data from similar varieties from all 4 seasons were grouped and statistically compared to evaluate chickpea quality. Only those nutrients which show some differences between varieties are discussed.

Table 4.1.9 Effect of season on mean trace mineral composition (mg/100 g) on dry weight basis of *desi* cultivars from different States

QLD	No. of samples	Sodium (mg)	Potassium (mg)	Phosphorus† (mg)	Calcium (mg)	Magnesium (mg)	Zinc (mg)	Iron (mg)	Copper (mg)
1992/93	7	12.9 ± 4.9	1016 ± 41	334 ± 32	213 ± 10	164a ± 5	3.9 ± 0.4	5.9a ± 0.2	0.89 ± 0.05
1993/94	5	15.3 ± 3.2	1037 ± 28	298 ± 32	203 ± 7	144b ± 2	3.1 ± 0.2	4.5a ± 0.3	0.90 ± 0.02
1994/95	4	15.3 ± 2.7	1032 ± 38	396 ± 13	211 ± 4	169a ± 6	4.2 ± 0.7	9.8b ± 1.4	0.76 ± 0.12
F value	16‡	0.1	0.1	3.5	0.4	7.7**	1.3	16.9**	1.11
NSW									
1992/93	8	12.0 ± 2.2	1024a ± 21	248a ± 3	188 ± 11	160 ± 4	2.9a ± 0.2	5.0 ± 0.2	0.83 ± 0.08
1993/94	2	13.1 ± 2.1	1276b ± 58	522b ± 85	185 ± 11	170 ± 7	4.1b ± 0.4	5.5 ± 0.6	0.85 ± 0.07
F value	10‡	0.1	25.8**	37.0**	0	1.5	8.8**	1.2	0.02
VIC									
1992/93	17	19.3 ± 1.7	1076a ± 13	274a ± 13	183ab ± 6	166a ± 2	2.5a ± 0.1	5.7ab ± 0.1	0.74a ± 0.02
1993/94	12	21.2 ± 2.3	1126a ± 19	331b ± 12	163a ± 7	153b ± 3	2.9a ± 0.1	5.3a ± 0.1	0.83b ± 0.02
1994/95	7	28.3 ± 4.7	1000b ± 21	369b ± 9	224b ± 35	156ab ± 4	4.5b ± 0.2	6.4b ± 0.6	0.72a ± 0.02
F value	36‡	2.8	10.5**	8.5**	4.3*	7.8**	33.1**	4.7**	5.8**
SA									
1992/93	2	20.8 ± 8	1103 ± 3	343 ± 22	232 ± 48	162 ± 5	4.4 ± 1.1	5.4 0.1	0.92 ± 0.04
1994/95	12	36.6 ± 4.1	1025 ± 21	327 ± 28	278 ± 10	153 ± 3.5	3.4 ± 0.2	5.7 ± 0.2	0.75 ± 0.06
F value	14‡	2.2	2.2	0.1	2.6	0.9	2.8	0.4	1.2
WA									
1992/93	2	39.4 ± 2.8	964 ± 13	287a ± 0	240a ± 14	156ab ± 6	3.6a ± 0	5.9 ± 0.1	0.81 ± 0.15
1993/94	10	27.5 ± 3.0	1033 ± 10	368b ± 5	195b ± 3.8	140a ± 1.3	2.4b ± 0.1	5.1 ± 0.3	0.79 ± 0.02
1994/95	5	32.0 ± 15	1028 ± 42	350b ± 29	199ab ± 13	157b ± 7	3.2a ± 0.4	5.8 ± 0.3	0.70 ± 0.07
F value	17‡	0.3	1.3	4.2*	4.7*	6.8**	7.8**	1.7	1.2

† analyses conducted on limited number of samples

‡ Total number of samples received

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Table 4.1.10 Effect of State (site) on mean trace mineral content (mg/100 g) on dry weight basis of *desi* cultivars between 1991and 1995

1992/93	No. of samples	Sodium (mg)	Potassium (mg)	Phosphorus† (mg)	Calcium (mg)	Magnesium (mg)	Zinc (mg)	Iron (mg)	Copper (mg)
QLD	7	12.9a ± 4.9	1016 ± 41	334a ± 32	213ab ± 10	164 ± 5	3.9a ± 0.4	5.9a ± 0.2	0.89 ± 0.05
NSW	8	12.0a ± 2.2	1024 ± 21	248b ± 3	188ab ± 11	160 ± 4	2.9b ± 0.2	5.0b ± 0.2	0.83 ± 0.08
VIC	17	19.3a ± 1.7	1076 ± 13	274b ± 13	183a ± 6	166 ± 2	2.5b ± 0.1	5.7a ± 0.1	0.74 ± 0.02
SA	2	20.8ab ± 8	1103 ± 3	343a ± 22	232ab ± 48	162 ± 5	4.4a ± 1.1	5.4ab 0.1	0.92 ± 0.04
WA	2	39.4b ± 2.8	964 ± 13	287ab ± 0	240b ± 14	156 ± 6	3.6ab ± 0	5.9ab ± 0.1	0.81 ± 0.15
F value	36‡	3.0*	2.5	10.0**	3.5*	0.9	6.4**	3.4*	1.9
1993/94									
QLD	5	15.3a ± 3.2	1037a ± 28	298a ± 32	203a ± 7	144a ± 2	3.1a ± 0.2	4.5 ± 0.3	0.90 ± 0.02
NSW	2	13.1a ± 2.1	1276b ± 58	522b ± 85	185ab ± 11	170b ± 7	4.1b ± 0.4	5.5 ± 0.6	0.85 ± 0.07
VIC	12	21.2ab ± 2.3	1126c ± 19	331ac ± 12	163b ± 7	153c ± 3	2.9a ± 0.1	5.3 ± 0.1	0.83 ± 0.02
WA	10	27.5b ± 3.0	1033a ± 10	368c ± 5	195a ± 3.8	140a ± 1.3	2.4c ± 0.1	5.1 ± 0.3	0.79 ± 0.02
F value	29‡	3.3*	13.3**	11.5**	7.6**	10.8**	10.0**	1.6	2.7
1994/95									
QLD	4	15.3 ± 2.7	1032 ± 38	396 ± 13	211ab ± 4	169 ± 6	4.2ab ± 0.7	9.8a ± 1.4	0.76 ± 0.12
VIC	7	28.3 ± 4.7	1000 ± 21	369 ± 9	224ab ± 35	156 ± 4	4.5a ± 0.2	6.4b ± 0.6	0.72 ± 0.02
SA	12	36.6 ± 4.1	1025 ± 21	327 ± 28	278b ± 10	153 ± 3.5	3.4b ± 0.2	5.7b ± 0.2	0.75 ± 0.06
WA	5	32.0 ± 15	1028 ± 42	350 ± 29	199a ± 13	157 ± 7	3.2ab ± 0.4	5.8b ± 0.3	0.70 ± 0.07
F value	28‡	1.5	0.3	1.1	3.6*	1.8	3.9*	10.4**	0.1

† analyses conducted on limited number of samples

‡ Total number of samples received

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$. F value** statistically significant at $p < 0.01$.

4.1.1.4.1 Physical Properties

The mean weight of 100 seeds and colour L*, a* and b* values of whole *desi* seeds and their ranges are presented in Table 4.1.11. Barwon and Semsen seeds were the heaviest (> 20 g/100 seeds) and Tyson was the lightest at 14 g/100 seeds with Amethyst and Dooen having intermediate sizes although all were significantly different from each other. The L* values of Semsen and Dooen were significantly higher than Amethyst, Barwon and Tyson while the b* value of Semsen was significantly higher than Tyson. This observation is in partial agreement with the previous finding where it was noted that L* and b* were positively correlated (section 4.1.1.3.1). The a* value of Semsen was significantly higher than Amethyst.

4.1.1.4.2 Proximate Composition

Table 4.1.12 gives the mean varietal composition and range (g/100 g) on a dry weight basis of whole *desi* seeds. A total of 129 samples from 6 varieties (major and minor) were analysed over 4 harvests. The mean protein content showed no significant difference between varieties. Barwon and Tyson had significantly higher levels of NPN than Amethyst, Dooen and Semsen. It must be mentioned that as the level of NPN increases the nutritive value of the seed decreases.

Tyson had a significantly higher level of TDF (26.4 g/100 g) and significantly lower level of carbohydrate (42.2 g/100 g) than Amethyst and Dooen. Tyson exhibited a significantly higher level of fat (5.3 g/100 g) than Dooen (4.7 g/100 g).

Despite differences in components that impact gross energy levels, there was no significant difference in the energy levels for ruminants or non-ruminants. Although the mean energy levels for non-ruminants (1370 kJ/100 g) and ruminants (1810 kJ/100 g) was possibly highest in Norwin, this could not be statistically verified.

4.1.1.4.3 Trace Minerals, Vitamins and Tannin Content

The varietal mean and range of 8 trace minerals (sodium, potassium, phosphorus, calcium, magnesium, zinc, iron and copper), 2 vitamins (thiamin and riboflavin) and the level of tannin (mg/100 g) on dry weight basis in whole *desi* seeds is presented in Table 4.1.13. The trace mineral content of 94 samples from 3 harvests between 1992/93 and 1994/95 were analysed and statistically compared while the vitamins and tannin were evaluated on selected samples from each season.

Table 4.1.11 Mean and range of weight (g/100 seeds) and colour of *desi* varieties (whole seeds)

Variety (alphabetical)	No.of samples	Weight (g)	L*	a*	b*
Amethyst	27	15.5**a** ± 0.19	41.5**a** ± 1.0	10.6**a** ± 0.3	22.7**ab** ± 0.6
		(11.4, 19.3)	(29.4, 48.0)	(7.4, 14.7)	(16.4, 27.7)
Barwon	5	21.3**c** ± 1.5	38.6**a** ± 2.5	10.5**ab** ± 1.2	22.4**ab** ± 1.2
		(15.8, 24.2)	(33.0, 47.5)	(6.9, 14.0)	(19.4, 26.8)
Dooen	25	17.4**b** ± 0.4	45.3**b** ± 0.9	9.6**ab** ± 0.3	21.4**b** ± 0.6
		(12.2, 19.5)	(35.2, 55.2)	(6.8, 11.8)	(17.6, 28.0)
Norwin	1	19.4	37.2	8.2	19.0
Semsen	8	20.6**c** ± 0.62	47.2**b** ± 1.7	8.9**b** ± 0.5	24.5**a** ± 0.9
		(18.3, 23.3)	(39.5, 53.2)	(6.9, 11.5)	(21.4, 28.4)
Tyson	28	13.9**d** ± 0.4	39.5**a** ± 0.9	9.8**ab** ± 0.3	21.5**b** ± 0.5
		(11.8, 20.5)	(32.3, 50.3)	(5.8, 12.1)	(17.6, 28.0)
Mean ± SE	94	16.3 ± 0.4	42.2 ± 1.1	9.9 ± 0.4	22.1 ± 0.6
		(11.4, 24.2)	(29.4, 55.2)	(5.8, 14.7)	(16.4, 28.4)
F value		32.9**	8.1**	5.9**	4.1*

L* = whiteness, a* = redness, b* = yellowness

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

Table 4.1.12 Mean varietal composition (g/100 g) and range (where applicable) on dry weight basis of whole *desi* seeds

Variety (alphabetical)	Amethyst	Barwon	Dooen	Norwin	Semsen	Tyson	Mean ± SE	F value
No.of samples	46	5	32	1	15	30	129	
Protein (g)(Nx6.25)	21.8 ± 0.3	22.1 ± 1.0	22.0 ± 0.2	23.2	22.3 ± 0.4	22.8 ± 0.3	22.1 ± 0.1	1.9
	(17.7, 27.9)	(18.6, 24.0)	(20.2, 24.1)		(19.9, 24.3)	(18.9, 26.0)	(17.7, 27.9)	
NPN† (g)	8.9**a** ± 0.5	11.5**b** ± 0.9	8.9**a** ± 0.7	10.3	9.4**a** ± 0.6	12.0**b** ± 0.6	9.1 ± 0.3	2.5*
	(7.5, 14.2)	(9.2, 15.2)	(8.1, 10.4)		(6.5, 11.4)	(8.9, 14.5)	(5.9, 14.2)	
Ash† (g)	2.9 ± 0.1	2.9 ± 0.1	2.9 ± 0	3.1	3.0 ± 0	2.9 ± 0	2.9 ± 0	0.5
	(2.4, 3.7)	(2.7, 3.2)	(2.6, 3.1)		(2.7, 3.2)	(2.7, 3.3)	(2.4, 3.7)	
TDF(g)	24.9**a** ± 0.3	25.6**ab** ± 1.4	24.7**a** ± 0.2	25.1	24.9**ab** ± 0.6	26.4**b** ± 0.4	25.2 ± 0.2	3.8**
	(21.8, 32.0)	(22.2, 29.8)	(22.7, 29.0)		(22.3, 29.2)	(23.2, 33.2)	(21.8, 33.2)	
Fat (g)	4.8**ab** ± 0.1	5.6**ab** ± 0.2	4.7**a** ± 0.1	6.1	4.7**ab** ± 0.3	5.3**b** ± 0.2	4.9 ± 0.1	2.9*
	(2.9, 7.3)	(5.0, 6.0)	(2.8, 6.1)		(3.2, 6.2)	(3.7, 7.6)	(2.8, 7.6)	
-CHO (g)	45.0**a** ± 0.6	43.7**ab** ± 1.4	45.7**a** ± 0.4	42.4	44.3**ab** ± 0.9	42.2**b** ± 0.9	44.4 ± 0.3	3.8**
	(27.3, 53.4)	(39.9 ± 47.0)	(40.1, 49.7)		(39.1, 49.9)	(25.8, 47.8)	(25.8, 53.4)	
Energy (NR) (kJ)	1305 ± 5	1325 ± 23	1300 ± 7	1370	1310 ± 6	1290 ± 8	1305 ± 3	0.6
	(1240, 1445)	(1275, 1405)	(1215, 1405)		(1260, 1345)	(1200, 1380)	(1200, 1445)	
Energy (R) (kJ)	1740 ± 6	1775 ± 22	1750 ± 16	1810	1740 ± 10	1755 ± 9	1750 ± 5	1.2
	(1690, 1870)	(1715, 1815)	(1665, 2195)		(1710, 1815)	(1705, 1875)	(1665, 2195)	

† analyses conducted on limited number of samples only

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

Table 4.1.13 Varietal mean (range where applicable) of trace minerals, vitamins and tannin content (mg/100 g) on dry weight basis of *desi* varieties (whole seeds)

Variety (alphabetical)	Amethyst	Barwon	Dooen	Norwin	Semsen	Tyson	Mean ± SE	F value
No.of samples	27	5	26	1	8	27	94	
Sodium (mg)	15.4**a** ± 1.6	13.6**a** ± 2.1	24.3**ab** ± 1.9	17	20.4**ab** ± 6.2	30.7**b** ± 3.5	22.7 ± 1.5	5.3**
	(2.5, 33.0)	(11.0, 22.0)	(3.5, 55.0)		(6.3, 54.0)	(10.4, 91.0)	(2.5, 91.0)	
Potassium (mg)	1061 ± 21	1095 ± 32	1063 ± 11	917	1091 ± 28	1023 ± 11	1053 ± 8	2.1
	(879, 1334)	(1034, 1218)	(958, 1206)		(964, 1178)	(884, 1114)	(879, 1334)	
Phosphorus (mg)	345 ± 18	366 ± 32	319 ± 22	419	305 ± 21	351 ± 10	342 ± 7	1.7
	(214, 606)	(254, 437)	(261, 392)		(243, 373)	(255, 449)	(214, 606)	
Calcium (mg)	215 ± 8	192 ± 11	186 ± 8	215	230 ± 18	207 ± 10	205 ± 5	2.1
	(133, 297)	(150, 218)	(127, 274)		(181, 318)	(133, 330)	(127, 330)	
Magnesium (mg)	159**ab** ± 2	169**a** ± 6	159**ab** ± 2	159	153**ab** ± 3	151**b** ± 3	157 ± 1	3.2*
	(139, 182)	(155, 187)	(136, 181)		(141, 166)	(131, 177)	(131, 187)	
Zinc (mg)	3.4 ± 0.2	3.9 ± 0.5	3.2 ± 0.2	3.7	3.1 ± 0.2	2.9 ± 0.2	3.2 ± 0.1	1.7
	(2.3, 5.5)	(2.5, 5.1)	(1.4, 5.4)		(2.1, 3.8)	(2.1, 5.4)	(1.4, 5.5)	
Iron (mg)	5.5 ± 0.2	6.4 ± 1.4	5.8 ± 0.2	5.9	5.5 ± 0.2	5.6 ± 0.2	5.7 ± 0.1	0.6
	(3.5, 10.6)	(4.6, 12.0)	(4.7, 9.3)		(4.7, 6.2)	(4.6, 10.5)	(3.5, 12.0)	
Copper (mg)	0.86**a** ± 0.03	0.78**ab** ± 0.07	0.78**ab** ± 0.02	1.11	0.71**b** ± 0.05	0.74**b** ± 0.03	0.79 ± 0.01	4.2**
	(0.44, 1.10)	(0.61, 1.00)	(0.57, 0.99)		(0.50, 0.96)	(0.26, 0.92)	(0.26, 1.11)	
Thiamin† (mg)	0.53**a** ± 0.04	0.94**b** ± 0.3	0.54**a** ± 0.04	0.8	0.85**b** ± 0.1	0.68**ab** ± 0.06	0.63 ± 0.05	5.6**
	(0.05, 1.65)	(0.40, 1.75)	(0.15, 0.90)		(0.35, 1.80)	(0.25, 1.20)	(0.15, 1.80)	
Riboflavin† (mg)	0.19 ± 0.02	0.22 ± 0.03	0.17 ± 0.02	0.07	0.17 ± 0.03	0.25 ± 0.06	0.19 ± 0.02	1.2
	(0.06, 0.50)	(0.13, 0.30)	(0.06, 0.37)		(0.06, 0.50)	(0.05, 1.2)	(0.05, 1.15)	
Tannin† (mg)	80.7**a** ± 0.1	47.0**b** ± 0.1	57.2**ab** ± 0.2	34.2	81.3**a** ± 0	52.4**b** ± 0.1	75.9 ± 0.1	2.9*
	(53.0, 102.0)	(36.1, 69.5)	(15.3, 99.2)		(78.4, 85.0)	(13.2, 80.4)	(13.2, 102.0)	

† analyses conducted on limited number of samples

Values presented are mean ± SE

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Mean sodium content of Tyson (30.7 mg/100 g) was significantly higher than Amethyst and Barwon. Potassium values ranged from 879 to 1334 mg/100 g while phosphorus values ranged from 214 to 606 mg/100 g but no significant differences were observed between varieties. The magnesium (151 mg/100 g) and copper (0.74 mg/100 g) contents of Tyson were significantly lower than Barwon (169 mg/100 g) and Amethyst (0.86 mg/100 g), respectively. Semsen also had a significantly reduced level of copper.

The thiamin contents of Amethyst (0.53 mg/100 g) and Dooen (0.54 mg/100 g) were significantly lower than Semsen and Barwon. The mean riboflavin content was 0.19 mg/100 g, with Norwin having the lowest level. This, however, could not be statistically proved due to only one Norwin sample received.

The tannin content of Amethyst and Semsen was significantly higher than Barwon and Tyson.

4.1.1.5 Statewide Comparison of *Desi* Chickpea

In order to study the mean effect of site, data on *desi* chickpea from the same location regardless of variety, were grouped and statistically analysed. Only those factors which show some differences between States are mentioned in the following text.

4.1.1.5.1 Physical Properties

Mean weight (g/100 seeds) and colour (L*, a* and b*) of whole *desi* seeds on a Statewide basis is given in Table 4.1.14. The weight (g) of *desi* chickpea from WA (13.5 g) was significantly lower than chickpea seed from all other States. The L* and b* values of WA seeds were significantly lower than SA seeds. The b* value of SA seeds was significantly higher than all other States and the L* value was higher than NSW and WA. The a* value of SA was significantly lower than from all other States.

4.1.1.5.2 Proximate Composition

Table 4.1.15 shows the mean and range of proximates (g/100 g) on dry weight basis of *desi* chickpea seeds from QLD, NSW, VIC, SA and WA. The protein content of WA (22.9 g/100 g) was significantly higher than that of VIC (21.8 g/100 g) with a national mean of 22.1 g/100 g. TDF values for SA and WA were significantly higher while the carbohydrate content was significantly lower than NSW and VIC.

Table 4.1.14 Mean and range of weight (g/100 seeds) and colour of whole *desi* seeds from different States

State	No.of samples	Weight (g)	L*	a*	b*
QLD	17	17.1a ± 0.8	41.8ab ± 1.3	10.4a ± 0.5	22.7a ± 0.7
		(13.1, 24.2)	(33.0, 48.0)	(6.9, 14.3)	(16.4, 26.1)
NSW	10	16.8a ± 0.7	40.3b ± 1.6	11.0a ± 0.5	20.9a ± 0.7
		(14.3, 20.6)	(29.4, 45.3)	(8.1, 14.0)	(16.8, 23.6)
VIC	36	16.8a ± 0.4	43.1ab ± 0.8	9.8a ± 0.2	21.3a ± 0.4
		(11.4, 22.3)	(34.7, 55.2)	(5.8, 11.5)	(17.6, 26.8)
SA	14	16.5a ± 0.8	45.8a ± 1.6	8.2b ± 0.3	25.2b ± 0.8
		(11.9, 22.5)	(31.2, 53.2)	(6.8, 10.0)	(18.3, 28.4)
WA	17	13.5b ± 0.4	39.4b ± 1.3	10.4a ± 0.3	21.5a ± 0.6
		(11.8, 17.5)	(32.3, 50.3)	(8.3, 14.6)	(17.6, 26.1)
Mean ± SE	94	16.3 ± 0.4	42.2 ± 1.1	9.9 ± 0.4	22.1 ± 0.6
		(11.4, 24.2)	(29.4, 55.2)	(5.8, 14.7)	(16.4, 28.4)
F value		5.6**	3.6*	7.3**	6.5**

L* = whiteness, a* = redness, b* = yellowness

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Table 4.1.15 Mean and range of proximates (g/100 g) on dry weight basis of whole *desi* seeds from different States

State	QLD	NSW	VIC	SA	WA	Mean ± SE	F value
No.of samples	17	19	53	23	17	129	
Protein (g)(Nx6.25)	22.4**ab** ± 0.6	22.1**ab** ± 0.4	21.8**a** ± 0.2	22.2**ab** ± 0.3	22.9**b** ± 0.3	22.1 ± 0.1	10.1**
	(18.3, 27.9)	(18.6, 24.1)	(17.7, 24.3)	(18.9, 24.3)	(21.1, 25.0)	(17.7, 27.9)	
NPN† (g)	11.4 ± 0.5	9.1 ± 0.6	9.2 ± 0.5	10.6 ± 0.5	13.1 ± 0.6	9.1 ± 0.3	1.6
	(6.5, 14.0)	(5.9, 11.0)	(6.4, 14.2)	(9.1, 11.7)	(7.0, 15.2)	(5.9, 14.2)	
Ash† (g)	3.0 ± 0.1	2.8 ± 0.1	2.9 ± 0	3.0 ± 0	3.0 ± 0.1	2.9 ± 0	2.1
	(2.6, 3.5)	(2.4, 3.4)	(2.6, 3.7)	(2.7, 3.5)	(2.7, 3.4)	(2.4, 3.7)	
TDF(g)	25.2**ab** ± 0.7	23.9**a** ± 0.2	24.7**a** ± 0.2	26.6**b** ± 0.6	26.6**b** ± 0.3	25.2 ± 0.2	9.1**
	(22.3, 33.2)	(21.8, 25.4)	(22.3, 28.1)	(23.6, 32.0)	(24.5, 29.9)	(21.8, 33.2)	
Fat (g)	5.2 ± 0.1	4.7 ± 0.2	4.7 ± 0.1	5.0 ± 0.3	5.2 ± 0.1	4.9 ± 0.1	1.5
	(4.2, 6.1)	(3.3, 6.1)	(2.9, 7.3)	(2.8, 7.6)	(4.7, 5.9)	(2.8, 7.6)	
-CHO (g)	44.1**ab** ± 1.2	45.6**a** ± 0.4	45.8**a** ± 0.3	41.9**b** ± 1.2	42.8**b** ± 0.7	44.4 ± 0.3	6.1**
	(30.0, 53.4)	(43.4, 50.9)	(41.0, 49.9)	(25.8, 49.7)	(36.7, 46.3)	(25.8, 53.4)	
Energy (NR) (kJ)	1305 ± 12	1305 ± 6	1305 ± 5	1305 ± 9	1285 ± 8	1305 ± 3	1.5
	(1210, 1445)	(1240, 1340)	(1215, 1405)	(1200, 1405)	(1260, 1375)	(1200, 1445)	
Energy (R) (kJ)	1745 ± 12	1725 ± 3	1750 ± 10	1770 ± 11	1750 ± 12	1750 ± 5	0.8
	(1690, 1870)	(1705, 1750)	(1665, 2195)	(1700, 1845)	(1715, 1875)	(1665, 2195)	

† analysed on selected samples only

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value *statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

4.1.1.5.3 Trace Minerals, Vitamins and Tannin Content

The mean and range for the trace minerals, vitamins and tannin content (mg/100 g) on a dry weight basis for *desi* whole seeds from the different States is presented in Table 4.1.16. The sodium content of SA and WA was significantly higher than QLD, NSW and VIC. The calcium content of SA was significantly higher compared to the other States, while the magnesium content of WA was lower than QLD, NSW and VIC. Zinc levels in QLD were significantly lower than those in VIC and WA.

4.1.1.6 Comparison of *Kabuli* Chickpea Varieties - Composition

The composition of Opal was very similar to Garnet and hence the only sample was grouped with two other Garnet samples for statistical comparisons.

4.1.1.6.1 Physical Properties and Proximate Composition

Table 4.1.17 gives the mean weight and range of 100 seeds and L*, a* and b* values for the two varieties of *kabuli* chickpea. The weight (40.7 g) and brightness (L* value) (55.2) of Kaniva was significantly higher than the Garnet and Opal samples.

Table 4.1.18 shows the mean and range of proximate content (g/100 g) on dry weight basis of whole *kabuli* seeds. The mean NPN content of Kaniva was (9.1 g/100 g) significantly higher than Garnet and Opal. The TDF and gross energy for ruminants was significantly higher in Kaniva seeds than in Garnet and Opal.

4.1.1.6.2 Trace Minerals, Vitamins and Tannin Content

The trace minerals, vitamins and tannin content (mg/100 g) on dry weight basis for *kabuli* seeds is presented in Table 4.1.19. Based on the limited number of samples analysed, the sodium content of Garnet and Opal was significantly higher than that of Kaniva.

The mean thiamin and riboflavin content of *kabuli* cultivars was 0.50 mg/100 g and 0.25 mg/100 g, respectively.

4.1.1.7 Comparison of *Desi* v/s *Kabuli* Types of Chickpea From VIC

The properties and composition of *desi* and *kabuli* types of chickpea were compared. As nearly 40% of the *desi* chickpea and nearly all the *kabuli* samples were received from the Wimmera region of VIC, data for *desi* and *kabuli* from VIC were compared with each other. Table 4.1.20 gives the mean composition (per 100 g) on dry weight basis, of *desi* and *kabuli* type of chickpea from VIC. As expected, *desi* chickpea was

Table 4.1.16 Mean and range (dry weight basis) of trace minerals, vitamin and tannin content (mg/100 g) of whole *desi* seeds on a Statewide basis

State	QLD	NSW	VIC	SA	WA	Mean ± SE	F value
No.of samples	17	10	36	14	17	94	
Sodium (mg)	14.3**a** ± 2.3	12.2**a** ± 1.8	21.6**a** ± 1.5	34.3**b** ± 3.9	30.2**b** ± 5.1	22.7 ± 1.5	8.0**
	(2.5, 37.0)	(3.5, 23.9)	(7.9, 44.0)	(12.8, 66.0)	(9.0, 91.0)	(2.5, 91.0)	
Potassium (mg)	1027 ± 21	1075 ± 38	1079 ± 12	1036 ± 19	1023 ± 14	1053 ± 8	2.4
	(879, 1171)	(950, 1334)	(937, 1256)	(946, 1199)	(884, 1112)	(879, 1334)	
Phosphorus (mg)	340 ± 21	326 ± 54	332 ± 10	330 ± 24	357 ± 10	342 ± 7	0.4
	(214, 419)	(243, 606)	(254, 406)	(244, 418)	(284, 449)	(214, 606)	
Calcium (mg)	209**a** ± 5	187**a** ± 9	184**a** ±8	272**b** ± 11	201**a** ± 6	205 ± 5	14.2**
	(169, 245)	(145, 237)	(127, 327)	(184, 330)	(150, 254)	(127, 330)	
Magnesium (mg)	159**a** ± 4	162**a** ± 3	159**a** ± 2	154**ab** ± 3	147**b** ± 3	157 ± 1	4.0**
	(140, 187)	(139, 176)	(134, 181)	(132, 176)	(131, 177)	(131, 187)	
Zinc (mg)	3.7**a** ± 0.3	3.1**ab** ± 0.2	3.0**b** ± 0.2	3.5**ab** ± 0.2	2.8**b** ± 0.2	3.2 ± 0.1	3.5**
	(2.5, 5.5)	(2.3, 4.5)	(1.4, 5.1)	(2.1, 5.4)	(2.1, 4.3)	(1.4, 5.5)	
Iron (mg)	6.4 ± 0.6	5.1 ± 0.2	5.7 ± 0.1	5.7 ± 0.2	5.4 ± 0.2	5.7 ± 0.1	2.3
	(3.5, 12.0)	(4.6, 6.2)	(4.6, 9.3)	(4.7, 7.2)	(4.2, 7.6)	(3.5, 12.0)	
Copper (mg)	0.86 ± 0.04	0.83 ± 0.06	0.77 ± 0.02	0.77 ± 0.05	0.77 ± 0.03	0.79 ± 0.01	1.7
	(0.61, 1.10)	(0.44, 1.00)	(0.57, 0.94)	(0.26, 0.99)	(0.51, 0.96)	(0.26, 1.11)	
Thiamin† (mg)	0.69 ± 0.10	0.52 ± 0.04	0.62 ± 0.03	0.70 ± 0.09	0.63 ± 0.06	0.63 ± 0.05	1.0
	(0.05, 1.65)	(0.3, 0.75)	(0.15, 1.15)	(0.27, 1.80)	(0.25, 1.00)	(0.15, 1.80)	
Riboflavin† (mg)	0.18 ± 0.02	0.16 ± 0.02	0.18 ± 0.02	0.20 ± 0.02	0.22 ± 0.03	0.19 ± 0.02	0.9
	(0.06, 0.37)	(0.06, 0.50)	(0.06, 0.37)	(0.09, 0.50)	(0.05, 0.37)	(0.05, 1.15)	
Tannin† (mg)	81.2 ± 0.1	80.5 ± 0.1	78.4 ± 0.1	74.8 ± 0.1	65.4 ± 0.1	75.9 ± 0.1	1.6
	(67.0, 102.0)	(69.5, 92.0)	(53.0, 99.2)	(13.2, 95.4)	(47.0, 80.0)	(13.2, 102.0)	

† analyses conducted on limited number of samples

Values presented are mean ± SE

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

Table 4.1.17 Mean and range of weight (g/100 seeds) and colour of whole *kabuli* seeds

Variety	No.of samples	Weight (g)	L*	a*	b*
Kaniva	5	40.7**a** ± 0.8	55.2**a** ± 1.4	7.0 ± 0.7	22.1 ± 1.1
		(38.8, 42.7)	(51.4, 58.1)	(5.2, 8.5)	(19.7, 25.4)
G+O	3	34.4**b** ± 1.2	64.7**b** ± 3.1	5.2 ± 2.1	23.3 ± 2.7
		(31.5, 36.8)	(61.2, 70.8)	(3.4, 7.2)	(19.0, 24.7)
Mean ± SE	8	38.3 ± 1.0	58.9 ± 2.0	6.3 ± 1.2	22.6 ± 1.9
		(31.5, 42.7)	(51.4, 70.8)	(3.4, 8.5)	(19.0, 25.4)

L* = whiteness, a* = redness, b* = yellowness

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

Table 4.1.18 Mean and range of proximates (g/100 g) on dry weight basis of whole *kabuli* seeds

Variety	Kaniva	G + O	Mean ± SE	F value
No.of samples	9	3	12	
Protein (g)(Nx6.25)	22.2 ± 0.4	22.6 ± 0.8	22.3 ± 0.5	0.01
	(21.1, 24.5)	(21.5, 24.2)	(21.1, 24.5)	
NPN† (g)	9.1**a** ± 0.2	5.3**b** ± 0.6	7.5 ± 1.5	16.2**
	(7.8, 10.2)	(4.3, 6.7)	(4.3, 10.2)	
Ash (g)	2.9 ± 0	2.9 ± 0.1	2.9 ± 0.1	0.2
	(2.7, 3.0)	(2.7, 3.0)	(2.7, 3.0)	
TDF(g)	15.9**a** ± 0.2	14.5**b** ± 0.5	15.6 ± 0.3	9.8**
	(15.3, 16.9)	(13.7, 15.5)	(13.7, 16.9)	
Fat (g)	6.4 ± 0.3	5.4 ± 1.0	6.3 ± 0.5	1.5
	(4.7, 7.3)	(3.4, 6.7)	(3.4, 7.3)	
-CHO (g)	52.3 ± 0.6	53.9 ± 0.7	52.7 ± 0.6	2.3
	(50.0, 54.3)	(52.8, 55.3)	(50.0, 55.3)	
Energy (NR) (kJ)	1485 ± 9	1475 ± 13	1485 ± 7	0.4
	(1460, 1520)	(1450, 1490)	(1450, 1520)	
Energy (R) (kJ)	1765**a** ± 6	1730**b** ± 9	1760 ± 7	9.6**
	(1745, 1790)	(1715, 1745)	(1715, 1790)	

G+O = Garnet+Opal

† analyses conducted on limited number of samples

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

Table 4.1.19 Mean and range (where applicable) of trace minerals, vitamins and tannin content (mg/100 g) on dry weight basis of whole *kabuli* seeds

Variety	**Kaniva**	**G + O**	**Mean ± SE**	**F value**
No.of samples	5	3	8	
Sodium (mg)	19.1**a** ± 2.8	45.6**b** ± 13.2	29.0 ± 6.7	11.9**
	(9.5, 31.0)	(21.0, 66.0)	(9.5, 66.0)	
Potassium (mg)	1153**a** ± 23	993**b** ± 19.4	1093 ± 21	5.1*
	(1090, 1227)	(664, 1336)	(664, 1336)	
Calcium (mg)	149**a** ± 4	173**b** ± 25	158 ± 12	4.4*
	(134, 154)	(141, 223)	(134, 223)	
Magnesium (mg)	152**a** ± 1	193**b** ± 37	167 ± 15	4.6*
	(149, 156)	(140, 265)	(140, 265)	
Zinc (mg)	3.1 ± 0.3	4.9 ± 0.4	3.8 ± 0.4	2.6
	(2.1, 3.5)	(4.2, 5.4)	(2.1, 5.4)	
Iron (mg)	4.7 ± 0.5	5.0 ± 0.7	4.8 ± 0.6	0.1
	(2.3, 7.3)	(4.0, 6.4)	(2.3, 7.3)	
Copper (mg)	0.86 ± 0.04	0.86 ± 0.03	0.86 ± 0.04	0
	(0.69, 0.94)	(0.43, 1.2)	(0.43, 1.2)	
Thiamin (mg)	0.51 ± 0.06	0.45 ± 0.05	0.50 ± 0.06	0.4
	(0.35, 0.70)	(0.40, 0.50)	(0.35, 0.70)	
Riboflavin (mg)	0.29 ± 0.13	0.11 ± 0	0.25 ± 0.09	1
	(0.10, 0.90)	(0.10, 0.11)	(0.10, 0.11)	
Tannin† (mg)	40.1	40.4	40.3	

† only 1 sample was assayed

Values presented are mean ± SE

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

Table 4.1.20 Mean (per 100 g) (dry weight basis) of *desi* and *kabuli* chickpea from VIC

Type	*Desi*	*Kabuli*	F value
No. of samples	36	8	
Weight (g)	16.8a ± 0.4	38.3b ± 1.0	369**
L*	43.1a ± 0.8	58.9b ± 2.0	28.8**
a*	9.8a ± 0.2	6.3b ± 1.2	16.3**
b*	21.3 ± 0.4	22.6 ± 1.9	0.5
Protein(g) (Nx6.25)	21.8 ± 0.2	22.3 ± 0.3	0.1
NPN† (g)	9.2 ± 0.5	7.4 ± 1.5	2.7
Ash† (g)	2.9 ± 0	2.9 ± 0	0.1
TDF (g)	24.7a ± 0.2	15.6b ± 0.3	504**
Fat (g)	4.7a ± 0.1	6.2b ± 0.3	20.3**
-CHO (g)	45.8a ± 0.3	52.7b ± 0.5	100**
Energy (NR) (kJ)	1305a ± 5	1485b ± 7	220**
Energy (R) (kJ)	1750 ± 10	1755 ± 7	0.1
Sodium (mg)	21.6 ± 1.5	29.0 ± 7.0	2.7
Potassium (mg)	1079 ± 12	1093 ± 21	0.1
Calcium (mg)	184 ± 8	158 ± 12	2.1
Magnesium (mg)	159 ± 2	167 ± 15	1.1
Zinc (mg)	3.0 ± 0.2	3.8 ± 0.4	4
Iron (mg)	5.7 ± 0.1	4.8 ± 0.6	0.2
Copper (mg)	0.77 ± 0.2	0.86 ± 0.04	1.5
Thiamin† (mg)	0.62 ± 0.03	0.50 ± 0.06	2.3
Riboflavin† (mg)	0.18 ± 0.02	0.25 ± 0.09	0.92
Tannin† (mg)	78.4 ± 0.1	40.3	

L* = whiteness, a* = redness, b* = yellowness

† analyses conducted on limited number of samples

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

significantly smaller and darker than the *kabuli* type but the a* value (redness) of the *kabuli* type was, however, significantly lower than the *desi* type. The TDF in *desi* type was significantly higher than the *kabuli* type, probably because of a heavier seed coat in the *desi* type. Carbohydrate and fat contents were significantly lower in *desi* type. As expected, energy for non-ruminants was significantly lower in the *desi* type. There was no significant difference in the micronutrient composition between *desi* and *kabuli* types. Although tannin levels were not analysed in many *kabuli* samples, tannin levels of *desi* were higher than in the *kabuli* type.

4.1.1.8 Comparison of Australian *Desi* and *Kabuli* Chickpea with Indian Types - Composition

It is logical to compare national *desi* and *kabuli* chickpea compositions with the Indian types because the Indian subcontinent is not only the largest producer and consumer of chickpea but is also the largest importer of *desi* chickpea from Australia.

4.1.1.8.1 Physical Properties and Proximate Composition

Table 4.1.21 gives the weight, colour and proximate composition (per 100 g) on a dry weight basis of all the Australian *desi* (129) and *kabuli* (12) varieties analysed and compares values with Indian chickpea data from Jambunathan and Singh (1978) and Singh *et al* (1981). The mean weight of 100 Australian *kabuli* seeds was significantly higher than *kabuli* seeds from India. No comparative data exists in the literature for colour of whole seeds thus colour could not be compared. It can, however, be noted that Australian *kabuli* chickpea has higher L* and a* values compared to the Australian *desi* type. There was no significant difference in the mean protein content of *desi* and *kabuli* chickpea from India and Australia. In a later study, however, the mean protein content of Indian *desi* chickpea varieties were reported to be 25.3 g/100 g, with a range of 23.7 to 26.8 g/100 g (Singh *et al* 1981) (not shown in Table). It must be highlighted that in Australia, pulse breeding programs endeavor to improve yield and disease resistance of varieties and do not emphasise on increasing protein content, unlike wheat. Also, the protein content of the chickpea is not factored into grower payments. The mean NPN values for Australian *desi* and *kabuli* were 9.1 g/100 g and 7.5 g/100 g, respectively, which are significantly lower than NPN values for Indian *desi* and *kabuli* types. The national mean ash content of *desi* type was significantly lower (2.9 g/100 g) than ash content in Indian *desi* (3.3 g/100 g). The

Table 4.1.21 National mean and range of weight, colour and proximates (g/100 g) on dry weight basis of whole seeds of *desi* and *kabuli* compared to mean values of Indian *desi* and *kabuli* chickpea

Type	*Desi*	Indian *Desi*[1]	F value	*Kabuli*	Indian *Kabuli*[1]	F value
No. of samples	129	16		12	14	
Weight (g/100 seeds)	16.3 ± 0.4 ‡	17.9 ± 1.2	3.2	38.3**a** ± 1.0 ‡	23.1**b** ± 1.4	52.6**
	(11.4, 24.2)	(10.6, 28.4)		(31.5, 42.7)	(15.8, 33.6)	
L*	42.2 ± 1.1 ‡	-		58.9 ± 2.0 ‡	-	
	(29.4, 55.2)	-		(51.4, 70.8)	-	
a*	9.9 ± 0.4 ‡	-		6.3 ± 1.2 ‡	-	
	(5.8, 14.7)	-		(3.4, 8.5)	-	
b*	22.1 ± 0.6 ‡	-		22.6 ± 1.9 ‡	-	
	(16.4, 28.4)	-		(19.0, 25.4)	-	
Protein(g) (Nx6.25)	22.1 ± 0.1	22.2 ± 0.5	0	22.3 ± 0.3	23.2 ± 0.4	2.9
	(17.7, 27.9)	(17.7, 25.9)		(21.1, 24.5)	(20.7, 25.6)	
NPN† (g)	9.1**a** ± 0.3	11.1**b** ± 0.6•	4.2*	7.5**a** ± 1.5	12.3**b** ± 0.5 •	8.5*
	(5.9, 14.2)	(9.5, 12.3)		(4.3, 10.2)	(10.9, 13.1)	
Ash† (g)	2.9**a** ± 0	3.3**b** ± 0.1	35.1**	2.9 ± 0.1	3.2 ± 0.1	4.1
	(2.4, 3.7)	(2.9, 4.2)		(2.7, 3.0)	(2.7, 4.3)	
TDF (g)	25.2 ± 0.2	8.8 ± 0.4 □		15.6 ± 0.3	3.0 ± 0.2 □	
	(21.8, 33.2)	(4.9, 10.8)		(13.7, 16.9)	(2.2, 4.7)	
Fat (g)	4.9**a** ± 0.1	4.3**b** ± 0.2	5.5*	6.3**a** ± 0.5	5.1**b** ± 0.2	9.8**
	(2.8, 7.6)	(3.1, 5.8)		(3.4, 7.3)	(4.3, 6.4)	
-CHO (g)	44.4 ± 0.3	50.0 ± 0.4••		52.7 ± 0.6	55.0 ± 0.4 ••	
	(25.8, 53.4)	(45.8, 56.6)		(50.0, 55.3)	(51.5, 57.5)	
Energy (NR) (kJ)	1305 ± 3	1395 ± 9		1485 ± 7	1520 ± 6	
	(1200, 1445)	(1350, 1640)		(1450, 1520)	(1390, 1650)	
Energy (R) (kJ)	1750 ± 5	1545 ± 8		1760 ± 7	1575 ± 4	
	(1665, 2195)	(1435, 1855)		(1715, 1790)	(1430, 1730)	

[1] Jambunathan and Singh (1978), 8 *desi* and 7 *kabuli* cultivars grown at two locations

L* = whiteness, a* = redness, b* = yellowness

† analyses conducted on limited number of samples, ‡ number of samples = 94 *desi* and 8 *kabuli*

• Singh *et al* 1981

□ Indian data reports crude fibre, •• starch + sugars

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Statistical comparisons are made between similar types of chickpea from different origins.

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

mean fat content in Australian *desi* (4.9 g/100 g) and *kabuli* (6.3 g/100 g) were significantly higher than that reported by Jambunathan and Singh (1978) (4.3 g/100 g and 5.1 g/100 g, respectively). Starch values were chemically estimated by Singh and Jambunathan (1978) and was reported to be 44.7 g/100 g and 49.0 g/100g for *desi* and *kabuli*, respectively. The starch content in Indian *desi* was similar to the calculated value for carbohydrate content of Australian *desi* varieties (44.4 g/100 g) but was lower than the calculated value for carbohydrate content of Australian *kabuli* varieties (52.7 g/100 g). Jambunathan and Singh (1978) reported crude fibre content in chickpea seeds and hence valid statistical comparisons could not be made between fibre levels. The use of different methods and concepts of estimating chemical composition makes it difficult to make valid comparisons of energy values. Based on the crude fibre and starch + sugar content reported by Jambunathan and Singh (1978), energy (calculated on their data) for non-ruminants is higher in the Indian *desi* and *kabuli* compared to Australian *desi* and *kabuli*. As expected then, the energy for ruminants is higher in the Australian *desi* and *kabuli* type of chickpea.

4.1.1.8.2 Trace Minerals, Vitamins and Tannin Content

Table 4.1.22 shows the national mean and range for trace minerals, vitamins and tannin content (mg/100 g) on dry weight basis for 94 *desi* and 8 *kabuli* varieties and similar data on Indian samples. Among the trace minerals, sodium and copper content of Australian *desi* seeds were significantly lower (23 mg/100 g, 0.79 mg/100 g, respectively), than Indian *desi* seeds (86 mg/100 g, 1.10 mg/100 g, respectively).

The mean thiamin content obtained in this study (0.63 mg/100 g) was higher than values in the literature which range from 0.28 to 0.50 mg/100 g (Pingale *et al* 1956). The riboflavin content of Australian *desi* was within the range reported in the literature (Pingale *et al* 1956).

The mean tannin content of Australian *desi* and *kabuli* varieties studied was 76 mg/100 g and 40 mg/100 g, respectively, which is lower than the mean of 179 mg/100 g, reported by Rao and Deosthale (1982), whose samples included seeds with dark and pale coloured seed coats.

Table 4.1.22 National mean and range of trace minerals, vitamins and tannin content (mg/100 g) on dry weight basis of whole seeds of *desi* and *kabuli* compared to mean values of Indian *desi* and *kabuli* chickpea

Type	*Desi*	Indian *Desi* [1]	F value	*Kabuli*	Indian *Kabuli* [1]	F value
No. of samples	94	16		8	14	
Sodium (mg)	22.7**a** ± 1.5	86.1**b** ± 26.5 [2]	53.4**	29.0 ± 6.7	12.7 ± 1.0 [3]	
	(2.5, 91.0)	(10.9, 167.2) [2]		(9.5, 66.0)	-	
Potassium (mg)	1053 ± 8	1087 ± 13	0.3	1093 ± 21	1105 ± 23	0
	(879, 1334)	(996, 1272)		(664, 1336)	(988, 1333)	
Phosphorus (mg)	342 ± 7	330 ± 5	0.1	-	331 ± 6	
	(214, 606)	(244, 458)		-	(268, 427)	
Calcium (mg)	205 ± 5	180 ± 11	0.5	158 ± 12	155 ± 0.5	0
	(127, 330)	(93, 259)		(134, 223)	(102, 179)	
Magnesium (mg)	157 ± 1	147 ± 5	1.1	167 ± 15	141 ± 1	0.8
	(131, 187)	(128, 168)		(140, 265)	(129, 151)	
Zinc (mg)	3.2 ± 0.1	2.9 ± 0.9	0.3	3.8 ± 0.4	3.4 ± 0.9	0.2
	(1.4, 5.5)	(1.5, 4.2)		(2.1, 5.4)	(2.0, 5.4)	
Iron (mg)	5.7 ± 0.1	6.4 ± 0.8	0.7	4.8 ± 0.6	6.6 ± 0	1.7
	(3.5, 12.0)	(3.0, 9.8)		(2.3, 7.3)	(5.1, 7.8)	
Copper (mg)	0.79**a** ± 0.01	1.10**b** ± 0.25	9.2**	0.86 ± 0.04	1.07 ± 0.11	2
	(0.26, 1.11)	(0.60, 2.10)		(0.43, 1.2)	(0.80, 1.40)	
Thiamin† (mg)	0.63 ± 0.05	0.43 •, □		0.50 ± 0.06	-	
	(0.15, 1.80)	(0.28, 0.50)		(0.35, 0.70)	-	
Riboflavin† (mg)	0.19 ± 0.02	0.25 ± 0 ••, □		0.25 ± 0.09	-	
	(0.05, 1.15)	(0.15, 0.30)		(0.10, 0.11)	-	
Tannin† (mg)	75.9 ± 0.1	192 ± 19.0 •••		40.3	78 •••	
	(13.2, 102.0)	-			-	

[1] Jambunathan and Singh (1981), 8 *desi* and 7 *kabuli* cultivars grown at two locations

[2] Tiwari *et al* (1977), [3] Meiners *et al* (1976)

• Pingale *et al* (1956), •• Vallidevi *et al* (1972) - *desi dhal*, ••• Rao and Deosthale (1982)

† analyses conducted on limited number of samples, □ insufficient data to calculate F value

Values presented are mean ± SE

Statistical comparisons are made between similar types of chickpea from different origins.

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value ** statistically significant at $p < 0.01$.

4.1.2 Composition of Advanced Breeding Lines of *Desi* and *Kabuli* Cultivars

Samples of the advanced breeding lines can be classified into two categories: (a) advanced breeding lines of established varieties such as Amethyst, Dooen, Semsen and Tyson which are modified by breeders to alter either flowering time, height of pods on the plant to facilitate easy harvest, or increase disease resistance and (b) includes new lines which are selected for their superior visual physical characteristics (K Meredith, Personal Communication VIDA 1997). Pure seeds belonging to group (a) were planted in experimental plots at research stations in QLD, NSW, VIC, SA and WA and seeds from the (b) category were grown only in VIC (Tables 3.1 and 3.2). Inter varietal comparisons of proximate composition of advanced breeding lines have been made in this study. Intra varietal differences due to effect of site and environment could not be conducted due to small number of samples received from each region. The proximate composition of 53 *desi* and 21 *kabuli* advanced breeding lines from the 1994/95 season and 52 *desi* and 21 *kabuli* from the 1995/96 season were evaluated.

4.1.2.1 Composition of *Desi* Lines

Tables 4.1.23 and 4.1.24 give the mean composition and range (g/100 g) on dry weight basis of advanced *desi* lines from the 1994/95 and 1995/96 seasons, respectively. There was a significant difference in the protein content between varieties within each season, but there was no significant difference between the two years. The mean protein content of Amethyst and Norwin was significantly higher than that of T 1587, while that of Dark *desi* and *Desi* were significantly lower than Desavic, Semsen and Tyson in 1994/95. In 1995/96, the protein content of Barwon was significantly higher than T 1239, T 1000 and T 2000 series samples.

The ash level of *Desi* from 1994/95 was significantly higher than Amethyst, Desavic, Norwin, Tyson and T 1414. The fat contents of T 1239 and T 1414 from both seasons (and T 1000 series in 1995/96) were significantly higher than Amethyst, Dark *desi* and *Desi* in 1994/95 and Amethyst, Barwon, Dooen and Tyson in 1995/96. The mean carbohydrate content of Amethyst (39.8 g/100 g) was significantly lower than Dark *desi*, *Desi* and Norwin in 1994/95. The mean energy for non-ruminants was 1310 kJ/100 g and 1330 kJ/100 g in 1994/95 and 1995/96, respectively. The gross energy for non-ruminants was significantly higher in T 1239 and T 1414 compared to *Desi* lines in 1994/95, while that of T 1239 was significantly higher than Tyson in 1995/96.

Table 4.1.23 Mean composition and range (g/100 g) on dry weight basis of advanced breeding *desi* lines, 1994/95 season

Variety (in alphabetical order)	No of samples	Protein (g) (Nx6.25)	Ash (g)	TDF (g)	Fat (g)	-CHO (g)	Energy (NR) (kJ)	Energy (R) (kJ)
Amethyst	3	23.7a ± 0.5	2.5a ± 0.2	29.0 ± 0.5	4.9b ± 0.3	39.8a ± 0.7	1260ab ± 17	1775ab ± 9
		(22.8, 24.6)	(2.3, 2.9)	(28.2, 30.0)	(4.6, 5.5)	(38.9, 41.4)	(1230, 1290)	(1760, 1790)
Dark desi	14	19.0bc ± 0.4	3.4ab ± 0.1	26.7 ± 0.9	5.4b ± 0.2	45.6b ± 0.8	1295ab ± 17	1765b ± 3
		(16.6, 21.6)	(3.0, 4.1)	20.3, 32.2)	(4.2, 6.6)	(41.5, 52.3)	(1165, 1390)	(1735, 1785)
Desavic	3	21.2ad ± 0.4	2.6a ± 0.1	27.3 ± 1.2	5.3ab ± 0.2	43.6ab ± 0.9	1300ab ± 23	1780ab ± 4
		(19.9, 21.8)	(2.3, 2.8)	(24.4, 29.2)	(4.9, 5.9)	(41.2, 45.5)	(1260, 1360)	(1775, 1790)
Desi	11	18.7bc ± 0.6	3.5b ± 0.1	28.3 ± 1.0	4.8b ± 0.1	44.7b ± 0.9	1255a ± 19	1755b ± 4
		(15.8, 21.0)	(2.7, 3.9)	(21.5, 32.3)	(4.1, 5.2)	(40.9, 49.4)	(1175, 1370)	(1735, 1770)
Dooen	2	21.5ab ± 0.2	2.8ab ± 0.1	25.4 ± 0.8	5.1ab ± 0.1	45.2ab ± 1.1	1325ab ± 13	1775ab ± 5
		(21.3, 21.8)	(2.8, 2.9)	(24.6, 26.2)	(5.0, 5.2)	(44.2, 46.3)	(1310, 1335)	(1770, 1775)
Norwin	8	23.3a ± 0.6	2.7a ± 0.1	26.8 ± 1.3	6.0a ± 0.3	41.1a ± 1.7	1320ab ± 26	1795a ± 6
		(21.6, 26.7)	(2.2, 3.0)	(23.1, 35.0)	(4.7, 6.9)	(30.0, 44.5)	(1165, 1400)	(1760, 1815)
Semsen	2	22.1ad ± 0.3	2.9ab ± 0.1	26.3 ± 0.6	5.3ab ± 0.3	43.4ab ± 0.1	1310ab ± 15	1775ab ± 5
		(21.8, 22.4)	(2.9, 3.0)	(25.7, 26.3)	(5.0, 5.6)	(43.3, 43.5)	(1295, 1325)	(1770, 1780)
Tyson	3	22.3ad ± 0.2	2.7a ± 0.1	29.6 ± 0.7	5.3ab ± 0.2	40.3ab ± 0.4	1260ab ± 14	1780ab ± 3
		(22.0, 22.5)	(2.4, 2.9)	(28.6, 30.9)	(4.8, 5.6)	(39.5, 40.7)	(1230, 1280)	(1775, 1785)
T1239	3	21.3ab ± 1.4	2.7a ± 0.1	23.5 ± 0.5	6.4a ± 0.1	46.2ab ± 1.3	1385b ± 8	1800a ± 5
		(19.1, 23.8)	(2.4, 2.9)	(22.7, 24.3)	(6.2, 6.7)	(43.6, 47.6)	(1375, 1400)	(1790, 1805)
T1414	2	21.2ab ± 0.8	2.5a ± 0.1	23.2 ± 0.9	6.4a ± 0.3	46.7ab ± 0.6	1390b ± 10	1800a ± 5
		(20.4, 21.9)	(2.4, 2.6)	(22.3, 24.2)	(6.1, 6.8)	(46.1, 47.2)	(1380, 1400)	(1795, 1805)
T 1587	2	20.2b ± 1.1	2.7a ± 0	29.0 ± 2.5	5.8ab ± 0.2	42.3ab ± 1.2	1280ab ± 47	1790a ± 5
		(19.1, 21.3)	2.7	(26.6, 31.5)	(5.6, 6.0)	(41.1, 43.4)	(1230, 1325)	(1785, 1795)
Total & Mean	53	20.6 ± 0.5	3.0 ± 0.1	26.1 ± 0.8	5.4 ± 0.2	43.5 ± 0.7	1310 ± 14	1775 ± 5
		(15.8, 26.7)	(2.2, 4.9)	(20.3, 35.0)	(4.2, 6.9)	(30.0, 52.3)	(1165, 1400)	(1735, 1815)
F value		7.6**	2.4*	1.4	4.8**	2.5**	9.2**	7.6**

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same column not followed by the same letter are statistically different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Table 4.1.24 Mean composition and range (g/100 g) on dry weight basis of advanced breeding *desi* lines, 1995/96 season

Variety In alphabetical order	No of samples	Protein (g) (Nx6.25)	Ash (g)	TDF (g)	Fat (g)	-CHO (g)	Energy (NR) (kJ)	Energy (R) (kJ)
Amethyst	5	21.8ab ± 1.4	2.8 ± 0.1	26.2 ± 0.8	5.0a ± 0.3	44.2 ± 0.8	1305ab ± 11	1770b ± 7
		(17.5, 26.4)	(2.6, 2.9)	(24.2, 28.1)	(4.2, 5.9)	(42.3, 46.6)	(1275, 1335)	(1755, 1795)
Barwon	5	23.4a ± 1.5	2.8 ± 0.1	24.8 ± 0.4	4.8a ± 0.1	44.2 ± 1.6	1325ab ± 7	1765b ± 3
		(18.4, 27.9)	(2.5, 3.0)	(23.6, 26.0)	(4.6, 4.9)	(40.3, 49.6)	(1305, 1345)	(1755, 1770)
Dooen	3	21.9ab ± 1.8	2.6 ± 0.1	24.0 ± 0.5	4.6a ± 0	46.9 ± 1.3	1340ab ± 9	1765b ± 3
		(19.3, 25.4)	(2.5, 2.9)	(23.3, 24.8)	(4.5, 4.6)	(44.2, 48.5)	(1320, 1350)	(1760, 1770)
Tyson	2	22.9ab ± 2.2	2.7 ± 0.1	27.5 ± 0.7	4.5a ± 0.4	42.4 ± 2.6	1280a ± 22	1765b ± 10
		(20.7, 25.1)	(2.6, 2.9)	(26.9, 28.2)	(4.1, 4.9)	(39.8, 45.0)	(1255, 1300)	(1755, 1775)
T1239	3	19.0b ± 2.3	2.7 ± 0.1	23.0 ± 1.0	6.8b ± 0.4	48.6 ± 2.2	1400b ± 20	1810a ± 8
		(15.4, 23.3)	(2.4, 2.9)	(21.1, 24.4)	(6.1, 7.2)	(44.3, 50.9)	(1375, 1440)	(1790, 1815)
T1414	3	21.4ab ± 1.8	3.0 ± 0.4	24.1 ± 0.2	6.1b ± 0.2	45.4 ± 2.0	1360ab ± 6	1775b ± 5
		(19.0, 24.8)	(2.5, 3.9)	(23.6, 24.4)	(5.8, 6.5)	(41.7, 48.4)	(1350, 1370)	(1765, 1785)
T1587	2	18.7ab ± 1.1	2.7 ± 0.1	27.5 ± 1.2	5.5ab ± 0.5	45.7 ± 0.8	1300ab ± 12	1785ab ± 8
		(17.6, 19.8)	(2.6, 2.9)	(26.2, 28.7)	(5.0, 6.0)	(44.9, 46.5)	(1285, 1310)	(1775, 1790)
T 1000 series	12	19.7b ± 0.3	2.9 ± 0.1	26.4 ± 0.8	5.8b ± 0.2	45.2 ± 0.7	1320ab ± 17	1770b ± 8
		(20.2, 22.4)	(2.9, 3.0)	(24.7, 27.4)	(4.8, 5.4)	(41.8, 47.3)	(1290, 1325)	(1760, 1775)
T 2000 series	2	21.3b ± 1.1	3.0 ± 0	26.1 ± 1.3	5.1ab ± 0.3	44.5 ± 2.8	1310ab ± 18	1785b ± 4
		(17.3, 21.5)	(2.7, 3.4)	(19.3, 28.8)	(4.9, 7.4)	(42.1, 51.3)	(1265, 1470)	(1770, 1810)
T 8000 series	14	19.2ab ± 0.2	2.7 ± 0.1	25.3 ± 0.7	5.5ab ± 0.2	47.3 ± 0.6	1335ab ± 30	1780b ± 4
		(17.5, 20.1)	(2.5, 3.1)	(20.4, 29.1)	(4.5, 6.5)	(44.2, 52.7)	(1265, 1400)	(1760, 1805)
Total & Mean	51	20.9 ± 0.5	2.8 ± 0	25.5 ± 0.5	5.4 ± 0.2	45.4 ± 0.6	1330 ± 11	1775 ± 6
		(15.4, 27.9)	(2.4, 3.9)	(19.3, 28.8)	(4.1, 7.4)	(39.8, 52.7)	(1255, 1470)	(1755, 1815)
F value		6.9**	1.1	1.5	4.2**	1.8	15.6**	3.8**

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same column not followed by the same letter are statistically different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Energy for ruminants was significantly higher in Norwin, T 1239, T 1414 and T 1587 compared to Dark *desi* and *desi* in 1994/95, whereas the following year T 1239 had higher energy levels than all varieties, except T 1587.

4.1.2.1.1 Composition of *Desi* Lines Evaluated Over Two Seasons

The mean composition and range (g/100 g) of 6 *desi* lines evaluated in both the seasons is summarised in Table 4.1.25. Significant differences between lines were that the mean fat contents of T 1239 and T 1414 were higher than Amethyst, Dooen and Tyson and the TDF values of Amethyst, Tyson and T 1587 were significantly higher than Dooen, T 1239 and T 1414. It is interesting to note there were no significant differences in TDF values within each year. The total carbohydrate content of Tyson was significantly lower than Dooen, T 1239 and T 1414. Amethyst, Tyson and T 1587 recorded significantly lower levels of energy for non-ruminants than T 1239 and T 1414. T 1239 had significantly higher gross energy for ruminants than Amethyst, Dooen and Tyson. Among the newer varieties, T 1239 and T 1414 had significantly higher fat, total carbohydrate content, and energy for non-ruminants and significantly lower TDF compared to advanced lines of existing varieties.

4.1.2.1.2 Comparison of Composition - Advanced Breeding *Desi* Lines v/s Commercially Traded Varieties

Advanced breeding lines are constantly emerging based on agronomic advantages but it is important to monitor composition to evaluate any nutritional changes. Amethyst and Tyson from the advanced breeding lines had significantly higher levels of TDF, carbohydrate and energy for ruminants compared to the commercially traded variety (Table 4.1.12). The energy for ruminants of commercially traded Dooen was significantly lower than Dooen from the advanced breeding line and the fat content of Barwon from the advanced breeding line was lower than commercially traded Barwon. From a human nutrition point of view, characteristics such as; higher TDF and carbohydrate content and/or lower fat level are advantageous. These are exhibited by Amethyst, Tyson and Barwon of the advanced breeding line. It is necessary that these changes be continually monitored, especially if the consumption of whole *desi* chickpea is to be successfully promoted.

Table 4.1.25 Mean composition and range (g/100 g) on dry weight basis of advanced breeding *desi* lines from 1994/95 and 1995/96

Variety In alphabetical order	No of samples	Protein (g) (Nx6.25)	Ash (g)	TDF (g)	Fat (g)	-CHO (g)	Energy (NR) (kJ)	Energy (R) (kJ)
Amethyst	8	22.5 ± 0.9	2.7 ± 0.1	27.3**a** ±0.7	5.0**a** ± 0.2	42.5**ab** ± 1.0	1290**a** ± 12	1775**b** ± 6
		(17.5, 26.4)	(2.3, 2.9)	(24.2, 30.0)	(4.2, 5.9)	(38.9, 46.6)	(1230, 1335)	(1755, 1795)
Dooen	5	21.8 ± 1.0	2.7 ± 0.1	24.6**b** ± 0.5	4.8**a** ± 0.13	46.2**a** ± 0.9	1330 ± 8	1770**b** ± 5
		(19.3, 25.4)	(2.5, 2.9)	(23.3, 26.2)	(4.5, 5.2)	(44.2, 48.5)	(1310, 1350)	(1760, 1775)
Tyson	5	22.5 ± 0.7	2.7 ± 0.1	28.7**a** ± 0.6	5.0**a** ± 0.3	41.1**b** ± 1.0	1270**a** ± 12	1775**b** ± 4
		(20.7, 25.1)	(2.4, 2.9)	(26.9, 30.9)	(4.1, 5.6)	(39.5, 45.0)	(1230, 1300)	(1755, 1785)
T1239	6	20.1 ± 1.3	2.7 ± 0.1	23.2**b** ± 0.5	6.6**b** ± 0.2	47.4**a** ± 1.3	1390**b** ± 11	1805**a** ± 6
		(15.4, 23.8)	(2.4, 2.9)	(21.1, 24.4)	(6.1, 7.2)	(43.6, 50.9)	(1375, 1440)	(1790, 1815)
T1414	5	21.3 ± 1.0	2.8 ± 0.3	23.7**b** ± 0.4	6.2**b** ± 0.2	45.9**a** ± 1.1	1370**b** ± 9	1785**ab** ± 5
		(19.0, 24.8)	(2.4, 3.9)	(22.3, 24.4)	(5.8, 6.8)	(41.7, 48.4)	(1350, 1400)	(1765, 1805)
T1587	4	19.4 ± 0.8	2.7 ± 0.1	28.3**a** ± 1.2	5.7**ab** ± 0.2	44.0**ab** ± 1.1	1290**a** ± 21	1790**ab** ± 5
		(17.6, 21.3)	(2.6, 2.9)	(26.2, 31.5)	(5.0, 6.0)	(41.1, 46.5)	(1230, 1325)	(1775, 1795)
Total & Mean	33	21.4 ± 0.5	2.7 ± 0	26.0 ± 1.0	5.6 ± 0.3	44.5 ± 1.0	1320 ± 20	1785 ± 5
		(15.4, 26.4)	(2.3, 2.9)	(21.1, 31.5)	(4.2, 7.2)	(38.9, 50.9)	(1230, 1440)	(1755, 1815)
F value		1.4	0.2	12.0**	14.1**	5.0**	17.4**	6.6**

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same column not followed by the same letter are statistically different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

4.1.2.2 Composition of *Kabuli* Lines

Mean composition and range (g/100 g) on dry weight basis of advanced *kabuli* lines from 1994/95 and 1995/96 seasons are presented in Tables 4.1.26 and 4.1.27, respectively.

The protein content of T 1000 (Iran) was significantly lower than all other varieties in 1994/95, while protein content of T 1000 (Russia) was significantly lower than Narayen in 1995/96. The ash content of T 1000 (Iran) was significantly higher than Garnet in 1994/95 and Narayen in 1995/96. T 1000 (Iran) had significantly higher levels of TDF than Garnet. The mean carbohydrate content was 50 g/100 g and 53 g/100 g in 1994/95 and 1995/96, respectively. More Narayen samples need to be analysed to confirm significant differences in composition observed between the two samples from each harvest.

4.1.2.2.1 Composition of *Kabuli* Lines Evaluated Over Two Seasons

Mean composition and range (g/100 g) on dry weight basis of 36 *kabuli* samples that were evaluated in both the seasons are presented in Table 4.1.28. The protein content of T 1000 (Iran) was significantly lower while ash content was significantly higher than Narayen and Garnet.

4.1.2.2.2 Comparison of Composition - Advanced Breeding *Kabuli* Lines v/s Commercially Traded Varieties

The mean composition of commercially traded *kabuli* varieties (Table 4.1.18) showed some significant differences compared to the advanced breeding lines. Seed size of the advanced breeding lines of Kaniva and Garnet (data given in section 4.3.2, Table 4.3.7) was 25.7 g and 41.2 g, respectively, and the trend was the reverse of that observed for commercially traded Kaniva (40.7 g) and Garnet (34.4 g) (Table 4.1.18). The reason for this difference was that 62% of Kaniva lines analysed were small seeded and had been selected for agronomic benefits.

The TDF contents of commercially traded Kaniva and Garnet were significantly lower (~12%) than the advanced breeding lines. Consequently, the carbohydrate levels in the advanced breeding lines were lower than the levels in commercially traded *kabuli* varieties. Thus, there were significant differences in the energy for ruminants between the advanced breeding *kabuli* lines and commercially traded varieties.

Table 4.1.26 Mean composition and range (g/100 g) on dry weight basis of advanced breeding *kabuli* lines, 1994/95 season

Variety In alphabetical order	**No of samples**	**Protein (g) (Nx6.25)**	**Ash (g)**	**TDF (g)**	**Fat (g)**	**-CHO (g)**	**Energy (NR) (kJ)**	**Energy (R) (kJ)**
Garnet	5	24.3**a** ± 0.7	2.8**a** ± 0.2	16.7**a** ± 1.2	6.4 ± 0.1	49.8 ± 0.6	1495 ± 22	1800 ± 8
		(22.5, 25.9)	(2.3, 3.2)	(13.7, 20.0)	(6.1, 6.8)	(48.0, 51.8)	(1435, 1555)	(1780, 1820)
T1000 Iran	8	18.5**b** ± 0.4	3.6**b** ± 0.1	22.5**b** ± 1.6	6.4 ± 0.3	49.0 ± 1.6	1380 ± 30	1780 ± 7
		(16.6, 19.7)	(3.3, 4.0)	(17.6, 32.1)	(5.3, 7.6)	(39.2, 53.0)	(1205, 1465)	(1760, 1810)
Kaniva	4	21.3**c** ± 0.6	3.2**ab** ± 0.2	19.0**ab** ± 1.0	6.3 ± 0.3	49.9 ± 1.0	1450 ± 24	1785 ± 8
		(20.0, 22.7)	(2.8, 3.5)	(16.6, 20.9)	(5.9, 7.1)	(47.1, 52.5)	(1400, 1510)	(1770, 1805)
L550	1	20.7	2.3	18.2	6.7	52.3	1485	1805
Mission	1	23.2	2.9	20.8	5.8	47.3	1415	1785
Narayen	1	21.2	2.5	16.5	6.6	53.1	1510	1800
UC5	1	21.2	2.8	17.0	7.5	51.6	1515	1815
Total & Mean	21	21.0 ± 0.7	2.9 ± 0.2	19.6 ± 0.9	6.5 ± 0.2	50.0 ± 0.8	1465 ± 19	1790 ± 7
		(16.6, 25.9)	(2.3, 4.0)	(13.7, 32.1)	(5.3, 7.60	(39.2, 53.1)	(1205, 1555)	(1760, 1820)
F value		35.5**	11.7**	4.3*	0.2	0.1	3.3	2.3

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same column not followed by the same letter are statistically different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Table 4.1.27 Mean composition and range (g/100 g) on dry weight basis of advanced breeding *kabuli* lines, 1995/96 season

Variety In alphabetical order	**No of samples**	**Protein (g) (Nx6.25)**	**Ash (g)**	**TDF (g)**	**Fat (g)**	**-CHO (g)**	**Energy (NR) (kJ)**	**Energy (R) (kJ)**
Garnet	3	20.7**ab** ± 2.7	2.7**ab** ± 0.1	15.8 ± 0.7	6.8 ± 0.4	54.1 ± 1.5	1545 ± 17	1820 ± 28
		(17.7, 25.8)	(2.6, 2.9)	(14.5, 16.9)	(5.7, 7.1)	(51.0, 55.7)	(1520, 1575)	(1785, 1875)
T1000 Iran	8	21.2**ab** ± 0.5	2.9**a** ± 0	16.7 ± 0.3	6.6 ± 0.2	52.7 ± 0.3	1500 ± 8	1790 ± 8
		(20.7, 25.8)	(2.4, 2.8)	(14.3, 16.5)	(5.4, 6.9)	(50.0, 54.9)	(1485, 1545)	(1770, 1805)
Kaniva	1	25.6	2.6	16.4	6.8	48.6	1515	1805
Mission	1	24.8	2.7	14.3	6.6	51.6	1545	1800
Narayen	2	25.1**a** ± 0.7	2.6**b** ± 0.2	16.3 ± 0.2	5.7 ± 0.3	50.4 ± 0.4	1495 ± 8	1780 ± 10
		(24.4, 25.8)	(2.4, 2.8)	(16.1, 16.5)	(5.4, 6.0)	(50.0, 50.1)	(1485, 1500)	(1770, 1790)
T1000 Russia	5	19.4**b** ± 0.5	2.7**ab** ± 0.1	16.9 ± 0.5	6.5 ± 0.2	54.6 ± 0.4	1500 ± 11	1820 ± 20
		(17.7, 25.8)	(2.6, 2.9)	(14.5, 16.9)	(6.1, 7.3)	(48.6, 55.7)	(1515, 1575)	(1785, 1875)
UC5	1	20.7	2.6	15.0	6.9	54.9	1540	1805
Total & Mean	21	21.4 ± 0.9	2.7 ± 0.1	16.2 ± 0.3	6.5 ± 0.1	53.0 ± 0.6	1515 ± 9	1800 ± 10
		(17.7, 25.8)	(2.4, 3.1)	(14.3, 17.9)	(5.4, 7.7)	(48.6, 55.8)	(1470, 1575)	(1770, 1875)
F value		3.5*	3.6*	2.3	1.5	1.8	2.2	1.3

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same column not followed by the same letter are statistically different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Table 4.1.28 Mean composition and range (g/100 g) on dry weight basis of advanced breeding *kabuli* lines from 1994/95 and 1995/96

Variety In alphabetical order	**No of samples**	**Protein (g) (Nx6.25)**	**Ash (g)**	**TDF (g)**	**Fat (g)**	**-CHO (g)**	**Energy (NR) (kJ)**	**Energy (R) (kJ)**
Garnet	8	23.0**a** ± 1.2	2.8**a** ± 0.1	16.3 ± 0.8	6.5 ± 0.2	51.4 ± 1.0	1515 ± 17	1810 ± 11
		(17.7, 25.9)	(2.3, 3.2)	(13.7, 20.0)	(6.1, 7.3)	(48.0, 55.7)	(1435, 1575)	(1780, 1875)
T1000 Iran	16	19.9**b** ± 0.5	3.3**b** ± 0.1	19.6 ± 0.1	6.5 ± 0.2	50.8 ± 0.9	1440 ± 21	1785 ± 7
		(16.6, 25.8)	(2.4, 4.0)	(14.3, 32.1)	(5.3, 7.6)	(39.2, 54.9)	(1205, 1545)	(1760, 1810)
Kaniva	5	22.2**ab** ± 1.0	3.1**ab** ± 0.2	18.4 ± 0.9	6.4 ± 0.2	49.6 ± 0.8	1460 ± 23	1790 ± 8
		(20.0, 25.6)	(2.6, 3.5)	(16.4, 20.9)	(5.9, 7.1)	(47.9, 52.5)	(1400, 1515)	(1770, 1805)
Mission	2	24.0**ab** ± 0.8	2.8**ab** ± 0.1	17.6 ± 3.2	6.2 ± 0.2	49.4 ± 2.1	1480 ± 65	1795 ±8
		(23.2, 24.8)	(2.7, 2.9)	(14.3, 20.8)	(6.9, 7.4)	(47.3, 51.6)	(1415, 1545)	(1785, 1800)
Narayen	3	23.8**a** ± 1.3	2.6**a** ± 0.1	16.3 ± 0.1	6.0 ± 0.4	51.3 ± 0.9	1500 ± 7	1790 ± 9
		(21.2, 25.8)	(2.4, 2.8)	(16.1, 16.5)	(5.3, 6.6)	(50.0, 53.1)	(1485, 1510)	(1770, 1800)
UC5	2	20.9**ab** ± 0.3	2.7**ab** ± 0.1	16.0 ± 1.0	7.2 ± 0.3	53.2 ± 1.6	1530 ± 13	1810 ± 5
		(20.7, 21.2)	(2.6, 2.8)	(15.0, 17.0)	(6.9, 7.5)	(51.6, 54.9)	(1515, 1540)	(1805, 1815)
Total & Mean	36	21.8 ± 0.9	2.9 ± 0.2	17.8 ± 0.9	6.5 ± 0	51.0 ± 0.2	1480 ± 19	1795 ± 6
		(16.6, 25.9)	(2.3, 4.0)	(13.7, 32.1)	(5.3, 7.7)	(39.2, 55.8)	(1205, 1555)	(1760, 1820)
F value		3.5*	3.4*	1.4	0.9	0.5	1.6	1.5

-CHO = Total carbohydrates

Energy (NR) = energy non-ruminants, Energy (R) = energy ruminants

Values presented are mean ± SE

Means in the same column not followed by the same letter are statistically different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

4.1.2.3 Correlation Between Analytes for Advanced Breeding *Desi* and *Kabuli* Lines

A study of the correlation matrix of the 7 analytes for advanced breeding *desi* and *kabuli* revealed some interesting observations. Tables 4.1.29 and 4.1.30 give the correlation matrix of analytes for *desi* and *kabuli* lines, respectively, analysed over two seasons. A negative correlation coefficient (r = -0.67) existed between protein and ash content of *kabuli* seeds but, *desi* seeds demonstrated no correlation. The correlations between protein with fat and carbohydrate were negative for both types of seeds. Ash content in *kabuli* seeds exhibited a highly significant positive correlation with TDF (r = 0.94) and negative correlation with energy for non-ruminants (r = -0.85) whereas *desi* seeds exhibited a reverse trend and a poor correlation.

A negative correlation coefficient (r = -0.91) existed between TDF and carbohydrate content for *desi* which suggests an increase in TDF content is accompanied by a decrease in carbohydrate content. The correlation between TDF and carbohydrate content for *kabuli* seeds (r = -0.52) was not as strong probably because of the inherently low levels of TDF in *kabuli* type. As expected, the TDF content was inversely proportional to the energy for non-ruminants for *desi* and *kabuli* types; a highly significant negative correlation coefficient (r = -0.97) existed for both types of chickpea. A positive correlation was observed for the *desi* seeds between fat and energy for non-ruminants (r = 0.77) and ruminants (r = 0.93), respectively, whereas the relations in *kabuli* seeds were significant although not as strong (r = 0.43, r = 0.75, respectively). The carbohydrate content of *desi* seeds had a strong positive correlation with energy for non-ruminants (r = 0.92) but the relation was not as strong for *kabuli* seeds (r = 0.64). This could probably be due to the presence of varieties with very diverse composition among the *kabuli* type. Further work is required to confirm the finding. These observations suggest that although the two types of chickpea usually demonstrate similar trends they have to be treated independently. Furthermore, there are major physical and compositional differences which affect processing, taste and end-use.

4.1.3 Composition of *Dhal* (Dry, Dehusked, Split Cotyledon)

Dhal was produced in the AGT mill from selected, non-conditioned, commercially released *desi* varieties obtained from the 1995/96 harvest and analysed for proximates

Table 4.1.29 Correlation matrix of analytes of *desi* seeds from 1994/95 and 1995/96

Mean *desi*	Protein	Ash	TDF	Fat	-CHO	ENR	ER
Protein	1						
Ash	0.01	1					
TDF	0.20	-0.46**	1				
Fat	-0.69**	0.43*	-0.59**	1			
-CHO	-0.53**	0.28	-0.91**	0.63**	1		
Energy (NR)	-0.38*	0.47**	-0.97**	0.77**	0.92**	1	
Energy (R)	-0.79**	0.06	-0.41*	0.93**	0.54**	0.62**	1

Table 4.1.30 Correlation matrix of analytes of *kabuli* seeds from 1994/95 and 1995/96

Mean *kabuli*	Protein	Ash	TDF	Fat	-CHO	ENR	ER
Protein	1						
Ash	-0.67**	1					
TDF	-0.46**	0.94**	1				
Fat	-0.68**	0.07	-0.19	1			
-CHO	-0.50**	-0.29	-0.52**	0.75**	1		
Energy (NR)	0.27	-0.85**	-0.97**	0.43*	0.64**	1	
Energy (R)	-0.03	-0.51**	-0.70**	0.75**	0.60**	0.85**	1

-CHO = Total carbohydrates

ENR = energy non-ruminants, ER = energy ruminants

* significant at $p < 0.05$.

** significant at $p < 0.01$.

such as moisture, protein, ash, fat, TDF while carbohydrate and energy for non-ruminants were calculated. Sodium, potassium, phosphorus, calcium, magnesium, zinc, iron and copper contents were also analysed.

4.1.3.1 Summary of Samples Received

Table 4.1.31 Distribution of *desi* chickpea that were dehulled (by genotypes and States)

	QLD	NSW	VIC	SA	WA
Amethyst	-	3	2	3	-
Barwon	2	3	-	-	3
Desavic	-	-	3	-	-
Dooen	-	-	2	3	3
Semsen	-	-	3	3	-
Tyson	-	-	-	-	3
Total 36	2	6	10	9	9

Table 4.1.31 lists the 36 samples; from 6 commercially traded varieties that were dehulled. As this study was conducted on only one harvest, seasonal variation could not be addressed. Desavic was bred for the Wimmera region of VIC, hence composition of *dhal* obtained from Desavic seeds was compared with *dhal* from other varieties from VIC.

4.1.3.2 Effect of Variety on Composition of *Dhal*

The mean composition and range (g/100 g) of *dhal* on a dry matter basis from different genotypes is presented in Table 4.1.32.

The mean protein content of Tyson *dhal* was the highest at 26.8 g/100 g with the other cultivars ranging from 24.6-25.5 g/100 g. The mean protein content for *dhal* was about 3 g/100 g higher than that for whole seed (22 g/100 g), with larger differences observed for Tyson (~4 g/100 g).

Amethyst, Barwon and Semsen *dhal* had significantly higher ash contents than Semsen and Tyson *dhal*. The mean ash content of *dhal* was significantly lower than in whole

Table 4.1.32 Mean composition and range (g/100 g) on dry weight basis of *dhal* from different cultivars of *desi* chickpea

Variety	Amethyst	Barwon	Desavic	Dooen	Semsen	Tyson	Mean ± SE	Range	F Value
No. of samples	8	8	3	8	6	3	36	36	
Protein (g) (N x 6.25)	25.2 ± 0.5	25.5 ± 0.8	24.6 ± 0.7	25.4 ± 0.9	24.6 ± 0.3	26.8 ± 1.9	25.6 ± 0.3	(21.9, 29.8)	0.6
Ash (g)	2.9**a** ± 0.1	2.7**a** ± 0.1	2.3**b** ± 0.1	2.4**b** ± 0.1	2.7**a** ± 0.1	2.2**b** ± 0.2	2.6 ± 0.1	(2.0, 3.1)	8.4**
TDF (g)	11.8 ± 0.4	11.3 ± 0.4	10.4 ± 0.2	11.5 ± 0.3	11.6 ± 0.3	11.4 ± 0.1	11.3 ± 0.2	(9.8, 13.2)	1.5
Fat (g)	5.6**a** ± 0.2	5.7**a** ± 0.2	6.6**b** ± 0.2	5.1**a** ± 0.2	6.0**b** ± 0.2	6.1**ab** ± 0.3	5.8 ± 0.2	(4.9, 6.9)	4.5**
-CHO (g)	54.3 ± 0.7	55.0 ± 0.6	56.2 ± 0.4	55.2 ± 0.9	54.8 ± 0.5	53.5 ± 1.9	54.8 ± 0.4	(50.3, 58.0)	0.7
Energy (NR) (kJ)	1570**a** ± 5	1580**a** ± 7	1620**b** ± 3	1570**a** ± 6	1580**a** ± 6	1590**ab** ± 10	1580 ± 8	(1540, 1620)	5.8**

-CHO = Total carbohydrates

Energy (NR) = Energy non-ruminants

Table 4.1.33 Mean trace mineral composition and range (mg/100 g) on dry weight basis of *dhal* (*desi*) from different cultivars

Variety	Amethyst	Barwon	Desavic	Dooen	Semsen	Tyson	Mean ± SE	Range	F Value
No. of samples	8	8	3	8	6	3	36	36	
Sodium (mg)	27.6 ± 3.7	20.4 ± 2.5	18.3 ± 7.3	17.6 ± 2.8	20.2 ± 6.0	21.3 ± 5.8	20.9 ± 1.5	(10, 40)	0.9
Potassium (mg)	1062**a** ± 27	990**bc** ± 25	880**b** ± 6	938**b** ± 16	1023**ad** ± 8	851**b** ± 17	980 ± 18	(822, 1170)	10.0**
Phosphorus (mg)	423**a** ± 30	398**ab** ± 23	327**ab** ± 19	342**b** ± 17	356**ab** ± 14	286**b** ± 48	369 ± 23	(213, 562)	3.0**
Calcium (mg)	44.4 ± 3.0	37.0 ± 4.1	37.0 ± 4.0	38.1 ± 2.1	40.3 ± 2.3	43.0 ± 0	40.0 ± 1.3	(22, 55)	1.0
Magnesium (mg)	111**a** ± 3	106**a** ± 2	85**b** ± 7	86**b** ± 4	98**ab** ± 2	89**b** ± 10	98 ± 4	(65, 123)	8.0**
Zinc (mg)	2.9 ± 0.2	3.1 ± 0.5	2.9 ± 0.1	3.1 ± 0.3	2.6 ± 0.3	2.8 ± 0.4	2.9 ± 0.1	(1.4, 5.9)	0.2
Iron (mg)	5.9 ± 0.3	5.4 ± 0.3	5.4 ± 0.2	5.3 ± 0.1	5.6 ± 0.1	5.1 ± 0.2	5.5 ± 0.1	(4.7, 7.8)	1.1
Copper (mg)	0.79 ± 0.06	0.72 ± 0.05	0.71 ± 0.03	0.71 ± 0.05	0.67 ± 0.07	0.61 ± 0.09	0.70 ± 0.02	(0.37, 0.97)	0.7

Values presented are mean ± SE

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value**statistically significant at $p < 0.01$

seed (2.9 g/100 g, Table 4.1.12) implying that the minerals are concentrated in the seed coat.

Desavic and Semsen *dhal* had significantly higher fat contents than Amethyst, Barwon and Dooen *dhal*. The mean fat content in *dhal* was at least 1% higher than in whole seeds, depending on the variety.

With the removal of the seed coat there was a significant decrease (55%) in the TDF content of *dhal* compared to whole seed. Mean TDF content of *dhal* was 11.3 g/100 g, with no significant differences between varieties.

The decrease in TDF content in *dhal* was complemented by an increase in available carbohydrate compared to whole seed. The carbohydrate content of *dhal* was 23% higher than whole seed which is reflected in the energy value of *dhal* for non-ruminants being higher than whole seed by nearly the same margin. Desavic *dhal* had significantly higher mean energy value (1620 kJ/100 g) than Amethyst, Barwon, Dooen and Semsen. The mean energy for non-ruminants of *dhal* was 17% higher than whole seed mainly due increases in carbohydrate, fat and protein contents and a decrease in TDF.

The mean trace mineral composition (mg/100 g) and range of *dhal* on a dry matter basis from different genotypes is given in Table 4.1.33. As there were no significant differences in mean sodium levels of whole seed (Table 4.1.13) and *dhal*, it appears that sodium was not concentrated in the seed coat. Potassium levels in Amethyst *dhal* was significantly higher (1062 mg/100 g) than Barwon, Desavic, Dooen and Tyson *dhals*. Semsen *dhal* (1023 mg/100 g) had significantly higher potassium than Barwon (990 mg/100 g). Mean potassium content for whole seed was 1053 mg/100 g with no significant differences between varieties. This suggests that the potassium content in the seed coat varies between varieties and its removal results in varying potassium content in the cotyledon. The data also suggests that Amethyst seed coat has low potassium levels as the potassium content of whole seed (1061 mg/100 g) and *dhal* (1062 mg/100 g) are similar. There was, however, a significant decrease (6% to 16%) in potassium content of Barwon, Dooen, Semsen and Tyson *dhals* compared to whole seed.

Amethyst *dhal* had significantly higher phosphorus level than Dooen and Tyson. The mean phosphorus content in all *dhals*, except Tyson was significantly higher than its

corresponding whole seed. The increases ranged from 8% in Barwon to 18% in Amethyst with Dooen and Semsen having intermediate increases.

The mean calcium content for Australian varieties was 40 mg/100 g. There is approximately 80% decrease in the calcium content of *dhals* as compared to *desi* whole seed making *dhals* a poor source of dietary calcium. The reduction in calcium content is similar to previous findings of Singh *et al* (1968) who conclude that most of the calcium in the seed is lodged in the seed coat.

Magnesium content of Amethyst and Barwon *dhals* were significantly higher than Tyson and Desavic. The mean magnesium content of *dhals* from Australian cultivars (96 mg/100 g) was 39% lower than that in whole seed. This suggests that the seed coat of Australian *desi* is high in magnesium as well as calcium.

The varietal means for zinc, iron and copper were 2.9 mg/100 g, 5.5 mg/100 g and 0.70 mg/100 g, respectively, with no significant differences between varieties. The whole seed mineral composition for these minerals is similar to the *dhal* composition.

4.1.3.3 Effect of State on Composition of *Dhal*

The Statewide mean values and range (g/100 g) on dry weight basis for *dhal* composition is given in Table 4.1.34. *Dhal* from QLD samples had the highest mean protein content (27.6 g/100 g) and *dhal* from VIC had the lowest (24.5 g/100 g). This trend was similar to the protein content of whole seeds from Australian States, with the exception of WA. WA *dhal* had the second lowest protein content, unlike the whole seed which had the highest protein content.

Dhal from QLD and NSW had significantly higher ash content than VIC and WA *dhal,* which had the lowest ash content (2.4 mg/100 g). Ash contents in *dhal* from WA, SA and VIC were lower than that in the whole seed from the corresponding States. As for Amethyst, the ash content in NSW *dhal* was similar to NSW whole seed. This could be due to 50% of the NSW samples being Amethyst. Although, there were no significant differences in ash content of *desi* whole seeds from different States, significant differences in ash content of *dhal* confirms that the distribution of inorganic material in the seed coat differs in samples from different States.

The TDF content of *dhal* from NSW was the lowest (10.9 g/100 g) and this trend was similar to the TDF content of whole seed from NSW (23.9 g/100 g) (Table 4.1.15). The fat content of *dhals* from VIC, SA and WA was identical. The mean carbohydrate

Table 4.1.34 Mean composition and range (g/100 g) of *dhal (desi)* on dry weight basis from different States

State	QLD	NSW	VIC	SA	WA	Mean ± SE	Range	F Value
No. of samples	2	6	10	9	9	36	36	
Protein (g) (N x 6.25)	27.6 ± 0.5	26.2 ± 0.4	24.5 ± 0.4	25.4 ± 0.5	24.9 ± 0.1	25.3 ± 0.6	(21.9, 29.8)	1.7
Ash (g)	2.9a ± 0.1	2.8a ± 0.1	2.5b ± 0.1	2.7ab ± 0	2.4b ± 0.1	2.3 ± 0.1	(2.0, 3.1)	6.3**
TDF (g)	11.5 ± 0.5	10.9 ± 0.4	11.6 ± 0.3	11.6 ± 0.3	11.6 ± 0.2	11.4 ± 0.1	(9.8, 13.2)	1.1
Fat (g)	5.4 ± 0.1	5.4 ± 0.2	5.9 ± 0.2	5.9 ± 0.2	5.9 ± 0.2	5.7 ± 0.1	(4.9, 6.9)	1.0
-CHO (g)	52.6 ± 0.1	54.7 ± 0.4	55.5 ± 0.6	54.5 ± 0.5	55.2 ± 0.1	54.9 ± 0.5	(50.3, 58.4)	0.8
Energy (NR) (kJ)	1560 ± 8	1570 ± 8	1580 ± 8	1570 ± 7	1580 ± 6	1575 ± 3	(1540, 1620)	0.4

-CHO = Total carbohydrates

Energy (NR) = Energy non-ruminants

Table 4.1.35 Mean trace mineral composition and range (mg/100 g) on dry weight basis of *dhal (desi)* from different States

State	QLD	NSW	VIC	SA	WA	Mean	Range	F Value
No. of samples	2	6	10	9	9	36	36	
Sodium (mg)	16.5 ± 5.5	27.7 ± 3.9	18.7 ± 3.7	20.8 ± 3.9	21.3 ± 2.5	21.0 ± 1.9	(10, 40)	0.9
Potassium (mg)	1075a ± 42	1064a ± 41	951b ± 22	1000ab ± 14	910b ± 19	980 ± 23	(822, 1170)	6.0**
Phosphorus (mg)	485a ± 29	432a ± 40	330b ± 7	383ab ± 12	330b ± 24	369 ± 19	(213, 562)	6.0**
Calcium (mg)	22a ± 0	42.6b ± 3.4	36.4bc ± 1.7	45.4bd ± 1.3	40.6b ± 2.4	40.0 ± 2.1	(22, 55)	7.3**
Magnesium (mg)	111ab ± 0.5	115a ± 4	92b ± 3	97b ± 4	93b ± 5	98 ± 4	(65, 123)	5.0**
Zinc (mg)	2.3 ± 0.8	3.1 ± 0.2	3.0 ± 0.1	2.6 ± 0.2	3.1 ± 0.4	2.8 ± 0.2	(1.4, 5.9)	0.8
Iron (mg)	5.2 ± 0.6	5.4 ± 0.2	5.8 ± 0.2	5.6 ± 0	5.4 ± 0.2	5.5 ± 0.1	(4.7, 7.8)	1.0
Copper (mg)	0.67ab ± 0.16	0.85a ± 0.06	0.79a ± 0.02	0.57b ± 0.03	0.71ab ± 0.04	0.72 ± 0.05	(0.37, 0.97)	6.3**

Values presented are mean ± SE

Means in the same row not followed by the same letter are significantly different at $p < 0.05$.

F value * statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$

content of *dhal* was 54.9 g/100 g and mean energy of *dhal* for non-ruminants was 1575 kJ/100 g.

Table 4.1.35 gives the Statewide mean values and range (mg/100 g) for the trace minerals in *dhal* from different States (sites). Mean potassium content of QLD and NSW *dhal* was significantly higher than the potassium content in VIC and WA. *Dhal* from NSW and SA exhibited a moderate decreases (9 mg/100 g - 36 mg/100 g) in potassium content, while *dhal* from WA and VIC had larger differences (113 mg/100 g-128 mg/100 g) in potassium content compared to whole seeds from the respective States. Potassium in QLD *dhal* was similar to whole seeds from QLD. The Statewide mean for potassium was marginally higher than that reported by Jambunathan and Singh (1981) for *desi dhal* grown at two sites in the subcontinent.

Dhal from QLD and NSW had significantly higher phosphorus levels than VIC and WA *dhals*. QLD and NSW *dhal* exhibited a significant increase (up to 30%) in phosphorus level compared to whole seeds from those States.

The calcium content in QLD *dhal* samples was significantly lower (22 mg/100 g) than that in *dhal* from all other States, while SA *dhal* had significantly higher calcium (45.4 mg/100 g) than *dhal* from VIC (36.4 mg/100 g). Reduction in calcium levels in *dhal* compared to whole seed ranged from 89% in QLD to 77% in NSW.

NSW and VIC *dhals* had significantly higher copper levels compared to *dhal* from SA.

This study proves that there are significant differences in *dhal* composition of different varieties and from different sites.

4.2 Evaluation of Soaking and Sprouting Properties of Chickpea Seed

4.2.1 Soaking

Soaking whole chickpea seeds in water is an essential pre-processing step which primarily helps to soften the seed. Varietal and statewide differences in the rate of water uptake as measured by hydration capacity (HC), and increase in the volume of the hydrated seed as measured by swelling capacity (SC) of selected, commercially traded *desi* and *kabuli* varieties is presented. Increase in weight was measured at 1, 2 or 3, 4, 6, 8 and > 20 hours.

4.2.1.2 Sample Distribution

Soaking and sprouting properties were evaluated over three harvests between 1992 and 1995. The varieties of chickpea selected for the studies were based on the varieties grown in a particular State during a given season. A poor harvest was reflected in a small number of samples received. Table 4.2.1 details the variety and origin of the samples on which soaking and sprouting tests were conducted.

Table 4.2.1 Samples of chickpea tested for soaking and sprouting properties

Year	1992/93					1993/94					1994/95				
	Q	N	V	S	W	Q	N	V	S	W	Q	N	V	S	W
A	1	1	-	1	1	1	-	1	-	1	1	-	-	1	-
B	-	1	-	-	-	-	1	-	-	-	2	-	1	-	-
Do		1	2	1	-	-	-	1	-	-	-	-	1	-	-
Se	1	1	1	-	-	-	-	1	-	-	-	-	-	1	-
T	1	1	1	-	-	-	-	1	-	2	1	-	1	1	-
De	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
No	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Total	**3**	**5**	**4**	**2**	**1**	**1**	**1**	**4**	**-**	**3**	**5**	**-**	**4**	**3**	**-**
G	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
K	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-
O	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
M	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Total	-	**1**	**1**	-	-	-	**1**	**2**	-	-	-	-	-	-	-

Q, N, V, S and W = QLD, NSW, VIC, SA and WA, respectively

A, B, Do, Se, T, De, No = Amethyst, Barwon, Dooen, Semsen, Tyson, Desavic and Norwin, respectively (*desi* varieties)

G, K, O, M = Garnet, Kaniva, Opal, Macarena, respectively (*kabuli* varieties)

Fifteen *desi* varieties were selected to conduct the soaking and sprouting tests from the 1992/93 harvest, 9 from 1993/94 season and 12 from 1994/95, a total of 36 *desi* samples. On a statewide basis, all the pulse producing States were represented in 1992/93, SA was excluded in 1993/94 and NSW and WA were excluded in 1994/95.

Only 5 *kabuli* samples were selected over two seasons with none in 1994/95. The size of the *kabuli* crop in Australia is small and unpredictable due to being prone to fungal and weather damage in hot and humid conditions (unseasonal rains during harvest). Furthermore, the *kabuli* crop is traded by only a few private traders, so obtaining a pure sample is difficult.

4.2.1.3 HC of *Desi* Chickpea

Figures 4.2.1, 4.2.2 and 4.2.3 show the effect of cultivar on HC (%) for 1992/93, 1993/94 and 1994/95, respectively. Amethyst (regardless of origin and season) (mean weight 15.2 g/100 seeds) had high HC during the first 4 hours of soaking. Rate of water uptake in Barwon during 1993/94 and 1994/95 was similar to Amethyst, but the only Barwon sample from QLD in 1992/93 (mean weight 20.1 g/100 seeds) had a low water uptake for the first 4 hours. Tyson (1994/95 season) had an impaired water uptake compared to Tyson (mean weight 14.8 g/100 seeds) in the previous two years. Dooen (1993/94) (mean weight 17.8 g/100 seeds) had high water uptake compared to other varieties in that season and Dooen from the other seasons. The large seeded Semsen (mean weight 21.0 g/100 seeds) had the lowest water uptake at any given time interval and in all seasons probably because of reduced surface area of the seeds. The rate of water uptake was the highest for Semsen between 8 and 20 hours. The weight gain between 8 and 20 hours was small in varieties that had a high initial water uptake.

HC of Desavic (mean weight 20.6 g/100 seeds) and Norwin (mean weight 19.4 g/100 seeds) were evaluated only for 1994/95 samples. The rate of water uptake for the two varieties were dissimilar at the onset but attained similar HC after 20 hours. Norwin had the highest HC for the first 8 hours among all the varieties studied. For the first two hours of the study, the water uptake of Desavic was marginally lower than Semsen but after 4 hours a rapid improvement in HC was observed and peak HC was attained at 20 hours. There was no significant difference in HC for any of the varieties after 20 hours.

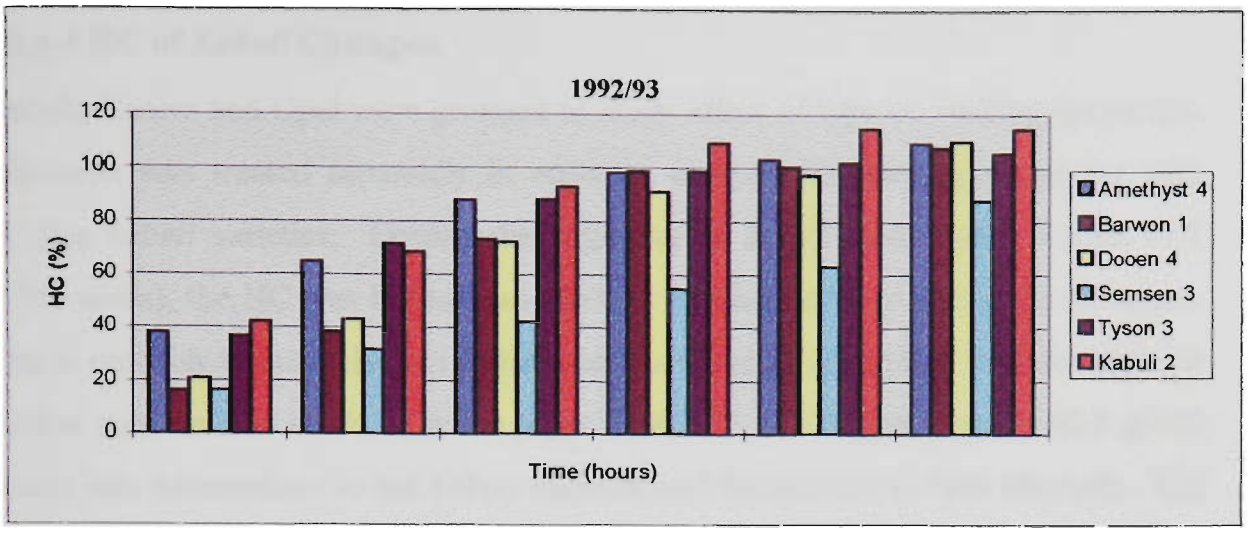


Figure 4.2.1 Effect of chickpea cultivars on HC (%) (1992/93)

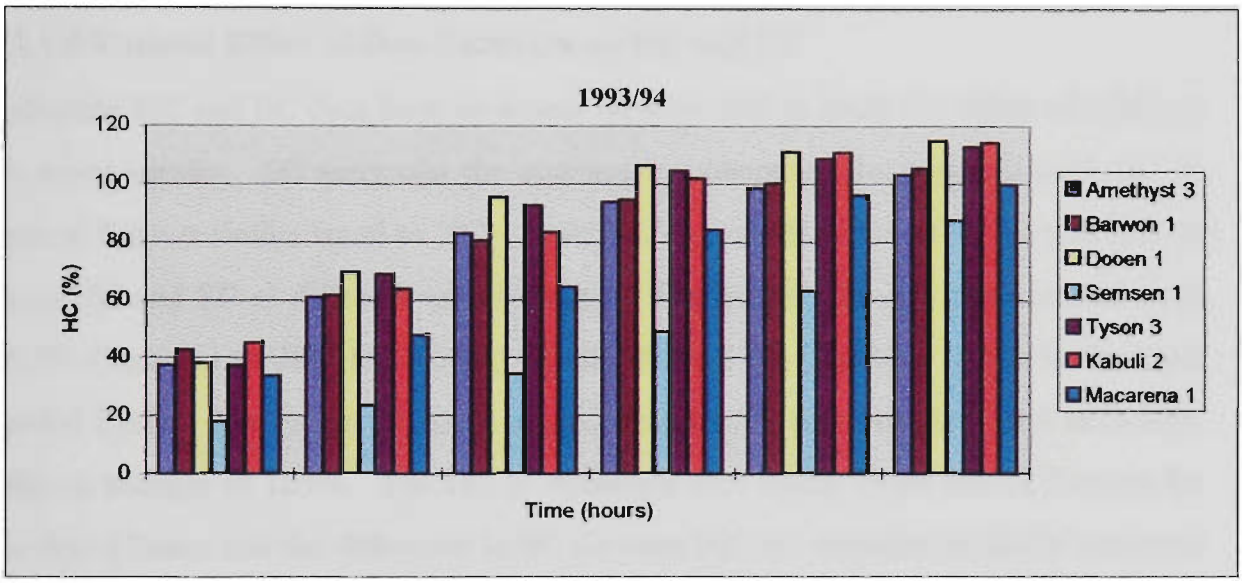


Figure 4.2.2 Effect of chickpea cultivars on HC (%) (1993/94)

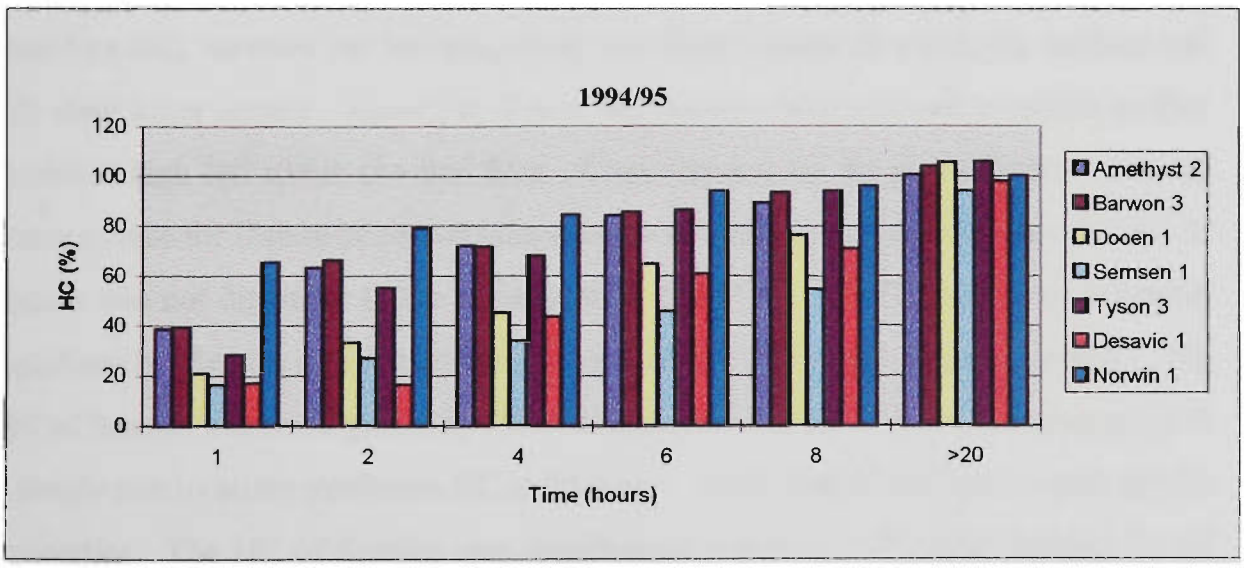


Figure 4.2.3 Effect of chickpea cultivars on HC (%) (1994/95)

4.2.1.4 HC of *Kabuli* Chickpea

Garnet, Kaniva and Opal were grouped to study effect of type on soaking properties. Macarena was treated separately in order to compare its soaking properties with existing *kabuli* varieties. Despite the large size of *kabuli* seeds (mean weight 41.2 g/100 seeds), the HC was higher than most of the *desi* varieties during the 20 hours. This is probably because the thin *kabuli* seed coat is more permeable to water than the thicker coat on *desi* seeds. On the other hand, HC of Macarena (mean 62.8 g/100 seeds) was intermediate to the *kabuli* varieties and Semsen for all time intervals. The sample of Macarena was (> 9 mm) larger than the *kabuli* varieties (average 8 mm).

4.2.1.5 Varietal Effect of *Desi* Cultivars on HC and SC

Individual HC and SC data from each year were pooled to study the effect of cultivars on water uptake. SC measures the increase in volume of the hydrated seed and in general follows similar trend to HC. Table 4.2.2 gives the effect of 6 *desi* varieties on mean HC and SC at different time intervals. The HC for the first hour ranged from 16.7% (Semsen) to 38% (Amethyst) and SC from 5.7% (Semsen) to 7% in the small seeded Tyson. The HC at 20 hours ranged from 89.8% (Semsen) to 110% in Dooen, with an average of 103%. The HC of Amethyst was nearly twice that of Semsen for the first 6 hours and the difference in SC between the two varieties gradually increased with time.

Based on HC, varieties can be categorised into three classes: (i) rapid, (ii) medium and (iii) slow water uptake. Amethyst, Tyson and Barwon had rapid water uptake as they exhibited high HC within the first hour of soaking and for the next 4 hours. Rate of water uptake for Dooen increased after 4 hours of soaking and after 6 hours the HC of Dooen was not dissimilar to the varieties with rapid HC. The HC of Dooen increased significantly after an initial 'equilibrium' period and had medium water uptake. The HC of Semsen increased gradually (10.9%/measurement) for 8 hours, then increased at a steady rate to attain maximum HC at 20 hours. Thus, Semsen had slow water uptake properties. The HC of Semsen was significantly lower than all other varieties for all time intervals. The HC of Tyson was significantly higher than Dooen (medium water uptake) at the 2 hour interval ($p < 0.05$).

There was no change in SC for any of the varieties in the first hour of the experiment and was similar to HC pattern. The SC of Semsen was significantly lower than all the

Table 4.2.2 Effect of selected *desi* cultivars on mean HC (%) and SC (%) at fixed time intervals studied over three seasons

1992-95	No. of	1 hour		2 or 3 hours‡		4 hours		6 hours		8 hours		>20 hours
Variety	samples	HC%	SC%	HC%	SC%	HC%	SC%	HC%	SC%	HC%	SC%	HC%
F value		5.3*	3.2	7.8**	6.6*	10.1**	13.4**	13.3**	17.1**	14.2**	15.5**	6.0*
Amethyst	9	38.0a ± 0.4	6.9 ± 1.2	63.0a ± 1.1	11.8ac ± 0.4	80.9a ± 4.8	15.4a ± 0.8	92.0a ± 4.2	17.1a ± 0.5	97.0a ± 4.1	18.4a ± 0.4	104.3a ± 2.6
Barwon	5	32.8a ± 8.3	6.4 ± 1.6	55.4a ± 8.6	9.8a ± 1.5	75.1a ± 2.8	14.4a ± 0.3	92.9a ± 3.9	16.2a ± 0.8	98.1a ± 2.4	17.8a ± 0.8	105.8a ± 1.1
Dooen	6	26.6 ± 5.7	6.2 ± 1.3	48.7ac ± 10.8	9.8ad ±1.6	70.9 ± 14.4	14.2 ± 1.6	87.4a ± 12.2	16.8a ± 0.8	95.0a ± 10.2	18.0a ± 0.5	110.2a ± 2.6
Semsen	5	16.7b ± 0.5	5.7 ± 1.9	27.4b ± 2.3	5.3b ± 0.6	36.7b ± 2.7	7.0b ± 0.9	49.8b ± 2.6	9.3b ± 0.8	60.3b ± 2.9	11.6b ± 0.2	89.8b ± 2.1
Tyson	9	34.2a ± 2.8	7.0 ± 0.6	65.2ad ± 5.1	12.2ae ± 0.9	82.9a ± 7.6	16.0a ± 1.1	96.5a ± 5.4	17.8a ± 0.7	101.7a ± 4.2	18.9a ± 0.7	108.2a ± 2.4
Mean ± SE	34	30.0 ± 3.7	6.4 ± 0.2	51.9 ± 6.8	9.8 ± 1.2	69.3 ± 8.4	13.4 ± 1.6	83.7 ± 8.6	15.4 ± 1.6	90.4 ± 7.6	16.9 ± 1.3	103.7 ± 3.6

‡ Measurements were recorded at 2 or 3 hours

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

other varieties after the second hour and the SC of Tyson was significantly higher than Dooen (medium water uptake) and Amethyst (rapid water uptake).

4.2.1.6 Statewide and Seasonal Variation of HC and SC on *Desi* Cultivars

Figures 4.2.4, 4.2.5 and 4.2.6 illustrate statewide differences of HC on *desi* cultivars. In 1992/93, *desi* samples from SA had maximum HC for the duration of the experiment followed by the sample from WA. In 1993/94, the sample from WA had the maximum HC. It must be noted that there were no samples from SA that year. In the same season, the HC of NSW sample was higher than WA for the first hour of the experiment but the HC of WA increased rapidly after the first hour.

In 1992/93, there was a trend for the HC of SA and WA to be higher than NSW, VIC and QLD. In 1993/94, the HC of WA was higher than samples from other States whereas in 1994/95, QLD had higher HC compared to VIC and SA.

Contrary to previous findings, SA had the lowest HC in 1994/95. Semsen was one of the SA samples which may have been responsible for the reduced HC. There were no Semsen samples from SA in the previous two years. Semsen samples in previous seasons were from QLD, NSW and VIC, which probably explains the 'average' HC for these States.

Owing to the small number of samples, HC could not be evaluated statistically for every variety from every State in each season. Analysis of variance between varieties, State and year (separately) were significant at $p < 0.05$ ($F = 25.1$, 9.6, 17.1, respectively).

Table 4.2.3 presents the mean HC (%) and SC (%) for *desi* cultivars from the 5 pulse producing States of Australia over three harvests. The HC for the first hour ranged from 29.1% to 39.6% and the SC ranged from 6% to 7.1%. The large varietal differences seen in Table 4.2.2 had disappeared. The HC at the 20 hours spanned a narrow range between 104.1% to 111.7%. There were no significant differences in HC or SC between the States at any time interval. Based on a statewide trend, the HC of WA was higher than SA, VIC and NSW which was higher than the HC of QLD.

These results suggest that cultivars (genotypes) had a statistically significant effect on HC and SC but the origin of the samples (site) had no effect on HC.

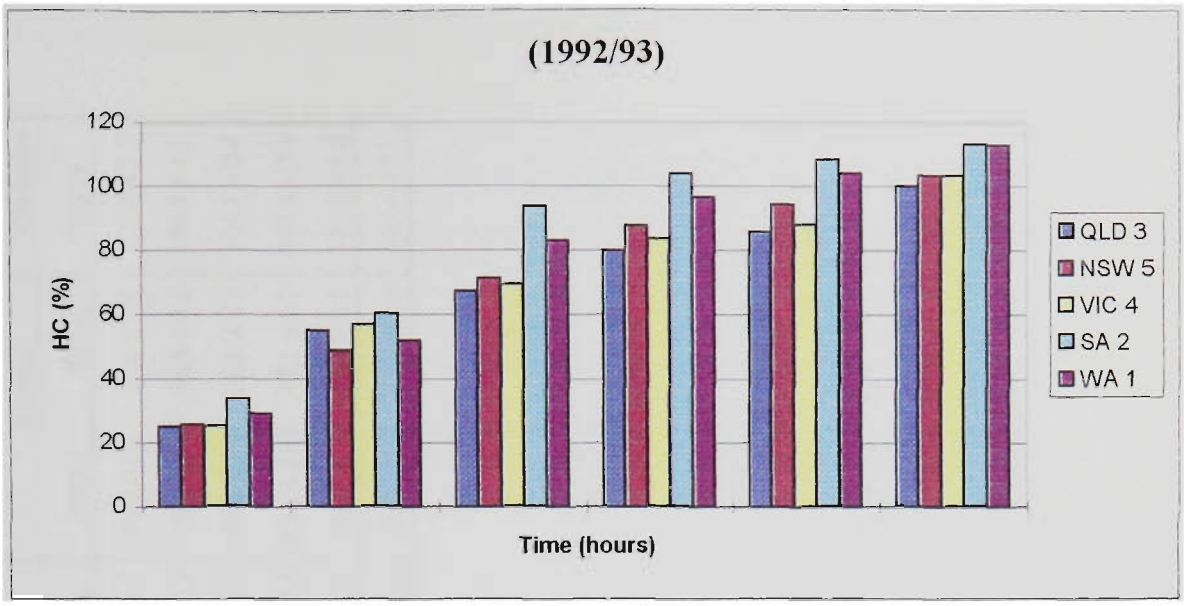


Figure 4.2.4 Statewide differences on HC (%) of *desi* cultivars (1992/93)

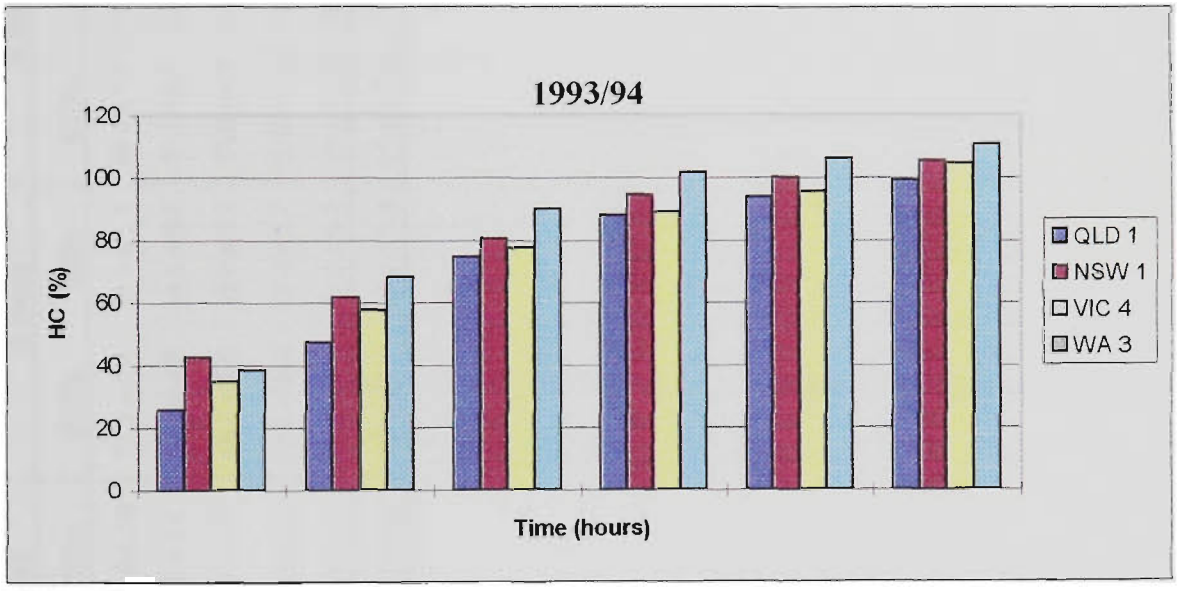


Figure 4.2.5 Statewide differences in HC (%) of *desi* cultivars (1993/94)

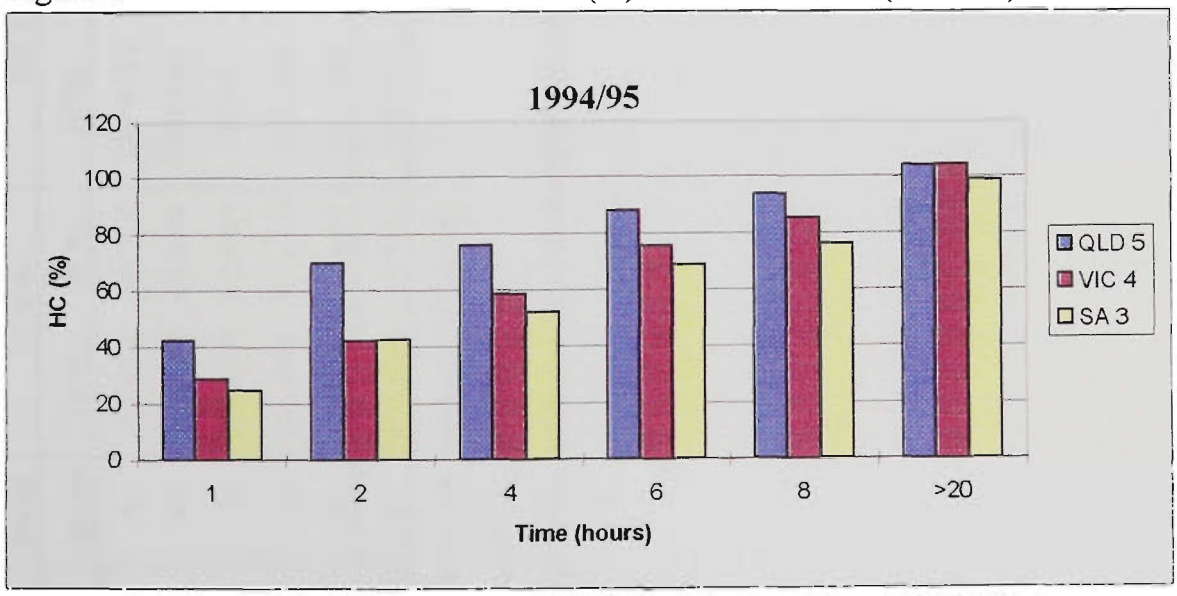


Figure 4.2.6 Statewide differences on HC (%) of *desi* cultivars (1994/95)

Table 4.2.3 Statewide differences on mean HC (%) and SC (%) of selected *desi* varieties at fixed intervals studied over three seasons

1992-95	No. of	1 hour		2 or 3 hours‡		4 hours		6 hours		8 hours		>20 hours
States	samples	HC%	SC%	HC%	SC%	HC%	SC%	HC%	SC%	HC%	SC%	HC%
QLD	9	34.1 ± 8.2	6.0 ± 0.8	58.6 ± 11.2	10.4 ± 2.6	75.5 ± 0.4	13.6 ± 1.5	88.0 ± 0.0	15.9 ± 1.2	93.9 ± 0.1	16.6 ± 1.9	101.5 ± 2.3
NSW	6	34.2 ± 8.4	6.5 ± 0.4	55.3 ± 6.6	9.8 ± 0.6	76.0 ± 4.7	14.1 ± 0.6	91.1 ±3.5	15.4 ± 0.7	97.3 ± 3.0	16.8 ± 0.4	104.2 ± 1.1
VIC	12	29.6 ± 2.8	6.2 ± 0.9	52.2 ± 5.1	9.4 ± 0.9	68.5 ± 5.6	12.9 ± 0.7	82.8 ± 4.0	14.9 ± 0.3	89.6 ± 3.1	16.9 ± 0.4	104.1 ± 0.4
SA	5	29.1 ± 4.4	6.1 ± 1.8	51.4 ± 8.8	10.3 ± 2.6	72.8 ± 20.6	13.6 ± 2.7	86.2 ± 17.5	15.9 ± 2.5	92.1 ± 15.9	17.1 ± 1.7	105.8 ± 7.1
WA	4	33.7 ± 4.6	7.1 ± 0.1	60.1 ± 8.2	11.6 ± 1.1	86.5 ± 3.6	17.3 ± 0.2	99.1 ± 2.7	18.5 ± 0.1	105.2 ± 1.2	19.8 ± 0.5	111.6 ± 1.0
Mean ± SE	36†	32.1 ± 1.1	6.4 ± 0.2	55.5 ± 1.7	10.3 ± 3.7	75.9 ± 3.0	14.3 ± 0.8	89.4 ± 2.8	16.1 ± 0.6	95.6 ± 2.7	17.4 ± 6.0	105.4 ± 1.7

‡ Measurements were recorded at 2 or 3 hours

Values presented are mean ± SE

† includes the Desavic and Norwin from VIC and QLD, respectively.

4.2.2 Sprouting

Sprouting (germination) properties of *desi* cultivars (except Desavic) used in the soaking studies were examined. Pre-soaked *desi* seeds (4 hours) were sprouted for 72 hours under controlled conditions and the number of sprouted seeds were counted every 24 hours.

4.2.2.1 Varietal Effect on Sprouting Properties

Data on sprouting properties from three seasons are presented in Table 4.2.4. The seasonal trends were not significantly different. At the end of 24 hours, the sprouted seeds ranged from 32.9 to 72.9%, with an average of 57.5%. The mean percent of sprouted seeds increased to 93.8% at the end of 3 days. The number of sprouted seeds in Semsen was significantly lower than all other varieties at all time intervals. After 48 hours, sprouting in Amethyst was significantly higher than in Dooen. The general trend observed was: Amethyst and Tyson had better sprouting ability than Dooen which was better than Barwon and Semsen.

Sprouting can be affected by random occurrence of 'hard seeds' in any population. Sprouting is affected by all factors that affect soaking but the presence of hard seeds has a deleterious effect on quality of sprouts. The reason for the formation of hard seeds is unknown. Semsen showed a 5% hard seed count which probably explains its poor soaking and sprouting properties. Desavic was excluded from the sprouting studies because it showed a 12% hard seed count. Sprouting properties of a larger number of Desavic seeds need to be further investigated.

Visual examination of the sprouts revealed that 48 hours of sprouting produced eating quality sprouts. Sprouts at the end of 72 hours showed signs of fungal growth which would have to be microbiologically examined. Tyson and Amethyst produced the maximum number of sprouted seeds at the end of 48 hours.

4.2.2.2 Statewide Differences in Sprouting Properties

Table 4.2.5 presents Statewide differences in sprouting properties of 36 *desi* cultivars evaluated over three seasons. At the end of 24 hours, 60% of the seeds were sprouted which increased to 95% at the end of the experiment. The presence of hard seeds or 'slow starters' makes 100 percent sprouting almost impossible. Like soaking, no significant differences in sprouting capacity was observed from samples originating from different States. There were, however, small changes to statewide trends of

Table 4.2.4 Effect of *desi* cultivars on mean sprouting (%)

1992-1995	No. of samples	24 hours	48 hours	72 hours
F value		7.0*	7.4*	3.4*
Amethyst	9	72.9**a** ± 3.9	97.8**ac** ± 0.6	99.3**a** ± 0.5
Barwon	5	48.0**a** ±16.6	84.0**a** ±11.1	89.3**a** ±9.2
Dooen	6	60.3**a** ± 13.7	90.7**ad** ± 7.8	96.8**a** ± 1.7
Semsen	5	32.9**b** ± 9.6	71.7**b** ± 8.9	85.3**b** ± 2.9
Tyson	10	73.6**a** ± 4.2	97.0**a** ± 0.6	98.2**a** ± 0.2
Total & mean	35	57.5 ± 7.7	88.2 ± 4.8	93.8 ± 2.7

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$.

Table 4.2.5 Statewide differences on mean sprouting (%) of *desi* cultivars

1992-1995	No. of samples	24 hours	48 hours	72 hours
QLD	9	69.9 ± 8.5	92.8 ± 4.7	98.2 ± 0.7
NSW	6	44.2 ± 11.5	84.7 ± 5.9	93.5 ± 4.7
VIC	12	57.7 ± 7.5	85.2 ± 6.2	92.3 ± 4.0
SA	5	62.8 ± 5.3	92.8 ± 3.8	96.0 ± 2.5
WA	4	65.0 ± 11.0	96.5 ± 1.0	97.8 ± 0.5
Total & mean	36†	59.9 ± 4.4	90.4 ± 2.3	95.6 ± 1.2

Values presented are mean ± SE

† includes 1 Norwin sample from QLD

sprouting. QLD and WA had the highest number of sprouts followed by SA. Number of sprouts from NSW and VIC were the lowest at all time intervals.

4.3 Cooking Quality of *Desi* and *Kabuli* Seeds

Traditional tests to estimate cooking quality such as boiling in water for extended periods and ascertaining the time required to soften the seeds when pressed between thumb and finger and penetrometer measurements are slow, lack reproducibility and tend to be operator dependent. Inconsistent and variable performances of taste panels in judging important food characteristics (Binder and Rockland 1964) and the cost of such exercises have been key factors for the present study attempting to develop a simple, rapid and robust objective texture test to determine cooking quality of *desi* and *kabuli* seeds through ranking.

4.3.1 Cooking Quality of Commercially Traded Varieties

Five *desi* samples consisting of Amethyst from QLD and WA and Tyson from QLD, WA and VIC from the 1993/94 season were soaked for 6, 8 or 16 hours in 0%, 1% and 2% salt solutions then pressure-cooked. Texture measurements were then made with the Lloyd texture analyser (model no. LRX) at constant load (450 N) and fixed crosshead speed (100 mm/min). Texture measurements are reported as maximum deformation (mm) of the cooked seed (X-axis) and work done (N-mm) to achieve the deformation is represented as area under the curve. Work done was computed at 50% and 75% of the maximum deformation value.

Five *kabuli* samples consisting of Garnet from NSW in 1992/93, Kaniva from VIC in 1992/93 and 1993/94, Opal from NSW in 1993/94 and Macarena from VIC in 1993/94 were similarly treated and tested. However, all tests could not be performed on Garnet 1992/93 and Macarena due to insufficient sample. Texture measurements on all 10 samples (5 *desi* and 5 *kabuli*) were also carried out on cooked samples that were not pre-soaked.

Figures 4.3.1 and 4.3.2 represent typical output graphs of deformation (mm) against load (N) of cooked *desi* and *kabuli* seeds (pre-soaked for 16 hours), respectively, as plotted by the Lloyd texture analyser. The Figures depict an overlay of three deformation profiles for each sample.

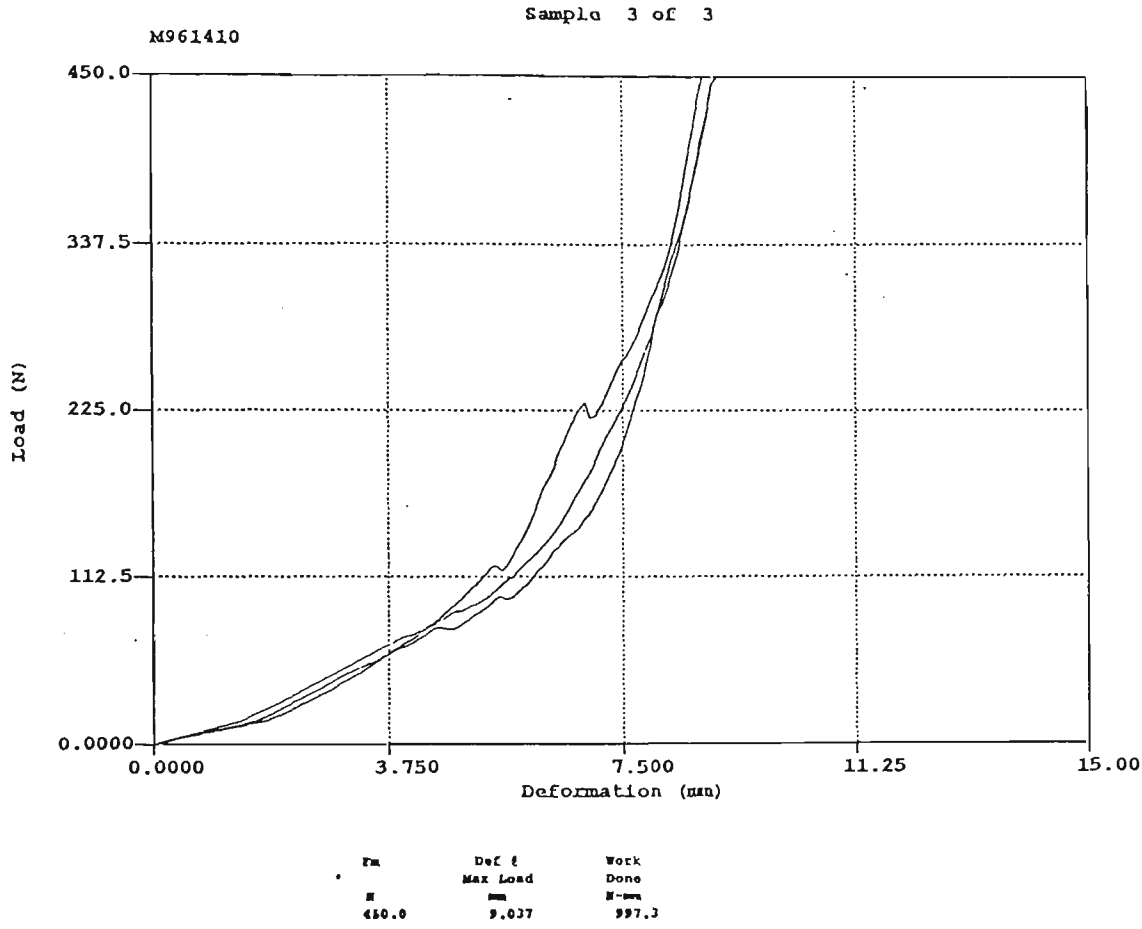


Figure 4.3.1 Typical deformation (mm) profile against load (N) of cooked *desi* seeds in a Lloyd texture analyser.
Each profile is a separate sub-sample of the same seed batch.

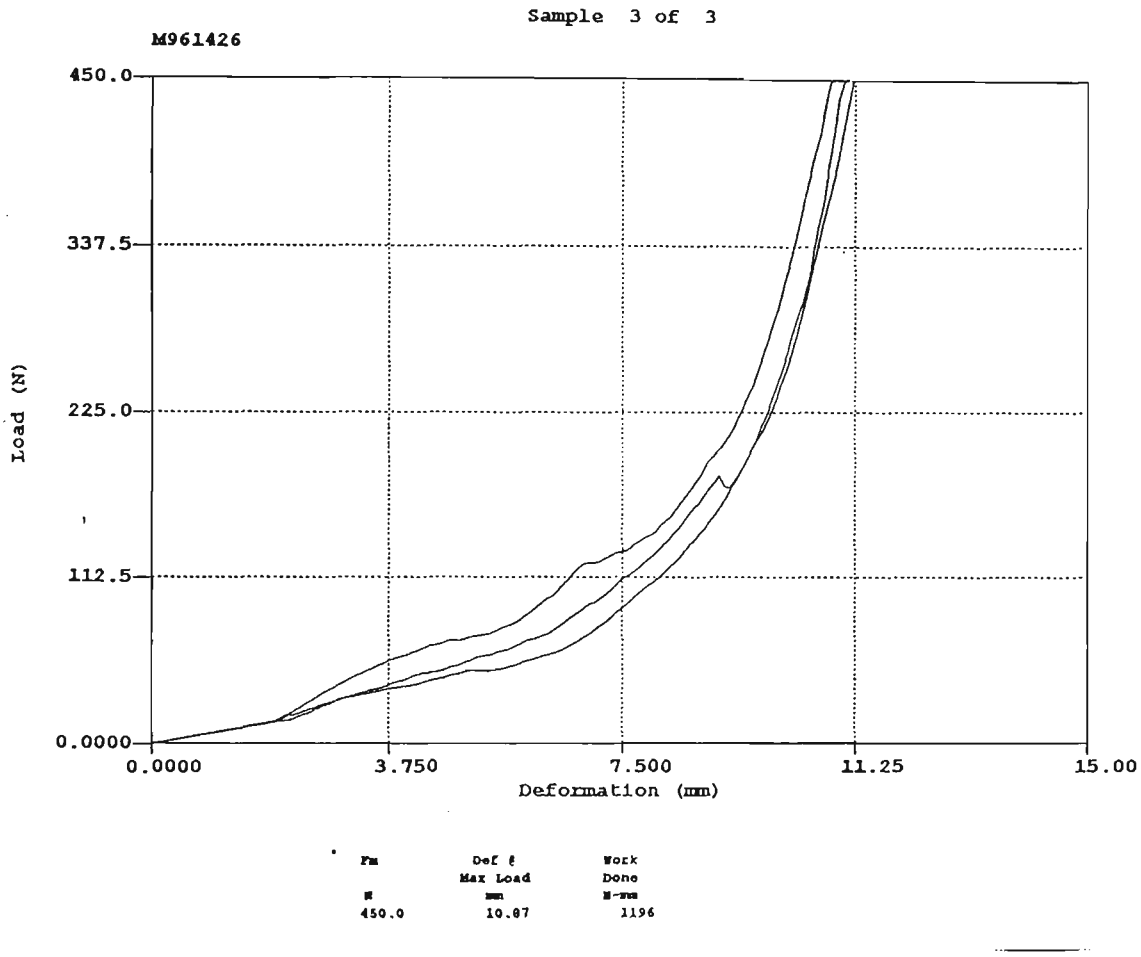


Figure 4.3.2 Typical deformation (mm) profile against load (N) of cooked *kabuli* seeds in a Lloyd texture analyser.
Each profile is a separate sub-sample of the same seed batch.

4.3.1.1 *Desi* Varieties

About 270 observations each for deformation and work done were obtained. *Desi* samples subjected to similar pre-treatments were grouped to study effect of pre-treatments if any, on deformation and work done.

The effect of soak time on work and deformation at the 3 levels of salt in the soak solution for *desi* and *kabuli* seeds is shown by plotting box-plots. The 'box' contains the middle 50% of observations for a given set of conditions and the horizontal black line in each box indicates the median value. The 'whiskers' on either side of the box represents the remaining 50% observations. Potential outliers, if any, are depicted as small, unfilled circles on either end of the box. Figures 4.3.3 and 4.3.4 illustrate the deformation (mm) and work done (N-mm) of cooked *desi* seeds, that were previously unsoaked or pre-soaked in salt solutions of varying strengths respectively. The principle of the method is that deformation of cooked seeds is inversely proportional to cooking time. Thus, for samples treated identically, the higher the deformation value, the greater is the degree of softness which then indirectly relates to a lower cooking time.

A factorial analysis of variance of deformation values using the MANOVA procedure in SPSS was conducted with sample, soak time and salt levels as factors. The high order interactions such as sample x salt, sample x soak, soak x salt and sample x soak x salt were statistically significant at $p < 0.05$ with $r^2 = 0.92$ (adjusted $r^2 = 0.88$ accounting for all interactions) for 235 cases. Similarly, MANOVA of 'work done' was significant at $p < 0.05$ with $r^2 = 0.72$ (adjusted $r^2 = 0.57$). These findings suggests that the pre-treatment and sample type have significant effects on deformation and 'work done' to attain the deformation.

An analysis of covariance was also conducted with deformation as the dependent variable and salt content and soak time as covariates, the $r^2 = 0.65$ and was statistically significant at $p < 0.05$. Regression assumes a linear model suggesting that deformation increased with salt level and soak time by a factor of 1.18 and 0.12, respectively. The factor is a constant and defined as the coefficient of variable. When 'work done' was similarly analysed, the r^2 value decreased to 0.33 and was not significant at the 5% level. 'Work done' was thus not as sensitive as deformation to changes in sample type as was evident in Figure 4.3.4.'

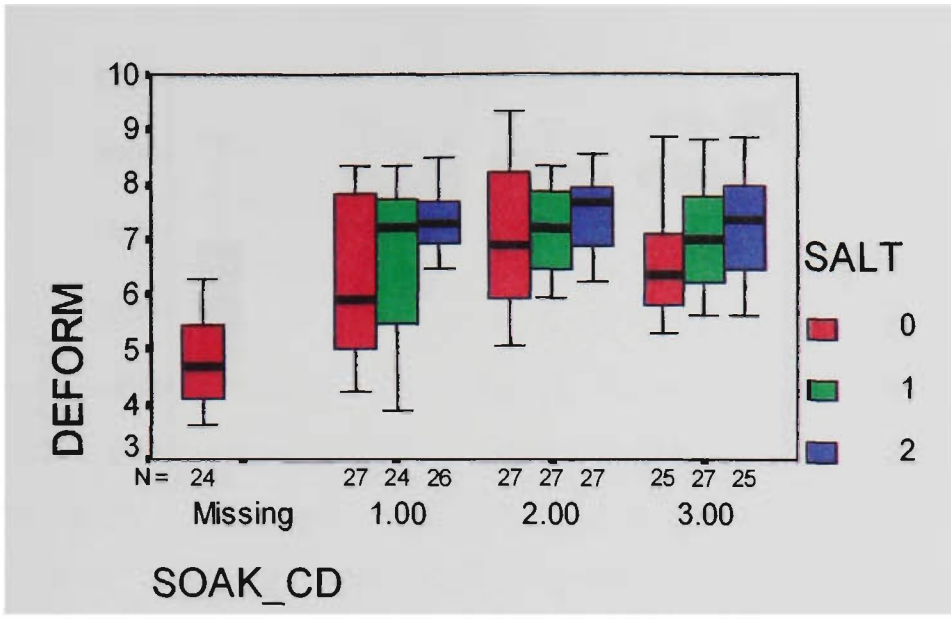


Figure 4.3.3 illustrates the deformation (mm) of cooked *desi* seeds; that were previously unsoaked or pre-soaked in salt solutions of varying strengths.

Salt 0 = water, salt 1 is soak solution containing 1% salt (0.5% each of sodium chloride and sodium bicarbonate) and salt 2 is soak solution containing 2% salt (1% each of sodium chloride and sodium bicarbonate).

Soak_cd represents the duration of soaking by code. Missing code indicate seeds were unsoaked. Code 1, 2 and 3 represent 6, 8 and 16 hours soak, respectively.

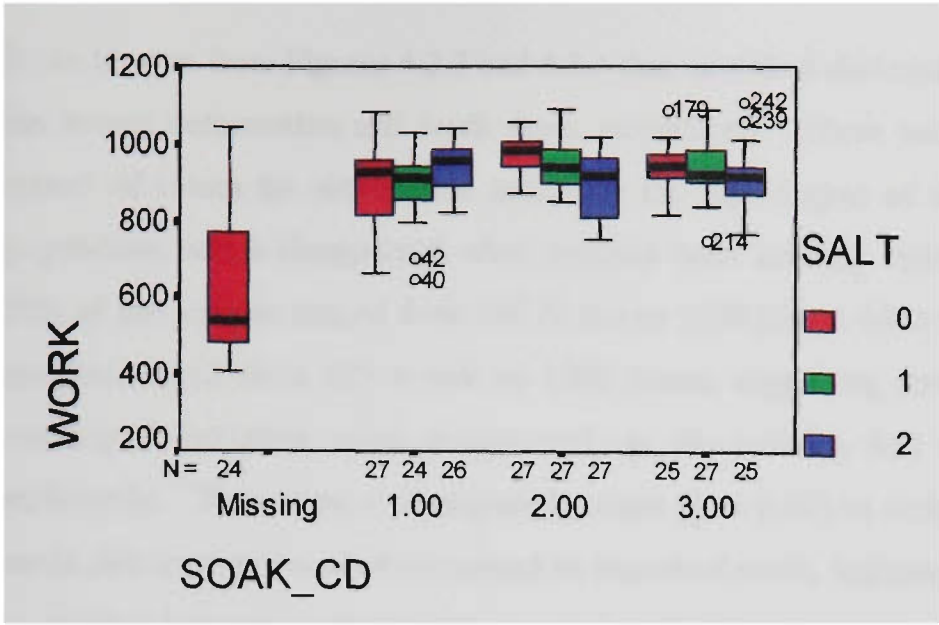


Figure 4.3.4 illustrates the work done (N-mm) to deform cooked *desi* seeds; that were previously unsoaked or pre-soaked in salt solutions of varying strengths.

Salt 0 = water, salt 1 is soak solution containing 1% salt (0.5% each of sodium chloride and sodium bicarbonate) and salt 2 is soak solution containing 2% salt (1% each of sodium chloride and sodium bicarbonate).

Soak_cd represents the duration of soaking by code. Missing code indicate seeds were unsoaked. Code 1, 2 and 3 represent 6, 8 and 16 hours soak, respectively.

It can be seen from Figures 4.3.3 and 4.3.4 that unsoaked *desi* seeds when cooked had the lowest deformation and work done, respectively. There was, however, a large spread of values for work done indicating the high degree of variability in sample populations which disappeared when samples were soaked. Work done by the top 50% of the samples ranged from 540 N-mm to 1040 N-mm while the range for all the samples ranged from 425 N-mm to 1040 N-mm suggesting that the samples were resisting deformation when compressed, as the cooking had not softened them sufficiently. There was a significant increase ($p < 0.01$) in deformation of cooked seeds that were pre-soaked compared to unsoaked seeds, implying that soaking prior to cooking increases softness of the cooked seed. When samples were soaked in water and then cooked, the overall deformation increased in the samples that were subjected to 8 hours soak compared to 6 hours soak ($p < 0.05$), but decreased to intermediate levels for the 16 hours soak. It is, however, worth noting that the deformation values had a narrower range for seeds cooked after 16 hours soak compared to 6 and 8 hours soak. In other words, seeds were uniformly cooked when soaked for 16 hours. The spread of values for work done for cooked seeds pre-soaked in water decreased with an increase in soak time suggesting uniformity in degree of softness within each sample.

There was greater variability in deformation values of cooked seeds that were pre-soaked in 1% salt solution for 6 hours compared to 8 hours implying that an increase in soak time narrowed the range for deformation. The median value for deformation of seeds soaked for 16 hours in 1% salt solution, however, showed a small decrease in deformation and a greater spread of values. The highest median deformation was observed for samples soaked for 8 hours in 2% salt solution, suggesting that these conditions could be the optimum level of soak time and salt strength for *desi* seeds. The overall decrease in deformation values for seeds soaked for 16 hours compared to seeds soaked for 8 hours at all salt levels could not be fully explained.

At any particular soak time, deformation increased when the salt content of the soak solution increased, except for seeds that were soaked in 2% salt solution for 6 hours whose deformation was similar to seeds soaked in 1% salt solution. The increase in deformation value was accompanied by a decrease in size of the 'boxes', implying greater uniformity in texture (softness) among sample populations. The increase in

deformation was complemented by a steady decrease in work done except, for seeds soaked in 2% solution for 6 hours which showed a slight increase. It should thus be noted that as median deformation increases with increase in salt levels for a given soak time, work done decreases, except for seeds that were cooked without soaking or after 6 hour soak. There was a significant increase ($p < 0.05$) in deformation between seeds soaked for 6 hours in water and those soaked for the same period in 1% salt. The work done values for a given soak time at different salt levels spanned a narrow range (900-1000 N-mm.) and did not adequately represent changes in sample type as clearly as deformation values. Figure 4.3.4 displays some outliers for seeds soaked for 6 hours in 1% salt solution and 16 hours at 1 and 2% salt solutions. Statistical analyses also suggested that work done was not sensitive enough to reveal differences between sample types.

4.3.1.2 *Kabuli* Varieties

One hundred and fifty observations were grouped to study the effect of soaking time and salt levels in the deformation and work done on cooked *kabuli* seeds. Figures 4.3.5 and 4.3.6 illustrate the deformation (mm) of and work done (N-mm) to deform cooked *kabuli* seeds, that were previously unsoaked or pre-soaked in salt solutions of varying strengths, respectively.

Statistical analysis, similar to the *desi* data, for deformation and work done were conducted on the *kabuli* samples. MANOVA for deformation was conducted with sample, soak time and salt levels as factors. The high order interactions (sample x salt, sample x soak, soak x salt and sample x soak x salt) were statistically significant at $p < 0.05$ with $r^2 = 0.92$ (adjusted $r^2 = 0.89$) for 134 cases. The r^2 value was identical to the value obtained for *desi* varieties. Similarly, tests of significance for 'work done' were significant at $p < 0.05$ with r^2 value of 0.82 (adjusted $r^2 = 0.73$). These findings suggest that pre-treatments and sample type have a greater effect on *kabuli* than *desi* seeds and significantly influence maximum deformation and work done.

In order to attain a more robust correlation, an analysis of covariance was also conducted with deformation as the dependent variable and salt content and soak time as covariates. The $r^2 = 0.74$ and was statistically significant at $p < 0.05$, for 149 cases.

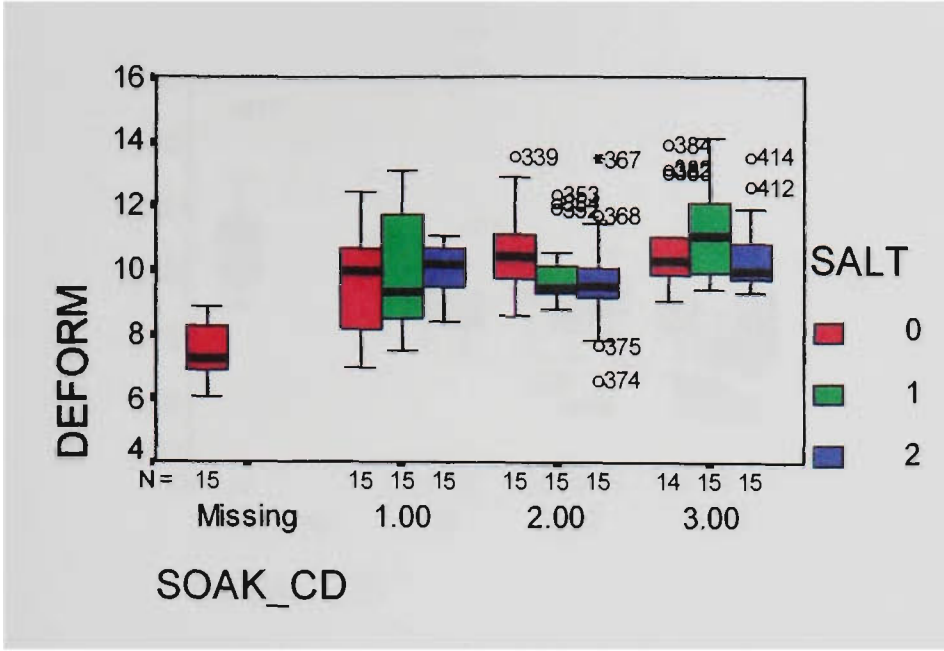


Figure 4.3.5 illustrates the deformation (mm) of cooked *kabuli* seeds; that were previously unsoaked or pre-soaked in salt solutions of varying strengths.

Salt 0 = water, salt 1 is soak solution containing 1% salt (0.5% each of sodium chloride and sodium bicarbonate) and salt 2 is soak solution containing 2% salt (1% each of sodium chloride and sodium bicarbonate).

Soak_cd represents the duration of soaking by code. Missing code indicate seeds were unsoaked. Code 1, 2 and 3 represent 6, 8 and 16 hours soak, respectively.

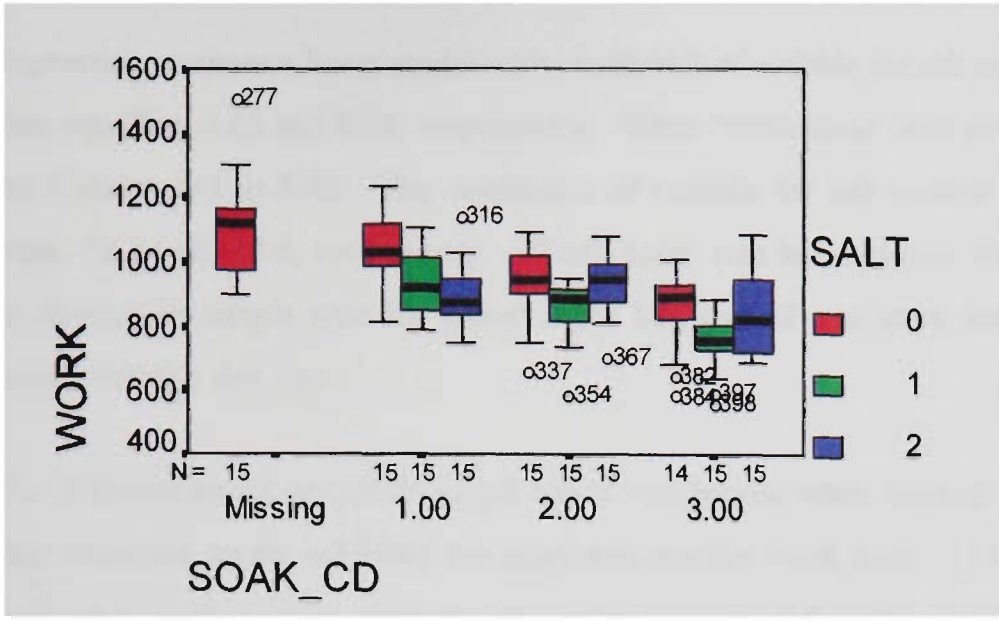


Figure 4.3.6 illustrates the work done (N-mm) to deform cooked *kabuli* seeds; that were previously unsoaked or pre-soaked in salt solutions of varying strengths.

Salt 0 = water, salt 1 is soak solution containing 1% salt (0.5% each of sodium chloride and sodium bicarbonate) and salt 2 is soak solution containing 2% salt (1% each of sodium chloride and sodium bicarbonate).

Soak_cd represents the duration of soaking by code. Missing code indicate seeds were unsoaked. Code 1, 2 and 3 represent 6, 8 and 16 hours soak, respectively.

Regression assumes a linear model with coefficient of variable for salt content and soak time equalling 0.68 and 0.21, respectively. When 'work done' was simiarly analysed, the r^2 decreased to 0.49. The coefficient of variable for salt content and soak time were -72.2 and -18.6, respectively. 'Work done' was less sensitive than deformation to changes in sample type for *kabuli* seeds but, overall was more responsive to the *kabuli* than the *desi* type.

The deformation of unsoaked *kabuli* seeds was lowest when cooked but, unlike the *desi* unsoaked seeds, exhibited the maximum median work done (1150 N-mm). An increase in work done at minimal deformation suggested that the sample was resisting deformation. In other words, the duration of the pressure-cooking was insufficient to produce the desired level of softness. Soaking for 6, 8 and 16 hours significantly increased ($p < 0.01$) deformation of cooked seeds compared to cooking unsoaked seeds. Consequently, the work done decreased ($p < 0.01$) with an increase in soaking time. With the exception of *kabuli* seeds presoaked in water and 1% salt solution for 6 hours, deformation values of cooked *kabuli* seeds exhibited a much narrower range compared to *desi* seeds. The positive outliers observed in the deformation values were that of Macarena which is known for its large seed size and short cooking time. Macarena seeds are rendered too soft if they are cooked for the same duration as ordinary *kabuli* seeds. Correspondingly, work done values for Macarena were depicted as negative outliers in Figure 4.3.6. The negative outliers for deformation in samples subjected to 8 hour soak in 2% salt solution exhibited by Garnet from 1992/93 are probably due to ageing (storage induced texture defect) of the sample while positive outliers for workdone in Figure 4.3.6 was due to Garnet as well. Deformation and hence work done of Kaniva sample from the same year was not affected by storage. This information suggests that deformation and work done are inversely related to each other.

Kabuli seeds soaked in water for 8 hours showed maximum deformation compared to soaking for 6 and 16 hours. An overall high deformation was observed for seeds soaked for 16 hours in 1% salt followed by seeds soaked for 6 and 8 hours in 1% salt. Pre-soaking in 1% salt for 16 hours appeared to be the optimum pretreatment for *kabuli* seeds to achieve maximum softness when cooked.

The area under the curve (work done) decreased when seeds were cooked after being soaked for increased periods at the same level of salt except, for seeds soaked for 8 hours in 2% salt which showed an increase.

Unlike *desi* seeds, no specific trend was observed for deformation at a particular soaking time with different salt levels. Work done showed a decreasing trend with increase in salt levels for a given duration of soak. The exception was for seeds soaked in 2% salt solution for 8 and 16 hours which showed an increase in work done. Deformation and work done exhibited a narrow range of values for *kabuli* seeds compared to *desi* seeds implying that there are smaller variations in the texture of cooked *kabuli* seed populations.

4.3.1.3 Effect of Soaking Status on *Desi* and *Kabuli* Chickpea

Deformation values and 'work done' for *desi* and *kabuli* seeds cooked without soaking and after 16 hours of soaking in water were compared and the data are shown in Figures 4.3.7 and 4.3.8. *Kabuli* seeds had significantly higher ($p < 0.01$) deformation value (7.4 mm) than *desi* seeds (4.7 mm) when cooked without soaking. After soaking for 16 hours in water, the deformation of cooked *desi* seeds (7.4 mm) was 26% lower than *kabuli* seeds (10.0 mm). Thus, *kabuli* seeds attain a greater degree of softness than *desi* seeds irrespective of soaking status, in the absence of salt. This could be due to a thinner seed coat that is more permeable to heat resulting in rapid absorption of cooking water that cause a series of changes to the cellular matrix causing it to soften. The composition of the cellular matrix may also influence the ease with which it degrades.

Cooking unsoaked *kabuli* seeds resulted in a significant increase ($p < 0.05$) in the work done compared to *desi* seeds. Work done on pre-soaked *desi* seeds was depicted by a narrow 'box' but had several potentially low outliers. Work done is a complex parameter and is affected to varying degrees by a large number of factors such as hard seeds in the sample population, resistance of the cooked seeds to deform and moisture content of the sample. As a result, it is less sensitive to changes in sample type. The median values for 'work done' for *desi* and *kabuli* seeds cooked after soaking in water for 16 hours were similar and intermediate to those for *kabuli* and *desi* seeds cooked without soaking.

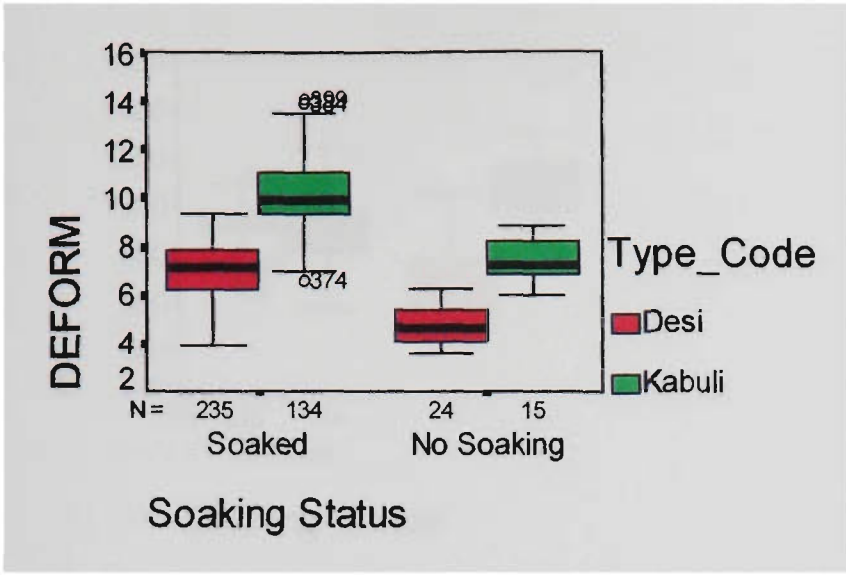


Figure 4.3.7 shows the deformation (mm) of cooked *desi* and *kabuli* seeds that were previously unsoaked or pre-soaked for 16 hours.

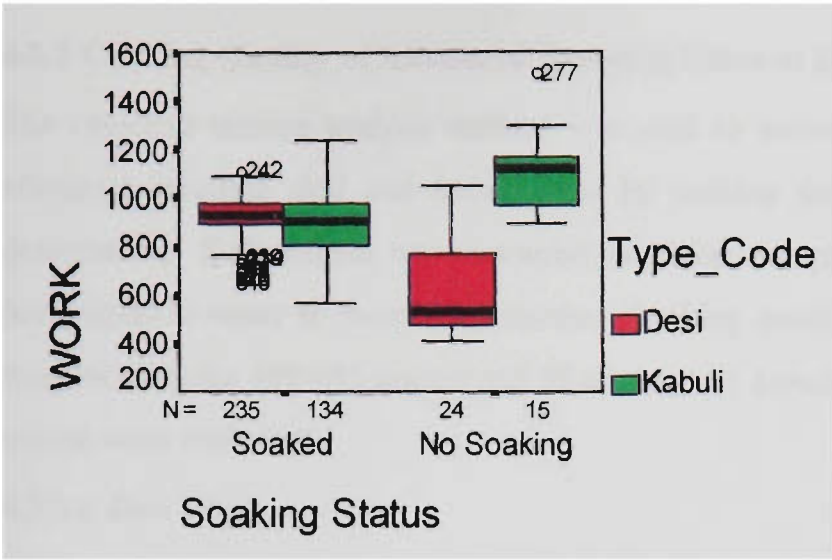


Figure 4.3.8 shows the work done (N-mm) to deform cooked *desi* and *kabuli* seeds that were previously unsoaked or pre-soaked for 16 hours.

4.3.2 Cooking Quality of Advanced Breeding Lines of *Desi* and *Kabuli* Cultivars

The objective texture analysis method was used to ascertain the cooking quality of advanced breeding *desi* and *kabuli* lines by ranking them in decreasing order of deformation. Deformation was measured on cooked samples pre-soaked for 16 hours (overnight) in water at room temperature. Cooking quality of 53 *desi* and 21 *kabuli* samples from the 1994/95 season and 52 *desi* and 21 *kabuli* samples from the 1995/96 season were evaluated.

4.3.2.1 *Desi* Lines

Tables 4.3.1 and 4.3.2 show the mean deformation (mm) and range of deformation for *desi* samples of the advanced breeding lines for 1994/95 and 1995/96 seasons. Deformation ranged from 4.95 to 9.02 mm in 1994/95 for the 11 *desi* lines tested and between 5.23 and 10.34 mm in 1995/96 for the 10 lines analysed. The mean deformation values were lower (7.28 mm) in 1994/95, compared to 1995/96 (7.81 mm) ($p < 0.05$).

T 1414 had significantly higher ($p < 0.05$) mean deformation relative to Norwin, Tyson and Amethyst in 1994/95 and significantly higher ($p < 0.05$) mean deformation in 1995/96 relative to all varieties except, T 1239 and Barwon. T 1239 and Norwin also had significantly higher deformation ($p < 0.05$) compared to Tyson and Amethyst in 1994/95. Mean deformation values of Dooen, T 1587, *Desi*, Dark *desi* and Semsen were intermediate to Norwin and Tyson in the same season.

The overall increase ($p < 0.05$) in the mean deformation of all the lines analysed in 1995/96 could probably be due to seasonal effects. About one-third of T 8000 had greater than 5% hard seeds which had a detrimental effect on deformation values. Hard seeds are known to have a slow rate of water imbibition which in turn impedes the process of seed softening and affects the overall processing quality of pulses.

The mean deformation values obtained for Amethyst and Tyson (1994/95) were in close agreement with the deformation observed for commercially traded Amethyst and Tyson (6.24 mm) (Figure 4.3.2). Although, advanced breeding lines of Amethyst and Tyson in 1995/96 were sourced from the same sites as in the previous year with the exception of one Amethyst sample from VIC, the mean deformation was significantly higher ($p < 0.01$) than in the previous year and that observed for commercial varieties.

Table 4.3.1 Mean deformation (mm) and range of deformation of advanced *desi* cultivars, 1994/95 season

Variety	No. of samples	Deformation	Range
T1414	2	8.52**bc** ± 0.50	(8.02, 9.02)
T1239	3	8.33**bc** ± 0.28	(7.95, 8.89)
Desavic	3	7.98**ab** ± 0.11	(7.81, 8.18)
Norwin	8	7.60**bd** ± 0.12	(7.20, 8.14)
Dooen	2	7.38**ab** ± 0.81	(6.57, 8.18)
T1587	2	7.15**ab** ± 0.33	(6.82,7.47)
Desi	11	7.05**ab** ± 0.30	(4.95, 8.63)
Dark *desi*	14	6.89**ab** ± 0.23	(5.48, 8.77)
Semsen	2	6.72**ab** ± 0.02	(6.70, 6.73)
Tyson	3	6.45**a** ± 0.24	(6.08, 6.91)
Amethyst	3	6.04**a** ± 0.21	(5.77, 6.46)
Total & Mean	53	7.28 ± 0.23	(4.95, 9.02)
F value		2.9*	

Table 4.3.2 Mean deformation (mm), ranking and range of deformation of advanced *desi* cultivars, 1995/96 season

Variety	No. of samples	Deformation	Range
T1414	3	9.04**a** ± 0.53	(8.49, 10.34)
T1239	3	8.45**ab** ± 0.18	(8.25, 8.81)
Barwon	5	7.96**ab** ± 0.23	(7.56, 8.86)
Dooen	4	7.94**b** ± 0.10	(7.73, 8.20)
Tyson	2	7.82**b** ± 1.05	(6.48, 8.97)
T 1000 Series	12	7.72**b** ± 0.18	(7.73, 8.20)
Amethyst	5	7.62**b** ± 0.34	(6.92, 8.86)
T1587	2	7.36**b** ± 0.02	(7.34, 7.37)
T 8000 series†	14	7.32**b** ± 0.28	(5.23, 8.77)
T 2000 series	2	6.83**b** ± 0.01	(6.82, 6.84)
Total & mean	52	7.81 ± 0.19	(5.23, 10.34)
F value		2.5*	

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* significant at $p < 0.05$, F value** significant at $p < 0.01$.

† 36% of the samples had > 5% hard seed content

4.3.2.1.1 Evaluation of *Desi* Lines Studied Over Two Seasons

Cooking quality of 6 *desi* lines were evaluated over two seasons and the results are summarised in Table 4.3.3. The mean deformation was 7.77 mm with a range from 5.77 to 10.34 mm. As expected, the deformation of T 1414 and T 1239 was significantly higher ($p < 0.05$) than Dooen, T 1587, Amethyst and Tyson. Advanced lines of Amethyst ($n = 8$) and Tyson ($n = 5$) (1994/95, 1995/96) had significantly higher ($p < 0.05$) mean deformation than Amethyst and Tyson that are currently traded.

The weight of 100 dry seeds ranged from 13.5 g (Tyson) to 24.6 g (T 1414) with a mean weight of 18.9 g. Seed weight of T 1587 was significantly lower ($p < 0.01$) than T 1239 and T 1414 and that of Dooen was significantly higher than Amethyst and Tyson at $p < 0.05$. A positive correlation between weight of 100 seeds and deformation values was observed in all cases, except for the large T 1414 (-0.40) and the medium sized T 1587 (-0.90). Overall, however, there was a significant positive correlation (0.71) at $p < 0.05$, between weight of 100 seeds and deformation. The weight of 100 seeds is therefore an indication of deformation values which in turn can provide some 'hints' to the time required to soften average sized *desi* seeds. T 1414 and T 1587 are new lines of *desi* varieties with a bolder seed size that exhibit a negative correlation with deformation, exposing another dimension to the already complex relationship between deformation and seed size in the new varieties compared to the average sized seeds of familiar *desi* varieties. It is possible that some other chemical constituent, e.g. fat or starch content, or physical factors, e.g. thickness and/or permeability of seed coat may be indirectly influencing deformation values in the larger *desi* seeds. Further work on the deformation values of new lines with large seed size needs to be evaluated to conclusively prove the negative correlation.

4.3.2.2 *Kabuli* lines

Tables 4.3.4 and 4.3.5 show the mean deformation (mm), ranking and range of deformation for advanced *kabuli* lines from 1994/95 and 1995/96, respectively. The deformation values ranged from 6.90 to 11.28 mm (mean 9.0 mm) for 1994/95 and from 8.09 to 10.98 mm (mean 9.5 mm) for 1995/96. Garnet had significantly higher deformation than the T 1000 series samples in 1994/95. Garnet had the highest mean deformation in 1995/96. The mean deformation of Kaniva (1994/95) (8.7 mm) was lower

Table 4.3.3 Mean deformation (mm), range, weight of 100 seeds (g) and correlation coefficient of advanced *desi* cultivars from 1994/95 and 1995/96

Variety	No. of samples	Deformation	Range	Wt of 100 seeds	Correlation (r)
T1414	5	9.04**a** ± 0.39	(8.02, 10.34)	24.6**a** ± 1.1	-0.40
T1239	6	8.39**a** ± 0.15	(7.95, 8.89)	25.0**a** ± 0.7	0.72
Dooen	6	7.75**b** ± 0.30	(6.57, 8.20)	18.3**ac** ± 1.9	0.36
T1587	4	7.25**b** ± 0.15	(6.82, 7.47)	17.0**b** ± 0.6	-0.90
Amethyst	8	7.21**b** ± 0.36	(5.77, 8.86)	15.1**ad** ± 0.8	0.52
Tyson	5	7.00**b** ± 0.50	(6.08, 8.87)	13.5**ad** ± 0.6	0.79
Total & mean	34	7.77 ± 0.33	(5.77, 10.34)	18.9 ± 2.0	0.71*
F value		5.9**		34.4**	

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* significant at $p < 0.05$, F value** significant at $p < 0.01$.

Table 4.3.4 Mean deformation (mm) and range of deformation of advanced *kabuli* cultivars, 1994/95 season

Variety	No. of samples	Deformation	Range
Garnet	5	9.96**a** ± 0.46	(8.64, 11.28)
Kaniva	4	8.71**ab** ± 0.51	(7.88, 10.12)
T 1000 (Iran)	8	8.53**b** ± 0.35	(6.90, 10.13)
Total & mean	17	8.99 ± 0.42	(6.90, 11.28)
F value		6.3**	

Table 4.3.5 Mean deformation (mm) and range of deformation of advanced *kabuli* cultivars,1995/96 season

Variety	No. of samples	Deformation	Range
Garnet	3	10.37 ± 0.23	(9.93, 10.98)
Kaniva	1	10.00	
T 1000 Russia	5	9.40 ± 0.21	(8.86, 9.89)
T 1000 Iran	8	9.16 ± 0.22	(8.09, 9.83)
Total & mean	17	9.52 ± 0.23	(8.09, 10.98)
F value		2.2	

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* significant at $p < 0.05$, F value** significant at $p < 0.01$.

than that observed for the commercial sample (10.2 mm) (Figure 4.3.5). Unlike the *desi* samples from 1995/96, all *kabuli* samples did not show an increase in deformation compared to samples from the previous season.

Although only one sample of UC5, Mission, Narayen and L550 was received each year, their cooking quality was evaluated over both seasons. Table 4.3.6 shows the mean deformation and weight of 100 seeds of some these new *kabuli* varieties from 1994/95 and 1995/96. Narayen exhibited high deformation in 1994/95, while it recorded a considerable decrease in 1995/96, despite no change in seed size. Mission, however, had no change in deformation value but a remarkable increase in seed size in 1995/96. UC5 had higher deformation values in 1995/96 which was accompanied by a decrease in seed size. More of these samples need to be analysed to predict on their cooking quality in relation to seed size.

4.3.2.2.1 Evaluation of *Kabuli* Lines Studied Over Two Seasons

Table 4.3.7 shows the mean deformation, range of deformation, weight of 100 seeds and correlation coefficients for 29 samples that were studied over two seasons. The mean deformation was 9.2 mm with a range from 6.90 to 11.28 mm. The mean weight of 100 seeds was 28.9 g. The mean weight of T 1000 samples was significantly lower ($p < 0.01$) than Garnet and Kaniva samples. A positive correlation coefficient was observed for all the groups at $p < 0.05$ with an overall correlation coefficient of 0.72 which was similar to the *desi* type. The weight of 100 seeds can thus provide an estimate of the deformation value for the common *kabuli* varieties.

Varieties exhibit differences in deformation values, possibly due to a combination of factors such as genotypic variations, age of sample, storage conditions, seed size, hydration ability, thickness of seed coat, starch-protein matrix, TDF and fat contents. The relation between deformation and seed size of some advanced breeding lines of *desi* and *kabuli* cultivars has been demonstrated in the present investigation.

Measuring deformation is a rapid method to evaluate degree of softness attained by a given set of chickpea seeds. It is an objective, comparative and reproducible test that can be used to monitor the cooking quality of chickpea, especially breeder's samples where sample size is a limiting factor.

Table 4.3.6 Mean deformation (mm), and weight of 100 seeds (g) of new *kabuli* cultivars from 1994/95 and 1995/96

Variety	1994/ 95		1995/ 96	
	Deformation (mm)	Weight (g) 100 seeds	Deformation (mm)	Weight (g) 100 seeds
UC5	10.03	45.95	11.06	39.22
Mission	9.61	29.85	9.55	43.91
Narayen	10.96	18.58	8.46	18.13
L550	8.43	24.51	-	-
Mean	9.76 ± 0.52	29.7 ± 5.9	9.69 ± 0.75	33.8 ± 7.9

Table 4.3.7 Mean deformation (mm), range, weight of 100 seeds (g) and correlation coefficient of advanced *kabuli* cultivars from 1994/95 and 1995/96

Variety	No. of samples	Deformation	Range	Wt of 100 seeds	Correlation (r)
Garnet	8	10.12a ± 0.30	(8.64, 11.28)	41.2a ± 3.5	0.77
Kaniva	5	8.96ab ± 0.47	(7.88, 10.12)	25.7b ± 5.3	0.93
T 1000 Iran	16	8.84b ± 0.21	(6.90, 10.13)	23.1b ± 1.7	0.82
Total & mean	29	9.20 ± 0.2	(6.90, 11.28)	28.5 ± 1.9	0.84**
F value		5.7**		16.6**	

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* significant at $p < 0.05$, F value** significant at $p < 0.01$.

4.4 Dehulling Properties of *Desi* Chickpea

4.4.1 Dehulling Efficiency - Comparative Study

The purpose of this study was to compare the purpose-built AGT mill with the commercial Satake and ICARDA mills for effectiveness in dehulling of chickpea that has been subjected to 3 different pre-treatments. Dehulling is an important post harvest operation of pulses especially, *desi* chickpea in the Indian subcontinent. Laboratory scale commercial roller mills (similar to the type used in the subcontinent) were difficult to purchase in Australia, so a low cost laboratory-sized pulse mill was designed and custom made under instructions. It is important to evaluate the quality of dehulled Australian chickpea genotypes on milling equipment similar to that used in the target country.

The dehulling efficiency of four most widely traded commercial chickpea varieties, Amethyst (WA), Dooen (VIC), Semsen (SA) and Tyson (VIC) were compared after determining the optimum dehulling time required for each mill. The differences/similarities, if any, between the three types of mills on the dehulling ability were examined on unconditioned and pre-conditioned samples. The effects of pre-conditioning with water, 1% (w/v) sodium chloride and 1% (w/v) sodium bicarbonate solutions were evaluated against *dhal* yield.

4.4.1.1 Determination of Optimum Dehulling Time for Laboratory Mills

The data in Figure 4.4.1 show the mean *dhal* yield (%) of unconditioned whole seeds for the three mills at different dehulling times. Optimum dehulling time for the three mills was determined based on repeated trials conducted on the variety Amethyst. *Dhal* yield was the highest in the Satake mill when dehulled for 10 seconds. The optimum dehulling time for the AGT mill was 60 seconds and 20 seconds for the ICARDA mill. It is evident from Figure 4.4.1, that *dhal* yields are very dependent on resident time in the mill.

As would be expected, the levels of undehusked material in the three mills were higher when dehulling time was less than the optimum time and the percentages of brokens and powder fractions were higher when dehulling time was greater than the optimum time. These results suggest that higher quantitative and qualitative losses would occur in genotypes that require longer time for dehulling as prolonged duration of the sample

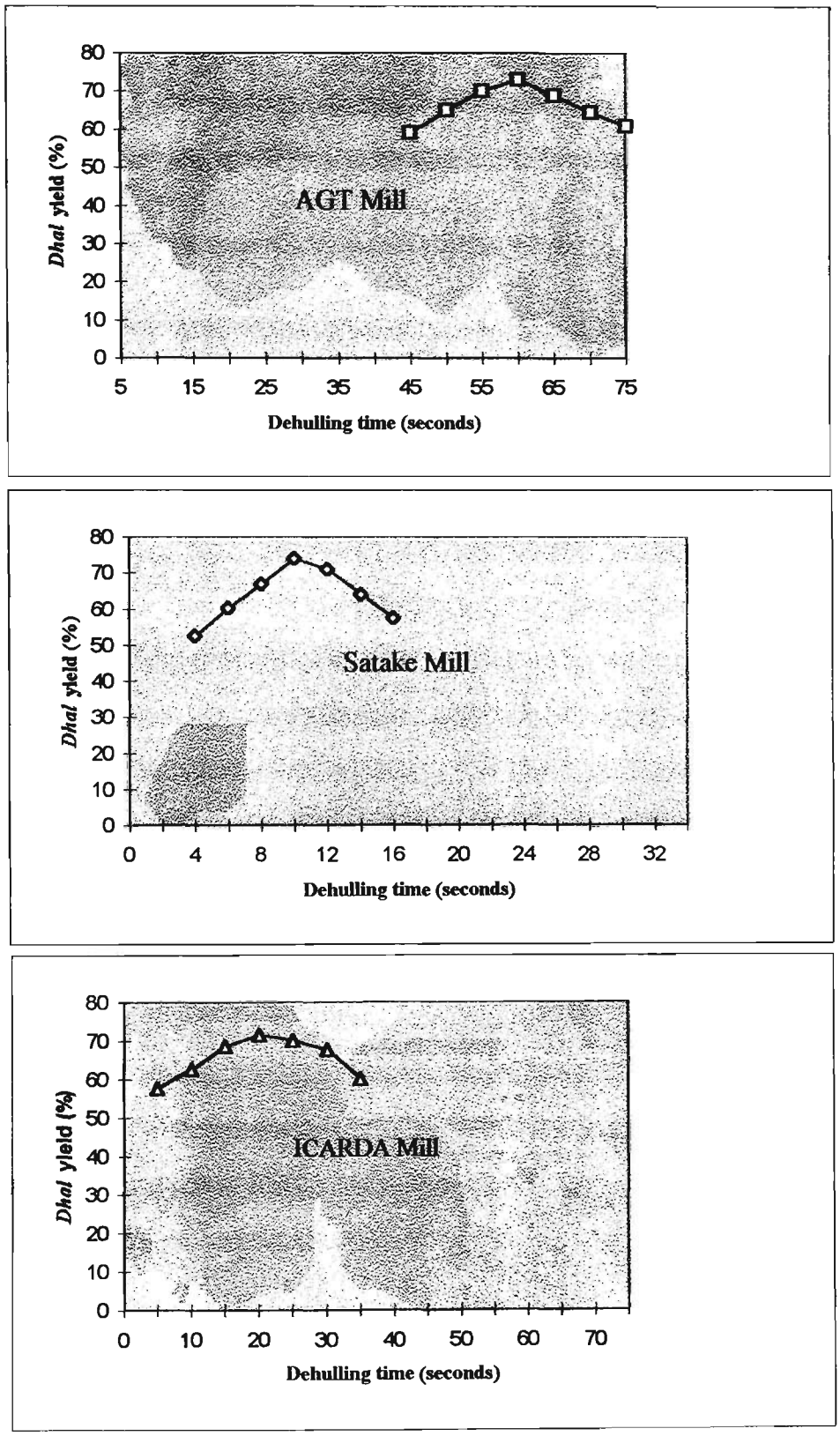


Figure 4.4.1 Effect of dehulling on *dhal* yields (%) achieved in three mills

in the mill would cause scouring of the *dhal* (quantitative loss) and hence loss of nutrients from the outer surface of the cotyledon (qualitative loss). The optimum time to dehull would depend on the speed of the carborundum roller or disc used for dehulling, age and size of seed material. All these factors need to be considered while evaluating the dehulling quality by such laboratory methods.

4.4.1.2 Effect of Chickpea Cultivars on *Dhal* Yield

Seed weight (per 100 seeds), seed coat content of 4 chickpea varieties and mean *dhal* yields (%) for 2 pre-treatments by the 3 different mills are presented in Table 4.4.1. Seed weight of varieties ranged between 15.8 - 20.1 g with an average seed coat content of 17.4%. Mean *dhal* yield of unconditioned samples was similar (70.7%) for all mills. The average *dhal* yield of unconditioned Tyson and Amethyst was significantly higher than for Dooen and Semsen. However, *dhal* yield of Tyson only was significantly higher than the other 3 varieties after pre-treatment with water. The increase in *dhal* yield due to pre-conditioning was not significant for any of the milling methods. Thus, significant differences ($p < 0.05$) in *dhal* yield were obtained due to varieties whereas differences due to milling methods were not significant. Despite the significant differences between varieties there was only a narrow range in dehulling characteristics of these varieties. A greater number of chickpea genotypes need to be evaluated in future to determine the variability in dehulling characteristics in chickpea.

The variety with higher 100-seed weight resulted in lower *dhal* yield indicating that bolder grains would incur higher dehulling losses in the form of brokens and powder when processed by these mills. These results suggest that seed size of varieties plays an important role in determining *dhal* yield or dehulling losses in chickpea.

4.4.1.3 Effect of Laboratory Mills on *Dhal* Yield

Table 4.4.2 shows the minimum, maximum and mean yield of major fractions (*dhal*, husk, brokens and powder) of dehulling by the 3 mills. The values are based on six independent determinations on control (without pre-treatment) sample of Amethyst cultivar. The mean *dhal* yield for the mills was 71.9%. Variable results on *dhal* yield was observed for the ICARDA mill (68.3% - 73.9%) compared to the other 2 mills. The brokens (4.8 g) and powder (5.9 g) fractions ie., dehulling losses were

Table 4.4.1 100-seed weight, seed coat content and *dhal* yields (%) of chickpea gentoypes milled by three different devices*

			Dhal yield (%)							
Variety	**100-Seed**	**Seed coat**	**AGT Mill**		**Satake Mill**		**ICARDA Mill**		**Mean ± SE**	
	Wt. (g)	**(%)**	**b**	**c**	**b**	**c**	**b**	**c**	**b**	**c**
Amethyst	15.8	16.1	71.6	72.4	72.4	74.4	71.0	72.1	71.7**a** ± 0.4	73.0**a** ± 0.6
Dooen	18.4	17.4	69.0	70.7	69.4	71.5	69.5	71.8	69.3**b** ± 0.7	71.3**a** ± 0.5
Semsen	20.1	17.2	68.2	70.0	68.9	71.8	70.1	70.6	69.1**b** ± 0.2	70.8**a** ± 0.8
Tyson	16.0	18.9	73.0	75.2	73.3	76.5	72.3	73.9	72.9**a** ± 0.3	75.2**b** ± 0.3
Mean ± SE	17.6 ± 0.4	17.4 ± 0.3	70.5 ± 0.6	72.1 ± 0.5	71.0 ± 0.5	73.6 ± 0.6	70.7 ± 0.9	72.1 ± 0.8		

*All values are means of three replicates.

b = *dhal* yield in control (no pre-treatment)

c = Water-soaked

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

Table 4.4.2 Standard error of determination of *dhal* yields (%) and other fractions (%) of chickpea milled by different devices*

	AGT Mill			Satake Mill			ICARDA Mill			
Component	***Dhal* yield**	**Husk**	**Brokens**	**Powder**	***Dhal* yield**	**Husk**	**Brokens**	**Powder**	***Dhal* yield**	**Husk**	**Brokens**	**Powder**
Minimum	71.9	13.8	2.7	2.4	72.8	13.6	2.8	2.9	68.3	13.9	3.6	4.8
Maximum	73.6	16.2	3.9	3.8	74.2	15.2	4.1	3.4	73.9	16.2	6.9	7.5
Mean ± SE	71.8 ± 0.3	14.9 ± 0.3	3.4 ± 0.1	3.2 ± 0.2	72.9 ± 0.3	14.7 ± 0.3	3.6 ± 0.1	3.0 ± 0.2	71.0 ± 0.8	15.2 ± 0.5	4.8 ± 0.4	5.9 ± 0.4
CV (%)	0.4	1.8	3.2	5.3	0.5	1.7	3.6	6.0	1.1	0.5	0.4	0.4

* Based on 6 independent determinations on control (without pre-treatment) sample of Amethyst cultivar.

CV = Coefficient of variance

substantially higher in the ICARDA mill. Accordingly, the coefficient of variation (CV) was the highest for *dhal* yield and standard error (SE) was the highest for all milling fractions of the ICARDA mill. Based on these results it can be concluded that the AGT and Satake mills are more suited to evaluate the dehulling quality of chickpea. The effect of different pre-treatments on dehulling efficiency was thus not conducted on the ICARDA mill.

Dehulling quality is primarily judged by the yield and the quality of the dehulled grain. The Satake mill produced the highest *dhal* yield (72.9% mean) followed by the AGT mill and ICARDA mill. The theoretical yields of splits for Amethyst should be nearly 84% as it contains about 16% seed coat (Table 4.4.1). *Dhal* yield obtained by these mills are therefore considerably lower than the theoretical *dhal* yield for all the varieties due to increased dehulling losses in the form of brokens and powder. Theoretical *dhal* yield is weight of whole seed minus weight of seed coat (husk). *Dhal* yield obtained for all the mills were, however, higher than those obtained from a quern (domestic dehulling method) and lower than those obtained by commercial *dhal* mills in India (Singh 1995).

4.4.1.4 Effect of Pre-Treatments on Dehulling Quality of Chickpea

Table 4.4.3 presents the effect of pre-treatment on yields of dehulling fractions and recovery values for the AGT and Satake mills. Data presented in Table 4.4.3 are means of four (Amethyst, Dooen, Semsen and Tyson) varieties. Pre-treatment of seeds with 1% sodium chloride and 1% sodium bicarbonate significantly increased *dhal* yield for both mills at $p < 0.05$. There was a significant decrease in undehusked material, as pre-conditioning in salt solutions loosens the seed coat. Conditioning the seeds reduced the dehulling losses in the form of brokens and powder for both mills. This supports the results of similar studies on lentils (Erskine *et al* 1991), field pea (Black *et al* 1995). There was no significant difference in *dhal* yield for any of the pre-treatments between the two mills. According to Kurien (1981), dehulling can be rendered easier by prolonged soaking in water. This process can, however, affect the cooking quality of the product. The duration of the soak must thus be better defined. Conditioning with sodium bicarbonate did not have any yield advantage over sodium chloride conditioning which is contrary to the findings of Saxena *et al* (1981). This

Table 4.4.3 Effect of different pre-treatments on dehulled fractions of chickpea obtained by the AGT and Satake Mills*

Treatment	Undehusked seed (g)		*Dhal* yield (%)		Husk (%)		Brokens (%)		Powder (%)		Recovery (%)	
	A	S	A	S	A	S	A	S	A	S	A	S
Control	4.9a	5.3a	70.5a	71.1a	14.5	16.4	5.9	3.4	4.2	3.7	100.6	99.8
Water	4.5a	4.4a	72.1a	73.6a	14.0	15.3	5.1	3.4	3.8	4.3	99.5	100.4
NaCl	2.9b	2.1b	74.6b	75.2b	14.6	14.5	4.3	2.2	2.9	3.6	99.3	97.6
NaHCO3	1.6c	1.8c	77.4b	76.1b	13.8	15.0	5.0	2.8	3.7	4.4	99.5	100.2
Mean ± SE	3.5 ± 0.6	3.4 ± 0.2	73.7 ± 0.5	74.0 ± 0.7	14.2 ± 0.5	15.3 ± 0.3	5.1 ± 0.5	3.0 ± 0.2	3.7 ± 0.2	4.0 ± 0.3	99.7 ± 0.3	99.5 ± 0.6

* Mean values of four varieties (Amethyst, Dooen, Semsen and Tyson)

A = AGT Mill, S = Satake Mill

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

may be due to; the use of a stronger solution of sodium bicarbonate as suggested by Srivastava *et al* (1988), increased contact time with seeds and genotypic variations.

4.4.1.4.1 Recovery

As the AGT mill was custom built for this study, dehulling performance and recovery of products were two key attributes that were evaluated. The recovery for all pre-treatments and all chickpea cultivars studied was ≥ 99.3% with a mean recovery of 99.7% (Table 4.4.3). This suggests that the AGT mill does not have a large dead volume and the optimum processing time (60 seconds) is the resident time for the seed in the mill.

The mean recovery for the Satake mill was also high (99.5%) which was not surprising because of the simple design of the mill.

4.4.2 Dehulling Efficiency of Advanced Breeding Lines of *Desi* Cultivars

This section examines the dehulling efficiency of advanced breeding lines of *desi* chickpea and compares the data with those of the commercially traded varieties. The aim of this study was to identify new varieties with good dehulling properties. The samples in this study were dehulled unconditioned with the AGT mill.

Tables 4.4.4 and 4.4.5 give the weight of 100 seeds, percent means of the milling fractions and recovery of the different genotypes for the 1994/95 and 1995/96, respectively. Table 4.4.6 shows the average percent of milling fractions for the 6 varieties evaluated in both seasons.

4.4.2.1 Weight of 100 Seeds

Weight of 100 seeds ranged from 12.9 g to 24.4 g in 1994/95 and 13.9 g to 25.7 g in 1995/96, with a mean of 17.8 g and 18.8 g, respectively. The 100-seed weight of T1239 and T1414 was significantly higher (24 g) than Tyson, Amethyst, *Desi*, Dark*desi* and Dooen lines in 1994/95 season. Similarly, in 1995/96, 100-seed weight of T1239 and T1414 (25.7 g) was significantly higher than all the lines evaluated except Dooen (20.3 g). Tyson seeds were the smallest (13.5 g) in both the seasons followed by Amethyst (15.1 g).

4.4.2.2 *Dhal* Yield

Dhal yield varied from 63.5% to 77.5% in 1994/95 and from 67.2 to 75.9% in 1995/96 with a mean yield of 70% and 73%, respectively. *Dhal* yield of Dark*desi* (65%) was significantly lower than Norwin (76%) and T1239 (78%) (1994/95) whereas *dhal* yield of

Table 4.4.4 Mean milling fractions (%) and recovery (%) of advanced breeding lines, 1994/95 season

AGT mill

Variety In alphabetical order	No. of samples	Wt of 100 seeds (g)	Whole seeds (g)	Husk (%)	*Dhal* (%)	Brokens (%)	Powder (%)	Recovery (%)
Amethyst	3	14.3a ± 0.2	2.5 ± 1.7	13.5 ± 0.7	73.7ab ± 3.8	6.3a ± 0.5	2.7ab ± 0.5	97.9ab ± 0.2
Darkdesi	14	15.5a ± 1.4	8.3 ± 1.9	12.5 ± 0.3	65.3a ± 3.0	6.5a ± 0.4	4.0ab ± 0.4	96.8a ± 0.6
Desavic	3	20.6†	1.6 ± 0.2	13.5 ± 0.4	70.0ab ± 0.6	9.8b ± 0.5	4.4a ± 0.3	94.8a ± 0.5
Desi	11	14.3a ± 0.9	4.4 ± 0.9	13.2 ± 0.4	68.8ab ± 1.4	7.4a ± 0.4	4.1ab ± 0.3	94.0a ± 1.8
Dooen	2	16.4a ± 0.8	6.4 ± 0.6	13.7 ± 1.5	63.5ab ± 1.2	8.3ab ± 0.5	5.3a ± 0.6	103.4b ± 7.0
Norwin	8	18.6ab ± 0.9	1.2 ± 0.4	11.3 ± 0.9	76.2b ± 1.5	7.3ab ± 0.3	3.4ab ± 0.2	95.7a ± 1.0
Semsen	2	17.5†	5.0 ± 1.0	13.8 ± 0.9	66.0ab ± 2.4	8.2ab ± 0	4.8ab ± 0	97.1ab ± 1.2
Tyson	3	12.9a ± 0.9	5.9 ± 0.9	14.6 ± 0.5	68.0ab ± 1.9	5.9a ± 0.9	2.4b ± 0.4	95.4a ± 0.3
T1239	3	24.4b ± 0.4	0.3 ± 0.2	11.8 ± 0.1	77.5b ± 0.5	6.9a ± 0.1	3.3ab ± 0.2	95.8a ± 0.2
T1414	2	23.5b ± 0.1	0.7 ± 0.5	11.5 ± 1.1	75.9ab ± 0.3	8.1ab ± 0.3	3.4ab ± 0.3	98.2ab ± 2.1
T1587	2	17.6ab ± 0.8	4.5 ± 0.2	13.3 ± 0.5	68.8ab ± 0.7	7.3a ± 0.2	3.9ab ± 0.8	94.8a ± 1.7
Total & Mean	53	17.8 ± 1.1	3.7 ± 0.8	13.0 ± 0.3	70.3 ± 1.4	7.5 ± 0.3	3.8 ± 0.3	96.7 ± 0.8
F value		6.8**	2.1	2.1	2.2**	3.9**	14.9**	2.2*

Values presented are mean ± SE

† weight of only one sample was recorded.

Means in the same column not followed by the same letter are significantly different at $p < 0.05$

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Table 4.4.5 Mean milling fractions (%) and recovery (%) of advanced breeding lines, 1995/96 season

AGT mill

Variety In alphabetical order	No. of samples	Wt of 100 seeds (g)	Whole seeds (g)	Husk (%)	*Dhal* (%)	Brokens (%)	Powder (%)	Recovery (%)
Amethyst	5	15.8a ± 0.4	4.0a ± 2.0	15.9 ± 0.2	74.4a ± 2.6	3.9a ± 0.3	4.2a ± 0.7	94.8 ± 0.7
Barwon	5	21.1b ± 1.1	0.6a ± 0.4	14.2 ± 0.3	71.7ab ± 1.4	3.8a ± 0.2	4.8ab ± 0.6	95.5 ± 0.5
Dooen	4	20.3ab ± 0.8	2.5a ± 1.2	14.8 ± 0.4	75.1a ± 2.1	3.8a ± 0.4	4.5ab ± 0.8	94.7 ± 0.4
Tyson	2	14.0a ± 2.8	9.9b ± 4.9	18.1 ± 1.0	67.2b ± 5.0	3.3a ± 0.1	4.0ab ± 0.5	96.3 ± 0.2
T1239	3	25.7bd ± 1.2	0.4a ± 0.2	14.5 ± 0.6	75.7a ± 0.9	4.7a ± 0.3	4.8ab ± 0.3	94.6 ± 0.5
T1414	3	25.7bd ± 1.9	0.5a ± 0.2	14.9 ± 0.3	75.9a ± 0.7	4.5a ± 0.3	4.8a ± 0.3	94.5 ± 0.6
T1587	2	16.4bc ± 0.3	2.8a ± 0.1	16.7 ± 0.1	67.4b ± 3.3	8.4b ± 2.7	5.6ab ± 0.6	97.0 ± 2.3
T 1000 series	12	17.7bc ± 1.1	3.2a ± 0.8	15.2 ± 0.3	71.3ab ± 0.6	4.6a ± 0.2	6.5b ± 0.4	95.5 ± 0.5
T 2000 series	2	13.9bc ± 0.6	1.9a ± 1.2	16.5 ± 1.0	74.4ab ± 2.4	3.5a ± 0.3	4.1ab ± 0.3	94.5 ± 0.9
T 8000 series	14	17.7bc ± 0.9	4.6a ± 0.7	16.4 ± 0.7	71.2ab ± 0.7	4.2a ± 0.2	4.8a ± 0.4	94.9 ± 0.3
Total & mean	52	18.8 ± 1.4	3.0 ± 0.9	15.7 ± 2.1	72.5 ± 1.0	4.5 ± 0.5	4.7 ± 0.2	95.2 ± 0.3
F value		5.5**	2.9**	2.1	2.8**	6.0**	2.5**	1.0

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Table 4.4.6 100-seed weight (g), mean milling fractions (%) and recovery (%) of selected varieties from 1994/95 and 1995/96

Variety In alphabetical order	**No. of samples**	**Wt of 100 seeds (g)**	**Whole seeds (g)**	**Husk (%)**	***Dhal* (%)**	**Brokens (%)**	**Powder (%)**	**Recovery (%)**
Amethyst	8	15.1**ad** ± 0.8	3.2**ab** ± 2.0	14.7 ± 1.2	74.0**ab** ± 0.4	5.1 ± 1.2	3.5 ± 0.7	96.3 ± 1.5
Dooen	6	18.3**ac** ± 1.9	4.4**ab** ± 1.9	14.2 ± 0.5	69.3**ab** ± 5.8	6.1 ± 2.3	4.9 ± 0.4	99.1 ± 4.3
Tyson	5	13.5**ad** ± 0.6	7.9**a** ± 2.0	16.4 ± 1.7	67.6**a** ± 0.4	4.6 ± 1.3	4.6 ± 0.1	95.9 ± 0.4
T1239	6	25.0**b** ± 0.7	0.4**b** ± 0	13.2 ± 1.4	.76.6**b** ± 0.9	5.8 ± 1.1	4.1 ± 0.7	95.2 ± 0.6
T1414	5	24.6**b** ± 1.1	0.6**b** ± 0.1	13.2 ± 1.7	75.9**b** ± 0	6.3 ± 1.8	3.9 ± 0.4	96.4 ± 1.9
T1587	4	17.0**a** ± 0.6	3.6**ab** ± 0.9	15.0 ± 1.7	68.1**a** ± 0.7	7.9 ± 0.6	4.7 ± 0.8	95.9 ± 1.1
Total & mean	34	18.9 ± 2.0	3.4 ± 1.1	14.5 ± 0.5	71.9 ± 1.7	6.0 ± 0.5	4.0 ± 0.3	95.5 ± 0.2
F value		34.4**	4.8**	2.1	4.1**	1.9	1.4	0.4

Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

Tyson and T1587 (67%) were significantly lower than Amethyst, Dooen, T1239 and T1414 (1995/96) at $p < 0.05$. The increase in *dhal* yield of 11.6% in Dooen (1995/96) was accompanied by an increase in 100 seed weight. Of the samples that were evaluated in both seasons, Tyson and T1587 had significantly lower *dhal* yields than T1239 and T1414.

Desavic (1994/95) had an average *dhal* yield of 70% but had significantly high brokens (9.8%) and powder (4.4%) fractions and was thus not suited to dehulling because of high dehulling losses. *Desi* (1994/95), Tyson and T1587 from both seasons had low *dhal* yields coupled with high dehulling losses.

Due to the consistently high dehulling efficiency (75.9%) obtained for the variety T1414 coupled with suitable physical properties (24.6 g/100 seeds, pale uniform colour) and agronomic advantages it was officially launched in late 1996 as a commercial trading variety under the name 'Lasseter'; suitable for production in the Wimmera and Southern Mallee regions of VIC.

4.4.2.2.1 Whole Seed and Husk

Dhal yield is an important criteria in dehulling studies but the amount of whole seeds (undehusked whole seeds) at the end of the dehulling process should also be considered prior to judging suitability of a variety. As the amount of whole seed increases, processing time increases, throughput decreases along with quality of the product and profits to the processor. Four (Dark*desi*, Dooen, Semsen and Tyson) of the 11 varieties evaluated from the 1994/95 season had ≥ 5 grams of whole seed fraction and Tyson (1995/96) had significantly higher (10 g) whole seed content at $p < 0.05$. The decrease in varieties exhibiting a higher whole seed fraction in 1995/96 could be a seasonal effect. There was, however, no difference in the mean whole seed content for the two seasons.

The whole seed content in Tyson was significantly higher (8 g) than the other varieties evaluated in both seasons. The higher whole seed content of Tyson lines could be due to its inherent small size, adherence of the seed coat to the cotyledon, age of the sample or some combination of the above. Variabilities generated due to the age of the sample were eliminated by: (a) all samples being milled 4-5 months after harvest and (b) not being exposed to direct sunlight.

Husk is an important by-product of the dehulling industry. Theoretical yield of husk should be 15%. In practice, however, smaller particles of husk usually get blown away and get collected as 'brokens' or 'powder' fractions. The mean husk content of the 1994/95 season was 12.4% and was lower than that for 1995/96 (15.7%). The decrease in husk content was compensated by an increase in the 'brokens' and 'powder' fraction in 1994/95 (11.3 g) as against 9.2 g in 1995/96.

Brokens and powder fractions not only affect *dhal* yield but increase dust in the mill which is an operational and health hazard. Conditioning of samples helps to reduce the powder fractions.

4.4.2.2.2 Recovery

Recovery for all varieties in both seasons, except Desavic, was greater than 95%, with an average recovery for the two years being 96%. Recoveries > 95% indicate that the amount of sample trapped in the mill rollers is minimal. Recovery values reflect on the efficiency of the mill and is more species (chickpea, lupins, field pea) specific, than variety specific (Iyer and Jarvis 1996). As three of the five fractions that are collected are very light, losses during the 'collecting' and 'weighing' stage is translated as reduced recovery.

4.4.2.3 *Dhal* yield and Seed Size

Varieties with a wide range (13.9 - 25.7 g) of 100-seed weight had *dhal* yields of > 70% (1995/96). A similar trend was also observed in 1994/95. Based on 105 samples milled over two seasons, it can be concluded that *dhal* yields were not dependent exclusively on seed size. This observation is not in complete agreement with the finding of Kurien (1984), who concluded that bold grains and grains stored for a long time (presumably due to drying) have better dehulling properties. Tables 4.4.5 and 4.4.6 show that bold grains (~20 g/100 seeds) had high *dhal* yield $\geq$ 70%, but smaller seeds (~13 - 15 g/100 seeds) such as Amethyst and T2000 also had good *dhal* yields.

Dhal yields, however, decreased with an increase in seed size of the genotypes; based on a small number of samples and a narrower range for weight of 100 seeds 15.8 g-20.1 g (Table 4.4.1). This trend was observed for the 3 mills that were evaluated. (It must be pointed out that dehulling of commercial samples could not be completed until 4-5 months after harvest due to delays incurred in sample receival).

It is thus evident that dehulling efficiency (measured as *dhal* yield) is dependent not only on seed size and type of mill (Singh *et al* 1992) but on several other factors such as genotypic variations, agroclimatic factors, age of sample, thickness of seed coat (Kurien 1971) and interactions between these factors. The complex relation between *dhal* yield and seed size highlights the need to continually monitor both; agronomic details and changes to dehulling properties with time (post harvest qualities) of advanced breeding lines.

It is worth mentioning that trade contracts are signed based on visual inspection of the seed and on the assumption that bold (~ 20 g/100 seeds) seeds have a higher *dhal* yield (S L Bhedha, Personal Communication Bhedha Bros. 1996). Bold seeds may posses high *dhal* yields, but a low d*hal* yield of 66% was obtained for Semsen with an average 100 seed mass of 17.5 g (1994/95). This reiterates the point that the 'seed size test' is not capable of predicting dehulling quality in chickpeas as is being suggested in the industry (Anon 1996).

The effect of seed size on dehulling efficiency has been discussed previously and correlations between weight of 100 seeds and dehulling efficiency for the varieties from both seasons were evaluated. There is a positive strong linear correlation ($r = 1.00$) (Pearson) between *dhal* yield for Norwin and the weight of 100 seeds and a strong correlation ($r = 0.852$) for dark *desi*; between *dhal* yield and 100 seed weight at $p < 0.05$. The correlation coefficient between *dhal* yield and 100 seed weight for varieties Amethyst, Dooen and Tyson exhibited large seasonal changes. T1414 exhibited a high degree of correlation ($r = 0.77$ at $p < 0.05$) over 2 seasons between seed size and dehulling efficiency. These findings prove that the effect of seed size on *dhal* yield is complex and probably dependent on seasonal/environmental factors plus a range of secondary factors and the interactions between them.

4.4.2.4 Comparison of *Dhal* Yields - Advanced Breeding Lines v/s Commercially Traded Varieties

It was necessary to determine whether differences in *dhal* yield occurred in the newer lines in order to establish a criteria for segregation at the receival sites. Some interesting observations were made when *dhal* yields of commercially released varieties were

compared with the advanced breeding lines. The properties (100 seed weight and *dhal* yield) of Amethyst from the advanced breeding line material (15.1 g, 74.0%) (Table 4.4.6) were similar to the commercially traded variety (15.8 g, 71.6%, respectively) (Table 4.4.1). The average *dhal* yield was the highest in Tyson (72.8%, 16.0 g/100 seeds), (Table 4.4.1) which is not surprising as Tyson is currently the processor's favourite in the sub-continent (D Jain, Personal Communication Navjivan *Dhal* mill 1996). However, the advanced line of Tyson had a low average *dhal* yield (67.6%) and were small seeded (13.5 g/100 seeds) (Table 4.4.6). As a result the new line of Tyson is not suited to dehulling. *Dhal* yield for the commercially traded Dooen was 69.0% and 100 seed weight was 18.4 g (Table 4.4.1) which was intermediate to *dhal* yield of the advanced breeding Dooen line in 1994/95 (63.5%, 16.4 g/100 seeds) and 1995/96 (75.1%, 20.3 g/100 seeds). Similarly, commercially traded Semsen (20.1 g/100 seeds) had a better *dhal* yield (68.0%) (Table 4.4.1) compared to the advanced breeding material (66.0%, 17.5 g/100 seeds) (1994/95). Seed size of Dooen and Semsen in the advanced breeding material should be improved if these varieties are to be promoted as varieties suited to dehulling. It thus appears that within a given variety, seed size may influence *dhal* yield, but seed size is not the only critical factor affecting *dhal* yield.

4.5 Functional Properties of Wheat Chickpea Composite Flours

A wide range of functional properties were evaluated in order to determine the suitability of wheat-chickpea composite flours to produce wheat-based products such as bread, biscuit and noodles.

Hard and soft wheat flours were mixed separately with dehulled *desi* (cv Amethyst, SA) and *kabuli* (cv Garnet, VIC) chickpea flours in the following proportions; 90:10, 70:30 and 50:50 to produce composite flours. These were evaluated for water and oil absorption, swelling power, emulsification capacity, flour solubility, nitrogen solubility, gelling capacity, peak viscosity and temperature.

4.5.1 Composition of Wheat, Chickpea and Composite Flours

The moisture, protein and fat contents of wheat, chickpea and their composite flours are tabulated in Table 4.5.1.

Moisture content ranged from 8.7 g/100 g (SW:CP *kabuli*, 50:50) to 9.8 g/100 g in the hard wheat flour. The mean moisture content of all types of flour was 9.4 g/100 g. The protein content of the composite flours containing *desi* ranged from 14.5-19.1 g/100 g whereas the protein content of composite flour containing *kabuli* was 11.0-17.7 g/100 g. The mean fat content of the *desi* chickpea flour was the highest at 6.4 g/100 g while that of the hard wheat was the lowest at 2.8 g/100 g.

Protein content of Amethyst *dhal* was similar to the mean protein content of *desi dhal* from SA (25.4 g/100 g Tables 4.1.30 and 4.1.32) and was higher than that of the *kabuli* (Garnet) variety. As expected, the protein content of soft wheat was considerably lower than the hard wheat flour.

Protein and fat contents of wheat flours were, as anticipated, considerably improved in the composite flour, especially at the higher levels of chickpea substitution. The protein content of the composite flours were on an average 1 unit higher than the theoretically calculated value except for SW:CP (*desi*) 90:10 which was 4 units higher than the expected value. These differences occur because the protein value in the composite flour was calculated using a factor of 6.25, giving artificially high results. Differences in protein content between experimental and theoretical value were greater in composite flours at low levels of substitution with pulse flour. The higher than expected value obtained for SW:CP (*desi*) 90:10 could not be explained.

Table 4.5.1 Moisture, protein and fat content (g/100 g) of wheat, chickpea and composite flours‡

	Moisture		Protein (N x 6.25)		Fat	
Flour type	***Desi***	***Kabuli***	***Desi***	***Kabuli***	***Desi***	***Kabuli***
HW (100%)*	9.8	-	13.4	-	2.8	-
CP (100%)	9.5	9.2	25.1	21.0	6.4	5.9
HW:CP 90:10	9.6	9.7	14.5	14.2	3.5	2.7
HW:CP 70:30	9.7	9.6	16.6	15.5	3.6	3.4
HW:CP 50:50	9.6	9.5	19.1	17.7	4.4	4.3
SW (100%)*	9.4	-	10.0	_	3.0	-
SW:CP 90:10	9.4	9.5	14.6	11.0	3.1	3.1
SW:CP 70:30	9.4	9.4	14.7	13.3	3.5	3.5
SW:CP 50:50	9.5	8.7	17.5	15.0	4.7	4.7
Mean	9.4	9.3	16.2	14.6	3.9	3.7

HW = Hard wheat, SW = Soft wheat, CP = Chickpea

* Protein (N X 5.7)

‡ values are from a single flour sample

4.5.2 Water and Oil Absorption, Emulsification Capacity, Flour Solubility and Nitrogen Solubility Index of Composite Flours

Table 4.5.2 presents the values for water and oil absorption, emulsification capacity, flour solubility and nitrogen solubility indices of control and composite flours of hard or soft wheat and *desi* chickpea flour. Data for the same functional properties for control and composite flours containing *kabuli* chickpea are presented in Table 4.5.3. To highlight differences in the functional properties between composite flours containing either *desi* or *kabuli,* flours with similar ratios regardless of the type of wheat were grouped together for statistical analyses.

Water absorption had a narrow range of 1.30-0.86 g/g among all flour types and oil absorption values ranged from 1.70-0.82 g/g sample. Emulsification capacity was the highest for the *desi* chickpea flour on a g/g basis (3.84 g/g), but the composite flour SW:DCP 90:10, recorded the highest emulsification capacity (21.61 g/g protein) on a g/g protein basis. Wheat flours had the lowest flour solubility (14.9 g/100 g @ 65 °C) while k*abuli* flour had the highest flour solubility value (52.4 g/100 g @ 95 °C). Hard wheat flour had the lowest nitrogen solubility index at pH 6.0 (14.6 g/100 g) and pH 7.0 (14.0 g/100 g) while *desi* chickpea flour had the highest nitrogen solubility index (63.7 g/100 g) with composite flours having intermediate values.

There was no significant decrease in water absorption with an increase in substitution of *desi* chickpea flour for soft and hard wheat flours. However, the water absorption of wheats containing 10% *kabuli* chickpea flour was significantly higher than for both types of wheat. High protein content and high water absorption are desirable features in baker's flour (Hoseney 1985). Water absorption was not affected in the composite flours with a higher protein content hence bread production using composites should be considered as a viable proposition. The oil absorption of *kabuli* flour was 70-80% higher than that of the soft and hard wheat flours and this resulted in considerable increase in oil absorption of their composite flours. This effect was not noticed in the composite flours with *desi* chickpea. Deep fried Indian snacks or nibbles are always made from *besan* (flour from dehulled *desi* splits) and rice/wheat flour to minimise oil absorption, decrease rancidity and increase shelf life (Singh and Seetha 1993, Midson 1996). Thus, composite flour containing *desi* is most suited for the production of deep

Table 4.5.2 Functional properties of wheat:*desi* (Amethyst) chickpea composite flours

Composite flour	Water absorption (g/g)	Oil absorption (g/g)	Emulsification capacity (g/g)	(g/g protein)	Flour solubility (g /100 g) 65 °C	95 °C	Nitrogen solubility (g /100 g) pH 6.0	pH 7.0
F value	2.2	2.8	3.7	3.9	7.8*	36.0**	10.6**	22.3**
HW (100%)	1.01	0.88	1.31	9.79	14.0a	24.0a	14.6a	14.0b
SW (100%)	0.93	0.82	1.38	13.80	15.7a	27.0a	18.6a	19.1b
DCP (100%)	0.92	0.92	3.84	15.31	43.8b	51.3b	63.7b	63.5ab
HW:DCP 90:10	1.02	0.91	1.93	13.31	19.2a	24.0a	16.0ab	16.1bc
SW:DCP 90:10	1.03	0.83	3.16	21.61	19.1a	29.5a	32.8ab	16.4bc
HW:DCP 70:30	0.99	0.92	2.09	12.61	15.6ab	32.4a	23.1a	22.7a
SW:DCP 70:30	0.88	0.96	3.15	21.38	26.1ab	28.9a	25.5a	27.4a
HW:DCP 50:50	0.93	1.05	3.61	18.91	23.5ab	34.6a	33.6ab	33.1b
SW:DCP 50:50	0.86	0.90	2.16	12.31	38.0ab	31.6a	38.4ab	35.8b

HW = Hard wheat, SW = Soft wheat, DCP = *Desi* chickpea

Table 4.5.3 Functional properties of wheat : *kabuli* (Garnet) chickpea composite flours

Composite flour	Water absorption (g/g)	Oil absorption (g/g)	Emulsification capacity (g/g)	(g/g protein)	Flour solubility (g/100 g) 65 °C	95 °C	Nitrogen solubility (g/100 g) pH 6.0	pH 7.0
F value	48.1**	2.5	7.0*	6.5*	35.3**	29.6**	8.1*	12.5**
HW (100%)	1.01a	0.88	1.31ab	9.79ab	14.0a	24.0b	14.6a	14.0b
SW (100%)	0.93a	0.82	1.38ab	13.80ab	15.7a	27.0b	18.6a	19.1b
KCP (100%)	1.10ab	1.55	3.13a	14.93a	42.5d	52.4a	51.4c	49.6ab
HW:KCP 90:10	1.30b	1.57	1.57ab	11.07a	16.3a	26.5b	15.7a	15.8b
SW:KCP 90:10	1.26b	1.70	1.98ab	13.19a	16.0a	31.6b	17.5a	15.7b
HW:KCP 70:30	1.05ab	1.60	1.71b	11.83a	21.7b	21.7b	25.3b	33.9a
SW:KCP 70:30	1.15ab	1.25	1.91b	14.34a	22.7b	24.8b	26.2b	27.9a
HW:KCP 50:50	1.14ab	1.49	3.32ab	18.76b	38.3c	35.2a	29.3bc	30.9b
SW:KCP 50:50	1.22ab	1.62	2.13ab	19.35b	29.5c	41.9a	54.0bc	45.1b

HW = Hard wheat, SW = Soft wheat, KCP = *Kabuli* chickpea

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

fried foods including those containing batters.

The emulsification capacity, flour solubility and nitrogen solubility index of chickpea flours were much higher than those of the wheat flours. These functional properties were thus considerably improved as a result of the supplementation of wheat flours with *desi* and *kabuli* chickpea flours. The emulsification capacity on a g/g protein basis of composite flour containing 50% *kabuli* chickpea was significantly higher than *kabuli* flour and other *kabuli* containing composites. The emulsification capacity of chickpea flours was 2-3 times higher than those of the wheat flours and this might be due to their higher protein content. *Desi* chickpea flour which contained the highest protein also showed the highest emulsification capacity.

As a general observation, flour solubility increased with an increase in temperature for all flours with the exception of the composite flours containing 50% *desi* or *kabuli* chickpea flour which recorded a small decrease. At 95 °C, flour solubility of *desi* and *kabuli* flours were significantly higher than their corresponding composites. The composite flours had intermediate levels of flour solubility which increased with degree of substitution. The increase in flour solubility of the composites compared to wheat flour can have a major application as a natural thickener in soups, sauces and gravy.

Nitrogen solubility index (NSI) of *desi* chickpea flour was much higher than *kabuli* flour. This trend was observed when these flours were extracted at pH 6.0 and pH 7.0, suggesting some qualitative differences in seed proteins of these two types of chickpea. Differences, if any, in NSI of the two types of chickpea flours and its composites must be evaluated at acidic pH, as is relevant for some fermented foods.

4.5.3 Viscoamylographic Characteristics of Composite Flours

Swelling capacity, gelation capacity, gel consistency, gel temperature, peak viscosity and peak temperature of pure (control) and composite flours are given in Tables 4.5.4 and 4.5.5, respectively. Among the control flours, *kabuli* flour had the lowest swelling power (2.7), while hard wheat flour had the highest (6.1). The gelation capacity spanned a narrow range from 9.5-11.5 g/100 mL for all flour types and gel consistency, measured as gel spread, was highest for wheat flours (mean 64 mm). Of the 4 control flours, peak viscosity was highest for hard wheat flour (510 B.U) and

Table 4.5.4 Viscoamylographic characteristics of wheat:*desi* (Amethyst) chickpea composite flours

Composite flour	Swelling capacity 65 °C	Swelling capacity 95 °C	Gelation capacity (g/100 mL)	Gel consistency (gel spread) (mm)	Gel temperature (°C)	Peak viscosity (B.U.)	Peak temperature (°C)
HW (100%)	6.1	9.3	11.5	61	67.5	510	94.5
SW (100%)	4.5	10.6	11.0	67	72.0	275	93.0
DCP (100%)	4.7	7.7	10.5	45	73.0	320	95.0
HW:DCP 90:10	4.8	9.0	11.5	49	72.0	505	95.5
SW:DCP 90:10	4.8	10.3	10.0	60	71.5	220	91.5
HW:DCP 70:30	6.2	11.1	11.0	48	73.5	580	95.5
SW:DCP 70:30	3.7	8.4	10.0	54	72.0	245	93.0
HW:DCP 50:50	6.5	8.0	10.5	47	74.5	660	94.0
SW:DCP 50:50	4.1	7.6	9.5	53	72.0	325	92.0

HW = Hard wheat, SW = Soft wheat, DCP = *Desi* chickpea, BU = Brabender units

Table 4.5.5 Viscoamylographic characteristics of wheat:*kabuli* (Garnet) chickpea composite flours

Composite flour	Swelling capacity 65 °C	Swelling capacity 95 °C	Gelation capacity (g/100 mL)	Gel consistency (gel spread) (mm)	Gel temperature (°C)	Peak viscosity (B.U.)	Peak temperature (°C)
F value	11.1*	7.4*	4.2	28.4*	3.9	4.6	2.9
HW (100%)	6.1**ab**	9.3**b**	11.5	61**a**	67.5	510	94.5
SW (100%)	4.5**ab**	10.6**b**	11.0	67**a**	72.0	275	93.0
KCP (100%)	2.7**a**	7.1**a**	10.5	43**b**	73.5	410	95.0
HW:KCP 90:10	5.0**b**	10.0**b**	11.5	40**b**	69.0	455	88.5
SW:KCP 90:10	6.4**b**	11.2**b**	10.0	40**b**	72.0	310	93.0
HW:KCP 70:30	6.3**b**	8.7**b**	11.0	45**b**	70.5	495	90.8
SW:KCP 70:30	6.6**b**	8.6**b**	10.0	50**b**	71.5	195	93.5
HW:KCP 50:50	6.5**b**	8.2**ab**	10.5	44**b**	70.5	450	90.8
SW:KCP 50:50	6.6**b**	8.4**ab**	9.5	42**b**	72.5	210	94.5

HW = Hard wheat, SW = Soft wheat, KCP = *Kabuli* chickpea, BU = Brabender units

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F* value statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

lowest for soft wheat flour (275 B.U) with *desi* and *kabuli* flours having intermediate values.

The swelling power of *desi* was higher than *kabuli* flour, irrespective of heating temperature. There appears to be strong interactions between heating temperature and swelling capacity of hard and soft wheat flours. The swelling capacity at 65 °C of soft wheat was considerably lower than hard wheat but the trend was reversed at 95 °C. However, this did not happen in case of *desi* and *kabuli* chickpea flours. Supplementation of hard wheat flour up to 10% and 30% with *desi* and *kabuli* flours, respectively, increased the swelling capacity when treated at 95 °C. The highest swelling capacity (11.2) was noted at 95 °C for the soft wheat-*kabuli* chickpea (90:10) composite flour. A comparatively higher increase at 95 °C in swelling capacity of low protein flours of soft wheat and *kabuli* chickpea indicates that this might be due to their higher starch content. There were no large differences in gelation capacity values as a result of supplementation. The swelling capacity of composite flours containing *kabuli* flour were significantly higher than *kabuli* flour at 65 °C and 95 °C.

Gelation capacity, also referred to as the least gelation concentration, for soft wheat supplemented flours was slightly lower than those of the hard wheat flour and masked any effects due to type of chickpea flour. Effect of higher degree of substitution with pulse flour on the gelation capacity needs to be investigated further. Least gelation concentration for chickpea flour was comparable with those reported for bean flour (Sathe *et al* 1982) and mung bean flour (del Rosario and Flores 1981).

The gelling ability of cereal and legume flours appears to be a function of the nature and type of protein and starch. The gel consistency expressed as gel spread showed a marked difference between wheat and chickpea flours. The gel consistency of wheat flour decreased as a result of supplementation with chickpea flours. The gel spread of composite flours containing *kabuli* was significantly less than wheat flour. There was no noticeable difference in the gel consistency of *desi* and *kabuli* flours. Although composite flours had a lower gel consistency and gel spread compared to wheat flours,

measuring the strength of the gel may provide information on possible food applications.

There were large differences in peak viscosity and gelatinisation temperature as calculated from the Brabender viscoamylograph. The peak viscosity of hard wheat flour was the highest followed by *kabuli* chickpea, *desi* chickpea and soft wheat flours. In case of chickpea flours, the peak viscosity value was recorded when the hot-paste reached 95 °C. This generally reflects the swelling capacity and cooking behaviour of the starch component, the principal constituent of cereal and legume flours. Unlike wheat starches, no breakdown of peak viscosity was noted in chickpea flours. The breakdown value was much lower in soft wheat flour as compared to hard wheat flour. Generally, wheat starches exhibit a sharp viscosity drop from the pasting peak reflecting the fragility of the swollen granules, which first swell and then breakdown under the continuous stirring of the Brabender. This characteristic was not noticed in the chickpea flours. This would suggest that chickpea starch granules have greater stability against the mechanical shear than those of the fragile swollen wheat starches, particularly of the hard wheat. As a result of supplementation, peak viscosity continuously increased up to 50% in hard wheat and *desi* chickpea composite flour, but it increased only up to 30% supplementation with *kabuli* flour. An increase in peak viscosity was marginal in soft wheat and chickpea composite flours. The peak viscosity increased when soft wheat flour was supplemented up to 10% with *kabuli* flour and up to 50% of *desi* flour. The increased peak viscosity observed in composite flours is a desired attribute in noodle flour, in order to obtain the necessary mouth feel when the noodles are eaten. Further, the addition of chickpea flour might delay the beginning of swelling as there were some differences in the initial pasting temperatures. Also, the composite flours had higher peak temperatures as compared to those of the wheat flours. Some earlier studies have reported a considerable increase in the initial pasting temperatures as a result of delaying of swelling of starch granules in wheat and bean composite flours (Deshpande *et al* 1983). The results of this study indicate that adding chickpea flours will not adversely affect some dough properties but will enhance the product stability as revealed by increases in emulsification capacity of the composite flours.

4.6 Production of Value Added Pulse Products

The results of a feasibility study on the ease of production and quality (composition and sensory) of: (A) instant noodles from composite flour and (B) pan bread from baker's flour supplemented with *kabuli* hull are presented.

4.6.1 Instant Noodles (IN) and Steamed and Dried Noodles (SDN)

Bright yellow coloured Chinese noodles are preferred in S E Asia (Galvez and Resurreccion 1992, N Azudin, Personal Communication AWB 1995). The use of composite flours containing *besan*, which has an inherent yellow colour is likely to enhance the colour of noodles. The feasibility of producing an instant noodle or snack type noodle using *besan* as an ingredient was examined. Composite flours containing wheat flour (grade ASW-N) and *besan* (flour from dehulled *desi*) were mixed in different proportions and their properties examined with respect to possible manufacturing of instant noodles (IN) and steamed and dried noodles (SDN). *Besan* was roasted prior to mixing with wheat flour and the effects of pre-treatment on the machineability of the dough and the overall taste of the products were evaluated.

4.6.1.1 Dough Texture

Doughs were visually examined to assess dough texture. Supplementation of noodle wheat flour with 5% and 10% raw *besan* and roasted *besan* produced a crumbly 'biscuit' dough similar to the wheat flour dough. The doughs were not sticky and did not exhibit any machineability/handling problems. As the dough contained only 34% water and no other binding agent, noodle doughs did not adhere until sufficient time had lapsed to cause moisture migration within the dough. The flours with 15% *besan* supplementation produced a dough with many irregular granules after mixing, but resulted in a smooth dough sheet. The 80:20 flours produced uniform globules approximately, 3-4 mm in diameter at the end of the mixing stage and a sticky dough sheet. These findings were similar to those of Hung and Nithiandan (1993). Fifteen percent substitution of wheat flour with *besan* therefore appears to be the optimum level of substitution for noodle preparation with respect to dough handling and strain on the cutting rollers. Doughs containing roasted *besan* appeared dry at the end of the mixing stage but by the end of the sheeting phase there was no visible difference between the doughs.

4.6.1.2 Flour Colour

Colour values, represented as L*, a* and b* for wheat flour, *besan*, roasted *besan* and for the instant noodles, steamed and dried noodles made from the range of composite flours are given in Table 4.6.1.

The L* value (whiteness/brightness) was highest for wheat flour (93.5) and lowest for roasted *besan* (82.2). The b* value (yellowness) was maximum for roasted *besan* (29.2) and was the lowest for white flour (8.7). This is expected because roasting causes considerable darkening of the flour. L* and b* value of all the 3 flour types were significantly different to each other at $p < 0.05$. It must be highlighted that due to the homogeneity of the flours, repeated colour measurements of different batches of flour produced identical readings and resulted in SE equalling zero. Although the reduction in b* value of wheat flour was not proportional to the increased L* value when compared with roasted *besan*, a formula consisting of both flours can have a compensatory effect on the final colour of the product. Qualitative market research has shown that colour is a very important attribute for noodles, perhaps second only to texture.

4.6.1.2.1 Noodle Colour - Within Noodle Types

Each noodle block consisted of 4 layers of wavy noodle strands compactly bound together. Colour observation was an average of 9 readings taken randomly over the noodle block. To minimise the heterogeneity of noodle blocks, colour readings on ground noodle samples were considered. However, the values obtained on ground noodle were not comparable to the colour of noodles *per se* as perceived by the customer. It is seen from Table 4.6.1 that for each noodle type, the L* value of the 100:0 noodle was the highest, except for SDN type containing roasted *besan*. The L* value of SDN containing roasted *besan* was significantly higher ($p < 0.01$) than 100:0 SDN, at all levels of substitution. In the same type of noodles, the L* value of 80:20 formula noodles was significantly higher than the 90:10 formula. Within the noodle types, the L* value of 95:5 noodles was reduced compared to all-wheat noodles (control) except for SDN containing roasted *besan*. A further reduction in L* value was observed for all noodle types in the 90:10 formula followed by a gradual increase in L* value with an increase in substitution level. At 5% and 10% substitution levels, *besan* particles were randomly scattered through the dough sheet reducing the overall

Table 4.6.1 Colour of flour and noodles made from wheat and chickpea flour mixes

Sample type	L*	a*(-ve)	b*	SDN			IN			SDN†			IN†		
ASW-N flour	93.5a ± 0	2.3a ± 0	8.7a ± 0												
Raw *besan* flour	88.4b ± 0	2.3a ± 0	27.5b ± 0												
Besan † flour	82.2c ± 0	0.2b ± 0	29.2c ± 0	L*	a*(-ve)	b*	L*	a*(-ve)	b*	L*	a*(-ve)	b*	L*	a*(-ve)	b*
100:0 noodle				60.2 ± 1.0	1.6 ± 0	17.9c ± 0.3	64.6 ± 1.3	2.1# ± 0.1	18.0a ± 0.4	60.2a ± 1.0	1.6a ± 0	17.9a ± 0.3	64.6 ± 1.3	2.1#a ± 0.1	18.0a ± 0.4
95:5 noodle				57.4 ± 1.7	1.7 ± 0.1	21.0a ± 0.5	61.9 ± 2.3	1.8 ± 0.1	21.1bd ± 0.5	72.9b ± 1.6	2.1c ± 0.2	27.6c ± 0.4	61.2 ± 1.5	1.8ac ± 0.2	22.1bc ± 0.4
90:10 noodle				53.8 ± 3.7	1.6 ± 0.1	22.5a ± 1.3	59.1 ± 2.7	1.6 ± 0.2	22.3bd ± 0.6	65.7bc ± 0.9	1.1b ± 0.2	31.8b ± 0.5	58.9 ± 3.2	1.6bc ± 0.1	24.3bd ± 0.9
85:15 noodle				57.0 ± 1.0	1.6 ± 0	25.6b ± 0.5	61.2 ± 1.5	1.9 ± 0.1	24.7bc ± 0.4	69.2b ± 0.6	0.9b ± 0.1	32.1b ± 0.4	61.8 ± 1.1	1.1bd ± 0.1	24.4bd ± 0.2
80:20 noodle				60.8 ± 2.9	1.3 ± 0.3	24.5b ± 0.3	60.0 ± 0.9	1.8 ± 0.1	21.8bd ± 0.4	71.8bd ± 1.2	0.8b ± 0.1	32.2b ± 0.4	62.2 ± 0.9	0.8bd ± 0.1	25.5bd ± 0.7
F value				1.5	0.8	19.2**	1.3	2.1	26.6**	22.0**	18.3**	233.1**	1.3	20.3**	26.4**

L* = whiteness/brightness, a*(-ve) = greenness, # = a (+ve) redness, b*(+ve) = yellowness

ASW-N = Australian Standard White-Noodle, SDN = Steamed and dried noodle and IN = Instant noodle

† = roasted *besan*

n = 3, Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

brightness of the product, but at 15% and 20% substitution, *besan* was uniformly distributed through the dough sheet enhancing brightness to a similar level as in the control. These findings clearly indicate that the L* value is unaffected at 15% to 20% substitution levels. In fact, at 20% substitution there is an improvement in L* value in SDN made with roasted *besan.*

The b* value (yellowness) of the experimental noodles was significantly higher than the control for all ratios and all noodle types at $p < 0.01$. Substitution at the 5% level had a significantly lower b* value than the 10%, 15% and 20% substitution levels for SDN and IN with roasted *besan.* There was no change to the yellowness value at 15% or 20% supplementation, (except for IN containing raw *besan*) suggesting that further substitution may not increase the b* value.

Negative a* value (greenness) was observed for all noodle types, except for 100:0 IN (2.1). The a* value spanned a narrow range between -2.1 to -0.8, which accounts for less than 5% of the spectrum for greenness. The a* value of 100:0 SDN was significantly different to the a* value of SDN supplemented with roasted *besan* at all levels of substitution. Greenness was eliminated at the 15% and 20% substitution in SDN and IN containing roasted besan.

4.6.1.2.2 Noodle Colour - Between Noodle Types

Table 4.6.2 highlights differences in colour between noodle types. The L* value of 100:0 IN was significantly higher (64.6) than 100:0 SDN (60.2), suggesting that the process of noodle production has an effect on brightness. Frying increases the porosity of wheat noodles and makes the product appear brighter. This difference in brightness is, however, masked for SDN and IN made with ASW-N flour supplemented with *besan*; with the exception of the 85:15 noodle. The inherently lower L* value for *besan* probably causes an overall reduction in brightness of the supplemented flour which frying cannot restore.

The L* value of SDN made with roasted *besan* was significantly higher than the L* value of all other noodle types at all levels of supplementation. The L* value of IN containing roasted *besan* was significantly lower than SDN because frying causes further darkening of the roasted particles.

There was no difference in the b* value of the SDN and IN wheat noodles. Similar to the L* value, yellowness of SDN made with roasted *besan* was significantly higher

Table 4.6.2 Colour of noodles made from wheat and chickpea mixes (highlighting differences between noodle types)

Noodle type	100:0			95:5			90:10			85:15			80:20		
	L*	a*(-ve)	b*	L*	a*(-ve)	b*	L*	a*(-ve)	b*	L*	a*(-ve)	b*	L*	a*(-ve)	b*
SDN	60.2a ± 1.0	1.6a ± 0	17.9 ± 0.3	57.4a ± 1.7	1.7 ± 0.1	21.0a ± 0.5	53.8a ± 3.7	1.6 ± 0.1	22.5a ± 1.3	57.0a ± 1.0	1.6a ± 0	25.6a ± 0.5	60.8a ± 2.9	1.3ab ± 0.3	24.5a ± 0.3
IN	64.6b ± 1.3	2.1#b ± 0.1	18.0 ± 0.4	61.9a ± 2.3	1.8 ± 0.1	21.1a ± 0.5	59.1a ± 2.7	1.6 ± 0.2	22.3a ± 0.6	61.2bd ± 1.5	1.9a ± 0.1	24.7a ± 0.4	60.0a ± 0.9	1.8b ± 0.1	21.8bc ± 0.4
SDN†				72.9b ± 1.6	2.1 ± 0.2	27.6b ± 0.4	65.7b ± 0.9	1.1 ± 0.2	31.8b ± 0.5	69.2bc ± 0.6	0.9b ± 0.1	32.1b ± 0.4	71.8b ± 1.2	0.8a ± 0.1	32.2bd ± 0.4
IN†				61.2a ± 1.5	1.8 ± 0.2	22.1a ± 0.4	58.9a ± 3.2	1.6 ± 0.1	24.3a ± 0.9	61.8bd ± 1.1	1.1b ± 0.1	24.4a ± 0.2	62.2a ± 0.9	0.8a ± 0.1	25.5a ± 0.7
F value	7.2*	19.2**	1.9	9.5**	1.2	53.7**	4.1*	2.9	25.1**	21.9**	16.5**	97.5**	10.5**	7.3**	84.8**

L* = whiteness/brightness, a*(-ve) = greenness, # = a (+ve) redness, b* (+ve) = yellowness

SDN = Steamed and dried noodle and IN = Instant noodle

† = roasted *besan*

n = 3, Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

than the b* value between all noodle types at all levels of supplementation. The b* value was unaffected by the process of manufacture when supplementation was with raw *besan*. Yellowness of IN containing roasted *besan* decreased due to frying.

SDN and IN containing roasted *besan* at the 20% level had the highest a* value (-0.8) ie., minimal greenness.

These results suggests that with respect to colour, SDN made with roasted *besan* had improved brightness and yellowness when compared to all experimental noodles (at all levels of substitution) including wheat noodles. Furthermore, Hussain *et al* (1989) have shown that roasting and autoclaving significantly reduce the phytic acid level of chickpea cultivars, thus the use of roasted *besan* in the formula has an added nutritional advantage.

4.6.1.3 Noodle Composition and Water Activity

Table 4.6.3 gives the protein (g/100 g), fat (g/100 g), thiamin (mg/100 g) and riboflavin (mg/100 g) contents and water activity of the flours, wheat noodles and noodles made from composite flours.

As expected, the protein content of raw and roasted *besan* was more than twice that of ASW-N flour. This resulted in the protein content of IN and SDN increasing with an increase in *besan* supplementation. However, this increase was not as evident in the IN probably because of the 'dilution effect' due to fat uptake in the frying process. As a result, the protein of SDN was significantly higher than protein content of IN.

The fat content of *besan* (raw and roasted) was significantly higher than the ASW-N flour. However, fat content of *besan* was lower than that reported in Table 4.5.1 (6.4 g/100 g). *Besan* for this experiment was purchased from the local grocery store which was probably a composite sample of different varieties of *desi* chickpea. The fat content in wheat SDN was only about one-eighth of the fat content in wheat IN. Accordingly, the fat content of SDN (made with raw and roasted *besan*) at all levels of supplementation was on average 11.4% less than the fat content of both types of IN. Further, the fat content in SDN was less than 4.0%, suggesting rancidity problems to be significantly reduced.

The fat content of IN made with raw *besan* increased with the level of supplementation, (up to 24.9% for 80:20 flour) but IN made from roasted *besan* had an average fat content of 20.6%. This implies that there is a nutritional advantage in

Table 4.6.3 Protein[1], fat[1], thiamin[2,3], riboflavin[2,3] and water activity of flours, wheat noodles, SDN and IN made from composite flours

Sample	Protein (g/100 g)(Nx5.7)	Fat (g/100 g)	Thiamin (mg/100 g)	Riboflavin (mg/100 g)	a_w
ASW-N (Flour)	9.1a	1.6a	0.20a	0.04a	0.51
Besan	21.9b	5.0b	0.65b	0.16a	0.46
Roasted *besan*	22.3b	5.0b	0.65b	0.16b	0.42
100:0 SDN	10.0a	2.6a	0.20	0.02	0.33
100:0 IN	7.3b	20.0b	-	-	0.44
SDN					
95:5	9.2	2.5	0.30	0.04	0.46
90:10	10.7	2.4	-	-	0.37
85:15	11.0	2.5	0.35	0.05	0.59
80:20	11.8	3.0	-	-	0.50
Mean	**10.7a**	**2.6a**	**0.33**	**0.05**	**0.48**
SDN**					
95:5	9.8	3.6	0.20	0.05	0.27
90:10	10.0	1.6	-	-	0.35
85:15	10.3	1.7	0.30	0.09	0.36
80:20	10.4	1.8	-	-	0.37
Mean	**10.1a**	**2.2a**	**0.25**	**0.07**	**0.34**
IN			a_w		
95:5	8.1	18.6	0.48		
90:10	8.4	19.9	0.59		
85:15	7.9	22.4	0.80*		
80:20	8.4	24.9	0.74		
Mean	**8.2b**	**21.5b**	**0.65**		
IN**			a_w		
95:5	7.6	20.7	0.38		
90:10	7.7	20.8	0.49		
85:15	8.0	20.7	0.44		
80:20	8.2	20.1	0.43		
Mean	**7.9b**	**20.6b**	**0.44**		

[1] g/100 g, [2] mg/100 g

[3] thiamin and riboflavin measured only on flours and selected SDN

* higher than expected water activity.

** roasted *besan*

For similar samples such as; flour types, 100:0 noodles and experimental noodles, means in the same column not followed by the same letter are significantly different at $p < 0.05$.

supplementing noodle flour with up to 20% roasted *besan.* Based on the previous study on functional properties of composite flours (Tables 4.5.2 and 4.5.3), *besan* (flour from *desi* chickpea splits) was better for supplementation purposes than flour from *kabuli* splits as composite flours containing *kabuli* flour had higher oil absorption. Thus, fat content of IN can be controlled by appropriate choice of raw material for supplementation.

Thiamin and riboflavin were estimated in the different flours and selected SDN samples only. They were not measured in IN because of the interference from fat in the samples. Thiamin and riboflavin levels in the *besan* were the highest compared to ASW-N flour and the noodles. There was a considerable increase in the levels of the two vitamins with an increase in supplementation levels. The increase in thiamin content with supplementation was affected in SDN containing roasted *besan.* Riboflavin levels, however, showed a small increase in SDN containing roasted *besan.* Supplementation at the 15% level improved thiamin and riboflavin levels in SDN by 65% and 250% respectively, over wheat SDN.

At a given level of substitution (regardless of the type of *besan* used) SDN had lower water activity than IN. This shows that the duration of the drying step following steaming was adequate and shelf life problems associated with microbial spoilage should be minimal. IN have a greater porosity in their structure compared to the SDN. The porous structure may absorb water from the atmosphere and increase water activity thereby increasing chances of spoilage too. Thus, the time between production of IN and the measurement of water activity was crucial.

The unexpectedly high water activity of the 85:15 IN (0.80) was probably because the polyethylene bags containing the sample was improperly sealed allowing moisture to penetrate the product.

Irrespective of the type of noodles ie. SDN or IN, flour containing the roasted *besan* always had lower water activity than the flour with raw *besan.* This is probably because the process of roasting lowers the moisture content of the resultant flour. Roasting eliminates beany flavours and enhances nutty aroma (Pushpamma and Geervani 1987) which was apparent while cooking and tasting the noodles .

4.6.1.4 Sensory Evaluation

Noodle colour (extremely yellow to extremely white, 1-5), strength (extremely strong to extremely weak, 1-5), firmness (extremely firm to extremely soft, 1-5), chewiness (extremely chewy to extremely tender, 1-5) and flavour (extremely wheaty to extremely beany, 1-5) was scored by a trained panel of two. Table 4.6.4 gives the mean score for wheat noodles, SDN and IN made from composite flours containing raw and roasted *besan.* A copy of the sensory evaluation form used is presented in Appendix-I.

The maximum score any type of noodle could receive was 30 and the minimum 5. Based on previous unpublished studies on sensory evaluation of IN and SDN conducted at the AGT, the following assumptions were made: (a) noodles scoring ≥ 20 were unacceptable products, (b) noodles scoring between 15-19 points were moderately acceptable, (c) noodles scoring between 10-14 highly acceptable and (d) noodles scoring between 5-9 were the most preferred.

SDN and IN made from the 80:20 composite flour with raw *besan* were therefore unacceptable. Apart from poor mouthfeel, the 80:20 SDN (containing raw *besan*) had a pronounced beany flavour and the IN had an oily flavour. Increased supplementation did not improve noodle firmness or chewiness.

SDN containing up to 10 parts of roasted *besan* had the preferred colour, desired mouthfeel and neutral flavour (total score = 11) which was better than wheat SDN (total score = 15). Most of the IN were in the moderately acceptable category, with the exception of 95:5 IN which was in the highly acceptable group. Composite flours at optimal (between 10-15%) substitution levels can produce a nutritive and acceptable SDN and IN. Slight modifications to the ingredients (eg. use of commercial starches in small quantities) and process (duration of noodles in the steam bath, time/temperature of frying and rate of drying) can considerably improve texture of the final product. The overall taste, however, will depend on the synergesis of the flavour of soup or sauce noodles are served in, and the roasted *besan* flavour.

4.6.2 Pan Bread

The selective use of hull, especially from the pale coloured *kabuli* seeds, in bread formulations could be useful in increasing the fibre content possibly without altering

Table 4.6.4 Sensory score for wheat noodles, SDN and IN containing raw and roasted *besan* at all supplementation levels

Noodle type	Colour	Strength	Firmness	Chewiness	Flavour	Total
100:0 SDN	1	4	4	4	2	15
100:0 IN	1	4	2	2	2	11
			SDN			
95:5	5	3	2	3	3	16
90:10	2	3	3	2	4	14
85:15	3	4	5	2	4	16
80:20	4	3	4	4	5	20
			SDN*			
95:5	3	4	4	4	3	18
90:10	2	2	2	3	2	11
85:15	2	4	5	4	4	19
80:20	2	4	4	4	5	19
			IN			
95:5	3	4	1	3	3	14
90:10	5	4	1	2	4	16
85:15	4	5	3	2	4	16
80:20	2	5	4	4	5	20
			IN*			
95:5	2	4	2	4	3	15
90:10	4	4	3	3	3	17
85:15	3	4	3	4	4	18
80:20	3	5	3	4	4	19

* roasted *besan*

the taste. The results of a study of producing European style pan breads by the rapid dough method at 10 and 20% substitution levels with *kabuli* hull are presented here. Baker's flour was supplemented with *kabuli* (cv Garnet and Kaniva) hull with the intent of fortifying the flour with fibre present in the seed coat, which is normally disposed as cheap stock feed.

4.6.2.1 Composition of Hull and Flour

Table 4.6.5 gives the yield, TDF, protein and fat content of the hull and wheat flour. About 70 g of hull was obtained by dehulling 1 kg of *kabuli* cultivar with no difference in yield of hull between cultivars. The seed coat of the *kabuli* type chickpea constitutes about 7% of the total seed weight which is higher than that reported by Kumar and Singh (4.9%) (1989). This difference could be due to; (a) the weight of seed coat in the present study is based on a small number of samples as compared to the work of Kumar and Singh (1989) n = 19, or (b) environmental and genotypic variations could give a higher seed coat weight for Australian varieties. In a later unpublished study, however, Singh (1993) reports *dhal* yield for *kabuli* to be in the range of 89.6-93.8% (n = 12) . Judging by these results, seed coat weight of 7% of whole seed is within range.

As the hull was derived from chickpea, a factor of 6.25 was used to estimate protein content in hull. Conventionally, a factor of 5.7 is used to determine the protein content in cereal and cereal based products and this factor was used in this study. There was a significant difference in the TDF content of the hull of the two *kabuli* varieties of chickpea. As expected, the protein, TDF and fat contents of the hull were significantly higher than in baker's flour. Studies by Esh *et al* (1959) on distribution of nutrients in the seed coat only report a crude fibre content of 48 g/100 g hence valid comparison with TDF of seed coat as reported here cannot be made. The mean protein (14.7 g/100 g) and fat content (3.9 g/100 g) of hull is higher than that reported in the literature (Esh *et al* 1959). This could be due to contamination of the hull by minute particles of powder and broken fractions during milling. The powder and broken fractions can contain small fragments of cotyledon splits and embryo which are rich in

Table 4.6.5 Yield of hull from *kabuli* cultivar (g), TDF, protein and ash (g/100 g) on dry matter basis in hull and wheat flour

***Kabuli* variety**	**Wt. of powdered hull (g)** (from 1 Kg whole seed)	**TDF**	**Protein** **(N x 6.25)**	**Fat**
Garnet	70	45.6a	14.5	4.4a
Kaniva	69	40.5b	12.2	3.4b
Baker's flour	-	4.2c	14.3*	2.2c

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

* N x 5.7

Table 4.6.6 Composition (g/100 g) on dry matter basis of control bread and bread supplemented with *kabuli* hull

Sample Bread	**Protein (N x 5.7) (g)**	**Ash (g)**	**TDF (g)**	**Fat (g)**	**-CHO (g)**	**ENR (kJ)**
100% Flour	14.4	3.1	5.1	3.8	73.6	1640
			Garnet Hull			
1% Hull	14.2	3.1a	7.6a	4.4	70.7a	1605a
2% Hull	14.1	3.1a	7.7a	4.8	70.4a	1615a
5% Hull	14.0	3.3b	9.8b	4.7	68.2b	1575b
			Kaniva Hull			
1% Hull	14.3	3.1ab	6.7a	4.3	71.6a	1620a
2% Hull	14.0	2.7a	6.8a	4.0	71.8a	1610a
5% Hull	14.1	3.2b	9.1b	4.4	69.2b	1460b
Mean 1%	14.3	3.1ab	7.2a	4.4	71.2a	1615a
Mean 2%	14.1	2.9a	7.3a	4.4	71.1a	1615a
Mean 5%	14.1	3.3b	9.4b	4.6	68.7b	1520b

ENR = Energy non-ruminants

Means in the same column of a given bread type, not followed by the same letter are significantly different at $p < 0.05$.

protein and fat.

4.6.2.2 Bread Composition

The protein, ash, TDF, fat, carbohydrate and energy for non-ruminants on a dry matter basis of control bread and breads made from baker's flour substituted with *kabuli* hull at 1%, 2% and 5% are shown in Table 4.6.6.

Physical properties and ease-of-handling of the dough were not affected at any level of substitution. This is primarily because additional water equivalent to twice the amount of hull was added to each experimental dough coupled with an increase in mixing time to achieve complete dough development. The mean protein, fat and carbohydrate contents of the control bread were 14.4 g/100 g, 3.8 g/100 g and 73.6 g/100 g, respectively, with an energy value of 1640 kJ/100 g.

Significant increases in ash and TDF contents were observed at the 5% substitution level compared to the control and breads at lower levels of supplementation for both cultivars. This increase was complemented by a significant decrease in the carbohydrate content and hence gross energy level with an increase in supplementation. The results were similar when experimental breads at the same level of substitution were compared regardless of the type of hull in them. There were no significant differences in composition between the 1% and 2% supplemented breads, however, there was a significant improvement in composition compared to control even at the low levels of supplementation. On average, experimental breads at 5% substitution had 46% more TDF and 6% more ash than control bread thus offering a nutritional advantage. There was a 7% decrease in carbohydrate content and gross energy levels of the 5% supplemented bread compared to control which is beneficial for weight conscious persons. The fibre component acts as a diluent in supplemented breads as a result the protein content was lower than the control whereas, the fat content of supplemented breads was higher than the control probably because of the presence of germ which is rich in fat in the hull component.

TDF of breads supplemented with Garnet hull were higher than Kaniva hull at all levels of supplementation because TDF level in Kaniva hull was lower than Garnet hull. Consequently, the carbohydrate and energy levels of breads containing Garnet hull were lower than those containing Kaniva hull.

4.6.2.3 Evaluation of Bread

4.6.2.3.1 Crumb and Crust Colour

The colour of the breads and their general appearance was evaluated 24 hours after production. Pup loaves were used to measure loaf volume, crumb and crust colour and evaluate general appearance before cutting to assess texture. Table 4.6.7 gives the mean crumb and crust colour for the control and experimental breads at the 3 levels of supplementation. The mean L*, a* and b* values of the crust containing Garnet hull was similar to that containing Kaniva. The b* value (yellowness) of the crust of control bread was significantly higher than experimental bread containing Garnet hull at all levels of substitution whereas the whiteness (L* value) of the supplemented breads containing Kaniva hull decreased with an increase in level of substitution. Whiteness of the bread containing 1% Kaniva hull was highest, followed by control bread and bread with 2% Kaniva hull. The L* value of bread with 5% Kaniva hull was significantly lower than 1% Kaniva supplemented bread. These observations suggest that the external appearance of experimental breads was not dramatically affected by supplementation.

The mean crumb whiteness of breads supplemented with Garnet hull was higher, while a* and b* values were lower than in breads containing Kaniva hull. Crumb whiteness of control bread was significantly lower than breads with 1% and 2% Garnet hull and the a* value was significantly lower than experimental breads containing Garnet at all levels of supplementation. The increase in crumb whiteness in the 1% and 2% Garnet supplemented breads is a desirable attribute in pan breads. The b* value of breads with 1% and 2% Garnet hull was significantly lower than the supplemented bread containing 5% hull. Experimental bread containing 5% Kaniva hull had significantly lower L* value and significantly higher a* and b* values compared to control bread and breads at lower level of substitution. Shehata and Fryer (1970) reported significant decrease in crust colour between control and chickpea flour supplemented Egyptian breads. Judging by crumb and crust colour of the bread types, bread supplemented with 5% Kaniva hull may be less acceptable.

Table 4.6.8 compares the crumb and crust colour of supplemented breads at the same level of supplementation. The mean L* values of the crust decreased while the mean a* values increased with an increase in supplementation. Similarly the mean L* values

Table 4.6.7 Crust and crumb colour of control and experimental breads supplemented with hull of *kabuli* culitvars, represented as L*, a* and b*

	Crust colour			Crumb colour		
Bread type	**L***	**a***	**b***	**L***	**a***	**b***
Control	63.4 ± 1.8	12.4 ± 0.6	34.6a ± 0.3	76.2a ± 0.4	0.9a ± 0.1	21.4ab ± 0.2
1% Garnet hull	63.4 ± 1.9	12.9 ± 0.8	33.2b ± 0.2	78.6b ± 0.4	1.2b ± 0.1	21.1a ± 0.3
2% Garnet hull	64.0 ± 1.1	12.7 ± 0.7	33.1b ± 0.4	78.6b ± 0.4	1.4b ± 0	20.8a ± 0.1
5% Garnet hull	63.9 ± 1.1	12.5 ± 0.5	32.9b ± 0.1	77.2ab ± 0.5	2.1c ± 0.1	21.9b ± 0.2
Mean Garnet	63.8 ± 0.2	12.7 ± 0.1	33.1 ± 0.1	78.1 ± 0.5	1.6 ± 0.3	21.2 ± 0.3
F value	0	0.1	8.6**	7.6**	53.0**	7.6**
Control	63.4ab ± 1.8	12.4 ± 0.6	34.6 ± 0.3	76.2a ± 0.4	0.9a ± 0.1	21.4a ± 0.2
1% Kaniva hull	67.4a ± 2.4	10.1 ± 1.9	33.2 ± 1.3	77.7a ± 0.2	1.3a ± 0.1	22.2b ± 0.2
2% Kaniva hull	62.1ab ± 1.5	13.4 ± 0.8	33.5 ± 0.5	76.3a ± 0.4	1.9b ± 0.2	22.1b ± 0.2
5% Kaniva hull	59.7b ± 0.4	14.2 ± 0.2	34.0 ± 0.2	73.3b ± 0.4	2.6c ± 0	23.3c ± 0
Mean Kaniva	63.1 ± 2.3	12.6 ± 1.3	33.6 ± 0.2	75.8 ± 1.3	1.9 ± 0.4	22.5 ± 0.4
F value	3.6*	2.7	0.8	25.1**	34.2**	26.7**

Table 4.6.8 Comparison of crust and crumb colour of breads supplemented with Garnet and Kaniva hull at the same level of supplementation

	Crust colour			Crumb colour		
Bread type	**L***	**a***	**b***	**L***	**a***	**b***
1% Garnet Hull	63.4 ± 1.9	12.9 ± 0.8	33.2 ± 0.2	78.6 ± 0.4	1.2 ± 0.1	21.1 ± 0.3
1% Kaniva hull	67.4 ± 2.4	10.1 ± 1.9	33.2 ± 1.3	77.7 ± 0.2	1.3 ± 0.1	22.2 ± 0.2
Mean	65.4 ± 2	11.5 ± 1.4	33.2 ± 0	78.2 ± 0.5	1.2 ± 0	21.7 ± 0.6
F value	1.2	1.8	0	3.9	0.3	10.0
2% Garnet Hull	64.0 ± 1.1	12.7 ± 0.7	33.1 ± 0.4	78.6 ± 0.4	1.4 ± 0	20.8a ± 0.1
2% Kaniva Hull	62.1 ± 1.5	13.4 ± 0.8	33.5 ± 0.5	76.3 ± 0.4	1.9 ± 0.2	22.1b ± 0.2
Mean	63.1 ± 1.0	13.1 ± 0.4	33.3 ± 0.2	77.5 ± 1.2	1.7 ± 0.3	21.5 ± 0.7
F value	1.0	0.3	0.4	14.2	4.0	37.0**
5% Garnet Hull	63.9 ± 1.1	12.5 ± 0.5	32.9a ± 0.1	77.2a ± 0.5	2.1a ± 0.1	21.9a ± 0.2
5% Kaniva Hull	59.7 ± 0.4	14.2 ± 0.2	34.0b ± 0.2	73.3b ± 0.4	2.6b ± 0	23.3b ± 0
Mean	61.8 ± 2.1	13.4 ± 0.9	33.5 ± 0.6	75.3 ± 2.0	2.4 ± 0.3	22.6 ± 0.7
F value	13.1	10	21.9**	41.4**	37.6**	74.7**

L* = whiteness/brightness, a* = redness, b* = yellowness

n = 3, Values presented are mean ± SE

Means in the same column not followed by the same letter are significantly different at $p < 0.05$.

F value* statistically significant at $p < 0.05$, F value** statistically significant at $p < 0.01$.

of the crumb decreased and a* values increased with increase in hull content in bread which is not a desirable change. The b* values of the crust and crumb were not affected by hull supplementation, however, the b* value of the crumb of bread with 2% Kaniva hull was significantly higher than bread with 2% Garnet hull. The yellowness of the crust and crumb of bread with 5% Kaniva hull was significantly greater than the b* value of bread containing 5% Garnet hull. The L* value of the crumb was lower and the a* value was higher in the 5% Kaniva supplemented bread compared to bread with 5% Garnet hull. These results again suggest that 5% supplementation with Kaniva hull may not provide the most visually appealing product.

4.6.2.3.2 Overall Score

The mean score obtained by two expert panelists when samples were presented blind for the different attributes of bread is given in Table 4.6.9. The breads were evaluated for volume (25), appearance (25), crumb colour (20), crumb texture (20) and aroma (10), totalling 100 points. Evaluation form for bread is presented in Appendix II.

Breads containing 1%, 5% Garnet hull and 1% Kaniva hull had significatnly higher total scores than the control bread and breads containing 2% Garnet hull, 2% and 5% Kaniva hull at $p < 0.05$. The loaf volume, general appearance, crumb colour and texture of supplemented breads containing 1%, 5% Garnet hull and 1% Kaniva hull were significantly improved compared to the control as indicated by the total score. Breads containing 2% Garnet and Kaniva hull were quite similar to the control bread while the bread containing 5% Kaniva hull had the lowest score, similar to the low score obtained for objective colour analysis. Crumb texture was a visual subjective test examining the uniformity of the cell structure, density of cells and presence of vacuoles which was not affected by supplementation, except in the case of bread containing 5% Kaniva hull. It was observed that bread containing Kaniva hull at 1% level had an open texture and was 'not as well' moulded.

There were no deleterious effect on the final product due to addition of non-glutenous substances as was initially suspected. All experimental bread samples had a distinct nutty aroma which was loosely described as a flavour similar to 'peanut butter'. Although the flavour was acceptable, the experimental breads did not score more than the control, as the expert panellists did not associate a nutty flavour with bread. Aroma was not affected at increased substitution levels.

Table 4.6.9 Evaluation of bread produced by supplementing with *kabuli* hull

Bread	Loaf Vol CC	Volume (25)	Appearance (25)	Crumb colour (20)	Crumb texture (20)	Aroma (10)	Total (100)
Control	403	20	18	15	14	8	75a
1% G	422	20	21	16	17	8	82b
2% G	407	19	21	14	15	8	77a
5% G	405	22	21	15	14	8	80b
Control	405	21	19	16	13	8	77a
1% K	421	20	21	16	17	8	82b
2% K	415	19	19	14	15	7	74a
5% K	360	16	16	11	11	8	62c

G=Garnet hull, K=Kaniva hull

Values are mean score of two panellists from two trials

Means in the same column not followed by the same letter are statistically different at $p < 0.05$.

The overall taste and acceptance of the breads with *kabuli* hull was favourable. Judging by the overall score it is evident that Garnet and Kaniva hull affect bread quality differently. Bread supplemented with 5% Garnet hull had a higher score than the bread containing 2% Garnet hull. It is thus possible that bread with a higher level of supplementation with Garnet hull may have a superior quality. On the contrary, overall bread quality declined with an increase in supplementation with Kaniva hull. In fact, supplemented bread of acceptable quality can be made with less than 5% Kaniva hull. Hallab *et al* (1974) reported that the organoleptic properties of chickpea supplemented bread compared favourably with the unsupplemented bread up to a level of 20% supplementation. Thus, it can be concluded that the overall acceptability of products supplemented with *kabuli* hull is similar to those supplemented with *kabuli* flour at a much lower level of supplementation.

Discussion

5 Discussion

5.1 Composition of Australian Chickpea and *Dhal*

5.1.1 Commercially Traded Varieties

As the pulse trade from Australia increased in early 1990, it became apparent that uniformity in colour and visual appearance of whole seeds were the two most important attributes that influenced sales. Due to the lack of technical information on composition and/or processing features of Australian pulses to support the trade much emphasis in this study was placed on physical properties, especially colour and size. An important aspect of the study was thus measurement of colour and objective comparisons of colours (shades) between varieties. From the data obtained in this thesis, a set of standard reference L*, a* and b* values for *desi* and *kabuli* types specific for each market is expected to be finalised following extensive consultations with end users. The concept of measuring colour of whole seeds using the tristimulus principle of Minolta Chroma meter has been introduced through this study and is now mandatory to the Australian pulse industry. Similarly L*, a* and b* values can be used to determine optimum colour of *dhal* and *besan*.

From a colour perspective, *desi* seeds from VIC and WA tended to be darker than QLD and NSW while seeds from SA had the highest L* values. Among the cultivars, Tyson had significantly lower L* and b* values compared to Semsen. The L* and b* values of QLD *desi* seeds were the highest in 1992/93 and 1993/94 but were the lowest in 1994/95, probably because of the inclusion for the first time of Barwon and Norwin in 1994/95. These differences are largely due to specific varieties grown in different States and to a small extent due to environmental factors.

Site, season and variety were all found to influence the composition of the 4 major commercially traded varieties of chickpea. The weight of 100 seeds was variety-specific and was generally not affected by season or site. Semsen had the largest seed size, Tyson had the smallest seed while Amethyst and Dooen were of intermediate size. The mean weight of 100 Indian *desi* seeds (17.9 g) (Singh and Jambunathan 1978) was not significantly heavier than that for *desi* seeds from Australia (16.3 g) but the difference was large enough to create a requirement for bolder seeds to be exported by Australia to the Indian consumer. This probably explains the continuing demand for larger/bolder seeds from the Indian subcontinent. One hundred seed weight of Barwon

(21.3 g) and Norwin (20.6 g) was, however, higher than the mean weight of *desi* grown in India.

The composition of *desi* seeds was affected largely by cultivar and to a smaller extent by season and site. Tyson was the most distinctive variety analysed. It had significantly higher TDF and fat contents and significantly lower carbohydrate levels compared to the other varieties. On a Statewide basis, however, WA protein was significantly higher than VIC, while TDF of WA and SA was higher than NSW and VIC. These findings suggest that the Pulse Industry should segregate chickpea based on cultivar and site like wheat, so that consistent quality product can be delivered depending on the quality requirements of the end user.

While protein quality and content in chickpea is well documented, information on the types of chickpea starch and their proportions is limited. One of the main problems in estimating amylose and amylopectin contents in chickpea starch is the lack of appropriate standards. Data on amylose and amylopectin levels helps to predict starch-protein interactions in food systems.

More than 75% of the annual Australian *kabuli* production (20,000 tonnes) (P McEvoy, Personal Communication AWB 1997) is handled by private traders as small parcels for niche markets in Europe and North America. The small number of *kabuli* samples received reflect the size of the *kabuli* crop in Australia. The effects of site and cultivar and seasonal trends in composition could not thus be monitored. The protein (22.3 g/100 g) and fat (6.2 g/100 g) contents of Australian *kabuli* were comparable with the Egyptian varieties, however the ash content was significantly lower (2.9 g/100 g) (Attia *et al* 1994). *Kabuli* seeds had a higher L* value and were larger than *desi* seeds. Australian *kabuli* was significantly larger than the Indian *kabuli* (Table 4.1.21) but was often smaller than *kabuli* seeds from Turkey or Mexico which were usually 9 or 10 mm in size (R Greening, Personal Communication BGA Farms 1997). Perhaps the most distinguishing feature in the composition between *kabuli* and *desi* seeds is the lower amount of TDF and higher level of fat in the *kabuli* seeds. This resulted in an increase in carbohydrate and energy levels for non-ruminants in *kabuli* seeds compared to *desi* seeds.

Chickpeas are not routinely used as stock feed and hence there is little information on how energy levels impact on the management of ruminants, poultry and aquaculture industries. Small, shriveled *desi* seeds, including immature grains with big variations in colour are downgraded and used as stock feed. This is undesirable as returns to the farmer is greatly reduced. For the *kabuli* types, however, every effort is made to sell into the food market. There is a worldwide shortage of *kabuli* seeds and they are seldom used as stock feed because of its extremely high price.

In the present study, sodium and potassium levels as expected, exhibited considerable variation between variety, site and season. However, calcium, magnesium, phosphorus, iron, zinc and copper were influenced to a greater extent by genotype and site than season. While some of the differences in mineral content within the *desi* and *kabuli* varieties were statistically significant, the differences were not large enough to affect nutritional status or impact on trade. Mean phosphorus content in *desi* chickpea from NSW in 1993/94 was the highest (522 mg/100 g) and calcium content was the highest in WA and SA samples with no trend observed for magnesium. WA had the lowest level of zinc in all the seasons, but considerable seasonal effect was observed in the zinc level of *desi* seeds from other States.

Contrary to the findings of Jambunathan and Singh (1981) who reported the effect of location on the mineral contents to be low, the findings in this thesis conclude that site has a significant influence on trace mineral content with sodium, calcium, magnesium and zinc significantly affected by site. This result is not entirely surprising, as significant differences in soil types have been reported in the chickpea growing regions of Australia (AWB Crop Forecasting Group 1996).

Calcium content of chickpea bought in the US has been reported at 103 mg/100 g (Meiners *et al* 1976) while mean calcium content of Australian *kabuli* varieties was 43% higher (180 mg/100 g). It was assumed that Meiners *et al* (1976) have reported data on *kabuli* chickpea although this was not specified in the paper. The mean calcium content of *kabuli* cultivars grown at two locations in Egypt was 217 mg/100 g (Attia *et al* 1994). Magnesium content of Australian *kabuli* varieties was significantly higher (167 mg/100 g) than American varieties (92 mg/100 g) (Meiners *et al* 1976). The potassium level in Australian *kabuli* cultivars (1093 mg/100 g) was higher than in

the US *kabuli* (692 mg/100 g) but similar to Indian *kabuli* (1105 mg/100 g) varieties. The iron and copper contents in Australian *kabuli* cultivars was the lowest, whereas the zinc content was the highest compared to the Indian and US *kabuli* varieties. The mean iron and copper contents in Egyptian *kabuli* were 7.0 mg/100 g and 1.0 mg/100 g, respectively (Attia *et al* 1994).

It is thus concluded that significant differences in mineral composition exist between Australian and US chickpeas, presumably due to variation in genotypes and soil types whereas mineral composition of Australian chickpea is similar to Indian and Egyptian chickpeas, probably due to genotypic similarities.

From a nutritional perspective, Australian chickpeas are an excellent source of many minerals (NHMRC 1991). Iron provides about 81% of the RDI for adult males (19-64 years) and post-menopausal females, magnesium supplies about half the RDI for adult men and nearly 60% of the RDI for women. Chickpeas contribute about 50% of the RDI for potassium based on an average RDI of 3705 mg and nearly one-third of the daily requirement of phosphorus and quarter of the daily requirement of calcium and zinc for adult males. Thiamin content of Australian chickpea supplies 55% of RDI for adult men and 75% of the RDI for adult women.

The mean tannin content in *desi* varieties (76 mg/100 g) was significantly lower than reported values. Of the 9 varieties studied by Rao and Deosthale (1982), tannin content ranged from 78 mg/100 g to 234 mg/100 g suggesting large variations existed between varieties. According to the same authors low tannin content was associated with pale coloured seed coats, however, Price *et al* (1980) did not find any association between the colour of the seed coat and tannin content. In the same study, Price *et al* (1980) also concluded that no tannin was present in chickpea or mung beans. The results obtained in this study also does not support any correlation between colour of seed coat and tannin levels in the same type of chickpea. The lower level of tannin in *desi* seeds had no bearing with the colour of the seed coat. Tyson had the darkest seed coat but tannin level in Tyson was not the highest.

Tannin content in *kabuli* seeds (40.3 mg/100 g) was lower than *desi* seeds. More work needs to be carried out to confirm the lower tannin levels in *kabuli* seeds. It is not known at this stage whether the low levels are genetic or related to the paler seed coat.

Petterson and Macintosh (1994) have reported 490 mg/100 g and 240 mg/100 g total tannin content in Australian *desi* and *kabuli* seeds, respectively, which is higher than that reported for chickpea in the literature and in this study. Reddy *et al* (1985) have reported tannin content in chickpea to be in the range of 78-272 mg/100 g. Quantitative variation in tannin values could be attributed to storage, cultivars, growing environment and method of assay. It has been shown by Griffiths (1981) that using tannic acid as a standard results in higher tannin values than the vanillin assay that uses catechin as a standard. There is also considerable debate on the type of tannin (condensed or total) each of the assay measures (Deshpande *et al* 1986).

5.1.2 *Dhal* from Commercially Traded *Desi* Seeds

The influence of the seed coat on the composition is most pronounced when whole seeds are dehulled to produce *dhal.* In the present investigation, protein, fat, carbohydrate and energy for non-ruminants increased significantly while TDF value decreased in *dhal* compared to whole seed. Energy for ruminants has not been tabulated for *dhals* as dehulled chickpea is seldom used as stock feed due to the substantial cost of the raw material and the additional cost of processing. Varietal differences influenced *dhal* composition more than site differences.

Irrespective of the variety, calcium and magnesium contents of *dhal* are lower than whole seed suggesting that the two minerals are lodged in the seed coat. Depending on the variety, potassium content in *dhal* was 6-16% lower compared to whole seed which is in agreement with the findings of Jambunathan and Singh (1981) who reported a 10% decrease in potassium content of *dhal* compared to whole seed. The iron, zinc and copper levels were not affected by dehulling. The increase in phosphorus content of *dhal* was variety specific, ranging from 8-18%.

The overall mean protein content of 25.4 g/100 g was similar to the mean protein for *desi dhals* from India (26.4 g/100 g) while the mean ash content (2.6 g/100 g) was significantly lower (2.8 g/100 g) than that reported by Jambunathan and Singh (1978). The mean fat content in *dhals* from Australian *desi* varieties was higher (5.8 g/100 g) than that in *desi dhals* grown at 2 different locations in India (5.3 g/100 g) (Jambunathan and Singh 1978).

Like *desi* whole seeds, d*esi dhals* are also a good source of iron; as 100 g *dhal* is equivalent to 80% of RDI for adult men and women over 54 years (RDI for iron = 7 mg/day) (NHMRC 1991).

There was no difference in the mean calcium content of Australian and Indian *dhals* but the magnesium levels in Australian *dhal* (96 mg/100 g) was lower than that reported by Jambunathan and Singh (1981) (121 mg/100 g). The decrease in magnesium levels of Australian *dhal* compared to whole seed was more than twice (39%) the decrease in Indian *dhal* (18%) (Jambunathan and Singh 1981). Phosphorus content in Indian *desi dhal* was higher than Australian *dhal* because phosphorus content in Indian *dhal* increased by an average of 18% compared to whole seed (Jambunathan and Singh 1981).

When the trace mineral composition of *dhal* was analysed on a Statewide basis many nutrients exhibited significant differences suggesting that mineral composition was affected to a greater extent by site differences than varietal differences. This observation is similar to the trend exhibited by whole seeds.

5.1.3 Advanced Breeding Lines

There are several published papers on the interactions between genotype and environment and its affect on quality of chickpea. Several researchers have stressed that differences between cultivars were less prominent than those due to cultivation in different agroclimatic regions (Dodd and Pushpamma 1980, Attia *et al* 1994). In other words environmental factors over ride genetic differences. Slinkard (1995) also believes that site has a major impact on agronomic performance of the same variety of field peas and lentils, in particular. Singh and Jambunathan (1978), however, reported that chickpea varieties could be developed at any site for propagation in different regions. Singh and Jambunathan (1978) have based their conclusion on similar compositional data obtained for like varieties grown at different sites in India. Slinkard argues that varietal differences in field pea is minimal, because 'cross over' is usually from genetic material obtained from already released commercial varieties. Differences in new releases are therefore largely due to environmental factors. Thus, if the genetic make up is similar the only factor responsible for differences in composition is the location of growth.

The original germplasm for all Australian chickpea varieties was imported from India *(desi),* Iran, Russia, USA *(kabuli)* and the varieties have been selected for Australian agronomic conditions such as soil pH, soil type, rainfall and disease resistance. Varieties suited to Australian growing conditions have been identified by a process of natural selection (J Carter, Personal Communication TLC 1997). Although genetic manipulation has not occurred to modify the proximate composition, processing properties or functional properties of any of the varieties, significant changes have been identified in these parameters between Australian and overseas varieties. While Slinkard's theory is valid in this instance, large varietal variation observed for some processing properties were absent when the data was analysed on a Statewide basis. These results suggest that both the hypotheses can be substantiated in a given context. Differences in composition could occur due to the influence of genotype and location, whereas differences in processing properties is due to the influence of cultivar only. This suggests that the composition and processing properties of advanced breeding lines should be routinely monitored and documented prior to release.

Significant improvements from a nutritional point of view were observed in the composition of advanced breeding lines of Amethyst, Tyson and Barwon. These lines had a higher TDF and lower carbohydrate and energy levels for non-ruminants compared to commercially traded varieties. New advanced breeding *desi* lines such as T 1414 and T 1239 exhibited excellent physical properties compared to other advanced breeding lines. With respect to composition, T 1239 and T 1414 had higher fat, carbohydrate and energy for non-ruminants. Some new advanced breeding *kabuli* lines such as UC5 had ideal physical properties especially with respect to size, while T 1000 exhibited below average physical properties coupled with low protein and high ash content.

The observed differences in correlation between individual components with the *desi* and *kabuli* chickpea type suggest that although the two types of chickpea belong to the same genus, for all practical purposes *desi* and *kabuli* types should be treated differently.

5.2 Processing Properties of Whole Seed

5.2.1 Soaking and Sprouting

Soaking of whole seeds is an essential pre-processing step prior to sprouting, cooking, dehulling, wet grinding and fermenting; although the duration of the soak and type of soak solution may vary with each process and pulse. Evaluation of soaking properties of *desi* whole seeds showed that the rate of water absorption of common Australian *desi* varieties can be classified into 3 categories; rapid, medium and slow. Seeds with rapid uptake exhibited maximum water absorption within the first hour of soaking and for the next 4 hours e.g. Amethyst, Tyson and Barwon, while those with medium water uptake displayed maximum water absorption after 4 hours of soaking e.g. Dooen. Slowest water uptake was observed in Semsen and Desavic. Thus, initial water uptake was the highest in the small seeded Amethyst and Tyson and slowest water uptake was in the larger seeded Semsen and Desavic. As expected, within a type of chickpea i.e., *desi* or *kabuli;* seed size, (either represented as seed weight or volume) had a major impact on water absorption. Norwin seeds were larger than the average *desi* seeds but, they exhibited an initial high rate of water absorption suggesting that other factors such as thickness and hence permeability of seed coat and varietal differences can override seed size.

Despite its larger size, *kabuli* seeds showed a higher rate of water absorption than *desi* seeds probably because of a thinner seed coat. More *kabuli* genotypes need to be evaluated to fully understand factors that influence water absorption.

During the initial stages of soaking, structural features such as hilum and micropyle, seed coat thickness (Sefa-Dedeh and Stanley 1979), seed size and temperature of soak water affect the rate of water absorption. It appears that once the resistance to water uptake is overcome (i.e. seed coat is tender) HC is affected by the surface area available for water absorption. Large seeds have a larger surface area (sq cm) but, grams of water absorbed per sq cm is small resulting in lower water uptake. Therefore, it must be noted that bold seeds may have visual appeal, however, it is the small wrinkly seeds that have high water absorption. The economic benefits of small seeds from a processor's point of view must be highlighted to traders who are always seeking bold seeds. Moreover, at the end of 8 hours there is practically no difference in HC between varieties with varying sizes. Although seed size and its effect on water

absorption cannot be over emphasised, seed permeability of certain newer varieties with bold seeds compensates for the slow water uptake due to large size (GRDC Final Project Report DAV 273A 1997).

Overall, genotypic variations had a greater effect on water absorption than did growing sites for soaking and sprouting. In other words, variations in water absorption were largely due to varietal differences and to a lesser extent due to environmental factors.

5.2.2 Cooking Quality

An attempt was made to measure the cooking time of *desi* and *kabuli* seeds and correlate the same with deformation values, but due to lack of consensus in the literature and between pulse researchers on the exact end-point of 'cooked seed status' the procedure was discontinued. According to some researchers (P. Burridge, Personal Communication SARDI 1997), the absence of the white central core is an indication that the seeds are cooked while others (U Singh, Personal Communication ICRISAT 1995) consider seeds to be cooked when they are easily deformed between thumb and finger. It was noted in this study that the size of the core does not always decrease proportionately with an increase in cooking time and the problem is compounded by the presence of hard seeds in samples. The problem is exacerbated when cooking time of pre-soaked seeds (which is a desirable pre-treatment prior to cooking, Silva *et al* 1981) is determined because (a) cooking time *per se* is reduced dramatically due to soaking and (b) identifying the 'end point' becomes extremely difficult. Measuring cooking time by the methods described above highlights the subjective nature of measuring cooking quality and the need to obtain a reliable and objective method.

In the last decade, Australia has become the only country outside the Indian sub-continent producing and exporting significant quantities of *desi* chickpea and is competing for the export *kabuli* market with Turkey, Mexico and Syria. Premium prices can be sought for products with superior cooking quality. Although most of Australia's chickpea production is usually destined for overseas markets soon after harvest, repeat orders especially for the *kabuli* type have been slow (R Greening, Personal Communication BGA Farms 1997). This is because of a perception by some importers of the apparently inferior cooking quality of Australian *kabuli* chickpea. The cooking quality of chickpea and its measurement has always been a highly debated issue among Australian researchers. It is difficult to challenge the perception of

inferior cooking quality of Australian *kabuli* unless there is a rapid and objective test that can reliably compare cooking quality between samples. Bourne (1972) has successfully used the Instron to conduct puncture test on several individual pre-cooked beans as a good index of textural quality. Although the method is rapid a reasonable degree of skill is required by the operator to place a cooked bean in the path of the probe in quick succession. Furthermore the method is practical for the large beans of the Phaseolus family. Bhatty *et al* (1983) have used an Instron texture meter to compare cooking quality of lentils. They found a shear force < 4 kg/g indicated cooked, and > 4 kg/g undercooked lentils. To attain a shear force of 4 kg/g, however, the lentils had to be cooked for 60 minutes, which can be time consuming.

Data obtained in this study show that deformation values obtained from the objective texture analysis method can estimate degree of softness of cooked *desi* and *kabuli* seed with a high degree of precision and small standard deviation. The advantages of using the texture meter are manifold. Deformation values (mm) obtained from identically treated samples are comparable, reproducible, not operator dependent, averages out the effect of hard seeds present because testing is conducted on 5 g of cooked sample and repeated thrice with a fresh sample. The information so generated has been shown to accurately predict cooking quality of chickpea since deformation is negatively correlated to cooking time for samples that were identically treated. Speed, ability to rank samples objectively on the basis of deformation values and requirement for only a small sample size are the other major advantages of the test. It is most suited to evaluate cooking quality of breeder samples in relation to an existing variety. Both samples can be processed simultaneously and results can be attained under identical conditions.

A major constraint for pulse consumption is storage-induced textural defect commonly referred to as hard-to-cook (HTC) phenomenon. Liu *et al* (1992) used a texture analysis method to measure the HTC phenomenon and observed that the hardness increased from 15.8 to 91.4 Newton force/g of 1 hour cooked cowpea seeds when storage increased from 0 to 18 months. In this study, cooking quality was evaluated by an objective texture analysis method measuring deformation of pre-cooked seeds at constant speed and fixed force. To minimise the effects of HTC, deformation studies were conducted soon after harvest.

Cooking quality has been evaluated by measuring the degree of deformation and was found to be dependent on a range of physical factors such as location of growth, genotypic variation, season, seed size, age of seed, presence of hard seeds in sample, thickness of seed coat and chemical factors such as starch-protein matrix, fat content and effect of polyphenols. Recent studies have shown that cooking quality of pulse seeds appears to depend, at least in part, on the sequence of coagulation of storage proteins and swelling of starch granules during heating (Liu 1997).

Texture analysis on limited number of commercially traded *desi* and *kabuli* samples showed that different pre-cooking soak times and salt strengths required to obtain maximum deformation were different for *desi* and *kabuli* seeds. *Desi* seeds soaked in 2% salt solution for 8 hours had maximum deformation while *kabuli* seeds soaked in 1% salt for 16 hours produced maximum deformation. Pre-treatments affected deformation and work done values of *desi* and *kabuli* seeds to different extents, but the effect on deformation value of cooking unsoaked seeds were similar for both the types. Soaking prior to cooking increased deformation values of *desi* and *kabuli* seeds which is in agreement with previous findings (Singh *et al* 1988) that soaking decreased cooking time.

It is also evident from this study that the overall deformation value (mm) for *kabuli* type is greater than the *desi* type. This correlates well with the findings of Singh *et al* (1988) who found *desi* seeds had a longer cooking time than *kabuli*.

Among the advanced breeding *desi* cultivars, T 1414 and T 1239 had significantly higher deformation than the other varieties evaluated. T 1414 is a semi-bold variety (24 g/100 seeds), has pale brown colour, good hydration capacity (results not reported) and superior cooking properties. Results obtained from this study in part has resulted in the commercialisation of T 1414 as Lasseter (G Rodger, Personal Communication AWB 1996). Lasseter is most suited to grow in the Wimmera and Southern Mallee regions of VIC and the first commercial crop is to be harvested in 1997/98. Due to its visual appeal, attempts are currently underway to market Lasseter as a 'table grade' type of chickpea at the retail level in the Indian subcontinent. The physical properties (size and colour) of pulses are considered to be of paramount importance and Lasseter's uniform pale colour and size are exploited in attempting to

market it as whole seeds. Furthermore, consumption of whole seeds increases intake of dietary fibre which is a nutritional advantage. It also has higher levels of carbohydrate and fat compared to other *desi* varieties (section 5.1.3) giving it a better taste (AWB 1997). *Desi* chickpea are traditionally processed to yield *dhal* or *besan*. It is expected that Lasseter will command a premium over existing *desi* varieties and as there is no processing cost if Lasseter is to be consumed as whole seeds, returns to the retailer are expected to be high which will then flow back to the primary producer in Australia.

Among the advanced breeding *kabuli* cultivars T 1000 (germplasms from Iran and Russia) had low deformation values and does not show potential for commercial release. UC5 from VIC and Narayen from 1994/95 season had high deformation values but, the effect of site and season for these two varieties needs to be investigated further before they can be recommended for commercial production; as UC5 from NSW and Narayen from 1995/96 season had only average deformation values.

A positive correlation was observed between weight of 100 seeds and deformation of *desi* and most *kabuli* cultivars providing some 'clues' on cooking quality of chickpea genotypes. Williams *et al* (1983) reported that seed size, whether measured as weight or volume, hydration capacity and swelling capacity were highly correlated to cooking time of *desi* and *kabuli* seeds. Singh *et al* (1988), however, observed a high positive correlation between seed size and cooking time for *desi* seeds only. They attributed the reduced cooking time of *kabuli* seeds to differences in thickness of seed coat between *desi* and *kabuli* seeds. A negative correlation was observed between TDF content and deformation value for both *desi* and *kabuli* seeds (GRDC Final Project Report DAV 273A 1997). In other words as TDF content decreased, deformation increased which partly explains the higher deformation values of Lasseter (*desi* type) and all *kabuli* seeds.

5.2.3 Dehulling

As *desi* chickpea are usually dehulled and consumed as *dhal* or *besan* in the Indian subcontinent, there was need to evaluate dehulling efficiency of *desi* lines and recommend varieties with higher *dhal* yield to the market. In order to draw meaningful comparisons it was imperative that *dhal* yields be measured in mills similar to those used in the target country. The absence of such a mill in Australia led to the

planning and designing of a prototype pulse mill. The successful manufacture of the custom-built AGT pulse mill was a major advance in evaluating dehulling efficiency of *desi* chickpeas. The high speed of the emery coated carborundum rollers provide the abrasive force required to 'peel' the seed coat from the cotyledon. The distance between the rollers and the perforated screen fitted around the carborundum rollers tapers from the feed end to the product end to allow the easy flow of the whole seed at the mouth of the mill and force the *dhal* out of the mill. This also prevents further scouring of the *dhal*. In order to ensure minimal scouring of the cotyledon and hence minimise losses, the mill was tilted with the feed end being positioned higher than the product end to allow the heavy splits to 'fall out' of the mill. The lighter husk is collected separately in a bag and the brokens and powder fractions are collected in a tray located under the roller. The noise level and the dust generated by the mill are within Australian Occupational Health and Safety Standards. The mill can be partly dismantled to clean the rollers between samples.

Thus the AGT mill is the only laboratory mill made in Australia that mimics dehulling conditions in majority of the Indian pulse mills and it is an important research tool since India is the largest buyer of Australian *desi* chickpea. The AGT mill can thus be considered a prototype for future commercial laboratory mills to dehull pulses although it will require continuous improvement and refinement. The areas of mill design that need further investigation include altering the angle of tilt of the mill to attain optimum resident time of pulses in the mill, modifications to mesh size to selectively release only the brokens and powder fractions and adjusting the speed of the carborundum rollers for untreated and pre-treated samples. The AGT mill also offers an economic advantage over other commercial mills that have to be imported in to the country. The AGT mill compared well in performance with the Satake and ICARDA (commercially built) laboratory mills.

Based on a limited number of samples, it appears that a wide variation does not exist in the dehulling characteristics of commercially traded chickpea genotypes. *Dhal* yields of commercially traded unconditioned Dooen (69%) and Semsen (69%) were significantly lower than Amethyst (72%) and Tyson (73%), however, *dhal* yield of only Tyson (75%) was significantly higher than the other 3 varieties after pre-treatment. Pre-conditioning with water did not significantly increase *dhal* yield in any

of the mills. Modifying pre-treatment procedures such as increasing contact time with conditioning liquid, changing the composition of the conditioning liquid or increasing temperature of drying may result in a significant increase in *dhal* yield and needs to be investigated. Pre-conditioning by soaking seeds in sodium chloride and sodium bicarbonate significantly increased *dhal* yields and decreased operational losses.

Richert *et al* (1984) have shown that greater than 75% of the variability in *dhal* yield of pulses could be accounted for by grain hardness and resistance to splitting of grain into individual cotyledons. This study suggests that seed size plays an important role in determining *dhal* yield or dehulling losses in chickpea. Iyer and Jarvis (1996) also reported that dehulling efficiency is largely dependent on seed size and found that the AGT mill preferred seeds weighing between 15-25 g/100 seeds.

Within a variety, an increase in seed size increased *dhal* yield. *Dhal* yield and seed size of commercially traded Semsen was higher and larger, respectively, than the advanced breeding line. Tyson from the advanced breeding line has a smaller seed size (13.5 g/100 seeds) and hence is not suited for dehulling (68% yield) compared to the commercially traded variety which had 73% yield (16.0 g/100 seeds).

However, commercially traded Semsen which was larger (20.1 g/100 seeds) than Tyson had a *dhal* yield of only 68%. Thus there are inter-varietal factors in addition to seed size which affects *dhal* yield. The *dhal* yield, like deformation is thus dependent on a range of physical and chemical factors. It is crucial then to monitor key processing properties of advanced breeding materials prior to release. As expected, uniformity in seed size improves dehulling efficiency. It is likely that there exists a positive correlation between seed size measured as seed diameter and *dhal* yield which would largely depend on the mill type and settings of the mill. Seed size measured as seed weight is probably not a good index of evaluating dehulling quality. Sample size was the limiting factor in some instances and hence seeds were not size graded before milling.

Dhal quality as judged by colour (L* brightness) was the highest when chickpea were soaked in 1% sodium bicarbonate and lowest for sodium chloride pre-treatment (Iyer and Jarvis 1996). The effect of soaking seeds in salt solutions on the sodium content of *dhal* needs to be investigated from a nutritional point of view.

Of special interest among the advanced breeding lines were T 1414 and T 1239 with consistently high *dhal* yields (mean 76% and 77%, respectively) and low whole seed count (0.6 g and 0.4 g, respectively). Amethyst also exhibited good *dhal* yield but with a slightly higher whole seed count. From a processor's point of view, desirable attributes for a good dehulling variety include: clean separation of husk from cotyledon, the cotyledon should not be prone to fracture, less re-work (low whole seed count) and the release of small amounts of the brokens and powder fractions to minimise losses and dust levels in the mill.

Owing to its superior cooking quality and excellent dehulling properties, T 1414 is a versatile variety and has a dual purpose; to be consumed as whole seeds or dehulled to produce *dhal*. Combined with its outstanding agronomic performance in experimental plots, it has recently been commercialised as Lasseter. In order to fetch premium prices it will need to be identity-preserved by setting up segregation programs at specific receival sites.

5.3 Functional Properties of Composite Flours

The emulsification capacity of wheat flour increased by 64% when supplemented at 50% level with chickpea flour. Flour solubility (14.9 g/100 g) improved with an increase in level of supplementation and with an increase in temperature (42 g/100 g @ 95 °C in SW:KCP 50:50). The improvement was more pronounced in composite flours containing soft wheat and *kabuli* flours. Swelling capacity of soft wheat (4.5) was considerably improved to 6.6 at 50% supplementation with *kabuli* flour. The study on functional properties of wheat-chickpea composite flour indicates that the pasting properties and emulsification capacities of wheat flours could be improved by supplementation with *desi* chickpea in food systems. It is advantageous to have increased emulsification capacity as this enhances product stability. As a significant difference in emulsification capacity was observed between *desi* and *kabuli* raw flours, the effect of heat treatment of pulse flours on the emulsification capacity of composite flours needs to be investigated. According to Singh (unpublished data), roasting considerably lowered emulsification capacity in *desi* and *kabuli* flours. *Desi* chickpea flour which contained the highest protein also showed the highest emulsification capacity. The observed differences in emulsification capacity of *desi* and *kabuli* types

suggest that detailed study on the nature of protein fractions and their emulsion properties would be very useful. Emulsification stability can be greatly increased when highly cohesive films are formed by the absorption of rigid globular protein molecules that are more resistant to mechanical deformation e.g. lysozyme (Graham and Phillips 1980). The higher emulsification capacity of composite flours is useful when foods are fried. Batters and coatings used for deep frying in Asian cuisine often consists of large portions of chickpea flour and small quantities of rice or wheat flour (N Malleshi, Personal Communication CFTRI 1993).

Heating (boiling and roasting) lowers NSI of mung bean flours (del Rosario and Flores 1981) and it can be extrapolated that composite flours containing roasted *desi* and *kabuli* flours may exhibit a similar change in NSI. Composite flours containing *desi* chickpea flour exhibited higher NSI than composite containing *kabuli* at pH 6.0 and pH 7.0, providing information on the effect of composite flours in low acid and near neutral foods. Viscoamylographic studies on composite flour highlighted the diverse nature of starch matrices of composite flours and its effect on starch paste viscosity and their possible applications. Some of these results were successfully used in the production of instant noodles where a high starch paste viscosity is a desirable characteristic.

Based on the analysis of a limited number of varieties, chickpea flour appears to have functional properties similar to those of other pulses indicating its good potential in various food applications.

5.4 Production of Value-Added Products

The research on 'value-added' products has successfully demonstrated that traditional wheat based recipes can be modified to include chickpea flour (*desi dhal*) or chickpea hull (*kabuli*) to improve functional properties and nutritive value without affecting taste and general acceptance of the product.

Since the recent popularity of instant noodles, opportunities have arisen to manufacture noodles from different raw materials to increase nutritional value and enhance taste. The food industry is seeking to increase market share with interesting and healthy alternatives utilising cheap and naturally occurring ingredients, to satisfy the growing needs of a demanding and discerning market. The nutritive advantages in

experimental noodles made from wheat flour supplemented with roasted *besan* included moderate increases in protein, thiamin and riboflavin contents, a decrease in fat content and a probable decrease in phytic acid level (not measured). The brightness and yellowness of SDN containing roasted *besan* was higher than all other noodle types at all levels of supplementation which is a distinct advantage in the acceptance of yellow alkaline noodles. As expected, the fat content of SDN was significantly lower than IN and the mean fat content of IN containing roasted *besan* was 21%, unlike IN containing raw *besan* where fat content increased with *besan* supplementation. SDN with roasted *besan* had lower water activity than the other noodles thereby reducing shelf life problems. SDN containing 10 parts of roasted *besan* was preferred over the control noodles with respect to colour, texture and acceptable flavour.

The low fat SDN has shown the potential to be promoted as a healthy noodle and IN containing 5% and 10% chickpea flour can be developed as a snack noodle. Recent studies on dietary requirements and purchasing pattern of young adults, especially women in the 18-35 years age group, depict an increased need for fat-free or low fat foods (Morris 1997). There is potential for the low fat SDN to be promoted specifically for this market segment. On the other hand, IN is popular among school children and the new product could be popularised as a snack with a range of flavours that fits in a lunch box. In fact the chickpea flour itself can act as a healthy (due to nutritional complementarity) flavour extender. Also, varietal effect of chickpea flour on quality of end product should be evaluated. Based on these results to date, a large food processing company has shown considerable interest in commercialising these products as healthy noodle alternatives.

About 8 million packs of IN (85 g each) are manufactured daily by one large food processing company in S E Asia (V Alisauskas, Personal Communication AWB 1997). At an approximate 10% adoption rate of the new product, 800,000 @ 85 g packets to be manufactured would require about 104,000 kg of flour at 15% supplementation. Flour yield is about 75% from whole seed which computes to 140,000 kg of *desi* seed per day. If this product were to be commercialised the economic implications for the Australian chickpea industry are enormous.

The overall quality and acceptance of bread made from bakers flour supplemented with hull from Garnet at 1%, 2% and 5% and Kaniva at 1% and 2% was very high and at

lower levels of supplementation was better than bread from wheat flour. TDF in all experimental breads was higher than wheat-only breads but the TDF content was similar in the 1% and 2% supplemented breads and higher in 5% supplemented breads. The increase in TDF value was accompanied by a decrease in carbohydrate content and a net decrease in available energy which is a beneficial health attribute in affluent societies.

The inclusion of hull from pale coloured *kabuli* seeds in bread formulations makes good use of a by-product that is otherwise disposed cheaply. Crust colour was unaffected by supplementation and yellowness of crumb increased only when flour was substituted with 5% Kaniva hull. Loaf volume and texture are two important parameters that are used to judge bread quality and these attributes were not compromised due to lower levels of supplementation. The addition of hull in experimental breads did not have any detrimental effect on bread quality. However, the effect on bread quality was different at various levels of substitution for the two types of hull. Bread quality deteriorated with an increase in level of Kaniva supplementation but quality of bread containing Garnet improved at 5% supplementation compared to bread containing 2% Garnet hull. Field pea hull in bread is claimed to have anti-staling properties (K K Lim, Personal Communication Prima Flour Mills 1997). It would be interesting to study the effect of *kabuli* hull on the shelf life and freezing ability of breads.

Evaluation of bread quality following the addition of a wide variety of non-glutenous substances such as milk powder and pulse flours with a view to increasing protein content or protein quality has been conducted by many researchers (Hallab *et al* 1974). Protein deficiency is not a problem facing developed countries and there is no nutritional advantage or commercial attraction in popularising products with high protein content. An increase in the incidence of colon and bowel cancer in Western societies has increased awareness of the merits of a fibre rich diet. Increasing fibre in bread with a natural and cheap ingredient has economic advantages to the processor and fulfills the needs of the consumer in a modern society.

Conclusions

6 Conclusions

Pulse production in Australia is increasing and targeted to reach 4 million tonnes by the year 2000 (Pulse Australia 1997). However, minimal efforts and resources are spent on developing the market based on quality parameters of pulses as food. In a free trade environment, there is no strategic plan to export pulses; exporters tend to be opportunistic and the markets are usually price sensitive. About 60% of Australian pulses is exported to the Indian subcontinent for food use as the region's pulse production is stagnant and there is a huge demand for plant proteins for its increasing population which is predominantly vegetarian. As domestic consumption of pulses for all practical purposes is non-existent in Australia, there is an urgent and continuing need to find new markets and service existing ones in order to obtain premium prices for pulses crops which demands greater management to grow than cereals.

The results in this thesis provide information on all aspects (physical, chemical, nutritional and functional) of Australian chickpea to the industry which should have positive ramifications to both export and import trading partners. This study has developed and improved the current knowledge of Australian chickpea quality and has helped foster better links with the market because of continuous exchange of technical information. This study has sent clear signals to the Indian Pulse Importers Association that the post harvest research conducted on Australian chickpea is customer focused and market driven (B Kothari, Personal Communication Kothari Group 1997).

This study provides the first detailed information on composition of the major commercially traded varieties over four seasons and between the main chickpea producing States and comparatively evaluates the quality of advanced breeding lines for *desi* and *kabuli* types. New objective data on the colour of chickpea seeds has been generated from this study which will help in making meaningful comparisons of colour between and within varieties, sites and seasons as it is an important consideration that influences price in the food market. This information has already been able to lift the profile of chickpea from stock feed status to human food, especially in Australia.

There are statistically significant differences in physical properties, composition and micronutrient content between *desi* varieties from different sites although more *kabuli*

samples need to be analysed to be conclusive about their differences. Despite the site and varietal differences, Australian chickpea is comparable in composition to the Indian type and should be readily accepted into the Indian subcontinent market. As data on quality of Australian chickpea emerges through this research, it is hoped the traditional market (Indian subcontinent) is converted from being price conscious to being quality conscious.

This study has shown an important finding: processing attributes are more relevant for quality assessment than composition alone, although the processing attributes are largely governed by a combination of physical and chemical characteristics of chickpea. An enhanced protein or fibre content will not assist in increasing returns to the primary producer as much as seed which gives increased *dhal* yield, or rapid sprouting or possesses superior cooking quality. This study has proved that evaluating chickpea composition by quantifying the proximates in a traditional manner as for wheat, does not give adequate information on processing properties. This is shown by the similarity in composition of the four commercially traded varieties but the large differences in processing properties of soaking, cooking and dehulling. This suggests that there should be differences between them in canning, roasting (puffing) and extrusion capabilities. Starch-protein interactions and its effect on the fibre content needs to be investigated to get a more detailed knowledge on processing properties.

Niche markets can be developed for specific end uses based on information obtained from this study on varieties with rapid water absorption, good sprouting properties, superior cooking quality and high dehulling efficiency. There is a clear message from this study that the industry should graduate from trading chickpea as a commodity to marketing it as a consumer product with specific end-use(s). Markets will be better serviced by traders being able to match appropriate varieties to end uses and this will in turn secure premium prices. As differences in processing attributes between varieties are highlighted there is a growing need to segregate based on cultivar and site to achieve premium prices. This will no doubt exert further pressure on the grain handling authorities to modify receival infrastructure but such investments will pay off in the long run. Being able to deliver specific quality products will also increase Australia's profile in the market place.

Cooking quality was evaluated by a rapid, objective ranking test developed during the study and its accuracy was tested by measuring deformation of *desi* and *kabuli* seeds that were subjected to a range of pre-treatments. The method is reliable, not operator dependent, requires only a small sample size and reproducible. Breeders lines from State Departments of Agriculture (Australia) are now regularly tested for cooking quality by this method and it is close to becoming the industry standard in Australia. The findings on Lasseter having exceptional cooking quality coupled with uniform colour and semi-bold size led to early commercialisation and it is now positioned itself to bridge the gap between the cheaper *desi* type and more expensive *kabuli* type. It is being promoted as a 'table grade' chickpea for the top end of the Indian market and should fetch a premium price.

Evaluating dehulling efficiency of *desi* seeds using equipment similar to that used in the target country was established as essential. The custom built mill generated by the study produces good quality *dhal* and can identify genotypic differences. The dehulling process is rapid and requires only small samples. It can also be used in a continuous process. Commercially traded Tyson had superior dehulling efficiency but the same was not true for the advanced breeding line of Tyson. Lasseter and T 1239 had higher *dhal* yields than other advanced breeding lines and produced brightly coloured bold *dhal*. Lasseter was thus shown to be a dual purpose versatile product.

The study on functional properties provided useful information on the behaviour of composite flours at different temperatures and environments (e.g. pH, water, oil) relevant in food formulations. The information will help to predict functionality of composite flours containing wheat and chickpea in product development studies.

The successful production and acceptance by the panelists of IN and SDN containing raw and roasted *besan* serves as a vehicle to popularise pulse based products. Significant increases in fibre content of bread was achieved by adding cheap and natural ingredients without affecting bread quality, appearance or taste. This product has also shown the potential to be commercialised as a specialty type of bread.

The data from this study will be useful in increasing direct exports to the Indian subcontinent (unprocessed grain) and if the new products are commercialised it will be reflected as increased sale of processed chickpea to non-traditional markets such as, S

E Asia and Europe (economic factors permitting). Domestic consumption may increase if the products are commercialised and promoted in Australia.

The findings will also benefit chickpea breeders who will for the first time have a complete profile of the different chickpea varieties grown in Australia. It will also provide them with accurate information on advanced breeding lines compared to commercially traded varieties.

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APPENDIX I
SENSORY EVALUATION OF NOODLES

Name:----------
Sample No:----------

Date:----------

Place a circle around the number that best describes the attribute for that sample. You may taste the sample marked C between 2 samples.

COLOUR

Extremely yellow	Moderately yellow	Creamy white	Moderately white	Extremely white
1	**2**	**3**	**4**	**5**

STRENGTH

Extremely strong	Moderately strong	Neither	Moderately weak	Extremely weak
1	**2**	**3**	**4**	**5**

FIRMNESS

Extremely firm	Moderately firm	Neither	Moderately soft	Extremely soft
1	**2**	**3**	**4**	**5**

CHEWINESS

Extremely chewy	Moderately chewy	Neither	Moderately tender	Extremely tender
1	**2**	**3**	**4**	**5**

FLAVOUR

Extremely wheaty	Moderately wheaty	Neither	Moderately beany	Extremely beany
1	**2**	**3**	**4**	**5**

Other comments:----------

Thank you

APPENDIX II
EVALUATION OF BREAD

Name:---------- Date:----------

Please score each of the breads for the following attributes. You may score the breads in any order.

MAXIMUM POINTS	VOLUME	GENERAL APPEARANCE	COLOUR	TEXTURE	AROMA	TOTAL
	25	25	20	20	10	100
S. No.-----						
S. No.-----						
S. No.-----						
S. No.-----						

Comments _____

_____

_____

Thank you