Wheat and Flour Properties Affecting Tandoori Bread Quality

Doctor of Philosophy

Irfan A.Hashmi 1996

VICTORIA UNIVERSITY OF TECHNOLOGY
3 0001 00501 1855

WHEAT AND FLOUR PROPERTIES AFFECTING TANDOORI BREAD QUALITY

Presented as a thesis for the degree of

Doctor of Philosophy

of

Center for Bioprocessing and Food Technology

Faculty of Science

Victoria University of Technology

Werribee, Australia

VICTORIA UNIVERSITY OF TECHNOLOGY

VICTORIA UNIVERSITY OF TECHNOLOGY LIBRARY

by

Irfan A. Hashmi

B.E. (Chemical Engineering, N.E.D. University of Engineering and Technology, Karachi, Pakistan)

M.S. (Chemical Engineering, University of Tennessee, Knoxville, USA)

December 1996

WER THESIS
664.7523 HAS
30001005011855
Hashmi, Irfan A
Wheat and flour properties
affecting tandoori bread
quality

CONTENTS

DECLARATION

I, Irfan Akhtar Hashmi, hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it 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.

[redacted]

Irfan A. Hashmi

ACKNOWLEDGMENTS

I would like to thank Dr. Michael Wootton for his advice, guidance and supervision throughout my research career. I would also like to thank Professor Stirk Kyle for his assistance throughout the period of my study.

The support of the Australian Wheat Board in funding this project is greatly acknowledged. I am thankful to the staff of the Academy of Grain Technology for their cooperation.

My thanks are also due to Mr. Essa Al Ghurair for his understanding and financial support throughout my stay in Australia.

My deepest gratitude is for my companion Rubina H. Hashmi, who has provided me with so much love and support.

LIST OF PUBLICATIONS/PRESENTATIONS

A. PAPERS PRESENTED AT DIFFERENT CONFERENCE DURING THIS STUDY.

B. PAPERS GENERATED FROM THIS STUDY AS OF DECEMBER 1996.

LIST OF FIGURES

LIST OF PLATES

Chapter 2

LIST OF TABLES

Chapter 2

Chapter 3

Chapter 4

LIST OF APPENDICES

ABSTRACT

Wheat and flour properties affecting Tandoori bread quality were studied. Tandoori bread, baked in a Tandoor (oven), is a single layered flat bread which is consumed in many countries of non-oriental Asia as the dominant wheat based product.

Among the 23 Australian wheat samples studied for the production of three different types of Tandoori breads (ie. Pakistani Roti, Indian Naan and Irani Taftoon), Batavia and Trident varieties (at protein levels of 11.4% and 10.3% respectively) ranked highest during the evaluation of all the cultivars.

A new test baking technique for Tandoori bread production was developed with the establishment of processing formulations and conditions for consistent and reproducible results with adequate precision. Comparison of the test baking method with commercial practice showed it to be relevant to commercial practice and can be used to predict the performance of flours for commercial production as it can easily be adopted for routine use in cereal testing laboratories.

A test Tandoor was designed, installed and commissioned which can be precisely set to a range of parameters controlling gas flow and air supply. With the use of this Tandoor, reliable and repeatable small scale manufacture of Tandoori breads in subsequent phases of this program was achievable.

A new evaluation procedure for Tandoori bread was developed. This system is capable of discriminating between wheat varieties and was used to investigate the effect of milling, processing and ingredients on the quality of Tandoori breads.

A Farinograph consistency of 500 BU was the best predictor of baking absorption for Tandoori bread. All test breads were baked with 1.5% salt, 0.5% dry yeast and 0.2% baking soda (of flour weight). A standard mixing time of 5 minutes and a proofing time of 80 minutes at 34^{0}C was used throughout the test baking. All doughs were divided into 40 g dough pieces and were rested for 5 minutes before a final sheeting to 1.5 mm thickness. This resulted in oval shaped dough pieces, which were then docked with nine holes and baked at 330^{0}C for 55 sec.

Results of ANOVA showed that each wheat, depending on its own properties resulted in significantly different Tandoori bread scores. However, no significant differences were observed in the evaluation carried out by the panellists.

A correlation matrix between selected wheat and flour properties, and Tandoori bread quality parameters showed quite a few significant correlations. Among those correlations between wheat and flour protein and each of Tandoori bread score, rolling quality, tearing quality, chewing quality, bread crust colour and the taste were strong. This indicates that the quality of Tandoori bread is dependent on wheat and flour protein content. Other significant correlations were between wheat ash versus bread crust colour, grain hardness, starch damage and Farinograph water absorption versus blisters, extensibility versus Tandoori bread score, rolling quality, tearing quality and chewing quality, Minolta flour "b" value and Minolta bread "b" versus bread crust colour, and Amylograph peak versus crust smoothness. Water absorption also affects the bread shape and a parabolic relationship existed between these two (ie. there was an optimum water absorption for a given wheat variety). It was also found that some of the bread quality parameters were highly correlated and influenced each other (ie. rolling quality, tearing quality, chewing quality, taste and Tandoori bread score).

Principal Component Analysis (PCA) revealed four major components that influenced the Tandoori bread quality. The fourth component which accounted for 8.6% of the variation, was related to only one factor crust smoothness which was influenced by the Amylograph peak viscosity. The third component which accounted for 12.4% of the variation, was related to grain hardness and starch damage which influenced blisters on the bread surface. The second component which accounted for 19.1% of the variation, was related to water absorption and its impact on blisters. The first component which accounted for 41.4% of the variation, was related to wheat protein, flour protein, wheat ash, and flour extensibility and their influences on bread score, rolling quality, tearing quality, chewing quality, taste and crust colour.

Prediction equations for several aspects of Tandoori bread quality were derived using the multiple regression technique. These related panel scores for some Tandoori bread qualities with wheat and flour quality parameters.

1. INTRODUCTION

Pakistan, India and Iran are important markets for Australian wheat. During the last 10 years Australia exported over 17 million tonnes of wheat to these three countries. It is important to expand background knowledge as to the products and wheat quality attributes specific to these markets. Of major importance are flat breads of various types and considerable research has been dedicated to those of the Middle East (Qarooni 1988; Quail et al. 1991). However, the Tandoori breads of Pakistan (Roti), India (Naan) and Iran (Taftoon) have received far less attention, although they represent a substantial share of wheat-based product consumption in these countries and have potential for increased consumption in non-traditional markets in other parts of the world.

HYPOTHESIS

This study of wheat and flour properties affecting Tandoori bread quality has been formulated upon the basis that although Tandoori bread production is a long established craft, there has been no systematic scientific study of the topic. It is very likely that different factors influence the quality of Tandoori breads compared to other products made from wheat flour. This study is based upon the hypothesis that the quality characteristics of Tandoori breads will depend upon a series of parameters. It is likely that the ultimate quality will be a function of the interaction of a number of parameters.

These parameters have been classified into four categories:

- intrinsic and enviromentally influenced grain characteristics;
- physical grain processing parameters;
- the chemical and biochemical components of the flour and other ingredients and the interactions between the components; and
- process variables related to the conditions applied at each stage of dough mixing, proofing, moulding, docking, baking and subsequent storage.

It is further hypothesised that for each of the three broad categories of Tandoori breads already identified (ie. Pakistani, Indian and Irani), different factors and interactions will influence product quality.

AIMS

The general aims of this study are to develop procedures for reproducible measurement of Tandoori bread quality; to identify and study factors influencing quality and to establish relationships with parameters which might allow prediction of end use quality from chemical and biochemical measurements of grain or flour samples. These aims are to be applied to each of the Pakistani, Indian and Irani variations of Tandoori breads already identified.

DESCRIPTION OF PROPOSED PROGRAM

Phase A - Survey of current practice

As there has been no systematic scientific study of the quality characteristics of Tandoori breads, it has been necessary to undertake a survey of current commercial practice in the regions where these breads are most popular. This survey represents a novel and integral part of the program as there is a need for clearly documented data on the ranges in parameters commonly used. These parameters include flour extraction rates, ingredient formulations, dough mixing times and intensity, proofing conditions (such as temperature and humidity), oven design and construction, and operating conditions (such as baking temperatures). The results of the survey will provide a rational basis for selecting the experimental conditions and establishing meaningful ranges for the parameters to be studied as well as background data relating to product quality and its assessment.

Phase B - Design and Installation of a Tandoor

In order to achieve reliable and repeatable small scale manufacture of Tandoori breads in subsequent phases of this program, it will be necessary to design, install, commission and evaluate a Tandoor which can be precisely set to a range of parameters controlling temperature, gas flow and air supply to the Tandoor. Currently there are no standards or appropriate specifications for such an oven.

Phase C - Development of Standardised Procedure for Tandoori Bread Production

As no procedures currently exist, a major phase of the program is the development of a new procedure for making each of the three main types of Tandoori breads. This will require the establishment of processing formulations and conditions so that consistent, reproducible evaluations can be carried out with adequate precision. The objective is to develop and standardise a procedure for the current study which can be adopted for routine use in other cereal testing laboratories.

Phase D - Development of an Evaluation Scheme for Tandoori Breads

A system for evaluation of product quality is to be developed for use with the procedure developed in Phase C. This will include:

(a) Development of Scoring System

A simple and easy to understand Tandoori bread scoring system based on the quality criteria will be developed.

(b) Establishment of Sensory Panel

Selection of sensory panel staff, their screening and training will be carried out for the sensory evaluation of Tandoori breads.

Phase E - Development of a Reference Set of Grain and Flour Samples

In order to study the significance of grain characteristics and grain processing variables thoroughly, it will be necessary to assemble a large set of grain and corresponding flour samples which vary widely in a comprehensive set of standard parameters. Samples will be analysed using established, standard procedures which are listed fully in the Materials and Method section. These procedures include analysis of chemical, biochemical and rheological parameters essential to subsequent phases of the program.

Phase F - Investigation of the Significance of Parameters

Using the samples assembled and analysed in Phase E, the relative significance of chemical components, biochemical and rheological parameters and a wide range of processing variables on the various components of quality for Tandoori breads will be studied. A comprehensive set of data will be available for interpretation. The relative importance of the many different processing parameters for grain and flour will also be thoroughly evaluated in this interpretative work.

Phase G - Investigation of the Relationship between Wheat and Flour Parameters and Tandoori Bread Quality

As a further step in the interpretative phase, the data relating to grain and flour analytical parameters will be thoroughly examined in relation to the quality of Tandoori breads. Statistical analysis of the data for a comprehensive set of testing procedures applied to many different wheat and flour samples will be required to develop predictive indices which can be applied with confidence.

This phase provides the potential for new knowledge on the use of existing analytical methods as predictors for routine use in cereal testing laboratories.

POTENTIAL OUTCOMES FROM THE RESEARCH PROGRAM

This research study results from the need of the Australian grain industry for fundamental knowledge of the products made from Australian and competitor grain classes in both current and potential markets. This fundamental knowledge needs to complement and build on the accumulated knowledge within the marketplace, much of which has evolved from the application of the craftsman's skill, often over considerable periods of time. The new knowledge to be obtained in this study is to be gained from the rigorous application of scientific principles and will include:

- a detailed fundamental understanding of the role of various molecular components and those of the biochemical and rheological parameters on the quality and production of Tandoori breads;
- a thorough understanding of the many processing variables involved through milling to the various steps in production of Tandoori breads;
- the elucidation of the genotypic and environmental influences on production of Tandoori breads;
- the development of new standardised method for laboratory production of the three major styles of Tandoori breads; and
- the establishment of new scoring and evaluation procedure for the three major styles of Tandoori breads.

THE POTENTIAL ECONOMIC BENEFITS OF THE PROPOSED RESEARCH

- enhanced access to the huge potential markets where Tandoori breads are a major component of the diet;
- provision of the basis for strong marketing push and a complementary technical marketing program to potential markets;
- the provision of product knowledge and the introduction of appropriate analytical methodology to cereal testing laboratories;
- the availability of definitive data on appropriate characteristics and genotypes as a basis for wheat breeders to develop "Tandoori wheats"; and
- the facilitation of expended manufacture in Australia of Tandoori bread products having enhanced quality.

2. LITERATURE REVIEW

2.1 TANDOORI BREAD

The product is called Tandoori bread because it is baked in a Tandoor. It is a single-layered leavened flat bread which is consumed in many countries of non-oriental Asia as the dominant wheat based product (Qarooni 1988). Local names of this product vary from one region to another (such as Tandoori, Tanoori, Roti, Naan, Taftoon, Taftan, Sheermal, Kulcha, Khamiri). These breads are traditionally made and sold hot (Mosses, 1981). Millions of people buy their breads twice or so a day which have been baked in traditional Tandoors. These Tandoors are oval shaped ovens, made of either clay or steel, and are fired by gas, diesel, charcoal or wood fire.

The word "Tandoor", derived from the Urdu and Hindi languages, means "keep your body away". It reflects the nature of the oven which is very hot with the potential to burn the hands and the other body parts if they come in contact with the Tandoor. In Arabic and Persian languages it is often called "Tanoor" which simply means an oven.

The clay Tandoor is made by moulding clay layers over a 17 day period until it reaches the required height (Ahmed, 1996). The clay used is red in colour which heats up quickly and retains the heat, yet does not crumble after it dries. Before it is moulded, the clay must be kept moist for about two months. Once a week the

Tandoor is coated with a greyish-white sand which is used to smooth out surface scratches caused by iron skewers used to remove the Tandoori breads. The clay works as a buffer between the Tandoor and the Tandoori bread, preventing it from burning when it comes into contact with the hot surface. The clay Tandoor is cleaned with a damp cloth a few of times a day to remove any burnt particles.

Tandoors made out of steel are also quite popular because they do not require any maintenance after installation, except cleaning with saline solution especially in the morning to remove any rust layer accumulated on the steel surface.

A commercial Tandoor is shown in Plate 2.1 and its diagram is presented in Figure 2.1.

2.2 FORMULATION

Tandoori breads of Pakistan, India and Iran basically differ in the type of flours used, the composition of ingredients and, somewhat, in the processing conditions. The basic ingredients of Tandoori breads are as follows:

- Flour
- Salt
- Yeast
- Baking soda
- Water

Plate 2.1 A commercial Tandoor

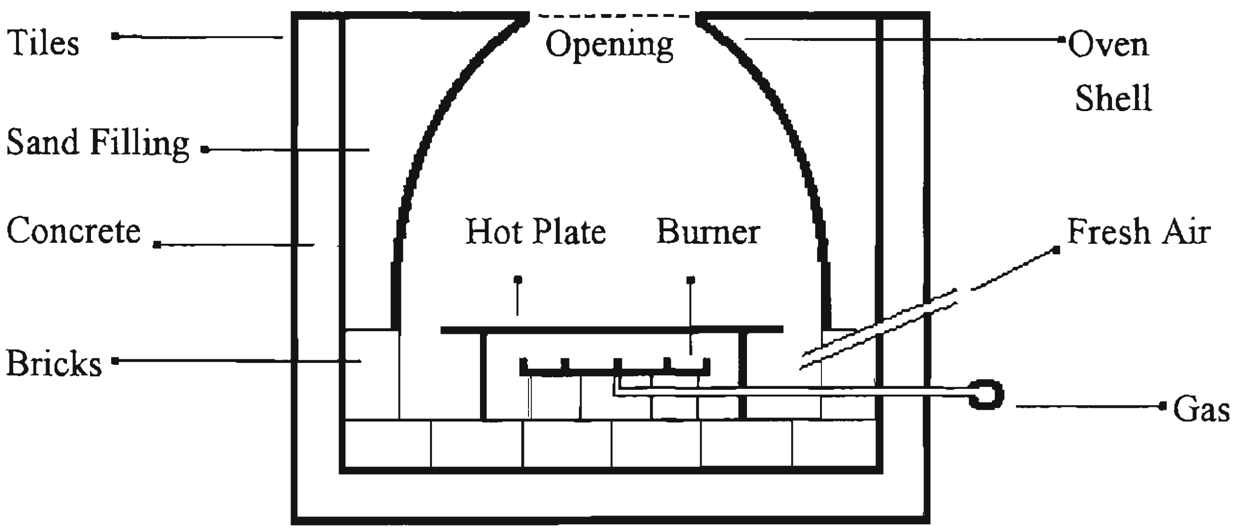


Figure 2.1 Diagram of a commercial Tandoor

There are many optional ingredients for the Tandoori breads which may be chosen to suit the types of food being served. Some of them are as follows:

- Sour dough
- Sugar
- Milk
- Yoghurt
- Eggs
- Sesame seeds
- Ghee (clarified butter)
- Cardamom powder
- Date syrup

Tandoori breads can also be filled with minced meat, garlic, cheese, mashed potatoes and some other vegetables as and when ordered in restaurants or in some Tandoor shops.

The basic formulation which is widely used for Tandoori breads in Pakistan, India, Iran and the Gulf countries is given in Table 2.1. The role of the ingredients presented in this table is described in Section 2.2.1-2.2.5.

Table 2.1. Basic Tandoori bread formulation

Ingredients	Parts
Flour	100
Salt	1.0-1.5
Dry Yeast	0.25-0.5
Baking Soda	0-0.3
Water	63-65

2.2.1 Flour

The major difference between the Tandoori breads produced in the different regions arises from the different flour types used in its production. Different flour types lead to variations in the characteristics of Tandoori bread between regions.

2.2.1.1 Pakistani Roti

In Pakistan, Roti is made from high extraction flours (ie. 88% extraction). Roti is soft and tender in texture, but of duller appearance due to the high level of bran present in it. This bread is circular in shape with an approximate diameter of 200 mm and a thickness of 20 mm (see Plate 2.2). It is baked in a Tandoor such as shown in Plate 2.1/Figure 2.1 that is mostly fired by gas. Roti is also popular in India, but Naan is the dominating product in that country.

2.2.1.2 Indian Naan

In India, Naan, the most common type of Tandoori bread, is made from straight run flours of about 72% extraction. Naan is chewy with a glossy appearance

(Rahim et al. 1993). This bread is oval in shape with an approximate length of 200 mm, maximum width of 150 mm and a thickness of 15 mm (see Plate 2.3). It is baked in a Tandoor similar to the one shown in Plate 2.1/Figure 2.1, which is either fired by charcoal or wood as natural gas is not widely available in India. Although Roti is the major Tandoori bread consumed in Pakistan, Naan is also available mainly in restaurants.

2.2.1.3 Iranian Taftoon

Iranian Taftoon is most commonly produced from a blend of the above two flour types or at 80% extraction (Hashmi & Wootton, 1995). Taftoon is intermediate in texture and appearance between the Pakistani and Indian products, but is thinner. It becomes hard more rapidly after baking than the others. This bread is circular in shape with an approximate diameter of 250 mm and a thickness of 10 mm (see Plate 2.4). It is baked in a Tandoor which is either fired by gas or diesel. The Irani Tandoor is slightly different from the one shown in Plate 2.1/Figure 2.1, as it is installed at a 45^0 angle rather than vertically.

The straight run and high extraction flours used in Tandoori breads would typically have the characteristics shown in Table 2.2 with the blend of Iranian product being intermediate between these two. The data presented in Table 2.2 were derived from information obtained from flour mills and Tandoors in the regions as part of the survey (Hashmi et al. 1994).

Plate 2.2 Pakistani Roti

Plate 2.3 Indian Naan

Plate 2.4 Irani Taftoon

Table 2.2. Characteristics of flours for Tandoori bread production

Flour Characteristic	Straight Run	High Extraction
Extraction %	72	88
Ash % (dry basis)	0.53	0.92
Protein % (14% moisture basis)	11	10.5
Water Absorption %	62.5	63

Wheats milled to produce these flours may be from various sources including domestically grown varieties and those imported from North America, Saudi Arabia and Australia. Quality of the wheats in terms of hardness, protein content and screenings, is variable depending on the region involved, and seasonal and economic factors.

2.2.2 Salt

Chemically speaking, the term salt refers to any compound produced by the interaction of a base with an acid in which part or all of the hydrogen of the acid is substituted by a metal or metal like radical. Common salt, or simply salt, refers to sodium chloride which is a white, crystalline product, consisting of the elements sodium and chlorine and has the chemical formula NaCl (Pyler, 1973).

Apart from imparting taste to bread, salt brings out the flavour of bread, and controls yeast activity thus keeping the fermentation speed under control. The tightening action of salt on flour proteins helps in gas retention of the dough. It also absorbs water and retards staling. The amount of salt normally present in

Tandoori breads is between 1.0-1.5% of the flour weight. It varies a lot in commercial practice, especially when the Tandoori breads are stuffed with other cooked items.

2.2.3 Yeast

The baking process involves a highly complex interplay of physical, chemical, and biological reactions. Perhaps the most important of these and certainly the most fundamental, is the fermentation process brought about by the activities of a unicellular plant, the microscopically small yeast cell (Pyler, 1973). Yeast is a living plant growing with warmth and food, such as flour and sugar. During its growing process, fermentation occurs giving off carbon dioxide gas. The bubbles of CO_2 are responsible for stretching and raising the dough. Currently instant yeast is widely used in Tandoori bread formulation. The instant yeast is easy to use for one has to simply stir it into the dry ingredients. The amount of dry yeast normally present in Tandoori breads is between 0.25-0.5 % of the flour weight (it varies from season to season in commercial practice and is highly dependent on the day time temperature).

Some dried yeast is packed with ascorbic acid as a preservative. Ascorbic acid is fast acting oxidising agent which tends to toughen doughs, and is often used as a gluten modifying agent for volume breads. Even in very small quantities, ascorbic acid tends to toughen doughs before sheeting which creates bread faults (Quail, 1996).

2.2.4 Baking Soda

Baking soda (Sodium Bicarbonate) is commonly used as a leavening agent in Tandoori breads and is used up to 0.30% of the flour weight. Its popularity as a leavening agent is based on its low cost, lack of toxicity, ease of handling and relative tastelessness. According to Faridi et al. (1983), when yeast and soda were combined (0.5% & 0.25% respectively), good results were obtained for Tandoori breads. Soda strengthens the dough and increases the water absorption. Soda prevents excessive acid levels in the fermented dough, especially during warm summer weather; and develops a desirable crust colour (Qarooni, 1996).

2.2.5 Water

The Australian breadmaking handbook (BRI, 1989) reports that water is more than a convenient adjunct to breadmaking. It is a primary ingredient of dough. An adequate amount of water in dough is essential for several vital changes to occur during the breadmaking. Water controls the dough consistency and the dough temperature. Much of the water in dough is combined with the gluten prior to commencement of baking. The starch holds only a small proportion of the water in dough until baking commences, although starch granules which have been damaged can absorb a considerable amount of water when cold. When heated in the presence of water, starch gradually swells and absorbs more and more water as the temperature rises. At approximately 60^0C rupturing of granules commences and the available water in the dough becomes bound in a starch gel which is the main structural material of bread. The amount of water added in a

Tandoori bread dough is higher than in most of the other flat breads and can be as high as 65%.

2.3 COMMERCIAL PRODUCTION OF TANDOORI BREAD

A survey was carried out in detail (Hashmi et al. 1994) in which opinions were asked from the people of different origins about their eating habits of wheat based end products where Tandoori breads are consumed in significant amounts and results are presented in Table 4.1.

From Table 4.1 it can be seen that although Tandoori breads are the major wheat based end product in Pakistan, Iran and Afghanistan, they are equally popular in other countries of the region. An interesting picture comes from India, where over 80% of the wheat produced is utilised in the preparation of various traditional products (flat breads) that also includes different type of Tandoori breads (Saxena et al. 1995a).

2.3.1 Automatic Production

Most Tandoori breads are commercially produced in small Tandoors. However, there are a few automatic Taftoon production lines in Iran (Qarooni, 1994), where breads are packed in plastic bags and sold in super markets. These breads are at times reheated before consumption, in ovens, toasters, hot plates or on open fire, but with a compromise of the fresh quality.

Faridi & Finney (1980) described automated production of Taftoon in which flour, salt, sugar dry yeast and water were mixed together to form a dough which was then rested up to 40 minutes. After dividing, the dough is rested again for up to 10 minutes before the dough pieces pass through three sets of rollers. Flattened doughs are docked with spiked roller. After a short proof, they are baked at 350^{0}C in a tunnel oven for up to 2 minutes.

Some twenty years ago quite a few automatic Roti production lines were commissioned throughout Pakistan (under the name of Roti Corporation of Pakistan) with huge investments and the product (Roti) was available in plastic bags, but it was not accepted by the consumers anywhere in the country because Tandoori breads are traditionally consumed hot and lose their quality when reheated. This resulted in converting all of those Roti production lines into pan bread production lines. No automatic Naan production line has so far been commissioned in India.

2.3.2 Manual Production

The manual procedure commonly used for the production of Tandoori breads of all regions and types follows the sequence below:

- Mixing
- Fermentation
- Dividing and Rounding
- Resting

- Sheeting
- Docking
- Baking

2.3.2.1 Mixing

The ingredients described in Table 2.1 are combined and mixed either by hand or by slow speed spiral mixer (depending on the amount of flour taken) for approximately 25-30 minutes to achieve the desired level of dough development with a final dough temperature of 30-40^{0}C. Amount of yeast varies from season to season and is dependent on the daytime temperature.

2.3.2.2 Fermentation

During fermentation, dough is either taken out and kept on a table or left in the mixer covered with a plastic sheet to prevent skinning. This normally takes place for 80-120 minutes at the ambient temperature in the bakery (25-40^{0}C).

2.3.2.3 Dividing and Rounding

Dough is divided by hand without any weighing into pieces of 150-250 g (or even more) and then rounded by hand using some dusting flour.

2.3.2.4 Resting

The dough pieces are allowed to rest on dusted trays at 25-40^{0}C under a plastic sheet for 5-10 minutes before sheeting.

2.3.2.5 Sheeting

The dough pieces are initially rolled to a thickness of about 10-15 mm using a rolling pin. Final dough thicknesses of 3-10 mm are achieved by stretching manually after docking (see Section 2.3.2.6) while tossing it back and forth between the two hands.

2.3.2.6 Docking

Dough sheets are docked or punctured (to prevent pocket formation during oven baking as well as for decorative purposes) by finger tips or by using metallic dockers.

2.3.2.7 Baking

Breads are baked at approximately 300-450^{0}C for 60-120 seconds. This is done in a Tandoor (see Section 2.1) of clay or steel construction and fired by gas, diesel, wood or charcoal fuel.

The bread adheres to the wall of the Tandoor when positioned by the baker using a moistened cushion and is removed with specially designed metal skewers when baking is completed. The process continues at a relentless pace, because as soon as one bread is ready, it is replaced by another. Up to six breads can be baked at a time in a commercial Tandoor and are taken out on first in first out basis. Design of a Tandoor is shown previously in Plate 2.1 & Figure 2.1.

2.3.2.8 Packing

As mentioned earlier, Tandoori breads are consumed when they are hot, therefore they should not be packed for commercial distribution like other breads in plastic bags. Breads baked in the small Tandoor shops are taken home in paper sheets by the customers for immediate consumption for lunch and dinner. Breads produced in restaurants are served to the customers as soon as they come out of the Tandoor.

2.4 TEST BAKING OF TANDOORI BREAD

Test baking methods provide a means of examining individual variables in the baking process, for example, in evaluating the baking quality of flour. A test baking method should relate to the commercial production targeted, using small sample size, and provide reproducible results (Quail et al. 1990).

Different baking methods can rank flour samples differently. Unlike other flat breads, test baking methods for Tandoori breads are not well established and only a few previously published test baking methods are available; these differ from each other (Faridi et al. 1981 & 1983; Qarooni (1988) & Qarooni & Posner (1993); Rahim et al. 1993, Saxena et al. 1995).

In the work specifically dedicated to Tandoori breads, Faridi et al. (1983) presented a laboratory scale baking procedure for the production of Irani Taftoon in which the ingredients (82% extraction flour 100 parts, salt 1.0 part, water 60 parts, date syrup 2.0 parts and variable levels of yeast, soda and sour dough) were mixed to optimum dough development and fermented for 60 minutes at 30^{0}C and 90% relative humidity. Dough was divided and rounded into 100 g dough pieces and sheeted to 2.5 mm thickness and 160 mm diameter. These were then punctured and baked on a preheated baking sheet in the oven for 2.5 minutes at 315^{0}C.

Faridi et al. (1981) also presented a laboratory scale method for the production of Pakistani Roti (which they called Naan) in which all the ingredients (whole wheat flour 100 parts, salt 1.5 parts, water 67 parts and variable levels of yeast, soda and sour dough) were mixed to optimum dough development and fermented for 90 minutes at 30^{0}C and 90% relative humidity. Dough was divided and rounded into 125 g dough pieces and sheeted to 4 mm thickness and 170 mm diameter. The sheeted dough pieces were then fermented again for 30 minutes at 30^{0}C and baked on a preheated baking sheet in the oven for 2-3 minutes at 315^{0}C.

Qarooni (1988) and Qarooni & Posner, (1993) described two more or less similar test baking methods for Tanoor (Tandoori) bread production. In these methods all ingredients were mixed (85% extraction flour 100 parts, dry yeast 0.5 parts, salt 1.0 part and amount of water according to the equation developed for Arabic bread production; baker's water absorption (%) = 18.8 + 0.596 x Farinograph absorption at 850 BU) to optimum dough development. Dough was fermented at 30^{0}C in a sealed container. The proofed dough pieces were sheeted to 1.5 mm, docked and then baked for 75 sec at 305^{0}C in an air impingement oven. They concluded that optimum quality Iranian Tandoori bread was obtained from 85% extraction flours of 11-13% protein.

Rahim et al. (1993), after surveying some restaurants suggested a laboratory method for the production of Indian Nan (or Naan). According to this method all ingredients (Maida or plain flour 100 parts, yoghurt 12 parts, milk 6 parts, salt 1 part, sugar 2 parts, egg 3 parts, fat 4 parts, baking soda 0.5 parts and water equivalent to Farinograph water absorption plus 1-3% extra amount) were mixed for 3 minutes in a Hobart mixer. After a 4 hr fermentation. Dough was divided into 80 g pieces which were then rolled to a thickness of 2.5 mm and baked in a portable gas Tandoor for 1.5 minutes.

Saxena et al. (1995b), presented a laboratory scale test procedure for the production of Roti after surveying some restaurants in India. According to this method, whole wheat flour (100 g), salt (1.5 g) and variable amount of water were mixed for 3 minutes in a Hobart mixer. After a 30 minutes fermentation, dough was divided into 55 g dough pieces which were sheeted by a rolling pin to a final dough thickness of 2.5 mm and then baked at 470^{0}C for 80 sec in a clay Tandoor which was fired by charcoal. They also used some established heat transfer mathematical equations (as described in McCabe et al. 1985 & Perry et al. 1984) to determine the total heat transferred to the product during baking and described as follows:

$$Q_T = q_c + q_f + q_{Rr} + q_{Rf}$$

where:

Q_T = Total heat transferred to the product

q_c = Heat transferred by conduction

q_f = Heat transferred by free convection

q_{Rr} = Heat transferred by radiation from refractory surface

q_{Rf} = Heat transferred by radiation from flame

Saxena et al. (1995b) concluded that while using a charcoal fired Tandoor, of the total heat transferred to the Roti, 51% was transferred by conduction from the Tandoor refractory wall and about 44% was transferred by radiation from the Tandoor refractory wall. On the other hand heat transferred to the Roti from flame and natural convection were relatively low (3.7% & 0.90% respectively).

2.5 BREAD EVALUATION

Quail et al. (1991) stated that bread scoring systems should provide reproducible evaluations of bread quality. These systems are necessary to compare breads made with different ingredients or processing conditions. Tests of quality can be objective, where measurements are made according to a defined process, and no judgment on behalf of the operator is required.

Sensory evaluation is a multi-disciplinary subjective science that uses humans to measure the acceptability and sensory properties of foods. Such a system is crucial to any meaningful research into wheat quality requirements with respect to end-product quality and must allow assessment of the different quality requirements of Tandoori breads of the three principal regions.

Limited work is available on the evaluation of Tandoori breads (Faridi et al. 1983; Qarooni (1988) and Qarooni & Posner, (1993); Rahim et al. 1993 & Saxena et al. 1995a). Faridi et al. (1983) have mentioned the bread evaluation of some types of Tandoori breads, but no actual scoring system was defined. Qarooni (1988) and Qarooni & Posner, (1993) presented two, more or less similar scoring systems for Tanoor (Tandoori) breads. According to these scoring systems (presented in Table 2.3) breads were assessed on day of baking and also on the next day. According to Rahim et al. (1993) Indian Nan (Naan) was graded on a 5 point scale shown in Table 2.4. This grading was carried out for the quality attributes presented in Table 2.5. Saxena et al. (1995a) presented an evaluation procedure for Roti (presented in Table 2.6) which was similar in many aspects to the one presented by Rahim et al. (1993) except the grading was carried out on a 7 point scale. This grading was carried out for the quality attributes presented in Table 2.7. Desirable and undesirable quality characteristics are also presented in this table for each quality attribute.

Table 2.3. Tanoor bread scoring systems by Qarooni (1988) and Qarooni & Posner (1993).

Quality Parameter	**Maximum Score**	
1st Day	ref. 1988	ref. 1993
Area Index	5	5
Crust Smoothness	10	10
Uniformity of Thickness	15	15
Crust Colour	10	10
Uniformity of Blisters	10	10
Rolling Ability	20	20
Quality of Tearing	20	20
Crumb Appearance	10	10
2nd DAY		
Rolling Ability	25	30
Quality of Tearing	25	20
TOTAL SCORE	150	150

Table 2.4. Naan's grading by Rahim et al. (1993)

Grades	**Points**
Poor	1
Fair	2
Satisfactory	3
Good	4
Excellent	5

Table 2.5. Naan's scoring system by Rahim et al. (1993)

Quality Attributes	**Maximum Score**
Appearance	5
Handfeel (Texture)	5
Chewing Quality	5
Eating Quality	5
Overall Quality	5

Table 2.6. Grading of Roti by Saxena and Rao (1995a)

Grades	Points
Very Poor	1
Poor	2
Fair	3
Satisfactory	4
Good	5
Very Good	6
Excellent	7

Table 2.7. Evaluation of Roti by Saxena and Rao (1995a)

Characteristics	Maximum Score	Desirable	Undesirable
Colour	7	wheatish yellow	burnt, dark brown
Appearance	7	uniformly distributed small blisters	large blisters
Handfeel	7	soft & pliable	brittle, hard
Texture	7	soft & slightly chewy	leathery & highly chewy
Mouthfeel	7	clean	doughy, sticky
Taste & Aroma	7	typical, pleasant, wheaty aroma	residual taste, charred

2.6 STATISTICAL ANALYSIS

Statistics are required to describe, quantify and understand relationships among individual parameters.

2.6.1 Analysis of Variance (ANOVA)

ANOVA permits a decision maker to conclude whether or not all means of the populations under study are equally based upon the degree of variability in the sample data (Sanders 1980). In statistics, the term "population" means the total of any kind of units under consideration (N) by the statistician and a "sample" is any portion of the population selected for study (n). ANOVA is based on two hypotheses (null: H_0 & alternative: H_1). According to the "null hypothesis" all the population means are same. This can be stated as follows:

$$H_0: \mu_1 = \mu_2 = \mu_3 = ... = \mu_k$$

(where μ is the sample mean)

On the other hand, if there are significant differences among the sample means, then the "alternative hypothesis" would be as follows:

$$H_1: \mu_1 \neq \mu_2 \neq \mu_3 \neq ..... \neq \mu_k$$

(not all population means are same)

Levin (1994) has stated that ANOVA is based on a comparison of two different estimates of the variance, σ^2, of overall population (described in the following paragraph).

Variance among the sample means is the estimate between-column variance ($\sigma^2_{between}$) and the variance between the samples is the estimate within-column variance (σ^2_{within}). Comparison of these two estimates of the population variance is given by the equation of "F" hypothesis test:

$$F = \frac{\text{between-column variance}}{\text{within-column variance}}$$

When these two estimates are approximately equal in value, the "null hypothesis" is true. If the estimate computed by the second approach is significantly different from the estimate of the first approach, then it can be concluded that the second estimate contains effects of population mean differences, thus H_0 should be rejected.

Sanders (1980) has reported that the maximum value the computed "F" ratio may attain (at a chosen level of significance) before the H_0 must be rejected, is specified in the "F" distribution tables. Thus, conclusions concerning the H_0 in ANOVA tests are based on comparisons of computed "F" ratios with values from the "F" distribution tables. If the computed "F" ratio value $\leq$ the table value, the H_0 is accepted; if the computed "F" ratio > the table value, the H_0 is rejected. The table value can be determined form Table 6 given in Levin (1994). However, by using the Minitab statistical package (Minitab, 1994), if the prob value ("P" value) is larger than the level of significance ($\alpha = 0.01$), H_0 is accepted. This means that there is no significant difference in the samples.

ANOVA will be used in this study to verify the null hypothesis among the sensory panellists for their Tandoori bread scoring results .

2.6.2 Correlation Matrix

According to Boyle (1989) the purpose is to determine the relationship of one set of measures to some other set, or sets, the correlation of one set with the other set.

Statements about the causes of relationship are the result of analysis after the correlation has been shown to exist.

Correlations may be of three kinds:

2.6.2.1 Positive Correlation

Two sets of measures are positively correlated when individuals well above average for one measure tend to be well above average for the other measure, those at or near the average of one measure are at or near the average for the other, and those well below average for one are also well below average for the other.

2.6.2.2 Negative Correlation

Some sets of measures exhibit a negative correlation, in that one measure is well below average and the other is well above average.

2.6.2.3 Zero Correlation

The term "zero correlation" is reserved for those instances in which no degree of positive or negative correlation or relationship is found to exist between the two attributes or sets of measures in question.

Correlation coefficient is an index of the degree of relationship between two sets of measures and is always between -1.00 to +1.00. A correlation coefficient of

-1.00 is indicative of a perfect negative correlation; 0 is indicative of no correlation; +1.00 is indicative of a perfect positive correlation.

The product-moment correlation coefficient (r) is often referred to as "the Pearson r". It is the mean of the products of the paired standard or z-scores of all individual items having measures in the two variables. It is given by the equation as follows:

$$r_{xy} = \frac{\sum z_x \cdot z_y}{n}$$

where:

z_x is the standard score on one variable for an individual parameter

z_y is the standard score on other variable for the same individual

n is the total number of individual parameters for which measure were obtained in both variables

Correlation coefficients will be determined for this study to assess the correlations between wheat and flour properties and Tandoori bread quality parameters.

2.6.3 Principal Component Analysis (PCA)

PCA is a data reduction technique used to identify a small set of variables that account for a large proportion of the total variance in the original variables. Output consists of the eigenvalues (ie. the variances of the principal components), the proportion and cumulative proportion of the total variance explained by each principal component, and the coefficients for each principal component (Minitab, 1994).

The PCA procedure allows derivation of a set of components from the original variables that are mutually not correlated and whose variances are maximal ie. the "first" component has the largest variance, the "second" component has the largest variance possible among all components that are not correlated with the first, and so on. Similarly the PCA will be applied for this project to determine the variances.

2.6.4 Multiple Regression

Multiple regression is a statistical process by which several variables are used to predict another variable and it is used to construct prediction equations between individual parameters. The principal advantage of multiple regression is that it allows utilisation of more of the information available to estimate the dependent variable (Levin, 1994). Multiple regression is by the following equation:

$$Y = a + b_1X_1 + b_2X_2$$

Where:

Y = estimated value corresponding to the dependent variables

a = Y - intercept

X_1 & X_2 = values of the two independent variables

b1 & b2 = slopes associated with X_1 & X_2 respectively

The total Tandoori bread score and selected quality parameters will be investigated using this technique.

2.7 SUMMARY

Most of the earlier work on flour quality, test baking and evaluation of Tandoori bread has been focused on the Middle Eastern products and must be expanded to include those of India and Pakistan. In particular, the differing blends of straight run and high extraction flours used between India, Pakistan and Iran will necessitate further work on flour properties and the impact of blending on product quality. These issues have yet to be addressed. With the exception of work by Rahim et al. (1993) and Saxena et al. (1995), research by others appears to represent extensions of research into Arabic flat bread types rather than being dedicated to Tandoori breads which have the distinct quality, formulation and baking requirements described earlier. For example, in bread scoring, second day evaluation of Tandoori bread is of little importance compared to most other flat breads due to its consumption soon after baking. Crumb texture is also likely to be a less important criterion because it is a single layered bread. Product evaluation and scoring systems must also take account of differing quality expectations between the regions where texture and appearance criteria are affected by the flour blends used and must match expectations of consumers in the regions. However, scoring of Tandoori breads will reflect appearance, texture, mouthfeel and rolling ability, and will no doubt have many similarities with the systems designed for other flat breads such as those described by Quail et al. (1991).

At present there is no generally accepted test baking or scoring procedure for Tandoori breads. No study is available on the sensory evaluation of Tandoori bread quality parameters. These procedures are crucial to any meaningful research into wheat quality requirements and must allow assessment of the different quality requirements of the three principal regions.

3. MATERIALS AND METHODS

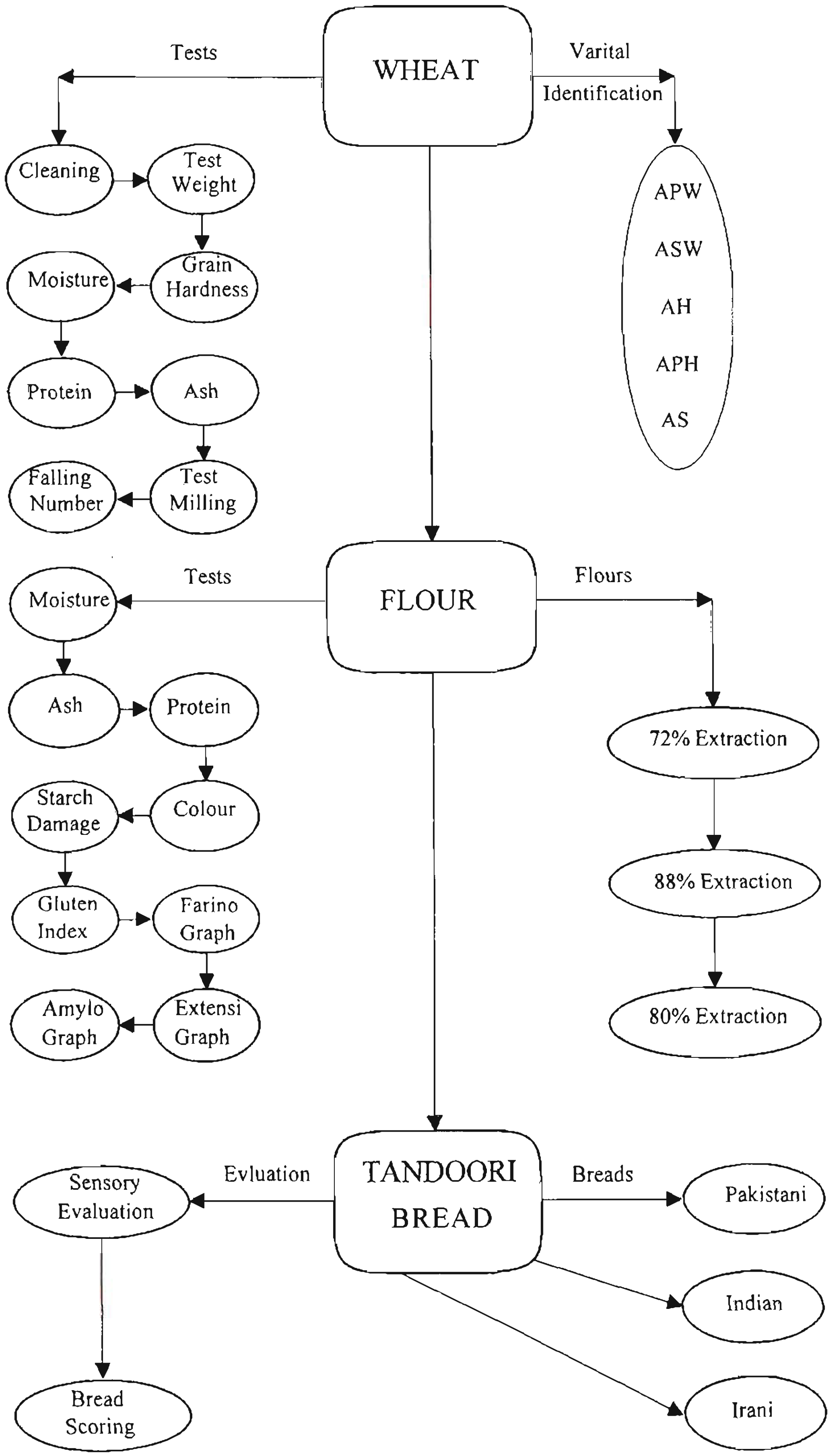


Figure 3.1 Flow chart of the research project

A flow chart of entire research plan to be used in the overall program is presented in Figure 3.1. It summarises specific wheat and flour properties to be assessed, the wheat types to be used and evaluation of the breads.

3.1 MATERIALS

3.1.1 Wheat

A wide range of Australian wheat varieties was taken into consideration for this project. A number of physical, chemical and rheological analyses (described in the following sections) were carried out on all the wheat varieties.

No study on the use of different Australian wheat varieties for the production of Tandoori breads exists. This research work therefore aims to provide a comprehensive information about suitable Australian wheat varieties for the Tandoori breads production.

3.1.1.1 Selection of Wheat Varieties

During the early stages of this project 23 different types of Australian wheats were collected from all around the country (shown in Table 3.1), out of which 15 were selected for initial testing depending on their range of parameters (see Appendix 8 for data).

Table 3.1. Australian wheat varieties used in this project.

#	Variety	Maximum Grade	State
1	Aroona	APW	WA
2	Barunga	AH	SA
3	Batavia	APH	QLD
4	Bodallin	AH	WA
5	Cadoux	ASW	WA
6	Dollarbird	AH	NSW
7	Gutha	AH	WA
8	Halberd	APW	SA
9	Hartog	APH	QLD
10	Janz	APH	NSW
11	Katunga	ASW	VIC
12	Kulin	ASW	WA
13	Machete	AH	SA
14	Meering	AH	VIC
15	Miskle	APH	NSW
16	Ouyen	AH	VIC
17	Oxley	APW	VIC
18	Spear	APW	SA
19	Suneca	APW	NSW
20	Tammin	ASW	WA
21	Trident	ASW	SA
22	Vectis	AS	VIC
23	Yanac	APW	VIC

Where:

APW = Australian Premium White Wheat

ASW = Australian Standard White Wheat

AH = Australian Hard Wheat

APH = Australian Prime Hard Wheat

AS = Australian Soft Wheat

WA = Western Australia

SA = South Australia

VIC = Victoria

NSW = New South Wales

QLD = Queensland

These wheats were used to carry out the following tasks:

- to develop test baking technique for Tandoori breads
- to determine the role of processing variables in Tandoori bread production
- to determine the role of ingredients in Tandoori bread production
- for the training of sensory panellists; and
- for the development of evaluation procedures

3.1.1.2 <u>Plantation of Wheat Varieties</u>

Based on the results of the 15 wheats initially used in this project (see Appendix 8 for data), 12 wheat varieties were selected and planted side by side in five Australian states (ie: VIC, NSW, QLD, SA & WA) at three sites in each state (see Appendix 11 for data). Wheats grown at the South Australian site "Yeelanna" were selected for the second phase of this project because of the comparable protein levels for the 12 varieties.

These wheats were used for the following tasks (between the cultivars):

- test baking

- sensory evaluation
- statistical evaluation; and
- determination of the effects of wheat and flour properties on Tandoori bread quality

Based on the results of the evaluation of these wheats, Batavia and Trident of them were further selected for final testing (within the cultivars). These two wheats which grown side by side in five states at three sites in each state, were chosen from three sites (ie. Horsham in VIC, Avondale in WA and Narrabri in NSW) on the basis of having three different protein levels between the sites (see Appendix 14 for data).

These wheats were used to determine the effect of wheat and flour properties among the cultivars on the quality of Tandoori breads.

3.1.2 <u>Flour</u>

Flour requirements for the three types of Tandoori breads are as follows:

- Pakistani Tandoori breads (Roti) required 88% extraction flour.
- Indian Tandoori breads (Naan) were produced from 72% extraction flour.
- Irani Tandoori bread (Taftoon) were produced from 80% extraction flour.

Laboratory scale wheat milling techniques were modified to produce the three required flours from each wheat variety (see Section 3.2.10). These three flours were analysed for all the necessary physical, chemical, biological and rheological tests before the test baking.

3.1.3 Tandoori Bread

Tandoori bread is the staple food in many non-oriental Asian countries and its consumption is rapidly increasing in other parts of the world. However, not much work has been done for the development of a test baking procedure that is comparable to commercial baking methods. One goal of this study was to develop a simple and easy to understand test baking technique that would have adequate precision and would be relevant to the commercial baking methods of the Pakistani Roti, Indian Naan and Irani Taftoon.

It was also intended to design and install a Tandoor (at the research facility) with controls over natural gas flow rate, air and temperature which would provide a model for Tandoor manufacturers in Australia and elsewhere.

3.2 METHODS

3.2.1 Varietal Identification

Different wheat varieties exhibit different morphological traits under field conditions which are used for varietal identification. The gliadin proteins are synthesised in the wheat grain under strict genetic control. Analysis of the gliadin composition by gel electrophoresis (RACI: Official Testing Methods) may therefore be used to provide information about the genotype of the grain. Separation of gliadin proteins on the basis of their electrophoretic mobility is dependent on charge density and the size of the molecule. The charged molecules are propelled through the pores of a gradient gel under the influence of an electric field and the resulting protein bands used for varietal identification, after staining with a suitable dye, by comparison with samples of authenticated known variety.

3.2.2 Wheat Cleaning

Wheat cleaning was carried out using a Carter Dockage Tester (according to the AWB Grain Quality Procedures Manual, Section M1) which separates small, broken and shrunken wheat from the sound grain. Wheat cleaning is always required prior to test milling to remove weed seeds and other foreign material which affect flour quality.

3.2.3 Test Weight

Test weight is the bulk density and is measured in kg/hl using a Chondrometer. Test weight is a function of grain size and weight as well as grain soundness. Test weight therefore provides a rough index of the yield of flour that can be obtained, the higher the Test weight the higher the expected flour extraction.

The dust free/dockage free sample of the grain was filled into the quarter litre tube of the Hectoliter Scale, and the excess grain was removed with the help of a slide. Finally the whole content was weighed and the test weight was obtained from the provided tables. This procedure was conducted in accordance to the AWB Grain Quality Procedures Manual.

3.2.4 Thousand Kernel Weight

The thousand kernel weight is a measure of average kernel size and therefore also is correlated with potential flour extraction. It is dependent on fewer variables than test weight and, in particular, the shape of the grain has no influence on thousand kernel weight. The level of impurities which may be a significant variable for test weight, is also eliminated in the thousand kernel weight.

The significance of grain size is much enhanced in the determination of thousand kernel weight. Since the ratio of endosperm to bran also varies with grain size, thousand kernel weight might be expected to provide better correlation with potential milling yield than does test weight, however this is not always the case.

A Tecator Numigral automatic seed counter was used for the determination of thousand kernel weight as per the method described by the manufacturer (Tecator; Sweden) in which 500 grains were counted by the seed counter and their weight was multiplied by 2 to get the thousand kernel weight in grams.

3.2.5 Particle Size Index

The most important effect of grain hardness is on starch damage which is then correlated to other flour properties and hence to the bread quality. Grain hardness is related to the granularity of wheatmeal and was determined by the method of Symes (1961) in which 10 g clean wheat was ground in a Falling Number mill (type 3303). The whole meal was sieved for 5 minutes on a 15 N mesh (85 μ) using a Henry Simon sifter. The PSI was measured as the percentage of flour released during this test.

3.2.6 Moisture

Determination of moisture in wheat and flour is important for a number of reasons. The higher the flour moisture the lower the amount of water added to the dough while the grain moisture is important in determining the correct water addition for conditioning the wheat for milling. Moisture content of grain and flour was determined as the loss in weight of a sample when heated under specified test conditions to the AACC method 44-15A.

3.2.7 Ash

The ash content of wheat and flour is the mineral matter remaining after complete combustion of the organic material (590^{0}C for 15 hrs) which comprises the major portion of the product. The mineral matter is distributed throughout the grain, but is concentrated primarily in the aleurone layer which is located between the bran layers and the starchy endosperm of the wheat grain. For this reason flour ash is related to milling extraction and is used both as a measure of flour grade and as an indication of milling efficiency. Ash was determined according to the AACC method 08-01 and was expressed on a dry basis for this project.

3.2.8 Protein

The determination of crude protein in wheat and flour was conducted using the Kjeldahl method (according to AACC method 46-10) in which nitrogen in the test material is determined and converted to protein through the application of a conversion factor (N x 5.7). The Kjeldahl procedure involves the following steps: digestion, distillation and titration.

1 g sample and 2 Kjeltabs containing K_2SO_4 and Se were placed in the digestion tube. 12 ml of H_2SO_4 and 5 ml of 30% H_2O_2 were also added and the contents digested at 420^{0}C for 45 minutes. The tube was then removed from the digestion unit and 50 ml distilled water was dispensed into it before it was placed in the auto analyser for distillation and titration. Protein was expressed on an 11% moisture basis for wheat and a 13.5% moisture basis for flour.

3.2.9 Falling Number

Falling Number is the time required (including an initial time of 60 seconds) to allow a viscometer stirrer to fall a measured distance through a hot aqueous gel prepared from finely ground whole meal (from a Falling # 3100 mill) contained in the viscometer tube. This was done without adjustment for moisture content, but otherwise according to the AACC method 56-81B.

This test was used as an indirect, but relatively simple means of estimating the α-amylase activity in wheat and especially for detecting and quantifying the effect of pre-harvest weather damage.

3.2.10 Test Milling

Test milling was carried out as follows with slight modifications (due to the requirements of this project) to the method given in the operating instruction manual for the Buhler type MLU-202 mill. Wheat was conditioned at an appropriate moisture content and milled in the Buhler laboratory mill, following which the flour extraction was calculated on a mill-products basis. Different flour milling extraction rates were required to produce three types of flours from each wheat sample, corresponding to the typical Tandoori breads of the 3 major regions of production, ie.

- IND Flour (72% Extraction for the Indian Naan)
- PAK Flour (88% Extraction for the Pakistani Roti); and
- IRN Flour (Half & half mixture of the above two flours {80% Extraction} for the Irani Taftoon)

3.2.10.1 Achievement of Desired Flour Extraction Rate

Cleaned wheat was conditioned for 24 hours and the moisture level adjusted in accordance with the PSI as shown in Table 3.2 (developed at the Academy of Grain Technology, Australia). It was then milled with a Buhler laboratory mill to

72% extraction rate. Extracted flour was mixed thoroughly and divided into two parts. Half of this straight run flour was taken as IND flour.

Table 3.2. Wheat conditioning according to PSI

PSI (%)	Conditioned Moisture %	Hardness Rating
11 & below	16.5	Very Hard
12-15	16.0	Hard
16-19	15.5	Medium Hard
20-23	15.0	Medium
24-29	14.5	Medium Soft
30 & above	14.0	Very Soft

3.2.10.2 Production of Bran and High Extraction Flours

Pollard and bran were separately passed through the bran finisher to get extra flour which was added into the remaining half of the straight run flour (IND flour) to increase its extraction rate. Bran was then separately ground in a Falling Number 3100 mill (ie. average particle size of 500 μ) and the required amount was added to the above high extraction flour to bring the extraction rate to 88% and was taken as PAK flour. Equal amounts of the IND flour and the PAK flour were mixed together to be taken as IRN flour (80% extraction).

3.2.11 Wet Gluten

Wet gluten is the cohesive, elastic substance which may be obtained from wheat after washing the starch and bran from a dough prepared from finely ground wheatmeal, or by washing the starch from a wheat flour dough. Wet gluten consists primarily of the water insoluble components of wheat endosperm protein in combination with water, and typically contains 25% protein and 65% water with the remaining material consisting of lipid, fibre, mineral matter and residual starch.

The test was carried out according to the ICC standard method 137 in which 10 g flour was washed with 4.9 ml of 2% salt solution for 2 minutes and then for 3 minutes with water in the Glutomatic washing chamber. Gluten is then centrifuged (Perten centrifuge model 2012) for 1 minute at 6000 rpm to remove excess water, prior to weighing.

3.2.12 Gluten Index

The Gluten Index test (carried according to the ICC standard method 155) provides a measure of gluten quality which in turn is related to bread making quality and involves the formation of a wet gluten ball by washing away the starch and fibre, after which the gluten ball was centrifuged at 6000 rpm for 1 minute in the Perten centrifuge model 2015 which has a different screen than the model 2012). The percentage of wet gluten that passed through the centrifuge sieve was measured as the Gluten Index and is calculated by the formula:

$$\text{Gluten Index} = \frac{W_2 - W_1}{W_2} \times 100$$

Where

W_1 Gluten collected from the centrifuge 2015

W_2 Gluten collected from the centrifuge 2012

3.2.13 Colour

The colour of both the flour and the Tandoori bread was measured using a Minolta Chroma Meter CR-300 according to its manual. This helped in differentiating the colours of different flours and breads produced from various wheat varieties. The Minolta "L" value indicates both whiteness and brightness on a scale of 0 to 100, with the whitest flours having the highest "L" values. The Minolta "a" and "b" values indicate the red and green, and yellow and blue respectively, on a scale of -60 to 60.

3.2.14 Starch Damage

Starch damage is any defect which destroys the integrity of intact starch granules, thus making the starch in the damaged granules more susceptible to attack by amylases. Starch damage in wheat flour arises as a consequence of the milling process, in which the structure of some starch granules is mechanically disrupted by roller milling, particularly on the reduction side of the flour mill. High starch damage levels in flour may be caused by excessive roll pressure, or by inadequate wheat conditioning. Starch damage levels in hard wheat flours are naturally higher than those in soft wheat flours. Increase in starch damage decreases the flour gluten and increases the amount of water to be added to the dough. Starch damage was determined in accordance to the AACC method 76-30A and AACC method 22-15.

3.2.15 Farinograph

The Barbender Farinograph is a physical dough testing instrument which records the resistance of dough to mixing, thereby providing information in regard to certain physical properties of the dough. The record produced by the Farinograph is in the form of a curved graph called Farinogram, which is essentially a plot of dough resistance on a vertical axis against time on a horizontal axis.

This test was carried out according to the AACC method 54-21, in which 50 g sample was placed in a Farinograph bowl. After 1 minutes of dry mixing sufficient water was added to centre the graph at maximum dough consistency and the test was run for 10 minutes beyond the point of maximum development. Information provided by the farinogram was divided into the following categories:

3.2.15.1 Water Absorption

The water absorption value is the amount of water, measured as a percentage of the flour weight, required to produce a dough of standard consistency at the development point such that the farinogram was centred on the 500 BU line. Flour water absorption measured by the Farinograph is an important quality parameter and is used to predict the water requirement of flour in baking. This test was carried and results reported on a 14% flour moisture basis.

3.2.15.2 Development Time

Development time is the interval in minutes from the first addition of water to the point of maximum consistency. It gives an indication of time required to mix the dough to full development.

3.2.15.3 Stability

Dough stability is the time minutes in between the point where the top of the curve first intersected the 500 BU line and the point where the top of the curve falls below the 500 BU line. It is an important characteristic since it indicates the susceptibility of the dough to over mixing.

3.2.15.4 Breakdown

This value is the difference (in BU) from the centre of the curve to the 500 BU line 10 minutes after development time. It also indicates the mixing tolerance of the dough which is an important parameter.

3.2.16 Extensigraph

The Extensigraph records a load-extension curve for a test piece of dough which is stretched until it breaks. Characteristics of load-extension curves or Extensigrams are used to assess flour quality with regard to the viscoelastic properties of the dough.

This method was carried out in accordance to the AACC method 54-10. A flour-salt-water dough was prepared under standard conditions in the Farinograph (except the water absorption is 1-4% less than the Farinograph water absorption depending on the strength of the flour) and moulded on the Extensigraph into a 150 g standard shape. After 45 minutes the dough was stretched and a curve was drawn recording the extensibility and resistance of the dough to stretching. The shape of the curves obtained is a guide to dough strength and hence the baking quality of the flour. Extensigram curve reflects dough extensibility, height and area. A balance between extensibility and height (resistance) is essential for good baking performance.

3.2.16.1 Extensibility

Extensibility is measured as total length of the Extensigram base in mm, indicates the stretchability of the dough.

3.2.16.2 Maximum Height

The maximum height achieved by the curve is expressed in BU. This gives an indication of the strength of the dough and its resistance to extension.

3.2.16.3 Area

The surface in cm^2 outlined by the curve indicates the total force used in stretching the dough. It is dictated by both extensibility and height.

3.2.17 Amylograph

The Brabender Amylograph is a recording viscometer used to measure and record changes in viscosity in fluid materials with changes in temperature over time under the effects of a constant stirring. The Amylograph viscosity was recorded in the form of an Amylogram which was continuously plotted on a chart as the test progressed. The viscosity in the sample system is quantified in terms of Brabender Units (BU).

According to the AACC method 22-12 and the AWB Grain Quality Procedures Manual, the Amylograph curve provides a graphic representation of the starch paste viscosity under conditions of steadily rising temperature (1.5^{0}C per minute, from 30^{0}C to 95^{0}C). Measurements taken from the Amylograph curve include starch gelatinisation temperature and peak viscosity, which is also termed the "starch paste viscosity".

The starch paste viscosity of sound wheat flour is a genetically determined factor, but this is also influenced by the presence of α-amylase which causes starch liquefaction in the early stages of the heating cycle. The Amylograph curve is therefore a function both of starch quality and α-amylase activity in the flour.

3.2.18 Test Baking of Tandoori Bread

A test baking procedure for Tandoori breads has been developed for this study (see Appendix 2) which has adequate precision and is relevant to commercial baking methods. This test baking procedure is derived from the survey of commercial baking methods conducted in the Middle East and the Sub-Continent by Hashmi et al (1994).

The following test baking equipment was designed and manufactured or modified especially for this project:

- Intermediate Resting Tray: This is a wooden box similar to the one described by Qarooni (1988), with a sliding lid in which the dough pieces were rested for 5 minutes (Plate 3.1).
- Space Guide: This is made of a wooden platform as described by Qarooni (1988), except the wooden strips on both sides were of 8 mm in height rather than 10 mm. Dough pieces were placed at the centre of the platform and were hand rolled with the help of a rolling pin that rolls on top of the strips. Hence the initial dough thickness was always 8 mm (Plate 3.2).
- Sheeting Machine: An "Impreria" Italian motorised pasta machine (model R220) was purchased and its dial (that indicates the distance between the two rolls) was modified to 0-4 mm scale with the subdivisions of 0.1 mm (Plate 3.3).
- Plastic Docker: A plastic docker was designed and made with 3 flat heads (10 mm x 2 mm) as a replacement of the tips of human fingers that are used in commercial practice for docking purposes (Plate 3.4).

Plate 3.1. Intermediate resting tray

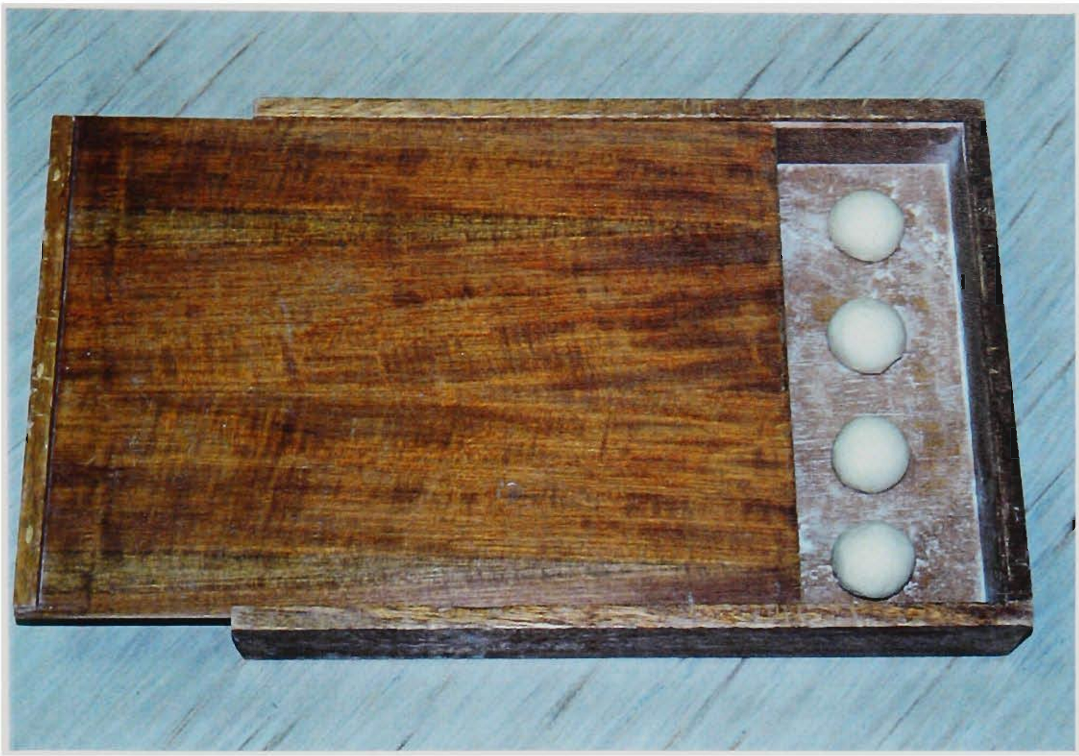


Plate 3.2. Space guide

Plate 3.3. Sheeting machine

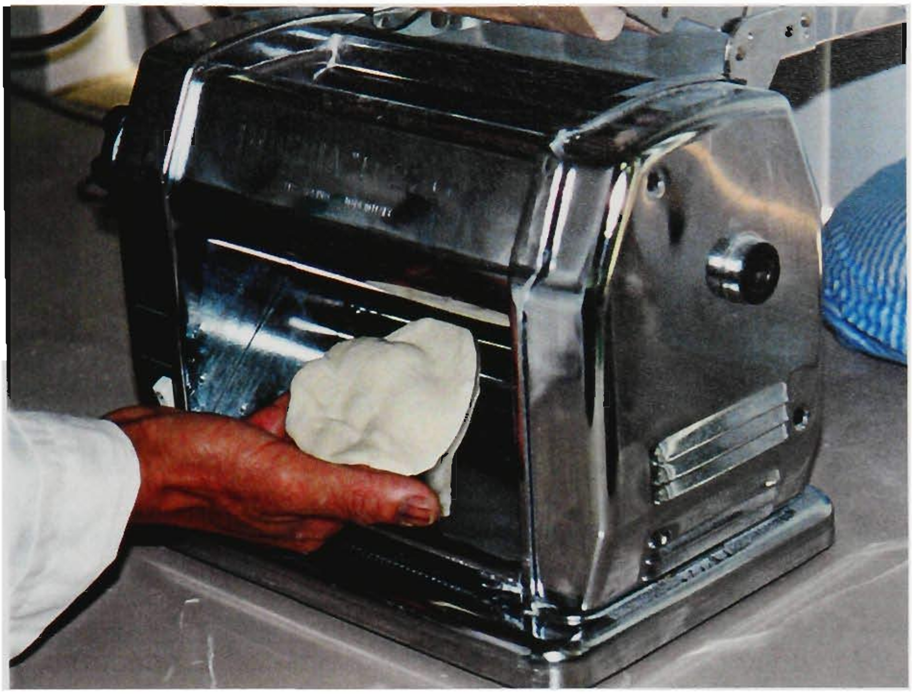
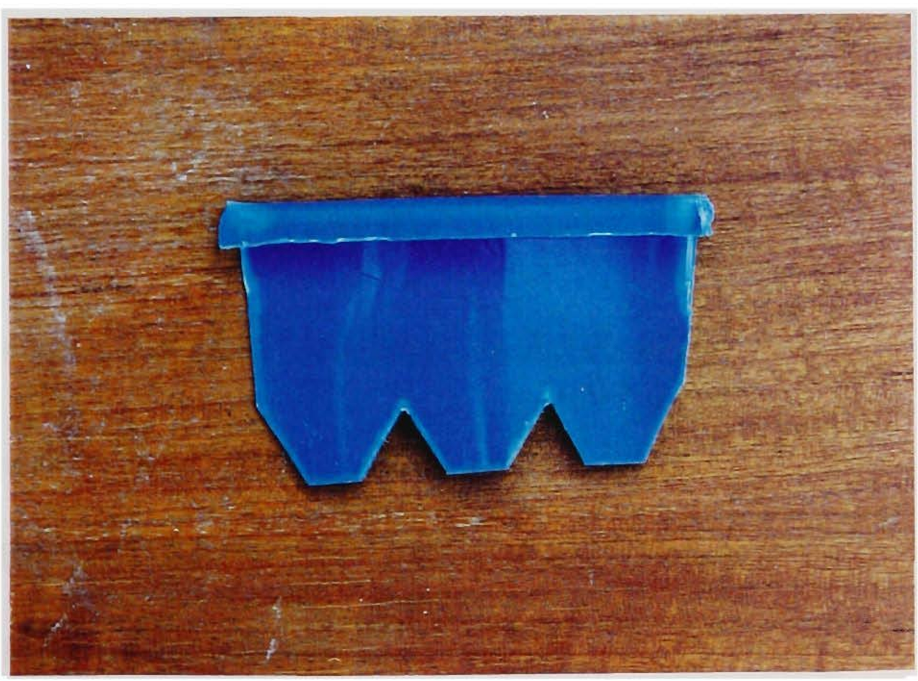


Plate 3.4. Plastic docker



Each wheat variety used in this project was milled to produce flours at three different extractions levels for the three different types of Tandoori breads (see Section 3.2.10 for details) which were produced using the following test baking procedure.

3.2.18.1 Mixing

As described in Appendix 2, 100 parts of wheat flour is taken with flour weight correction at 14% moisture basis (according to the formula given below). All the other dry ingredients (1.5 parts salt, 0.5 parts yeast and 0.2 parts baking soda) were weighed and initially mixed together in a Hobart mixer (model N50) for one minute. Water at 38^{0}C was then added according to the Farinograph water absorption (at 500 BU line) and further mixing was carried out for 3 minutes at speed 2, and 2 minutes at speed 3 for a well developed homogeneous dough of desired consistency.

Formula used for flour weight correction:

$$\text{Flour weight correction at 14 \% moisture} = \frac{W(100-14)}{(100-M)}$$

Where

M = Flour moisture %

W = Flour weight (g) at M

3.2.18.2 Fermentation

Dough was kept in a sealed container in an APV prover at 34^{0}C for 80 minutes which resulted in a non sticky and adequately leavened dough with desired softness. Dough temperature after fermentation was also recorded (desirably 29^{0}C).

3.2.18.3 Dividing and Rounding

After degassing the dough by hand it was divided manually into twelve 40 g dough pieces (using a digital weighing balance at $\pm$ 0.5 g), which were then hand moulded into balls.

3.2.18.4 Resting

These dough balls were then kept for 5 minutes in the intermediate resting tray which was dusted with the same flour as used in test baking. This tray was covered with a sliding lid to avoid skinning on the dough balls due to surface moisture evaporation.

3.2.18.5 Sheeting

Two dough balls were taken out from the intermediate resting tray at a time and were initially hand rolled to 8 mm thickness using the space guide and a rolling pin and then passed twice through the rollers of the sheeting machine (rotating at 50 rpm). The gap between the rolls was adjusted to 2 mm for the first sheeting and then (by turning the it to 180^0 or simply first out first in basis) they were finally sheeted at 1.5 mm. Final sheeted dough pieces were oval in shape.

3.2.18.6 Docking

Sheeted dough pieces were docked with the plastic docker three times to get 9 holes on the surface.

3.2.18.7 Baking

Sheeted and docked dough piece were individually kept on a moist cushion and then were individually placed on the wall of the test Tandoor operating at 330^0C (see Section 3.2.19). Baked bread was taken out from the Tandoor after 55 sec with the help of two steel rods and was cooled for 10 minutes at room temperature on cooling racks. They were then kept in sealed plastic bags for 30 minutes before quality assessment was carried out by the sensory panel (see section 4.3).

3.2.19 Designing and Installation of a Tandoor

In order for reliable and repeatable small scale manufacture of Tandoori breads, it was necessary to design, install, commission and evaluate a test Tandoor which could be precisely set to a range of parameters controlling gas flow and air supply to the Tandoor. This Tandoor was used for all test baking and should also provide a standard tool for commercial Tandoori bread baking, because at present commercial Tandoors do not control the above mentioned factors resulting in variations of the end products even from the same mixing batch.

3.2.19.1 Designing of the Test Tandoor

One steel oven shell, two hot plates, burner and gas-air controller were designed and made to order in Pakistan and purchased and imported from the United Arab Emirates to Australia especially for this project. A local supplier of commercial clay Tandoors in Melbourne was involved to assemble the components as per the specification provided to him. The Australian Gas and Fuel Department was also involved in certifying the design according to their standards for the use of natural gas in test baking.

3.2.19.2 Installation of the Test Tandoor

This newly designed test Tandoor is presented in Figure 3.2.

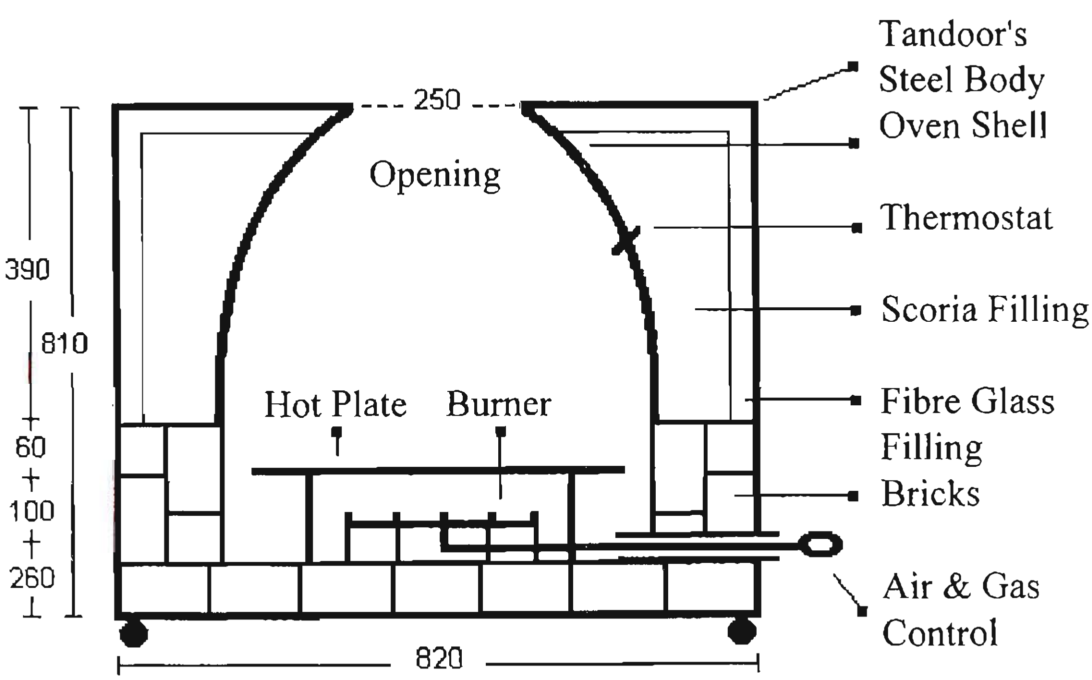


Figure 3.2 Diagram of the newly designed Tandoor (All dimensions are in mm)

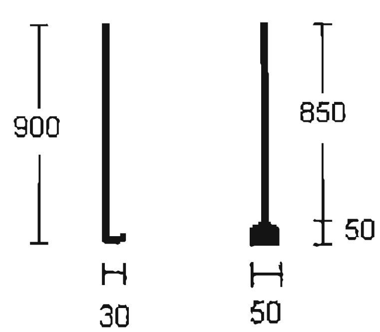
Specific components of the new Tandoor are as follows:

- Base: Fire proof bricks were fixed on top of the stainless steel plate at the base of the Tandoor.
- Oven shell: The oven shell was fixed on top of the fire proof bricks 420 mm from the base (breads were placed horizontally on the oven wall at an approximate distance of 180 mm from the hot plates).
- Burner: A burner was fixed on the base having gas and air inlets (to get the desired amount of gas with 1 kPa pressure). A push button spark igniter was attached to the burner for convenience.
- Hot Plates: Two removable hot plates with six adjustable steel legs were placed on the base of the Tandoor and the distance between the hot plates and the burner was kept at 100 mm to maintain even burning.
- Temperature: A digital thermometer was installed and connected to the main gas supply with an auto cut off and on switch. The thermometer probe was fixed in the baking chamber to control the temperature at the oven wall (for test baking purposes the temperature was set at 330^{0}C on the digital dial of the thermometer. However, it was interesting to note that because of the intensity of the flames the temperature at the top opening of the Tandoor was measured at around 430^{0}C).
- Body: The Stainless steel outer body (810 mm x 820 mm) was bolted to the bottom on all four sides.
- Insulation: Heat and fire resistant fibreglass insulation was placed on all four sides along the stainless steel body as well as on the top except on the

opening. The remaining empty space was filled with scoria (pieces of volcanic rocks having air bubbles inside which act as insulation).

- Top: A stainless steel top was also bolted to the baking chamber (with a round opening of 250 mm diameter at the centre). A steel ring was fixed at the top opening. A steel lid with a handle was especially manufactured to cover the top opening when the Tandoor is not in use or to partially cover the top opening to get to the desired temperature when the burner is first ignited.
- Position: Four wheels were fixed at the bottom of the Tandoor for easy movement (if required).
- Loading and unloading: A moist cushion was used to load the bread in the Tandoor and two steel rods (shown in Figure 3.3) were used to remove the bread. One of the rod is the scraping rod while the other is a piercing rod to hold the bread while unloading.

Piercing rod



Scraping rod

Figure 3.3 Tandoori bread unloading rods (All dimensions are in mm)

Newly designed test Tandoor, loading of Tandoori bread, test baking, and unloading of the Tandoori bread are shown in Plates 3.5-3.8.

Plate 3.5. Test Tandoor

Plate 3.6. Loading of test bread

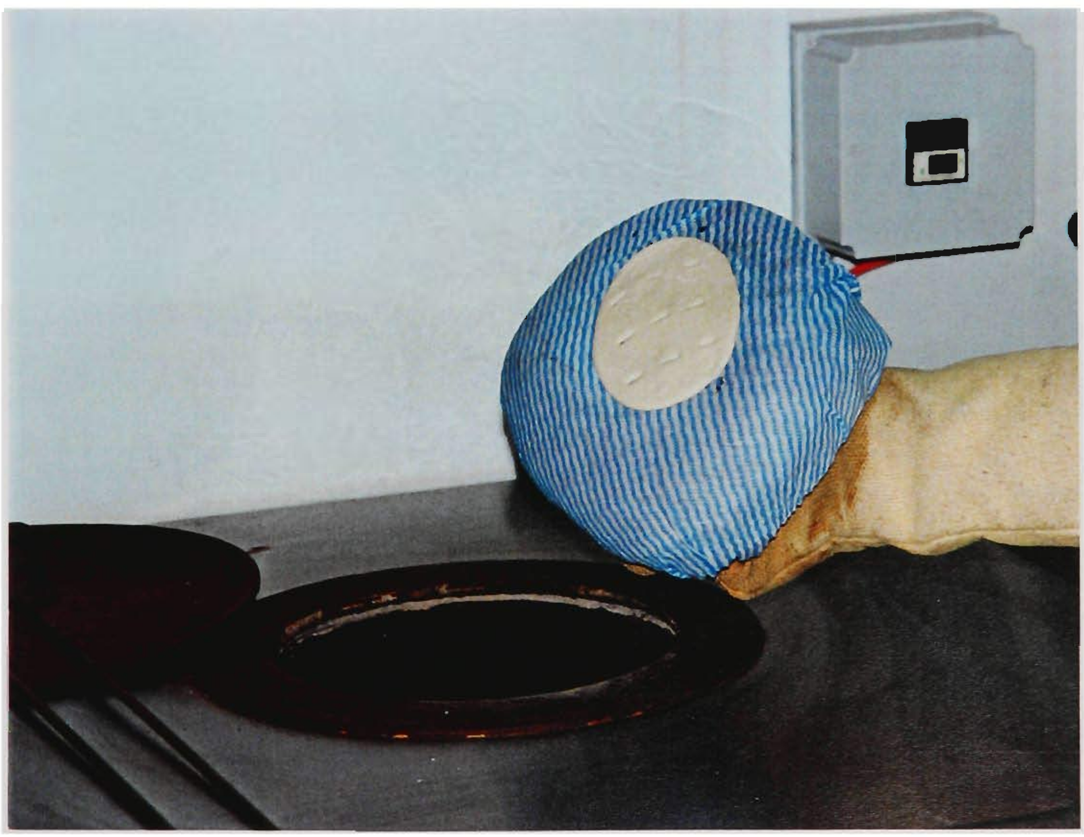
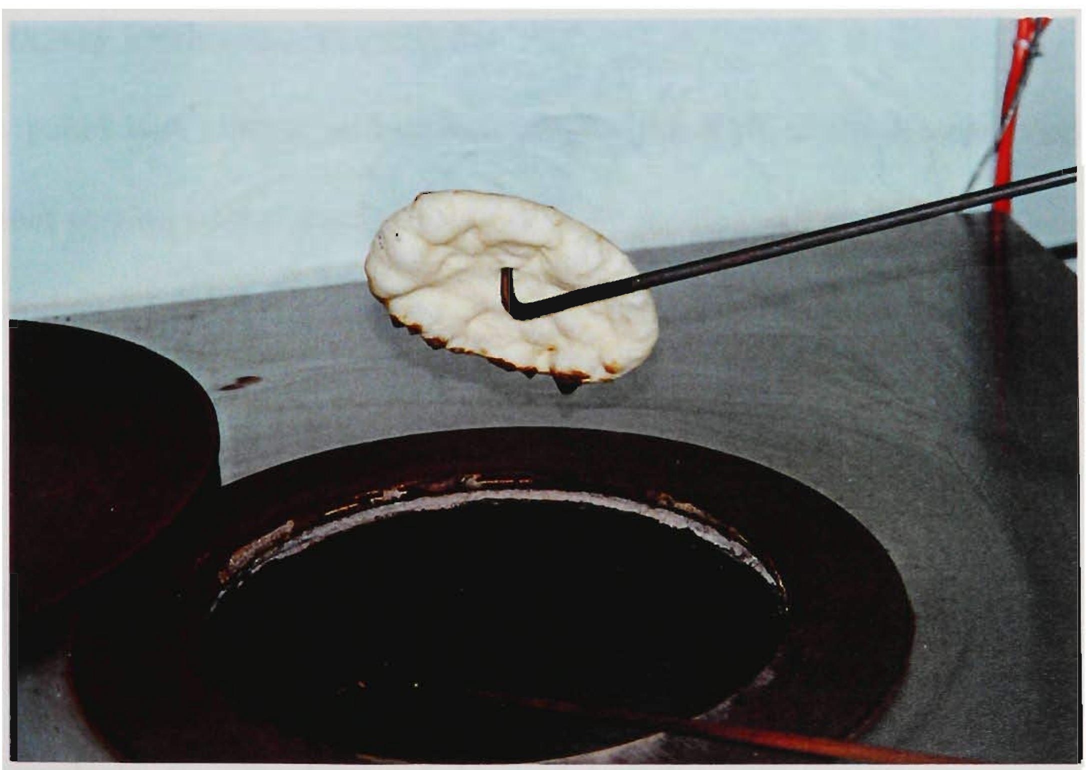


Plate 3.7. Test baking

Plate 3.8. Unloading of test bread



3.2.20 Tandoori Bread Evaluation

Bread evaluation was based on the scoring system and carried out by a trained sensory panel described as follows:

3.2.20.1 Scoring System

A simple and easy to understand scoring system to evaluate the bread quality was developed (see Section 4.1.7.1). This system was capable of discriminating between wheat varieties and was used to investigate the effect of different variables such as milling, baking and ingredients on the quality of Tandoori bread. This system was based on a survey of current commercial practice and quality expectations in the region where these breads are most popular.

3.2.20.2 Sensory Evaluation Techniques

A sensory panel was chosen and trained among the staff at the Research and Development section of the Academy of Grain Technology to evaluate the bread qualities produced from different types of Australian wheat varieties (see Section 4.3 for details).

3.2.21 Statistical Analysis

Statistical software "Minitab for Windows (Minitab, 1994)" was used to perform statistical analysis (ie. Analysis of Variance, Correlation Matrix, Principal Component Analysis and Multiple Regression).

4. RESULTS AND DISCUSSION

4.1 SURVEY OF INTERNATIONAL PRODUCTION OF TANDOORI BREAD

4.1.1 Australian Wheat Exports and their Uses in Tandoori Bread Consuming Countries

Tandoori breads are widely consumed in the countries where Australian wheat is marketed which are listed in Table 4.1. This table is based on a survey conducted by Hashmi et al. 1994 of the people of the Middle East and the Sub-Continent (where Australian wheat is exported) in which their eating habits of the wheat based end-products were determined.

Table 4.1. Eating habits of wheat based end-products of the people of the Middle East and the Sub-continent.

Country	Tandoori Breads %	Arabic Breads %	Other Flat Breads %	English Breads %	Confect-ionary %	House-hold %
Afghanistan	88	0	0	1	1	10
Bahrain	30	33	5	15	5	12
Bangladesh	20	0	15	20	5	40
Egypt	1	75	3	15	5	1
India	20	0	10	15	5	50
Iran	40	5	25	20	5	5
Iraq	15	65	5	10	3	2
Oman	15	50	5	15	5	10
Pakistan	40	0	5	15	5	35
Qatar	30	33	5	15	5	12
UAE	30	33	5	15	5	12
Yemen	5	70	2	10	3	10
Eating Habits %	28	30	7	14	4	17

In this survey, wheat based end-products were divided into six categories ie. Tandoori breads, Arabic breads, other flat breads, English breads, confectionary and house hold products. According to the feed back from the people of the countries mentioned in the above table, it was found out that Tandoori breads have a market share of 28% among all the wheat based end-products.

From Table 4.2 it can be seen that total Australian wheat exported to these countries between 1991-96 was around 18 million tonnes, out of which about 4 million tonnes of wheat was milled for the production of Tandoori breads. Table 4.2 is based on the eating habits of people of different countries and total export of Australian wheat.

Table 4.2. Wheat consumption in different countries.

Country	Wheat Export *	Tandoori Breads	Arabic Breads	Other Flat Breads	English Breads	Confect -ionary	House Hold
Afghanistan	14,995	13,196	0	0	150	150	1,500
Bahrain	58,695	17,609	19,369	2,935	8,804	2,935	7,043
Bangladesh	515,600	103,120	0	77,340	103,120	25,780	206,240
Egypt	5,058,437	50,584	3,793,828	151,753	758,766	252,922	50,584
India	1,049,902	209,980	0	104,990	157,485	52,495	524,951
Iran	6,113,798	2,445,519	305,690	1,528,450	1,222,760	305,690	305,690
Iraq	1,470,771	220,616	956,001	73,539	147,077	44,123	29,415
Oman	792,672	118,901	396,336	39,634	118,901	39,634	79,267
Pakistan	908,901	363,560	0	45,445	136,335	45,445	318,115
Qatar	207,676	62,303	68,533	10,384	31,151	10,384	24,921
UAE	1,043,775	313,133	344,446	52,189	156,566	52,189	125,253
Yemen	1,082,500	54,125	757,750	21,650	108,250	32,475	108,250
Total Wheat	18,317,722	3,972,645	6,641,953	2,108,307	2,949,365	864,221	1,781,230

* Australian wheat exports (million tonnes) between 1991-96

4.1.2 Tandoori Bread Consumption in Australia

According to the information supplied by the local Tandoor manufacturers, it is estimated that there are around one thousand Tandoors operating in Australia, mainly in the Pakistani, Indian and the Middle Eastern restaurants in all major cities. Some of the Tandoors are installed at homes to bake Tandoori breads as well as to cook other foods. It is therefore difficult to find out the exact number of Tandoori breads produced in these Tandoors daily. Most of these Tandoors are fired by charcoal. In addition to its use for this research project, designing and installation of a gas controlled Tandoor at the research facility would be useful for Tandoor manufacturers in Australia as a model for new commercial Tandoors and for modification of existing Tandoors from charcoal fire to gas which is not only cheaper, but also very convenient to use.

4.1.3 Baking Technique for Tandoori Bread

It was necessary to undertake a survey of current commercial practices in the regions where these breads are most popular to collect clearly documented data on the ranges in parameters commonly used. This is a necessary prerequisite to the development of the baking procedure for three types of Tandoori breads and the design of a test oven.

Hashmi et al. (1994) carried out such a survey in the United Arab Emirates, Pakistan and India for this project. Part of this survey was reported by Hashmi & Wootton (1995). The survey provided information about current commercial practices of Pakistani, Indian and Irani origin which includes parameters such as the flour extraction rates, ingredient formulations, dough mixing timing and intensity, proofing conditions (such as temperature and humidity), dough dividing, moulding, sheeting, docking and Tandoori oven design and construction and operating conditions (information provided in Section 2.3.2 is based on this survey).

The results of the survey provided a rational basis for selecting the experimental conditions and establishing meaningful ranges for the parameters studied and a test baking procedure for Tandoori breads was developed as part of this project and is described in Section 3.2.18; this included appropriate mixing, fermenting, moulding, resting, sheeting, docking and baking techniques as well as designing and installation of a test Tandoor. Information about scoring of Tandoori breads was obtained (see Section 4.1.7 for details).

4.1.4 Comparison of the Test Tandoor with the Commercial Tandoor

The test Tandoor is more scientifically designed than the commercial Tandoors. It has absolute controls over air, gas and temperature. Its insulation is also very effective as its outer body never gets hot, therefore the heat loss is minimum and operational safety is enhanced. Due to constant baking temperature, no variations occur in the bread qualities when many breads are baked. The oven can also be relocated if the setting of the baking room is changed.

Comparison between commercial Tandoors and the Test Tandoor designed for this study is presented as follows:

- Body: Most of the commercial Tandoors have a ceramic tiled body. The test Tandoor has stainless steel body.
- Position: Commercial Tandoors are installed permanently and cannot be relocated. The test Tandoor is on wheels and can be relocated easily if required.
- Base: Commercial Tandoors as well as the test Tandoor have fireproof bricks at the base.
- Filling: Commercial Tandoors are filled with white sand and concrete for insulating purposes. The test Tandoor is filled with heat and fire resistant fibreglass and scoria.
- Tandoor shell: Commercial Tandoors have either clay or steel shells. The test Tandoor has steel shell.
- Burner: In commercial Tandoors, matches are used to fire the burner. In the test Tandoor a spark igniter is used to fire the burner.
- Hot plate: Those commercial Tandoors which are fired by charcoal or wood fire don't have hot plates while others have hot plates at fixed heights. The test Tandoor has hot plates with adjustable legs to allow alteration of the height between the burner and the hot plates to achieve uniform distribution of heat.

- Air-inlet: Commercial Tandoors normally have angular air supply through a pipe without any controls. The test Tandoor has a horizontally installed control valve for the inlet air.
- Gas-inlet: In those commercial Tandoors which are fired by gas, the gas supply is controlled manually. The gas supply in the test Tandoor is controlled at a defined pressure using a gas valve.
- Fire source: Commercial Tandoors are fired either by gas, charcoal, wood or diesel. The test Tandoor is fired by natural gas.
- Temperature: Commercial Tandoors do not have any control over temperature except by manually setting the gas supply. The test Tandoor has a thermostat inside the baking chamber that is connected to a digital thermometer and a gas auto cut off and on switch for maintaining constant temperature.

4.1.5 Comparison of Different Test Baking Methods and Commercial Practice

As described in the literature review Section 2.4, there have been few test baking methods for Tandoori breads reported in the literature. These are discussed below in comparison with commercial practice in terms of their advantages and disadvantages.

The Tandoori bread test baking method presented by Faridi et al. (1983) did not include the intermediate resting of the rolled dough pieces before sheeting which is common in commercial practice. Test baking was also not carried out in a Tandoor.

In another test baking method presented by Faridi et al. (1981) a second fermentation of 30 minutes after sheeting was mentioned, which is common for Arabic bread (Khubz) but not for Tandoori bread which is baked immediately after sheeting and docking. The docking step was absent in this method and again test baking was also not carried out in a Tandoor.

The test baking methods described by Qarooni (1988) & Qarooni & Posner (1993) for Tandoori bread production were described in considerable detail, but the equation used for calculating the baker's water absorption was actually suitable for Arabic bread production only, because the baker's water absorption is much higher in Tandoori bread compared to Arabic flat bread (Hashmi & Wootton 1995). In these test methods, baking was not carried out in an actual Tandoor.

The laboratory scale method for the production of Tandoori bread suggested by Rahim et al. (1993) had some fixed features according to the observations gathered from the restaurants (such as a long list of ingredients), while some variables were tuned to give optimum bread quality. No control of conditions such as fermentation temperature and baking temperature was described, which is vital in developing a test procedure.

The laboratory scale method for the production of Tandoori bread presented by Saxena et al. (1995b) was an extension of the work carried out by Rahim and Vatsala (1993) which did not give details about some of the processing variables. These include final dough temperature and temperature during fermentation. Fermentation time was also very short. Important processing steps such as intermediate resting and docking were also absent. Baking was also carried out at 470^{0}C refractory wall temperature, well above temperatures used in commercial practice (Hashmi et al. 1994). The baking time of 80 sec was quite long for the temperature used in the Tandoor.

4.1.6 Comparison of the New Test Baking Method with Commercial Baking

Comparison of the test baking method with the commercial baking method is described in the following sections:

4.1.6.1 Mixing

In commercial Tandoori bread baking, ingredients are mixed either by hand or by slow speed spiral mixer for approximately 25-30 minutes to achieve the desired level of dough development. In the new test baking method, dough development was achieved in only 5 minutes using a small Hobart spiral mixer.

4.1.6.2 Fermentation

Test baking dough was kept in sealed container in a prover for 80 minutes at 34^{0}C compared to the dough in commercial practice which is either taken out from the mixer and kept on a table or remains in the mixer and is covered with a plastic sheet to prevent skinning for 80-120 minutes at the variable ambient temperature in the bakery (20-40^{0}C).

4.1.6.3 Dividing and Rounding

Size of the test dough piece was much smaller (40 g) than the commercial dough (150-250 g) mainly because of the amount of flour available for testing and also because of the use of a mechanical sheeting machine which was not designed to take bigger samples.

4.1.6.4 Resting

Intermediate resting in the test method was carried out using a wooden tray (covered with a lid) for 5 minutes rather than resting the dough pieces under a plastic sheet for 5-10 minutes before sheeting as in the commercial method.

4.1.6.5 Sheeting

In commercial practice the dough pieces are initially rolled to a thickness of about 10-15 mm using a rolling pin. Final dough thickness of 3-10 mm is achieved by stretching them manually when they are placed on the moist cushion after docking. In the test method, a space guide with a rolling pin was used to get the initial dough thickness of 8 mm and then a sheeting machine was used to get the desired shape at a final 1.5 mm thickness (mainly due to the dough weight).

4.1.6.6 Docking

In the test method, docking was always carried out after final sheeting with the help of the precise plastic docker while in commercial practice docking is mostly done by finger tips or sometimes with a metallic docker, but as mentioned in the previous section, the dough is further stretched after docking.

4.1.6.7 Baking

In commercial practice breads are baked at 300-450^{0}C for 60-120 sec in a Tandoor where the bread adheres to the wall of the Tandoor's shell when positioned by the baker using a moistened cushion. Breads are removed with special metal rods when baking is completed. Test baking, time and temperature were around the ranges used commercially with all the breads baked at 330^{0}C for 55 sec.

4.1.7 Development of a Scoring System

Tandoori bread evaluation was based on a scoring system and was carried out by a sensory panel (see Section 4.3 for details). It is described in the following paragraphs.

A simple and easy to understand scoring system to evaluate the bread quality was developed. This system is capable of discriminating between wheat varieties and was used to investigate the effect of different variables such as milling, baking and ingredients on the quality of Tandoori bread.

This scoring system was designed for all the three types of Tandoori breads and is based on a survey of several Tandoori bread shops of the Middle East and the Pakistani-Indian Sub-Continent (Hashmi et al. 1994). In this survey, a questionnaire was given to the bakers to get their opinion about the customers' preferences for Tandoori bread quality (see Appendix 1). In the light of the responses form the bakers a preferred scoring system was developed and is presented in Table 4.3.

Table 4.3. Tandoori bread scoring system

according to bakers' preferences.

Quality Parameter	**Maximum Score**
Shape	15
Crust Colour	15
Crust Smoothness	10
Blisters	5
Rolling Quality	10
Tearing Quality	20
Chewing Quality	15
Taste	10
TANDOORI BREAD SCORE	100

This preferred scoring system for the Tandoori bread reflects quality parameters such as "Shape", "Crust Colour", "Crust Smoothness", "Blisters", "Rolling Quality", "Tearing Quality", "Chewing Quality" and "Taste". Allocations of maximum scores for each quality parameter were given according to the bakers and their customers' preferences and choices. For example the "Tearing Quality" of the bread was given a share of 20 points out of the total 100 points, but on the other hand "Blisters" were assigned only 5 points because of it was attributed less importance.

The bakers, however, thought that it was not wise to take into account the "Area" and the "Crumb Appearance" of the Tandoori bread (as was suggested in the questionnaire shown in Appendix 1) because the Tandoori bread is stretched by hand to achieve the final thickness which does not leave any room to observe the expansion or shrinkage (Area) when the bread is baked commercially. Also the "Crumb Appearance" is of no importance while scoring because Tandoori bread is a single layered flat bread in which the top and the bottom crusts are not separated hence the crumb is unexposed except from the sides when small pieces are torn or bitten off.

The selected quality parameters for the test baked breads should have the features presented in sections 4.1.7.1 to 4.1.7.8.

4.1.7.1 Shape

Tandoori bread should be of oval shape. Points were deducted for lack of symmetry.

4.1.7.2 Crust Colour

The three types of Tandoori breads differ in crust colours due to the different extraction rates of the flours used (Pakistani Roti is brown, Indian Naan is cream and the Irani Taftoon is light brown in colour). Points were deducted for crust colours which were different from that required for each bread type.

4.1.7.3 Crust Smoothness

Tandoori bread should have even and smooth crust without wrinkles and cracks. Points were deducted for lack of smoothness.

4.1.7.4 Blisters

Tandoori bread should have evenly distributed small blisters. Marks were deducted for very large, black and unevenly distributed blisters. Marks were also deducted for absence of blisters.

4.1.7.5 Rolling Quality

Tandoori bread should withstand rolling without cracks on the crust. Marks were deducted if the bread was difficult to roll or if cracks appeared while rolling the bread.

4.1.7.6 Tearing Quality

Tandoori bread should be easy to tear. Marks are deducted if the bread is difficult to tear.

4.1.7.7 Chewing Quality

Tandoori breads should be easy to chew, but the level of chewing differs for each of the three bread types. Roti is very easy to chew while Taftoon is moderate, but Naan is tougher than the two because of no bran in it. Marks were deducted if the bread was too difficult to chew for its particular type.

4.1.7.8 Taste

Tastes of the three types of Tandoori breads differ due to the type flour used and are as follows: Pakistani Roti (Taste of Bran), Indian Naan (No taste of Bran) and Irani Taftoon (Slight taste of Bran). Divergence from the required taste for each bread type resulted in deduction of marks.

4.2 COMPARISON OF DIFFERENT SCORING SYSTEMS

As described in Section 2.5, the two Tandoori bread scoring systems presented by Qarooni (1988) and Qarooni & Posner (1993) involve assessment on the day after baking. However, the quality assessment of Tandoori bread should not involve such assessment because the Tandoori breads are preferably consumed immediately after they are baked (when they are still hot). These evaluation schemes have also considered the crumb appearance in the bread, which is indeed quite important for Arabic flat bread, but has no significance for Tandoori bread whose layers are never separated, hence crumb should not be taken as a quality parameter for this product. Uniformity of thickness is also graded for Tandoori breads due to the presence of blisters. Both of these scoring systems appear to represent extension of research into Arabic flat bread types rather then specific derivatives for Tandoori breads.

Rahim and Vatsala (1993) presented a scoring system for the evaluation of Naan which was based only on day one scoring as required by Tandoori breads. However, it did not give further details of some of the quality attributes such as crust characteristics, ability to roll and tearing quality which are vital in developing an evaluation scheme. In this scoring system the distribution of markings was kept same for every quality parameter. However, these quality parameters should have different markings according to their importance, as it was found out from the survey of Appendix 1.

The scoring system for the evaluation of Roti presented by Saxena and Rao (1995a) appears to be an extension to the scoring procedure presented by Rahim and Vatsala (1993) for the production of Naan as both reports originated from the same facility. Although it had taken under consideration a few extra parameters such as colour, and taste & aroma, it did not give further details about the break up of the characteristics such as handfeel and mouthfeel. Not only is the grading long (because of its 7 point scale), but also the maximum score for each quality characteristic is the same, which means that according to this system each quality characteristic is of similar importance. This grading also looks like an extension of the work carried out by Rahim and Vatsala (1993) where they presented a 5 point grading scale. Also in this scoring system the distribution of markings was the same for every quality parameter rather than assigning different weighting to different quality parameters according to their importance.

None of the above scoring systems described any sensory evaluation technique that had been used for the end product evaluation (as presented in the following sections).

4.3 DEVELOPMENT OF SENSORY EVALUATION TECHNIQUES

Development of sensory evaluation techniques was based on the selection of a sensory panel and its training as described in the following sections.

4.3.1 Selection of a Sensory Panel

To produce reliable and valid data, a sensory panel must be treated as a scientific instrument. It was therefore necessary that panellists were free from any psychological features and physical conditions which might affect human judgements. Panellists must have an ability to perform the task and to repeat their judgements. The following criteria for screening of panellists were considered (Quail 1995):

4.3.1.1 Sensory Ability

It was necessary that each panellist must be free from the following defects:

- taste perception disorders
- odour perception disorders

- colour blindness
- denture defects

4.3.1.2 **Health**

It was necessary that each panellist must be free from the following defects:

- allergies
- use of those medications which effect the ability to taste
- prone to minor infections of nose and throat

4.3.1.3 **Attitude and Interest**

It was necessary that each panellist must have the following:

- motivation
- availability

Based on the above criteria a sensory panel was chosen, screened and trained among the staff at the research facility to evaluate the Tandoori bread qualities produced from different Australian wheat varieties.

4.3.2 **Training of the Sensory Panel**

Initially eleven panellists were selected, but the majority of them had no previous experience in Tandoori breads, it was therefore necessary to train them about the products first and then to take into account of differing quality expectations between the three principal regions, where texture and appearance criteria were affected by the flour extraction rates used and must match expectations of specific consumers. Tandoori breads from the three principal regions were baked on successive occasions for the sensory panel to taste while explaining to them the basic differences between the Tandoori breads and other flat breads of the Middle East and also the differences between the three different types of Tandoori breads. Based of the individual performance of each panellist, five were finally chosen for the sensory evaluation work and one was kept as a reserved panellist who was used in the absence of any of the main five.

Once the panellists gained an appreciation of Tandoori bread quality, product oriented triangular tests (see section 4.3.2.1 & 4.3.2.2) were carried out between the three different types of Tandoori breads and within each type.

4.3.2.1 **Discriminative Tests**

All panellists were assessed for the following two types of tests:

- Difference Tests: Tests to find a difference between the control and other products.
- Sensitivity Tests: To test the ability of panellists to detect sensory characteristics.

4.3.2.2 **Descriptive Tests**

Descriptive tests were carried out among the panellists to measure their ability to evaluate qualitative and quantitative characteristics of Tandoori breads.

4.3.3 Psychological Factors Affecting Sensory Panel

Some of the psychological factors that influenced the sensory measurements of the panellists were rectified (see section 4.3.3.1 to 4.3.3.7):

4.3.3.1 Expectation Error

This occurs when panellists are given too much information about the samples. Therefore the panellists were not informed about the types of wheat used in the sensory testing.

4.3.3.2 Stimulus Error

This occurs when panellists are influenced by some characteristics of the sample (ie. size, shape, colour, etc). Therefore the panellists were instructed and trained not to impose the marking of one quality parameter on others.

4.3.3.3 Suggestion Error

This occurs when panellists are aware of reactions of others during the sensory evaluation. This was addressed by providing panellists with individual sensory booths.

4.3.3.4 Halo Effect

Sometimes panellists evaluate more than one quality characteristic at a time. They were therefore, trained and instructed to evaluate each quality parameter separately.

4.3.3.5 <u>Lack of Motivation</u>

Lack of motivation may be present among the panellists due to a number of reasons, but because of the management support, proper sensory schedules and the keen interest of all the panellists lack of motivation was not observed.

4.3.3.6 <u>Central Tendency Error</u>

Panellists may choose the mid range to avoid extremes. All panellists were therefore, advised to choose the correct scale for each quality characteristic rather than just selecting the mid range of the scale to avoid extremes (the evaluation scheme was based on a five point criterion as mentioned in Section 4.3.4).

4.3.3.7 <u>Order Effect</u>

This may affect the panellists if the sensory samples are provided in a defined order. All samples were presented in a random order with a three digit number assigned to each sample to avoid the order effect.

4.3.4 <u>Sensory Evaluation of Tandoori Breads</u>

Tandoori bread evaluation sheets presented in Appendices 3-5 were based on the scoring system according to a five point scale given in Table 4.4.

According to the table a panellist could grade each Tandoori bread quality parameter according to his or her choice based on the five point scale. For example, if a panellist thought that the "Crust Smoothness" of the bread was satisfactory then he or she had to give 6 points based on the maximum 10 points assigned to the "Crust Smoothness".

Table 4.4. Tandoori bread evaluation (point scale).

Max Points	Poor	Fair	Satisfactory	Good	Excellent
5	1	2	3	4	5
10	2	4	6	8	10
15	3	6	9	12	15
20	4	8	12	16	20

Tandoori breads produced from each batch were distributed among the panellists for evaluation according to the scoring sheets presented in Appendices 3-5. During this sensory evaluation work each panellist was presented with one bread sample that was evaluated in comparison to the control sample (see Section 4.3.5) and was rated as per the performance of each individual quality parameter shown in Table 4.4 in accordance to the rating given in Table 4.5.

The results from the scoring of the Tandoori breads using the above procedure (see Appendices 10, 13 & 16) were analysed for statistical purposes and are presented in Section 4.6.

4.3.5 <u>Reference (Control) Flours</u>

Reference (control) flours for the three different types of Tandoori breads were obtained from a commercial flour mill in the Middle East (see Appendix 17 for data). Wheats milled to produce these reference flours were from Australia, United States and India. Reference test breads were produced from these flours for each sensory schedule and were used as control samples for the evaluation procedure. Scoring on these control breads was carried out and is presented in Table 4.5 (according to Appendices 3-5). Each test bread produced was evaluated in comparison to these control breads and was rated on the assessment of each individual quality parameter that may be better or worse than the control bread.

Table 4.5 Scoring of control breads

Quality Parameter	**Maximum Score**	**Control Breads' Scoring PAK**	**IND**	**IRN**
Shape	15	12	9	12
Crust Colour	15	9	12	12
Crust Smoothness	10	6	6	8
Blisters	5	3	3	4
Rolling Quality	10	8	6	6
Tearing Quality	20	16	12	12
Chewing Quality	15	12	9	9
Aroma & Taste	10	8	8	8
TOTAL SCORE	100	74	65	71

4.4 ROLE OF PROCESSING VARIABLES

All three reference flours were used in determining the role of different processing variables which is based on the scoring results in Appendix 6 and Tables 4.6 to 4.12 Interpretations of the scoring results and observations are described in the following sections.

4.4.1 Mixing

After the initial 1 minute dry mixing, in the 5 minutes normal mixing the addition of amount of water equal to Farinograph water absorption gave well developed homogenous doughs with desired consistency.

4.4.1.1 Effect of Level of Water Addition

Farinograph water absorption (FWA) at the 500 BU line was taken as the standard baking absorption for Tandoori breads. Effects of levels of water addition on the quality of Tandoori breads are summarised in Table 4.6.

Table 4.6 Effect of addition of water on Tandoori bread quality

Parameter	FWA-2 %	FWA+2 %
Shape	Long	Round & short
Colour	Same as control bread	Light
Smoothness	Few cracks	Wrinkles
Blisters	Same as control bread	Nil
Rolling	Slightly difficult	Slightly difficult due to size
Tearing	Slightly difficult	Same as control bread
Chewing	Difficult	Easy
Taste	Dry	Sticky crumb

When 2% less water than the Farinograph water absorption was added in dough mixing, the resultant bread was long in shape with a few cracks on the surface. It was, also slightly difficult to roll and tear, and was quite difficult to chew as it was dry. When 2% extra water than the Farinograph water absorption was added in dough mixing, the resultant bread was round and short in shape, light in colour, with some wrinkles. It was also slightly difficult to roll because of its size, but easy to chew with a sticky crumb.

4.4.1.2 Mixing Time

A 5 minutes mixing time was taken as the standard mixing time irrespective of the Farinograph development time. Other doughs were mixed for 4 and 6 minutes respectively. Table 4.7 summarises the effects mixing time on the quality of Tandoori breads.

Table 4.7 Effect of mixing time on Tandoori bread quality

Parameter	4 minutes	6 minutes
Shape	Slightly uneven	Same as control bread
Colour	Same as control bread	Light
Smoothness	Cracks	Wrinkles
Blisters	Flat	Uneven
Rolling	Same as control bread	Same as control bread
Tearing	Same as control bread	Same as control bread
Chewing	Same as control bread	Easy
Taste	Same as control bread	Same as control bread

When the mixing time was reduced to 4 minutes from 5 minutes, it was observed that the Tandoori bread was slightly uneven in shape with cracks on the surface and no blisters. When the mixing time was increased from 5 minutes to 6 minutes, it was observed that the colour of the bread was lighter than that of the control bread, with wrinkles on the surface and uneven blisters. The bread was also found to be easier to chew due to over mixing.

4.4.2 Fermentation

A fermentation time of 80 minutes of the dough (in sealed containers) at 34⁰C was found to be optimum, resulting in a dough with proper handling properties and a bread with even shape, crust and blisters.

4.4.2.1 Fermentation Temperature

Fermentation was carried out at 34⁰C (control), 30⁰C and 38⁰C for 80 minutes. Table 4.7 shows the effects of fermentation temperature on the quality of Tandoori breads.

Table 4.8 Effect of fermentation temperature on Tandoori bread quality

Parameter	30⁰ C	38⁰ C
Shape	Slightly long	Same as control bread
Colour	Same as control bread	Same as control bread
Smoothness	Few cracks	Same as control bread
Blisters	Few	Uneven
Rolling	Same as control bread	Same as control bread
Tearing	Same as control bread	Same as control bread
Chewing	Same as control bread	Better
Taste	Same as control bread	Same as control bread

The lower fermentation temperature of 30⁰C resulted in a dry dough which was difficult to mould and produced breads of long sizes with few a cracks and less blisters on the surface. On the other hand, the higher fermentation temperature of 38⁰C resulted in slack doughs which were difficult to handle. These breads had uneven blisters.

4.4.2.2 Fermentation Time

Fermentation was carried out at 34^{0}C for 80 minutes (control), 60 minutes and 100 minutes. Effects of fermentation time on the quality of Tandoori breads are presented in Table 4.9.

Table 4.9 Effect of fermentation time on Tandoori bread quality

Parameter	60 minutes	100 minutes
Shape	Long	Round & short
Colour	Same as control bread	Same as control bread
Smoothness	Rough & Dry	Rough & Sticky
Blisters	Flat	Too many & uneven
Rolling	Same as control bread	Easy
Tearing	Same as control bread	Easy
Chewing	Same as control bread	Easy
Taste	Dry	Same as control bread

After 60 minutes fermentation time the resultant bread was elongated and had a rough, dry and flat surface with a dry taste. After 100 minutes fermentation time the resultant bread was found to be round and short in shape, with a rough and sticky surface with too many uneven blisters. However, the bread was found to be easier in rolling, tearing and chewing than the control bread.

4.4.3 Dividing

40 g dough pieces gave appropriate size and shape. Dough pieces with higher dough weights were difficult to sheet in the moulder and dough pieces with lower weights were too small in size which created difficulties during evaluation.

4.4.4 Resting

5 minutes resting time was sufficient to mature the dough pieces resulting in good handling properties. At higher resting timings skin formation occurred on the dough pieces which also became sticky and difficult to handle. At lower resting timings it was difficult to get the desired dough shape during sheeting, because of stretching of the dough.

4.4.5 Sheeting

Initially the dough pieces were moulded to a thickness of 8 mm using a space guide and a rolling pin. The second sheeting was carried out using the automatic sheeting machine (see Section 3.2.18 for details) with a gap of 2 mm between the two rolls and then (with a turn of 90^0 of the sheeted dough or simply first out first in basis) the final sheeting at 1.5 mm final dough thickness. Table 4.10 shows the effects of sheeting thickness on the quality of Tandoori breads.

Table 4.10 Effect of sheeting thickness on Tandoori bread quality

Parameter	1 mm	2 mm
Shape	Slightly long	Round & Short
Colour	Same as control bread	Same as control bread
Smoothness	Cracks	Better
Blisters	Good	Flat
Rolling	Difficult	Slightly difficult due to size
Tearing	Difficult	Easy
Chewing	Hard to chew	Too chewy
Taste	Dry	Some sticky crumb

Doughs were sheeted to final thickness of 1.5 mm (control), 2 mm and 1 mm. The control dough gave oval shaped bread. At a 2 mm final thickness bread was smaller and round in shape with a plain flat surface without cracks and blisters. It was easy to tear, but was slightly difficult to roll due to its size and was found to be too chewy with some sticky crumb. When the final sheeting thickness was reduced to 1 mm, elongated bread with cracks on the surface resulted although it had evenly distributed blisters. However, it was difficult to roll and tear and hard to chew as it was quite dry.

4.4.6 Docking

Increasing and decreasing of total number of holes (9 holes for control bread) on the bread affected the number of blisters. By increasing the total number of holes, too many small blisters appeared. With reduced total number of holes, bread separated into two layers.

4.4.7 Baking

The standard test baking was carried out at 330^{0}C for 55 sec.

4.4.7.1 Baking Time

Breads were baked at 330^{0}C from 45 sec, 55 sec (control) and 65 sec. The effects of changes in baking time Tandoori bread quality are presented in Table 4.11 and in Figure 4.1.

Bread with the shorter baking time of 45 sec was found to be light in colour and had uncooked crumbs, but was easy to roll and tear compared to the control. Bread with longer baking time of 65 sec was dark with black blisters and was also difficult in rolling, tearing and chewing due to its dry crumb.

Table 4.11 Effect of baking time on Tandoori bread quality

Parameter	45 sec	65 sec
Shape	Same as control bread	Same as control bread
Colour	Light	Dark
Smoothness	Same as control bread	Same as control bread
Blisters	Same as control bread	Over burned
Rolling	Easy	Difficult
Tearing	Easy	Slightly difficult
Chewing	Same as control bread	Slightly difficult
Taste	Sticky crumb	Dry

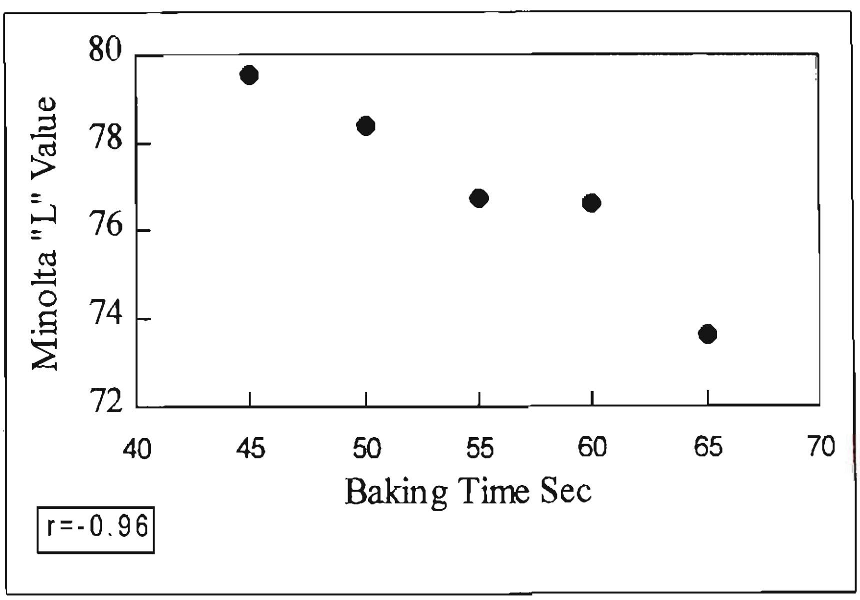


Figure 4.1 Effect of baking time on Tandoori bread colour

In Figure 4.1 we can see that baking time effects the Tandoori bread colour with a high linear correlation (r = -0.96) which shows that as the baking time increases the Minolta "L" value decreases.

4.4.7.2 Baking Temperature

Test baking was carried out 330°C (temperature maintained at the refractory wall). Breads were baked for 55 sec at each of 300°C, 330°C (control) and 360°C. The effects of changes in baking temperature on Tandoori bread quality are presented in Table 4.12.

Table 4.12 Effect of baking temperature on Tandoori bread quality

Parameter	300°C	360°C
Shape	Same as control bread	Same as control bread
Colour	Light	Dark
Smoothness	Same as control bread	Same as control bread
Blisters	Few	Over burned
Rolling	Easy	Difficult
Tearing	Easy	Difficult
Chewing	Bit Chewy	Difficult
Taste	Sticky crumb	Dry

Compared to the control, bread baked at lower baking temperature was light in colour with a few blisters. Although it was easy to roll and tear, it was a bit chewy due to the sticky crumb. On the other hand bread baked at 360°C was dark in colour with too many over burned blisters and was difficult to roll, tear and chew due to its dry crumb.

4.5 ROLE OF INGREDIENTS

The role of different ingredients on the scoring results is presented in Appendix 7 and Tables 4.13 to Table 4.15. Interpretations of the scoring results and observations are described in the following sections.

4.5.1 Water

The effect of the amount of water added into the bread dough was discussed in section 4.4.1.1.

4.5.2 Salt

Breads were baked with salt levels of 1.5% of flour weight (control), nil and 2.5 %. Effects of salt level on Tandoori bread quality are presented in Table 4.13.

Table 4.13 Effect of slat on Tandoori bread quality

Parameter	Nil	2.5%
Shape	Long	Short & round
Colour	Dark	Bright
Smoothness	Cracks	Wrinkles
Blisters	Same as control	Many
Rolling	Easy	Same as control
Tearing	Difficult	Difficult
Chewing	Difficult	Difficult
Taste	Dry and with less flavour	Salty

Breads with the higher amount of salt were not only too salty in flavour, but the doughs were also found to be too tight during moulding and sheeting. They were, therefore, short and round in shape and difficult to tear and chew. On the other hand, breads without any salt were long in shape with dark colour and cracks on the crust.

4.5.3 Yeast

Addition of yeast in the bread dough was tried at three levels of 0.5% (control), nil and 1.5 %. Effects of yeast on Tandoori bread quality are presented in Table 4.14.

Table 4.14 Effect of yeast on Tandoori bread quality

Parameter	Nil	1.5%
Shape	Uneven	Same as control
Colour	Dark	Bright
Smoothness	Wrinkles	Same as control
Blisters	Few	Many
Rolling	Difficult	Same as control
Tearing	Difficult	Same as control
Chewing	Difficult	Same as control
Taste	Less flavour	Too much crumb & yeast flavour

Bread dough with increased amount of yeast was difficult to roll and sheet as it became sticky during fermentation, but resulted in a bread of good shape and bright colour with too many blisters due to the high amount of yeast activity during fermentation. However, the bread was found to have yeast flavour and was too thick. No yeast in the bread dough resulted in a dark bread with uneven shape and wrinkles on the crust. This bread was difficult to roll, chew and tear.

4.5.4 Baking Soda

Addition of baking soda in the bread dough was tried at three levels of 0.2% (control), nil and 0.5%. When compared to the control, breads baked with the higher amount of baking soda were of pale yellow colour and with too many blisters on the upper crust, but the other parameters were good. On the other hand breads without baking soda were very bright in colour , but had flat crusts without blisters and were difficult to roll, tear and chew. Effects of baking soda on Tandoori bread quality are presented in Table 4.15.

Table 4.15 Effect of baking soda on Tandoori bread quality

Parameter	Nil	0.5%
Shape	Uneven	Better
Colour	Bright	Yellow
Smoothness	Cracks	Better
Blisters	Few	Many
Rolling	Difficult	Same as control
Tearing	Difficult	Same as control
Chewing	Difficult	Same as control
Taste	Same as control	Soda flavour

4.6 EFFECT OF WHEAT AND FLOUR PROPERTIES ON TANDOORI BREAD QUALITY

It was possible to compare different types of wheats for their suitability in Tandoori bread production by applying the test baking procedure described in Section 3.2.18. It was however, important to examine the effects of individual wheat and flour properties to determine their direct relationships to Tandoori bread quality.

Wheats planted for this project (as discussed in Section 3.1.1.2) were milled at three different extraction rates (88%, 72% and 80%) for the production of three different types of Tandoori breads (Roti, Naan and Taftoon) and their performance for Tandoori breads was studied. The data collected from the scoring of the breads (described in Section 4.3.4) of the samples presented in Appendices 11 and 12 were analysed for statistical purposes in the following manner:

- Scoring results of each panellist for each quality parameter were used to run ANOVA to find out whether or not all means of the populations under study are equal based upon the degree of variability in the sample data (as explained in Section 2.6.1). This in turn explained the differences in the quality characteristics of each and every wheat variety used for the production of three types of Tandoori breads (see Section 4.6.1 for details).
- Final score of each bread produced was used to construct the correlation matrix (as described in Section 2.6.2) that exists between the variables (see Section 4.6.2 for details).
- PCA (as described in Section 2.6.3) was also carried out to identify a set of predominant quality parameters (see Section 4.6.3).
- Scoring results of each quality parameter were also used in carrying out multiple regression to determine linear equations between (as described in Section 2.6.4) the total bread score and some selected quality parameters (see Section 4.6.4).

4.6.1 Analysis of Variance

ANOVA was carried out between the scoring of each panellist and each Tandoori bread quality parameter results are presented in Table 4.16.

Table 4.16 Results of ANOVA ("P" values)

Quality Parameter	Prob Value for Wheats	Prob Value for Panellists
Shape	0.000	0.023
Smoothness	0.000	0.297
Blisters	0.000	0.402
Rolling	0.000	0.013
Tearing	0.000	0.891
Chewing	0.000	0.052
Taste	0.000	0.758

From the above table it can be seen that the "prob" values for all the wheats were less than our customary level of significance ($\alpha = 0.01$) rejecting the null hypothesis (H_0), which means that each wheat, depending on its own properties, resulted in significantly different Tandoori bread scores. However, no significant differences were observed in the evaluation carried out by the panellists as all the "prob" value were larger than the customary level of significance ($\alpha = 0.01$), accepting the null hypothesis (H_0). This proved that the sensory evaluation and the scoring ability of the panellists were consistent, reliable and similar to each other.

4.6.2 Correlation Matrix

This is based on the wheats mentioned in Section 3.1.1.2.

Table 4.17 Correlation Matrix between selected wheat and flour properties and Tandoori bread quality parameters

	WPT	WAS	PSI	FPT	FAS	S.D	W.A	EXT	AMP	LF	bF	LB	bB	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
WPT (Wheat Protein)	1.00																					
WAS (Wheat Ash)	0.80	1.00																				
PSI (Particle Size Index)	*	*	1.00																			
FPT (Flour Protein)	0.86	0.69	*	1.00																		
FAS (Flour Ash)	*	*	*	*	1.00																	
S.D (Starch Damage)	*	*	-0.90	*	*	1.00																
W.A (Water Absorption)	*	*	-0.68	*	0.50	0.73	1.00															
EXT (Extensibility)	0.70	0.65	*	*	*	*	*	1.00														
AMP (Amylograph Peak)	*	*	*	*	*	*	*	*	1.00													
LF (Flour Minolta "L")	*	*	*	*	-0.97	*	*	*	*	1.00												
bF (Flour Minolta "b")	-0.58	-0.65	*	*	*	*	*	-0.72	*	*	1.00											
LB (Bread Minolta "L")	*	*	*	*	-0.89	*	*	*	*	0.90	*	1.00										
bB (Bread Minolta "b")	-0.51	-0.50	*	*	*	*	*	-0.68	*	*	0.69	*	1.00									
SHP (Shape)	*	*	*	*	*	*	*	*	*	*	*	*	*	1.00								
CLR (Colour)	-0.68	-0.79	*	-.050	*	*	*	-0.65	*	*	0.80	*	0.74	*	1.00							
SMT (Crust Smoothness)	*	*	*	*	*	*	*	*	0.66	*	*	*	*	*	*	1.00						
BLS (Blisters)	*	*	-0.73	*	*	0.83	0.71	*	*	*	*	*	*	*	*	*	1.00					
ROL (Rolling Quality)	-0.83	-0.60	*	-0.66	*	*	*	-0.69	*	*	0.66	*	0.54	*	0.60	*	*	1.00				
TER (Tearing Quality)	-0.89	-0.67	*	-0.73	*	*	*	-0.66	*	*	0.67	*	0.56	*	0.69	*	*	0.84	1.00			
CHW (Chewing Quality)	-0.88	-0.62	*	-0.70	*	*	*	-0.73	*	*	0.63	*	0.60	*	0.69	*	*	0.85	0.91	1.00		
TST (Taste)	-0.68	*	*	-0.57	*	*	*	-0.53	*	*	*	*	*	*	*	*	*	0.69	0.69	0.69	1.00	

4.6.2.1 Between the Cultivars

A correlation matrix between 13 selected wheat and flour properties and 9 Tandoori bread quality parameters showed quite a few significant correlations Those that were significant ($P<0.01$) were interrelated (Table 4.17) and are discussed in the following sections.

4.6.2.1.1 Wheat Protein

Wheat protein showed the strongest negative correlations with Tandoori bread score ($r = -0.85$), rolling quality ($r = -0.83$), tearing quality ($r = -0.89$), chewing quality ($r = -0.88$) and the taste ($r = -0.68$). This was probably because at higher protein, the dough becomes stronger and affects the bread matrix. Wheat protein was also correlated to the bread crust colour ($r = -0.68$). This was due to the Maillard reaction that affects the bread colour and makes is darker. This over all result indicates that the quality of Tandoori bread is dependent on wheat protein. The effects of wheat protein on the quality of Tandoori breads are shown in Figures 4.2-4.5.

4.6.2.1.2 Wheat Ash

Wheat ash was correlated to the bread crust colour ($r = -0.79$) showing the lower the wheat ash the brighter the bread crust colour because of the presence of less bran.

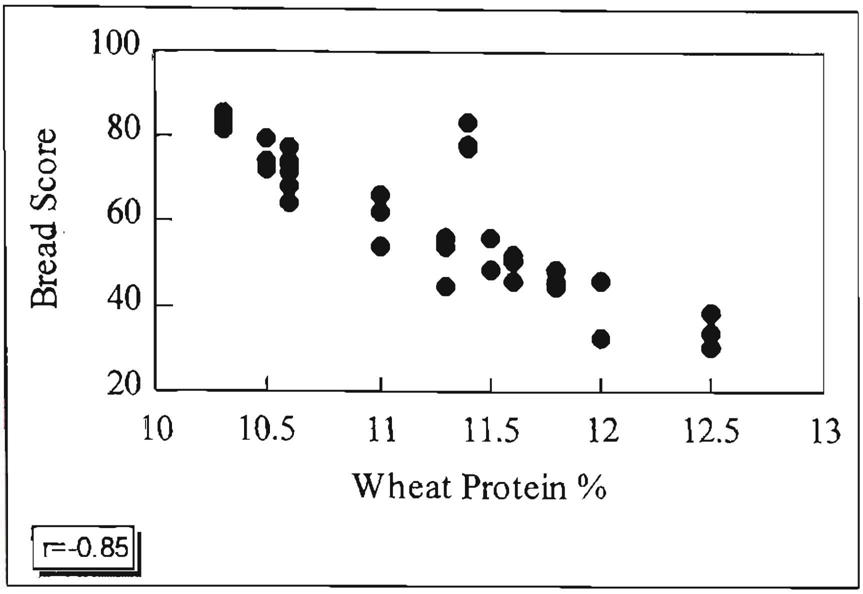


Figure 4.2 Effect of wheat protein on Tandoori bread score

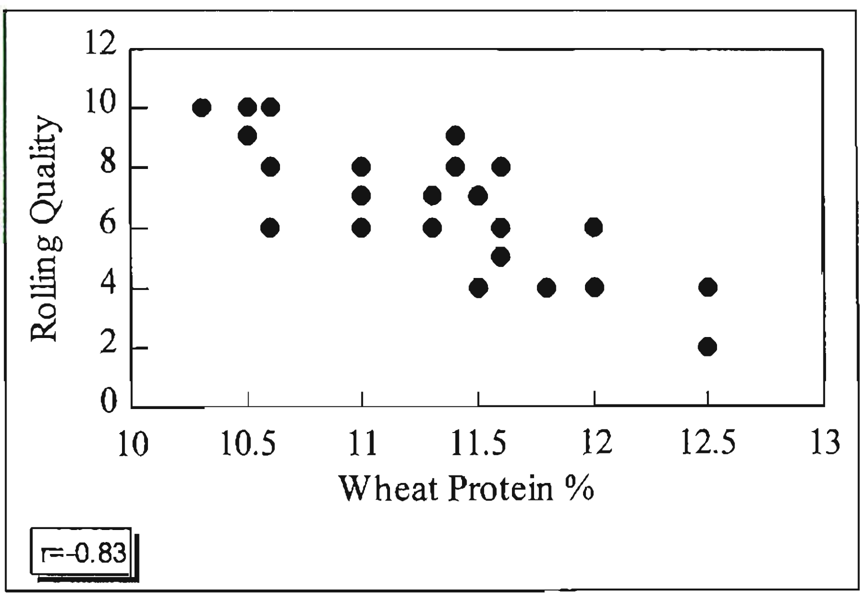


Figure 4.3 Effect of wheat protein on rolling quality

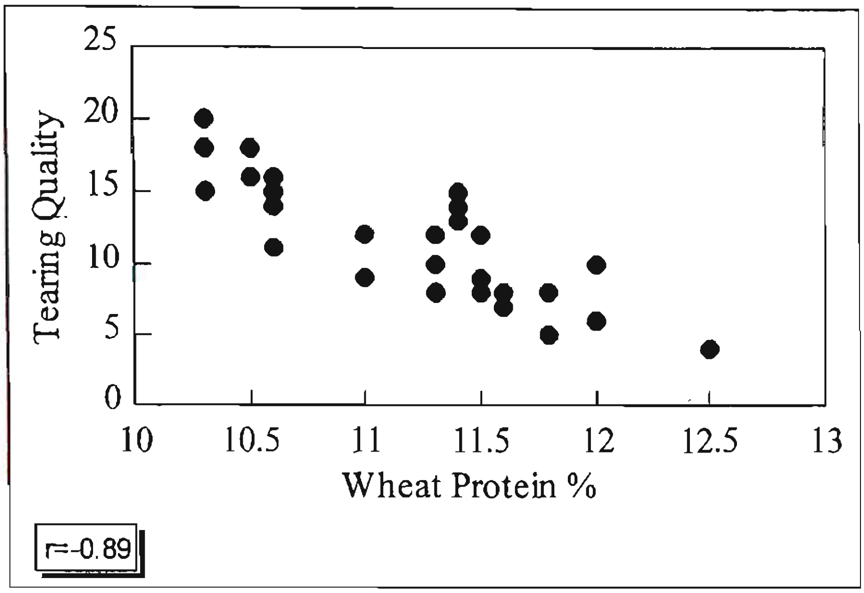


Figure 4.4 Effect of wheat protein on tearing quality

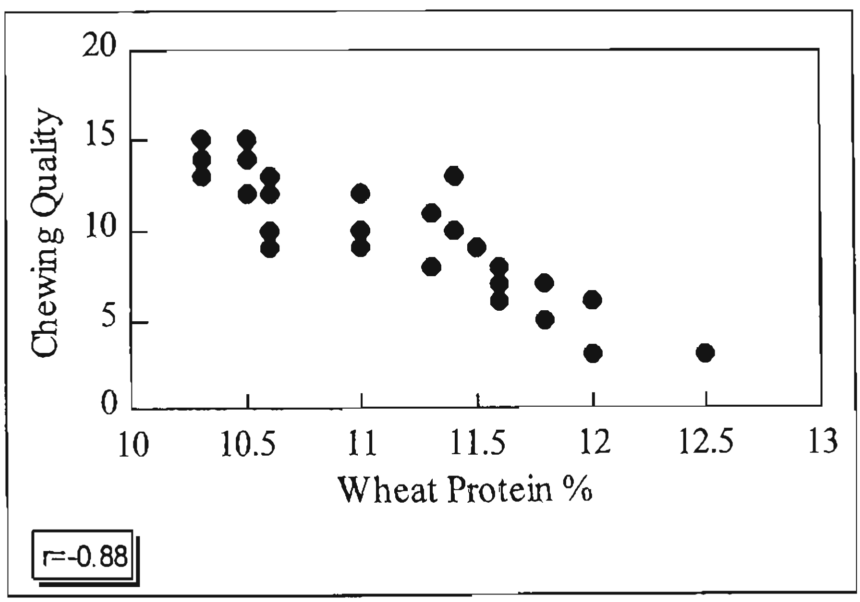


Figure 4.5 Effect of wheat protein on chewing quality

4.2.6.1.3 Grain Hardness

Grain hardness (PSI) was negatively correlated to blisters (r = -0.73) showing that hard grained wheat wheats gave good and even blisters while the soft grained wheats resulted in breads with flat surfaces (see Section 4.6.2.1.9 for details).

4.6.2.1.4 Flour Protein

Similar to the wheat protein, flour protein also influenced the quality characteristics of Tandoori breads having significant correlations with Tandoori bread score (r = -0.64), rolling quality (r = -0.66), tearing quality (r = -0.73), chewing quality (r = -0.70) and as well as to the bread crust colour (r = -0.50) and the taste (r = -0.57).

4.6.2.1.5 Water Absorption

Water absorption was positively correlated to blisters (r = 0.71), proving that wheats high in starch damage and water absorption had even blisters on the bread surface. Water absorption also affects the bread shape and resulted in the parabolic graph shown in Figure 4.6. This indicates that an optimum water absorption exists for bread shape. Water absorption is related to both protein content and starch damage which, in combination, affect bread shape.

4.6.2.1.6 Extensibility

It can be noted that extensibility was also negatively correlated to Tandoori bread score (r = -0.75), rolling quality (r = -0.69), tearing quality (r = -0.66) and chewing quality (r = -0.73) showing that flours with high extensibility resulted in poor quality breads. In general high extensibility doughs yielded breads which were too soft and extensible, probably due to a weaker dough and bread matrix.

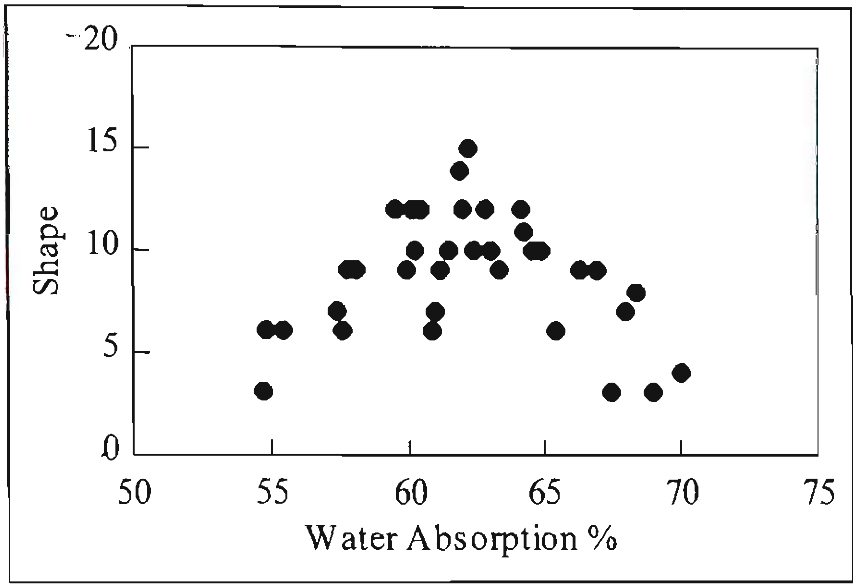


Figure 4.6 Effect of water absorption on Tandoori bread shape

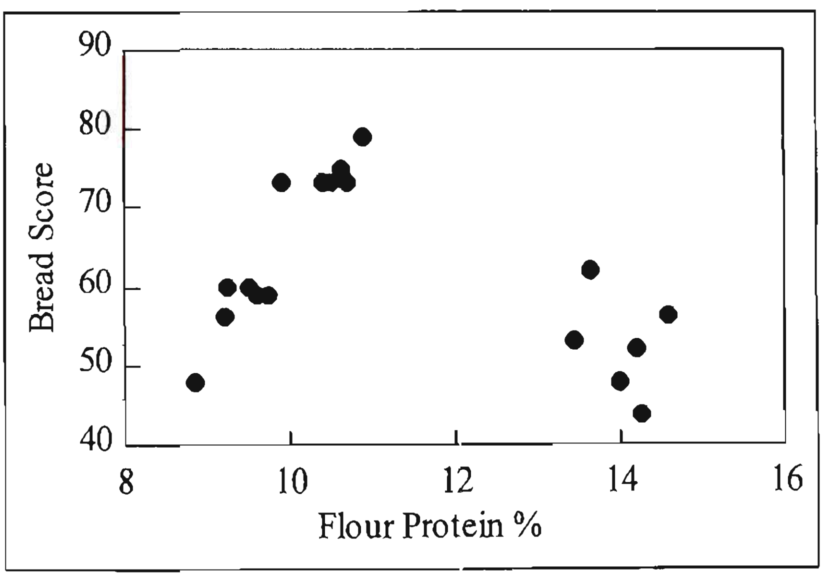


Figure 4.7 Effect of flour protein on Tandoori bread score

(wheats within the cultivars)

4.6.2.1.7 Minolta "b" Value

Minolta flour "b" value and Minolta bread "b" value were positively correlated to the bread crust colour (r = 0.80 and r = 0.74 respectively), showing the higher the "b" value the yellowier the bread colour. This is a reflection of the carryover of flour colour into bread colour.

4.6.2.1.8 Amylograph Peak Viscosity

Amylograph peak viscosity was correlated to the crust smoothness (r = 0.66) showing that flours with higher peak viscosity influenced the quality of bread crust. This may be attributed to the stronger pasting properties resisting cracking and wrinkling.

4.6.2.1.9 Starch Damage

Starch damage was positively correlated to blisters (r = 0.83) showing that flours of higher starch damage resulted in evenly distributed blisters on the bread surface. Starch damage was, as expected, negatively correlated to PSI for grain hardness. This is explainable on the basis of higher starch damage leading to higher water absorption.

4.6.2.1.10 Correlations Between Bread Quality Parameters

It can also be noted that some of the bread quality parameters were highly correlated and influence each other. Rolling quality was correlated to Tandoori bread score (r = 0.87), tearing quality (r = 0.84), chewing quality (r = 0.85).

Tearing quality was correlated to Tandoori bread score (r = 0.94) and chewing quality (r = 0.91). Chewing quality was correlated to Tandoori bread score (r = 0.94). Taste was correlated to Tandoori bread score (r = 0.72).

4.6.2.2 Within the Cultivars

The two wheat varieties (Batavia and Trident), which ranked highest during the evaluation of all the cultivars, were considered for further testing.

As the wheat protein was the major property that effected Tandoori bread quality between the cultivars. Batavia and Trident wheats with three different protein levels were selected from sites in Western Australia, Victoria and New South Wales. Protein levels of Batavia and Trident form the Horsham site in Victoria (see Appendix 14) were close to the protein levels of the wheats of Yeelanna site which was used for the evaluation between all the cultivars. However, wheat protein levels of the Narrabri site in New South Wales were higher and wheat protein levels of the Avondale Research farms in Western Australia were lower than those from the Yeelanna site (see Appendix 11).

During the evaluation of the three types of Tandoori bread produced from Batavia and Trident wheats at three proteins, it was observed that the breads produced from lower protein wheats from Avondale were long and dry. Breads produced from higher protein wheats from the Narrabri site were found to be

Plate 4.1 Effect of flour protein on Pakistani Roti (9.7%, 10.9% & 14.2%)

Plate 4.2 Effect of flour protein on Indian Naan (9.2%, 10.5% & 13.6%)

Plate 4.3 Effect of flour protein on Irani Taftoon (9.5%, 10.7% & 14%)

out of shape, thick and too chewy due to their uncooked crumb. However, breads produced from the Horsham site in Victoria were ranked highest possibly because of their moderate wheat protein levels which were close to that of the Yeelanna site.

From the evaluation of the breads produced from the wheats within the cultivars (18 Batavia and Trident wheat samples from Horsham, Avondale and Narrabri sites) it was reconfirmed that wheat and flour protein contents are the most important properties that affects the quality of Tandoori breads as shown in Figure 4.2-4.5.

The influence of flour protein content can also be seen in Plates 4.1-4.3 in which three different types of Tandoori breads are shown at three different protein levels as discussed in the above paragraphs. These samples show a consistent effect of an optimum intermediate protein level on bread characteristics (see Appendix 16 for baking scores). These have been discussed above.

4.6.3 Principal Component Analysis

Principal component analysis of wheat and flour properties (as discussed in Section 2.6.3) was based on the correlation matrix (Table 4.17), and their effects on Tandoori bread quality parameters are presented in Table 4.18.

Table 4.18 The Principal Component Analysis of wheat and flour properties (based on the correlation matrix) and their effect on Tandoori bread quality parameters

Components **Properties**	1st (41.4%)	2nd (19.1%)	3rd (12.4%)	4th (8.6%)
Wheat Protein	0.29	*	*	*
Wheat Ash	0.25	*	*	*
Particle Size Index	*	*	0.42	*
Flour Protein	0.21	*	*	*
Flour Ash	*	*	*	*
Starch Damage	*	*	-0.47	*
Water Absorption	*	0.35	*	*
Extensibility	0.28	*	*	*
Amylograph Peak	*	*	*	0.54
Flour Minolta "L"	*	*	*	*
Flour Minolta "b"	-0.27	*	*	*
Bread Minolta "L"	*	*	*	*
Bread Minolta "b"	-0.24	*	*	*
Shape	*	*	*	*
Colour	-0.26	*	*	*
Crust Smoothness	*	*	*	0.59
Blisters	*	0.21	-0.59	*
Rolling Quality	-0.29	*	*	*
Tearing Quality	-0.30	*	*	*
Chewing Quality	-0.30	*	*	*
Taste	-0.23	*	*	*
Tandoori Bread Score	-0.32	*	*	*

From the table it can be seen that the PCA revealed four major components that influenced the Tandoori bread quality. The fourth component, which accounted for 8.6% of the variation, was related to only one factor ie. crust smoothness which was influenced by the Amylograph peak. The third component, which accounted for 12.4% of the variation, was related to grain hardness and starch damage which influenced blisters on the bred surface. The second component which accounted for 19.1% of the variation, was related to water absorption and its impact on blisters. The first component which accounted for 41.4% of the variation, was related to wheat protein, flour protein, wheat ash, and flour extensibility and their influences on bread score, rolling quality, tearing quality, chewing quality, taste and crust colour. Crust colour was also found to be influenced by the Minolta "b" values of flour and bread.

4.6.4 Multiple Regression

Multiple regressions were carried out using the parameters which were correlated in the correlation matrix and linear prediction equations were derived for Tandoori bread score and other bread quality parameters. However, these prediction equations had one or at the most two predictors explaining maximum variability (r^2) at $p \leq 0.01$ and are presented in Table 4.19.

Table 4.19 Best prediction equations for Tandoori bread quality and wheat and flour parameters

Quality Parameter	**Equation**	r^2
Tandoori Bread Score	= 166 - 15.1 WPT + 6.35 bF	83
Colour	= 16.2 - 15.8 WAS + 1.66 bF	76
Blisters	= 0.351 + 0.322 S.D	68
Rolling Quality	= 38.0 - 2.78 WPT	68
Tearing Quality	= 56.5 - 4.97 WPT + 1.05 bF	82
Chewing Quality	= 63.7 - 4.83 WPT	78

(Where: WPT=Wheat Protein, WAS=Wheat Ash, bF=Minolta "b" value of flour & S.D=Starch Damage)

4.7 AUSTRALIAN WHEATS SUITABLE FOR TANDOORI BREADS

From the scoring results of Appendix 13 it can be seen that Trident and Batavia wheat varieties (at protein levels 10.3% and 11.4% respectively) behaved very well in the production of each of the three types of Tandoori breads (ie. Roti, Naan and Taftoon). The wheat varieties Janz, Meering, and Tammin at a protein level of around 10.5% also produced breads of reasonably good quality.

It can be concluded from the evaluation and statistical interpretation of the Tandoori breads, that Australian wheats with medium protein levels (10.5-11.5%) and hard PSI values (11-15) were most suitable for (each of the three types) Tandoori bread quality. Wheat and flour properties such as ash, dough extensibility, Minolta "b" value, Amylograph peak viscosity and starch damage did have some effect on some of the Tandoori bread quality parameters. However, Tandoori bread quality was not effected to a significant extent by other wheat and flour properties such as test weight, thousand kernel weight, falling number, wet gluten, gluten index, dough development time, dough stability, breakdown, maximum height and area.

5. CONCLUSIONS

- A major phase of the program was the development of analytical procedure for making each of the three main types of Tandoori breads. This required the establishment of processing formulations and conditions so that consistent, reproducible evaluations could be carried out with adequate precision. This test baking method was simple and easy and can easily be adopted for routine use in cereal testing laboratories.

- Comparison of the test baking method with commercial practice showed that the test method is not only relevant, but it could be used to predict the performance of flours for commercial practice.

- A test Tandoor was designed, installed and commissioned. It can be precisely set to a range of parameters controlling temperature, gas flow and air supply. With the use of this Tandoor, reliable and repeatable small scale manufacture of Tandoori breads in subsequent phases of this program was achievable.

- A Farinograph consistency of 500 BU was the best predictor of baking absorption for Tandoori bread. Divergence from this optimum led to difficulties in processing and defects in the final product. As flours with low Farinograph water absorptions resulted in dry and long shaped breads and flours with high Farinograph water absorptions resulted in sticky and round breads.

- A standard mixing time of 5 minutes was used throughout the test baking irrespective of the Farinograph development time, because in commercial baking also the mixing time always remain the same. When the mixing time was reduced it was observed that the Tandoori bread was slightly uneven in shape with cracks on the surface and no blisters. On the other hand when the mixing time was increased, it was observed that although the colour of the bread was lighter than that of the control bread, but there were wrinkles and uneven blisters on the surface .

- A fermentation time of 80 minutes of the dough (in sealed containers) was found to be optimum resulting in a dough with proper handling properties and a bread with even shape, crust and blisters. All test breads were fermented for 80 minutes. Lower fermentation time resulted in bread with elongated shape and had rough, dry and flat surface. Higher fermentation time resulted in breads with short and round shape, with a rough and sticky surface with too many uneven blisters. However, the bread was found to be easier in rolling, tearing and chewing than the control bread.

- The fermentation temperature was maintained at $34^{0}C$. By lowering it, the dough was found to be dry, was difficult to mould and produced breads of long sizes with few cracks and less blisters on the surface. On the other hand, the higher fermentation temperature resulted in slack doughs which were difficult to handle. These breads had uneven blisters.

- 40 g dough pieces gave appropriate size and shape. Dough pieces with higher dough weights were difficult to sheet in the moulder and dough pieces with lower weights were too small in size which created difficulties during evaluation.

- 5 minutes resting time was sufficient to mature the dough pieces resulting in good handling properties. At higher resting timings, skin formation occurred on the dough pieces which also became sticky and difficult to handle. At lower resting timings it was difficult to get the desired dough shape during sheeting, because of stretching of the dough was observed.

- All the three types of bread doughs were sheeted to final thickness of 1.5 mm which resulted in oval shaped bread. At higher thickness, breads were smaller and round in shape with a plain flat surface without cracks and blisters. They were easy to tear, but were slightly difficult to roll due to the size and were found to be too chewy with some sticky crumb. With reduced sheeting thicknesses, elongated breads with cracks on the surfaces resulted although they had evenly distributed blisters. However, they were difficult to roll and tear, hard to chew and were quite dry.

- Breads with 9 docking holes were best in terms of results. Excessive docking resulted in too many blisters. Insufficient docking resulted in pocket formation with separation of upper and lower layers.

- Bread with the shorter baking time of 45 sec was found to be light in colour and had uncooked crumbs, but was easy to roll and tear compared to the control. Bread with a longer baking time of 65 sec was dark with black blisters and was also difficult in rolling, tearing and chewing due to its dry crumb. Baking time effects the Tandoori bread colour with a near perfect linear correlation which showed that as the baking time increases the Minolta "L" value decreases.

- Compared to the control breads which were baked at 330^{0}C, breads baked at lower temperature were light in colour with few blisters. Although they were easy to roll and tear, but they were bit chewy due to the sticky crumb. On the other hand bread baked at a higher baking temperature was dark in colour with too many over burned blisters and was difficult to roll, tear and chew due to their dry crumb.

- All test breads were baked with salt levels of 1.5% of flour weight. Breads with the higher amount of salt were not only too salty in flavour, but the doughs were also found to be too tight during moulding and sheeting. They were, therefore, short and round in shape and difficult to tear and chew. On the other hand, breads without any salt were long in shape with dark colour and cracks on the crust.

- All test breads were baked with dry yeast levels of 0.5% of flour weight. Bread doughs with increased amount of yeast were difficult to roll and sheet as they became sticky during fermentation, but resulted in good shape and bright colour with too many blisters due to the high amount of yeast activity during fermentation. However, the breads were found to have yeast flavour and too thick. No yeast bread doughs resulted in comparatively darker breads with uneven shape and wrinkles on the crust and were difficult to roll, chew and tear.

- When compared to the control (0.2%), breads baked with excessive amount of baking soda were of pale yellow colour and with too many blisters on the upper crust, but the other parameters were good. On the other hand breads without baking soda were very bright in colour , but had flat crusts without blisters and were difficult to roll, tear and chew.

- A system for evaluation of product quality was developed for use with the analytical procedure developed for this study. This system was actually based on the views of the commercial bakers and their customers in the regions where these breads are produced. It takes into account the relative importance of individual bread characteristics and simpler, easier and more realistic to use than the earlier scoring systems.

- ANOVA had shown that each wheat, depending on its own properties, resulted in significantly different Tandoori bread scores. However, no significant differences were observed in the evaluation carried out by the panellists.

- A correlation matrix between selected wheat and flour properties and Tandoori bread quality parameters showed quite a few significant correlations.

- Wheat and flour protein showed the strongest negative correlations with Tandoori bread score, rolling quality, tearing quality, chewing quality. Wheat protein was also correlated to the bread crust colour and the taste. It indicates that the quality of Tandoori bread is dependent on wheat and flour protein.

- Wheat ash was correlated to the bread crust colour showing the lower the wheat ash the brighter the bread crust colour.

- Grain hardness (PSI) was negatively correlated to blisters showing that hard wheats gave good and even blisters while the soft wheats resulted in breads with flat surfaces. It however, did not effect any other bread quality.

- Water absorption was also positively correlated to blisters, proving that wheats high in starch damage and water absorption resulted appropriate number of blisters on the bread surface. Water absorption also effects the bread shape and resulted in a parabolic relationship.

- It can be noted that extensibility was also negatively correlated to Tandoori bread score, rolling quality , tearing quality and chewing quality showing that flours with high extensibility resulted in poor quality breads.

- Minolta flour "b" value and Minolta bread "b" value were positively correlated to the bread crust colour, showing the higher the "b" value the yellowier the bread colour.

- Amylograph peak was correlated to the crust smoothness showing that flours with higher peak viscosity influenced the quality of bread crust.

- Starch damage was positively correlated to blisters showing that flours of higher starch damage resulted in evenly distributed blisters on the bread surface. This was negatively correlated to the grain hardness.

- It was also found out that some of the bread quality parameters were highly correlated with, and influenced, each other. Rolling quality was correlated to Tandoori bread score, tearing quality, chewing quality. Tearing quality was correlated to Tandoori bread score and chewing quality. Chewing quality was correlated to Tandoori bread score. Taste was correlated to Tandoori bread score.

- Among the 23 Australian wheat samples studied for the production of three different types of Tandoori breads (ie. Roti, Naan and Taftoon), Batavia and Trident (at protein levels of 11.4% and 10.3% respectively) which ranked highest for all the three breads during the evaluation of all the cultivars, were used for further testing. During the evaluation of the three types of Tandoori bread produced from Batavia and Trident wheats at three protein levels, it was observed that, for both varieties the breads produced from lower protein wheats from Avondale site were long and dry. Breads produced from higher protein wheats from the Narrabri site were found to out of shape, thick and too chewy due to their uncooked crumb. However, breads produced using wheats from the Horsham site were ranked highest possibly because of their moderate wheat protein levels which were close to that of the Yeelanna site and the flour protein levels of 10.9%, 10.5% and 10.7% gave the best Pakistani Roti, Indian Naan and Irani Taftoon.

- PCA revealed four major components that influenced the Tandoori bread quality. The fourth component, which accounted for 8.6% of the variation, was related only to crust smoothness which was influenced by the Amylograph peak. The third component which accounted for 12.4% of the variation, was related to grain hardness and starch damage which influenced blisters on the bred surface. The second component which accounted for 19.1% of the variation, was related to water absorption and its impact on blisters. The first component, which accounted for 41.4% of the variation, was related to wheat protein, flour protein, wheat ash, and flour extensibility and their influences on bread score, rolling quality, tearing quality, chewing quality, taste and crust colour. Crust colour was also found to be influenced by the Minolta "b" values of flour and bread.

- Prediction equations for several aspects of Tandoori bread quality were derived using the multiple regression technique (see Table 4.19 for details). These included wheat and flour properties of wheat protein, wheat ash, starch damage and Minolta "b" vale.

- On the basis of this study, wheats of protein 10.5-11.5% and PSI hardness 11-15 are best for Tandoori bread quality. These should yield flours of starch damage 8-10%, low ash and bright colour.

6. APPENDICES

APPENDIX 1

TANDOORI BREAD'S SURVEY REPORT

---

1. BASIC INFORMATION

Tandoor:__________________ Contact Person:____________________

Address:____________________________________ Tel:______________

---

2. BREAD & FLOUR TYPE

Main Bread Produced: Roti/Naan/Taftoon

Straight Run Flour in use: ____ kg/Day

Brown Flour in use: ____ kg/Day

---

3. TANDOORI BREAD FORMULA

Ingredient	Amount (kg)
Flour	
Salt	
Yeast	
Bakisng Soda	
Water	
Other	

4. PREFERRED SCORING SYSTEM

Quality Parameter	Bakers Score*
Area(Expension/Shirinkage)	
Shape	
Crust Colour	
Crust Smoothness	
Blisters	
Rolling Quality	
Tearing Quality	
Chewing Quality	
Crumb Appearance	
Aroma & Taste	
TOTAL SCORE	100

*Please write maximum score for each quality parameter according to to your preference

5. REMARKS

____

____

APPENDIX 2

TANDOORI BREAD TEST BAKING REPORT

INGREDIENT		%
Flour		100
Salt		1.5
Yeast		0.5
Soda		0.2
Water		FWA
PARAMETER		
Dough Temp	^{0}C	29
Scaled Weight	g	40
Sheeting #1	mm	8
Sheeting #2	mm	2
Sheeting #3	mm	1.5
TIMINGS		
Mix	min	5
Proof	min	80
Divide/Round	min	5
Rest	min	5
Sheet/Dock	min	5
Bake	sec	55
PERFORMANCE		COMMENTS
Mixing		
Proofing		
Rounding		
Sheeting		
Minolta L (Bread Colour)		
Minolta a (Bread Colour)		
Minolta b (Bread Colour)		

REMARKS: ______________________________

____

____

APPENDIX 3

SENSORY EVALUATION SHEET OF PAKISTANI TANDOORI BREAD

Date:	Sample #:	Evaluator:

You are presented with 1 sample that should be evaluated in comparison to the control sample and rated according to specific parameters indicated (see shaded box). Please **X** the box of your choice.

SHAPE

3	6	9	12	15
Uneven				Even

COLOUR

3	6	9	12	15	12	9	6	3
White				Brown				Dark Brown

SMOOTHNESS

2	4	6	8	10
Wrinkles				Smooth

BLISTERS

1	2	3	4	5
Uneven				Even

ROLLING

2	4	6	8	10
Difficult				Easy

TEARING

4	8	12	16	20
Difficult				Easy

CHEWING

3	6	9	12	15
Difficult				Easy

TASTE

2	4	6	8	10
Bad				Good

REMARKS:

APPENDIX 4

SENSORY EVALUATION SHEET OF INDIAN TANDOORI BREAD

Date:	Sample #:	Evaluator:

You are presented with 1 sample that should be evaluated in comparison to the control sample and rated according to specific parameters indicated (see shaded box). Please **X** the box of your choice.

SHAPE

3	6	9	12	15

Uneven — Even

COLOUR

3	6	9	12	15	12	9	6	3

White — Cream — Yellow

SMOOTHNESS

2	4	6	8	10

Wrinkles — Smooth

BLISTERS

1	2	3	4	5

Uneven — Even

ROLLING

2	4	6	8	10

Difficult — Easy

TEARING

4	8	12	16	20

Difficult — Easy

CHEWING

3	6	9	12	15

Difficult — Easy

TASTE

2	4	6	8	10

Bad — Good

REMARKS:

APPENDIX 5

SENSORY EVALUATION SHEET OF IRANI TANDOORI BREAD

Date:	Sample #:	Evaluator:

You are presented with 1 sample that should be evaluated in comparison to the control sample and rated according to specific parameters indicated (see shaded box). Please **X** the box of your choice.

SHAPE

3	6	9	12	15

Uneven — Even

COLOUR

3	6	9	12	15	12	9	6	3

White — Light Brown — Brown

SMOOTHNESS

2	4	6	8	10

Wrinkles — Smooth

BLISTERS

1	2	3	4	5

Uneven — Even

ROLLING

2	4	6	8	10

Difficult — Easy

TEARING

4	8	12	16	20

Difficult — Easy

CHEWING

3	6	9	12	15

Difficult — Easy

TASTE

2	4	6	8	10

Bad — Good

REMARKS:

All Abbreviations used in Apendices 6-17 are given below:

A.R = Area (cm^2)
aB = Minolta Bread "a" value
aF = Minolta Flour "a" value
AMP = Amylograph Peak (BU)
bB = Minolta Bread "b" value
bF = Minolta Flour "b" value
BLS = Blisters
BRK = Breakdown (BU)
CHW = Chewing Ability
CLR = Colour
D.T = Development Time (minutes)
EXT = Extensibility (mm)
FAS = Flour Ash (% on dry basis)
FLG = Falling Number (sec)
FMS = Flour Moisture (%)
FPT = Flour Protein (13.5 % moisture basis)
G.I = Gluten Index
LB = Minolta Bread "L" value
LF = Minolta Flour "L" value
M.H = Maximum Height (BU)
PSI = Particle Size Index
ROL = Rolling Ability
S.D = Starch Damage (%)
SHP = Shape
SMT = Smoothness
STB = Stability (minutes)
T.W = Test Weight (kg/Hl)
TBS = Tandoori Bread Score
TER = Tearing Ability
TKW = Thousand Kernel Weight (g)
TST = Taste
W.A = Water Absorption (%)
W.G = Wet Gluten (%)
WAS = Wheat Ash (% on dry moisture basis)
WMS = Wheat Moisture (%)
WPT = Wheat Protein (% as is N x5.7)

APPENDIX 6

ROLE OF PROCESSING VARIABLES ON TANDOORI BREAD QUALITY

Q.P	BAKING ABSORPTION		MIXING TIME		FERMENTATION TEMP		FERMENTATION TIME		SHEETING THICKNESS		BAKING TIME		BAKING TEMP	
	Lower	Higher	Lower	Higher	Lower	Higher	Lower	Higher	Lower	Higher	Lower	Higher	Lower	Higher
SHP	Long	Round & short	Slightly uneven	Same	Slightly long	Same	Long	Round & short	Slightly long	Round & Short	Same	Same	Same	Same
CLR	Same	Light	Same	Light	Same	Same	Same	Same	Same	Same	Light	Dark	Light	Dark
SMT	Few cracks	Wrinkles	Cracks	Wrinkles	Few cracks	Same	Rough & Dry	Rough & Sticky	Cracks	Better	Same	Same	Same	Same
BLS	Same	Nil	Flat	Uneven	Few	Uneven	Flat	Too many & uneven	Good	Flat	Same	Over burned	Few	Over burned
ROL	Slightly difficult	Slightly difficult due to size	Same	Same	Same	Same	Same	Easy	Difficult	Slightly difficult due to size	Easy	Difficult	Easy	Difficult
TER	Slightly difficult	Same	Same	Same	Same	Same	Same	Easy	Difficult	Easy	Easy	Slightly difficult	Easy	Difficult
CHW	Difficult	Easy	Same	Easy	Same	Better	Same	Easy	Hard to chew	Too chewey	Same	Slightly difficult	Bit Chewey	Difficult
TST	Dry	Too much crumb	Same	Same	Same	Same	Dry	Same	Dry	Some sticky crumb	Sticky crumb	Dry	Sticky crumb	Dry

APPENDIX 7

EFFECTS OF INGREDIENTS ON TANDOORI BREAD QUALITY

Q.P	Salt		Baking Soda		Yeast	
	Lower	Higher	Lower	Higher	Lower	Higher
SHP	Long	Short & round	Uneven	Better	Uneven	Same as control
CLR	Dark	Bright	Bright	Yellow	Dark	Bright
SMT	Cracks	Wrinkles	Cracks	Better	Wrinkles	Same as control
BLS	Same as control	Many	Few	Many	Few	Many
ROL	Easy	Same as control	Difficult	Same as control	Difficult	Same as control
TER	Difficult	Difficult	Difficult	Same as control	Difficult	Same as control
CHW	Difficult	Difficult	Difficult	Same as control	Difficult	Same as control
TST	Dry and with less flavour	Too much crumb & Salty	Same as control	Soda flavour	Less flavour	Too much crumb & yeast flavour

APPENDIX 8

ANALYTICAL DATA FOR WHEAT SAMPLES

(1994-95 Season)

#	Wheat	WMS	WAS	WPT	T.W	TKW	FLG	PSI
1	Aroona	9.5	1.77	13.0	75.0	33.3	498	14
2	Batavia	9.2	1.35	12.6	81.0	36.1	415	11
3	Batavia	9.6	1.27	14.6	79.5	31.1	442	13
4	Cadoux	9.4	1.36	10.3	81.0	35.0	382	24
5	Cadoux	9.5	1.57	14.5	78.0	33.8	449	26
6	Halberd	9.4	1.21	9.3	81.5	36.4	425	13
7	Hartog	9.5	1.81	10.3	80.5	37.5	432	13
8	Hartog	9.5	1.68	10.2	80.5	37.1	454	13
9	Machete	9.2	1.33	10.7	82.5	43.3	523	11
10	Machete	9.2	1.16	12.6	80.5	42.6	485	14
11	Meering	8.9	1.34	10.5	84.0	36.6	399	13
12	Meering	8.4	1.36	13.0	82.5	33.3	472	14
13	Oxley	8.8	1.40	8.3	82.0	34.5	410	14
14	Trident	8.8	1.50	11.7	84.0	43.6	475	12
15	Trident	8.9	1.72	16.1	80.5	34.6	459	16

Note: All the above wheats were collected from different sites in Australia.

APPENDIX 9

ANALYTICAL DATA FOR FLOUR SAMPLES (1994-95 Season)

(@ 88% Extraction for the Pakistani Roti)

#	Wheat	FMS	FPT	FAS	S.D	W.A	D.T	STB	BRK	EXT	M.H	A.R	AMP	W.G	G.I	LF	aF	bF	LB	aB	bB
1	Aroona	12.7	12.7	1.31	7.2	66.1	2.8	4.2	65	174	138	38	480	43.2	94	89.6	-0.9	12.7	78.8	2.3	24.1
2	Batavia	13.2	12.2	1.20	7.9	66.6	3.0	3.0	65	189	159	48	630	41.8	97	87.8	-1.2	11.6	78.6	2.5	23.2
3	Batavia	13.0	14.3	1.05	6.3	68.6	2.7	10.5	25	180	207	58	800	53.2	90	87.6	-0.7	13.1	77.4	2.9	24.3
4	Cadoux	12.0	9.9	1.25	4.3	64.0	3.0	2.8	95	125	235	44	600	29.0	99	90.4	-1.2	9.6	78.3	2.4	23.7
5	Cadoux	12.0	14.1	1.30	3.9	68.0	2.5	3.2	70	162	229	56	400	48.4	93	89.9	-0.7	10.7	76.7	3.1	25.6
6	Halberd	12.9	8.7	1.00	9.3	64.4	2.3	2.5	100	108	155	26	510	20.0	98	88.6	-0.9	12.1	79.4	2.1	23.3
7	Hartog	13.3	9.9	1.40	8.8	65.9	2.3	4.5	75	135	245	51	500	25.4	98	88.5	-0.8	10.6	79.8	1.9	20.7
8	Hartog	13.2	9.8	1.34	8.1	66.2	3.0	4.3	80	137	249	52	500	32.1	97	88.4	-0.8	10.5	79.7	2.2	22.2
9	Machete	13.3	10.3	1.04	10.9	73.6	2.7	3.5	80	162	132	33	420	36.0	99	88.7	-0.7	9.8	79.7	2.0	20.3
10	Machete	13.1	12.2	0.94	8.5	74.5	3.4	3.2	80	169	85	23	680	37.7	97	87.3	-0.7	10.3	78.5	2.6	20.7
11	Meering	13.3	10.1	0.95	8.2	65.5	2.8	3.2	85	166	139	36	300	33.3	95	86.7	-1.1	10.5	81.6	1.4	20.3
12	Meering	13.2	12.7	0.90	6.6	68.1	3.2	7.9	55	187	176	51	340	43.3	91	88.4	-0.7	10.8	80.9	1.6	20.6
13	Oxley	12.6	8.0	1.08	7.5	60.6	1.8	4.9	120	127	150	30	330	19.1	96	88.7	-0.7	10.9	75.9	1.9	21.3
14	Trident	13.1	11.1	1.10	9.5	69.1	3.5	6.7	60	144	132	30	390	35.4	95	89.3	-1.1	11.7	81.1	1.5	22.5
15	Trident	12.7	15.5	1.36	6.2	70.9	4.2	14.6	35	169	147	39	440	61.0	64	87.3	-0.7	12.2	79.2	1.6	21.6

Appendix 9 continued.........

Appendix 9 (Continued)

Analytical Data for Flour Samples (1994-95 Season)

(@ 72% Extraction for the Indian Naan)

#	Wheat	FMS	FPT	FAS	S.D	W.A	D.T	STB	BRK	EXT	M.H	A.R	AMP	W.G	G.I	LF	aF	bF	LB	aB	bB
1	Aroona	9.5	13.0	1.81	75.0	33.3	498	14	10	211	310	93	810	36.0	88	93.9	-2.7	12.3	88.0	-1.9	20.6
2	Batavia	9.2	12.6	1.35	81.0	36.1	415	11	40	217	374	115	1,170	32.2	99	92.8	-2.4	10.7	88.8	-1.6	18.7
3	Batavia	9.6	14.6	1.27	79.5	31.1	442	13	35	227	351	114	1,270	41.1	84	92.5	-2.7	12.7	88.4	-2.0	21.1
4	Cadoux	9.4	10.3	1.36	81.0	35.0	382	24	90	188	294	80	960	24.5	98	94.1	-2.6	9.6	88.9	-2.2	20.6
5	Cadoux	9.5	14.5	1.57	78.0	33.8	449	26	45	231	260	87	690	38.8	94	93.6	-2.4	10.0	88.1	-1.9	22.3
6	Halberd	9.4	9.3	1.21	81.5	36.4	425	13	55	133	245	49	790	20.3	87	93.3	-2.7	11.1	89.4	-2.2	20.3
7	Hartog	9.5	10.3	1.81	80.5	37.5	432	13	40	158	403	88	750	23.4	100	92.7	-2.2	9.6	88.3	-1.5	17.5
8	Hartog	9.5	10.2	1.68	80.5	37.1	454	13	30	174	442	107	760	25.7	99	92.6	-2.2	9.6	88.6	-1.4	16.9
9	Machete	9.2	10.7	1.33	82.5	43.3	523	11	65	178	267	70	580	29.1	99	93.0	-2.0	8.9	88.7	-1.3	16.4
10	Machete	9.2	12.6	1.16	80.5	42.6	485	14	50	200	288	83	1,120	33.0	93	92.4	-2.0	9.5	88.1	-1.0	15.6
11	Meering	8.9	10.5	1.34	84.0	36.6	399	13	50	206	243	73	470	29.6	94	93.3	-2.3	9.4	89.7	-1.5	16.6
12	Meering	8.4	13.0	1.36	82.5	33.3	472	14	40	240	260	91	530	34.6	96	92.8	-2.1	9.5	89.3	-1.1	16.3
13	Oxley	8.8	8.3	1.40	82.0	34.5	410	14	110	137	221	46	480	18.4	99	93.3	-2.3	9.2	80.0	-1.5	15.3
14	Trident	8.8	11.7	1.50	84.0	43.6	475	12	50	192	293	74	590	31.0	93	93.0	-2.5	10.8	89.7	-2.0	19.1
15	Trident	8.9	16.1	1.72	80.5	34.6	459	16	15	222	243	78	700	46.1	70	91.5	-2.2	11.0	86.8	-1.3	17.6

Appendix 9 continued.........

Appendix 9 (Continued)

Analytical Data for Flour Samples (1994-95 Season)

(@ 80% Extraction for the Irani Taftoon)

#	Wheat	FMS	FPT	FAS	S.D	W.A	D.T	STB	BRK	EXT	M.H	A.R	AMP	W.G	G.I	LF	aF	bF	LB	aB	bB
1	Aroona	13.1	12.3	1.02	7.4	63.6	3.2	4.7	55	195	191	57	600	41.3	93	91.2	-1.5	12.6	81.8	0.5	22.6
2	Batavia	13.6	11.7	0.90	7.5	63.2	3.2	3.2	50	206	232	73	850	40.4	97	89.9	-1.3	11.2	82.3	0.8	21.3
3	Batavia	13.3	14.1	0.81	6.4	65.7	3.4	12.7	20	196	255	74	1,040	49.1	90	89.8	-1.6	12.4	81.9	1.0	23.0
4	Cadoux	12.5	9.7	0.82	4.5	59.0	2.0	3.6	85	153	243	56	710	28.7	99	92.0	-1.8	9.4	82.5	0.7	22.3
5	Cadoux	12.3	13.7	0.98	3.8	62.7	2.5	4.5	60	194	242	70	510	47.4	91	91.3	-1.5	10.0	81.3	1.3	24.1
6	Halberd	13.4	8.5	0.80	9.4	60.8	1.8	3.5	75	125	188	36	620	26.8	94	90.4	-1.4	11.3	83.9	0.7	17.4
7	Hartog	13.3	9.6	0.98	8.9	64.3	3.5	6.6	65	153	297	66	600	24.5	100	90.0	-1.3	10.2	83.3	0.7	19.1
8	Hartog	13.3	9.5	0.98	9.1	63.5	3.0	7.0	55	148	343	75	600	28.6	99	90.2	-1.3	10.1	83.1	1.0	19.7
9	Machete	13.2	10.0	0.77	10.8	72.0	3.0	4.5	75	178	201	50	470	35.3	97	90.0	-1.0	9.1	82.5	1.0	18.6
10	Machete	13.2	11.8	0.66	8.8	70.9	3.8	5.4	65	197	183	55	860	30.9	96	88.6	-1.2	10.8	82.5	1.3	19.1
11	Meering	13.5	9.9	0.69	8.1	64.5	3.0	2.6	85	201	168	52	360	31.5	96	91.2	-1.7	10.2	85.0	0.6	19.2
12	Meering	13.2	12.5	0.71	6.5	66.6	3.8	5.1	65	192	204	60	430	38.9	97	90.4	-1.3	10.1	84.1	0.6	18.7
13	Oxley	12.8	7.6	0.77	7.6	58.7	1.8	4.1	110	133	180	37	380	26.6	96	90.7	-1.3	10.0	83.3	0.8	21.5
14	Trident	13.1	10.9	0.77	10.8	68.1	3.5	7.9	65	171	180	47	450	34.5	93	90.8	-1.7	11.3	84.4	0.2	21.2
15	Trident	12.8	15.3	0.97	7.8	69.9	7.9	14.9	10	193	188	54	540	54.3	58	89.2	-1.3	11.4	82.3	0.7	20.4

APPENDIX 10

TEST BAKING SCORES (1994-95 Season)

(Pakistani Roti)

#	Wheat	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
1	Aroona	10	9	7	3	7	14	10	7	67
2	Batavia	6	11	8	3	9	17	9	7	70
3	Batavia	5	10	7	3	7	18	11	7	68
4	Cadoux	5	11	6	2	6	12	8	7	57
5	Cadoux	8	10	6	2	7	14	8	6	61
6	Halberd	5	11	5	2	7	12	9	7	58
7	Hartog	7	11	5	2	6	13	9	7	60
8	Hartog	11	13	7	3	7	15	11	7	74
9	Machete	5	11	4	2	10	16	11	6	65
10	Machete	6	9	2	2	10	19	11	6	65
11	Meering	8	8	5	3	9	18	11	7	69
12	Meering	4	10	5	3	8	12	8	6	56
13	Oxley	6	10	6	2	6	12	9	6	57
14	Trident	10	8	6	3	9	14	10	6	66
15	Trident	6	10	6	3	8	18	10	8	69

Appendix 10 continued.........

Appendix 10 (continued)

Test Baking Scores (1994-95 Season)

(Indian Naan)

#	Wheat	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
1	Aroona	8	9	6	3	8	10	8	8	60
2	Batavia	6	11	6	3	7	11	7	8	59
3	Batavia	3	7	3	2	7	15	11	8	56
4	Cadoux	7	8	6	4	6	16	8	6	61
5	Cadoux	5	10	7	3	6	15	11	8	65
6	Halberd	8	10	5	3	8	15	10	8	67
7	Hartog	10	9	7	3	9	20	13	8	79
8	Hartog	12	10	7	4	8	17	12	8	78
9	Machete	5	9	6	2	9	17	13	8	69
10	Machete	6	9	5	3	10	19	13	7	72
11	Meering	7	10	6	3	8	15	10	7	66
12	Meering	7	9	6	4	8	18	11	7	70
13	Oxley	5	10	4	2	6	17	10	7	61
14	Trident	8	11	7	3	8	15	11	7	70
15	Trident	4	10	4	2	9	18	12	5	64

Appendix 10 continued.........

Appendix 10 (continued)

Test Baking Scores (1994-95 Season)

(Irani Taftoon)

#	Wheat	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
1	Aroona	10	11	6	3	9	14	10	6	69
2	Batavia	10	10	8	3	8	17	10	7	73
3	Batavia	5	10	5	3	8	18	11	8	68
4	Cadoux	4	10	4	2	6	14	9	7	56
5	Cadoux	7	11	7	3	6	17	11	8	70
6	Halberd	7	10	5	3	7	16	11	7	66
7	Hartog	8	10	6	3	9	17	13	8	74
8	Hartog	10	10	8	4	9	18	11	9	79
9	Machete	8	11	6	4	9	16	13	6	73
10	Machete	8	13	7	3	8	16	9	6	70
11	Meering	8	10	6	3	9	17	11	8	72
12	Meering	6	11	5	2	8	17	10	7	66
13	Oxley	4	10	5	2	6	12	8	6	53
14	Trident	10	8	7	3	8	17	13	7	73
15	Trident	5	8	4	2	8	14	10	6	57

APPENDIX 11

ANALYTICAL DATA FOR WHEAT SAMPLES

(1995-96 Season-Between the Cultivers)

#	Wheat	WMS	WAS	WPT	T.W	TKW	FLG	PSI
1	Batavia	11.3	1.51	11.4	80.5	34.7	445	14
2	Cadoux	11.7	1.42	11.0	80.5	33.7	393	24
3	Hartog	11.3	1.58	11.6	80.0	32.6	441	11
4	Janz	11.4	1.52	10.5	83.0	37.7	410	13
5	Katunga	12.8	1.56	12.0	79.5	33.7	412	26
6	Machete	11.7	1.52	11.5	80.5	40.8	447	13
7	Meering	12.3	1.42	10.6	83.0	33.1	445	11
8	Suneca	11.3	1.62	12.5	84.0	38.6	358	13
9	Tammin	11.9	1.30	10.6	83.0	45.6	414	19
10	Trident	11.2	1.38	10.3	82.5	45.3	441	11
11	Vectic	11.6	1.54	11.3	78.0	41.0	396	19
12	Yanac	12.0	1.54	11.8	79.0	34.1	492	14

Note: All wheats were grown side by side at "Yeelanna" in South Australia.

APPENDIX 12

ANALYTICAL DATA FOR FLOUR SAMPLES

(1995-96 Season-Between the Cultivers)

(@ 88% Extraction for the Pakistani Roti)

#	Wheat	FMS	FPT	FAS	S.D	W.A	D.T	STB	BRK	EXT	M.H	A.R	AMP	W.G	G.I	LF	aF	bF	LB	aB	bB
1	Batavia	13.9	10.7	1.11	8.3	64.1	3.3	4.4	65	163	170	45	770	32.7	96	89.4	-1.0	11.3	74.8	1.4	25.7
2	Cadoux	12.9	10.3	0.93	3.8	60.9	3.2	3.1	90	166	232	60	580	29.3	98	90.8	-1.5	9.9	80.1	1.7	24.7
3	Hartog	13.8	11.2	1.10	8.6	68.0	4.5	5.6	65	173	249	68	340	28.6	99	88.5	-1.1	9.6	75.2	1.2	20.2
4	Janz	13.7	9.8	1.02	7.0	64.6	4.0	5.1	60	163	212	54	290	25.1	98	88.9	-0.9	10.0	77.1	1.3	24.0
5	Katunga	12.9	11.2	1.06	2.5	61.2	2.7	2.4	95	217	150	52	330	35.3	96	90.2	-1.1	8.7	76.2	2.3	22.1
6	Machete	13.5	10.9	1.05	10.1	70.0	4.5	4.4	75	171	195	53	590	30.0	99	89.3	-1.0	9.9	76.3	1.6	24.1
7	Meering	13.7	10.2	0.98	9.2	64.9	3.5	3.8	65	163	172	45	320	28.0	98	89.5	-1.3	11.0	78.5	1.2	25.1
8	Suneca	13.5	12.1	0.97	9.2	61.5	4.8	5.0	70	194	290	85	280	31.1	99	90.2	-1.5	9.9	79.3	-0.3	22.9
9	Tammin	13.2	9.9	0.90	5.3	62.0	2.7	3.2	90	154	175	43	690	29.0	96	90.4	-1.2	12.4	79.0	2.3	25.3
10	Trident	13.8	10.3	0.99	10.7	68.4	4.5	7.3	60	151	178	43	360	27.6	97	89.7	-1.6	11.8	77.5	0.9	26.1
11	Vectic	12.4	10.6	1.10	3.7	61.0	2.5	1.9	110	175	125	36	270	32.9	93	88.7	-1.7	10.2	77.3	1.4	23.3
12	Yanac	13.3	11.4	1.08	7.0	64.3	3.3	4.5	55	193	198	61	630	36.2	98	88.6	-0.6	9.3	77.2	2.4	22.5

Appendix 12 continued ....

Appendix 12 (Continued)

Analytical Data for Flour Samples

(1995-96 Season-Between the Cultivers)

(@ 72% Extraction for the Indian Naan)

#	Wheat	FMS	FPT	FAS	S.D	W.A	D.T	STB	BRK	EXT	M.H	A.R	AMP	W.G	G.I	LF	aF	bF	LB	aB	bB
1	Batavia	14.4	10.3	0.53	8.7	59.5	4.3	8.6	50	186	338	91	1,160	27.8	92	92.8	-2.6	11.7	83.0	-2.4	21.8
2	Cadoux	13.4	9.7	0.42	4.2	55.4	2.3	4.4	90	190	331	90	840	24.0	97	93.9	-2.6	9.4	85.6	-2.8	21.0
3	Hartog	14.2	10.5	0.48	10.7	63.3	5.7	13.6	35	206	408	118	890	26.3	99	93.0	-2.3	8.7	85.2	-2.3	18.5
4	Janz	14.3	9.3	0.48	7.2	60.1	4.0	8.6	40	183	393	102	450	24.4	97	93.3	-2.0	10.3	84.8	-1.8	20.3
5	Katunga	12.7	10.4	0.47	3.3	54.7	2.8	2.9	90	245	240	89	480	28.3	91	93.6	-2.2	10.0	85.3	-2.5	21.2
6	Machete	13.6	10.3	0.56	10.4	67.4	4.8	8.8	60	196	305	87	780	26.8	98	92.9	-2.1	9.6	80.6	-2.1	20.3
7	Meering	14.5	9.7	0.44	10.3	62.2	4.2	5.8	60	203	296	87	450	25.3	91	93.6	-2.3	9.8	86.2	-2.4	21.3
8	Suneca	14.4	11.4	0.49	8.9	58.1	6.4	15.0	40	217	510	148	470	27.9	99	93.4	-2.2	8.8	84.1	-2.5	19.7
9	Tammin	13.3	9.2	0.47	6.2	57.8	2.7	4.6	85	159	290	69	970	22.4	98	93.9	-2.0	11.0	83.5	-2.2	20.9
10	Trident	13.8	9.8	0.56	11.7	66.3	5.3	10.1	40	170	320	78	470	27.0	78	93.1	-2.6	11.4	83.2	-2.2	23.7
11	Vectic	13.3	9.8	0.50	3.5	54.8	2.8	3.0	100	229	220	78	420	25.8	79	92.9	-2.6	8.6	83.3	-2.0	20.2
12	Yanac	13.9	11.1	0.52	6.3	60.5	4.2	5.8	55	235	282	98	1,120	30.6	96	92.8	-1.7	9.3	83.5	-1.4	20.1

Appendix 12 continued ....

Appendix 12 (Continued)

Analytical Data for Flour Samples

(1995-96 Season-Between the Cultivers)

(@ 80% Extraction for the Irani Taftoon)

#	Wheat	FMS	FPT	FAS	S.D	W.A	D.T	STB	BRK	EXT	M.H	A.R	AMP	W.G	G.I	LF	aF	bF	LB	aB	bB
1	Batavia	14.2	10.6	0.89	8.6	61.9	3.5	3.6	70	180	232	65	920	30.8	94	90.3	-1.5	11.3	75.6	-0.1	26.0
2	Cadoux	13.0	10.1	0.69	3.8	58.0	2.8	3.6	95	180	256	71	640	27.4	98	91.8	-1.8	10.1	79.7	-0.4	21.0
3	Hartog	13.8	10.8	0.77	9.9	65.4	4.7	6.6	60	183	315	87	550	29.7	99	90.7	-1.6	10.4	78.1	0.2	20.3
4	Janz	14.1	9.5	0.72	7.0	62.8	4.0	5.9	60	179	261	71	350	25.7	99	90.8	-1.3	10.1	77.8	0.0	21.8
5	Katunga	12.8	10.8	0.77	2.8	57.4	2.7	2.6	90	216	200	68	400	31.8	94	91.4	-1.6	9.4	78.6	0.9	19.4
6	Machete	13.6	10.6	0.80	9.7	69.0	4.5	5.1	70	189	255	72	670	30.4	99	90.8	-1.6	9.7	77.3	-0.4	22.5
7	Meering	14.2	9.8	0.73	8.6	63.0	3.8	4.7	60	188	210	62	370	27.7	95	91.4	-1.8	10.0	79.3	-1.2	24.0
8	Suneca	13.9	11.6	0.72	8.4	59.9	4.7	8.8	60	225	360	116	360	30.6	99	91.0	-1.9	9.3	78.0	0.2	20.7
9	Tammin	13.4	9.6	0.68	5.4	60.2	2.8	3.2	100	157	205	51	780	27.8	94	91.5	-1.6	11.0	80.8	0.8	25.4
10	Trident	13.8	10.1	0.80	11.1	66.9	5.0	7.6	55	158	237	57	380	27.1	91	90.9	-2.1	11.0	78.2	-0.6	28.6
11	Vectic	12.8	10.1	0.78	3.4	57.6	2.5	2.7	100	198	170	54	310	31.0	90	91.2	-2.1	9.6	77.6	-0.9	22.1
12	Yanac	13.8	11.3	0.81	6.8	62.4	3.5	4.0	60	208	227	73	780	34.7	95	90.4	-1.2	8.2	76.3	0.0	18.9

APPENDIX 13

TEST BAKING SCORES

(1995-96 Season-Between the Cultivers)

(Pakistani Roti)

#	Wheat	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
1	Batavia	12	12	10	4	8	14	10	8	78
2	Cadoux	6	12	7	1	6	12	12	6	62
3	Hartog	7	3	6	3	8	8	8	8	51
4	Janz	10	9	4	4	10	16	15	6	74
5	Katunga	9	6	5	2	6	6	6	6	46
6	Machete	4	8	6	4	4	8	9	6	49
7	Meering	10	13	4	3	10	15	13	6	74
8	Suneca	10	7	2	3	4	4	3	6	39
9	Tammin	12	13	8	2	8	16	12	6	77
10	Trident	8	14	6	4	10	18	15	8	83
11	Vectic	7	12	2	1	7	8	11	6	54
12	Yanac	11	7	6	2	4	8	7	4	49

Appendix 13 continued ....

Appendix 13 (continued)

Test Baking Scores

(1995-96 Season-Between the Cultivers)

(Indian Naan)

#	Wheat	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
1	Batavia	12	12	8	4	9	13	13	6	77
2	Cadoux	6	9	5	2	8	9	9	6	54
3	Hartog	9	5	6	3	6	7	7	9	52
4	Janz	12	6	4	3	9	16	12	10	72
5	Katunga	3	9	4	1	4	6	3	3	33
6	Machete	3	9	5	4	4	9	9	6	49
7	Meering	15	12	2	3	6	15	12	8	73
8	Suneca	9	4	4	3	2	4	3	2	31
9	Tammin	9	12	7	2	8	11	9	6	64
10	Trident	9	15	5	4	10	20	14	8	85
11	Vectic	6	6	2	1	6	10	8	6	45
12	Yanac	12	6	6	3	4	5	5	4	45

Appendix 13 continued ....

Appendix 13 (continued)

Test Baking Scores

(1995-96 Season-Between the Cultivers)

(Irani Taftoon)

#	Wheat	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
1	Batavia	14	12	8	4	8	15	13	9	83
2	Cadoux	9	12	6	2	7	12	10	8	66
3	Hartog	6	9	4	3	5	8	6	5	46
4	Janz	12	8	5	3	9	18	14	10	79
5	Katunga	7	6	4	1	6	10	6	6	46
6	Machete	3	9	5	4	7	12	9	7	56
7	Meering	10	10	3	2	8	14	12	9	68
8	Suneca	9	6	4	2	4	4	3	2	34
9	Tammin	10	12	6	2	8	14	10	9	71
10	Trident	9	15	6	4	10	15	13	9	81
11	Vectic	6	9	2	1	7	12	11	8	56
12	Yanac	10	6	6	3	4	8	5	4	46

APPENDIX 14

ANALYTICAL DATA FOR WHEAT SAMPLES

(1995-96 Season-Within the Cultivars)

#	Wheat	WMS	WAS	WPT	T.W	TKW	FLG	PSI
1	Batavia-H	11.1	1.34	11.4	81.1	36.8	457	15
2	Batavia-A	9.7	1.56	10.4	81.5	33.3	446	12
3	Batavia-N	11.8	1.87	14.5	80.0	33.9	470	14
4	Trident-H	10.4	1.15	11.3	84.0	42.3	434	14
5	Trident-A	9.8	1.43	10.1	83.0	39.4	370	13
6	Trident-N	11.0	1.92	15.3	82.5	39.1	481	18

Where:

Batavia-H & Trident-H are form Horsham in VIC,

Batavia-A & Trident-A are form Avondale in WA &

Batavia-N & Trident-N are from Narrabri in NSW.

APPENDIX 15

ANALYTICAL DATA FOR FLOUR SAMPLES

(1995-96 Season-Within the Cultivars)

(@ 88% Extraction for the Pakistani Roti)

#	Wheat	FMS	FPT	FAS	S.D	W.A	D.T	STB	BRK	EXT	M.H	A.R	AMP	W.G	G.I	LF	aF	bF	LB	aB	bB
1	Batavia-H	13.5	10.9	0.83	6.7	62.2	3.2	4.5	85	192	190	57	940	34.5	89	89.7	-1.1	11.3	78.9	0.4	22.6
2	Batavia-A	13.4	9.7	1.02	7.1	62.8	2.7	2.8	95	150	135	31	740	29.6	88	89.3	-1.1	11.6	78.8	0.7	24.2
3	Batavia-N	13.3	14.2	1.12	7.8	67.3	4.3	6.2	77	222	111	40	700	46.0	75	89.3	-1.0	11.1	73.3	1.4	23.0
4	Trident-H	13.4	10.6	0.83	11.4	67.7	3.8	7.1	75	166	180	47	480	30.7	83	89.9	-1.4	11.0	77.5	-0.5	20.4
5	Trident-A	13.4	9.6	1.04	11.2	68.7	3.5	5.0	95	137	165	35	280	23.3	99	89.9	-1.4	11.1	75.2	0.5	21.4
6	Trident-N	14.0	14.6	1.31	5.6	67.5	4.7	14.1	35	210	124	40	530	44.1	76	87.8	-0.9	12.0	76.5	0.7	24.6

Appendix 15 continued ....

Appendix 15 (Continued)

Analytical Data for Flour Samples

(1995-96 Season-Within the Cultivars)

(@ 72% Extraction for the Indian Naan)

#	Wheat	FMS	FPT	FAS	S.D	W.A	D.T	STB	BRK	EXT	M.H	A.R	AMP	W.G	G.I	LF	aF	bF	LB	aB	bB
1	Batavia-H	13.7	10.5	0.51	6.9	59.5	3.8	7.6	60	206	330	98	1,380	26.1	99	91.6	-2.1	10.8	83.2	-2.7	19.9
2	Batavia-A	13.8	9.2	0.52	8.1	60.0	2.8	5.0	70	189	215	63	1,190	23.5	96	92.8	-2.4	10.6	80.3	-3.0	19.6
3	Batavia-N	13.6	13.6	0.52	8.0	64.4	5.5	15.0	31	260	231	90	1,150	40.5	81	92.5	-2.1	11.4	82.6	-2.0	22.1
4	Trident-H	13.6	9.9	0.49	11.2	66.1	4.8	15.0	30	173	380	94	660	26.8	87	93.1	-2.5	10.5	84.0	-2.7	20.4
5	Trident-A	13.8	8.9	0.50	12.1	65.5	4.2	12.1	45	156	290	67	410	20.5	99	93.1	-2.7	11.2	83.4	-2.9	19.9
6	Trident-N	13.8	13.4	0.52	7.5	66.0	5.7	15.0	30	210	262	80	740	36.5	81	92.3	-2.4	11.4	80.8	-2.5	20.8

Appendix 15 continued ....

Appendix 15 (Continued)

Analytical Data for Flour Samples

(1995-96 Season-Within the Cultivars)

(@ 80% Extraction for the Irani Taftoon)

#	Wheat	FMS	FPT	FAS	S.D	W.A	D.T	STB	BRK	EXT	M.H	A.R	AMP	W.G	G.I	LF	aF	bF	LB	aB	bB
1	Batavia-H	13.6	10.7	0.65	6.2	60.7	3.7	5.9	70	206	240	75	1,120	34.5	89	91.1	-1.6	11.0	75.7	-0.6	24.1
2	Batavia-A	13.6	9.5	0.82	7.9	61.3	2.7	3.2	90	173	170	47	920	29.6	88	91.2	-1.7	11.1	79.3	-0.4	23.5
3	Batavia-N	13.3	14.0	0.84	7.5	66.1	6.2	8.2	61	256	157	63	900	46.0	75	90.7	-1.4	10.7	75.7	0.2	22.6
4	Trident-H	13.4	10.4	0.66	10.9	67.0	4.0	8.6	60	165	255	64	530	30.7	83	91.6	-1.9	11.6	80.4	-1.0	24.0
5	Trident-A	13.7	9.3	0.82	11.9	67.2	3.7	6.1	90	143	220	49	330	23.3	99	91.1	-1.8	11.2	71.9	-1.0	23.5
6	Trident-N	14.0	14.3	0.93	7.1	67.1	5.3	13.1	40	199	171	53	610	44.1	76	90.0	-1.6	10.6	70.4	0.5	22.2

APPENDIX 16

TEST BAKING SCORES

(1995-96 Season-Within the Cultivars)

(Pakistani Roti)

#	Wheat	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
1	Batavia-H	11	11	4	4	8	20	14	7	79
2	Batavia-A	7	7	4	2	8	14	10	7	59
3	Batavia-N	4	9	3	2	7	13	9	5	52
4	Trident-H	10	13	5	2	9	16	12	8	75
5	Trident-A	7	11	4	1	8	12	10	6	59
6	Trident-N	7	7	4	2	7	14	10	5	56

Appendix 16 continued ....

Appendix 16 (continued)

Test Baking Scores

(1995-96 Season-Within the Cultivars)

(Indian Naan)

#	Wheat	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
1	Batavia-H	9	10	10	3	8	15	11	7	73
2	Batavia-A	7	9	8	2	6	13	5	6	56
3	Batavia-N	3	14	4	1	8	15	11	6	62
4	Trident-H	7	10	8	3	9	19	11	6	73
5	Trident-A	6	10	4	2	6	7	7	6	48
6	Trident-N	3	13	6	1	6	12	8	4	53

Appendix 16 continued..........

Appendix 16 (continued)

Test Baking Scores

(1995-96 Season-Within the Cultivars)

(Irani Taftoon)

#	Wheat	SHP	CLR	SMT	BLS	ROL	TER	CHW	TST	TBS
1	Batavia-H	12	12	10	3	5	13	10	8	73
2	Batavia-A	10	9	6	3	6	12	8	6	60
3	Batavia-N	3	8	8	1	5	13	7	3	48
4	Trident-H	12	11	8	4	8	14	9	7	73
5	Trident-A	8	9	5	3	9	13	7	6	60
6	Trident-N	4	7	6	1	5	11	7	3	44

APPENDIX 17

ANALYTICAL DATA FOR REFERENCE (CONTROL) FLOUR SAMPLES

Parameter	72% Extraction Flour	80% Extraction Flour	88% Extraction Flour
FMS	14.0	13.5	13.1
FPT	11.0	10.9	10.8
FAS	0.59	0.72	0.90
S.D	8.3	7.5	7.8
W.A	63.1	64.5	64.7
D.T	5.5	5.2	4.7
STB	14.1	12.7	9.0
BRK	41	52	47
EXT	194	177	150
M.H	380	360	360
A.R	103	92	79
AMP	540	500	440
W.G	27.4	27	28
G.I	97	98	97
LF	92	90.5	88.7
aF	-2.1	-1.8	-1.3
bF	9.8	10.6	11.7
LB	83.9	77.7	78.8
aB	-1.5	-0.4	0.7
bB	19.7	22.3	21.3

APPENDIX 18

A. PAPERS PRESENTED AT DIFFERENT CONFERENCES DURING THIS STUDY.

1. Hashmi, I.A. & Wootton, M. Tandoori bread production. Poster presentation at 45th RACI conference in Adelaide, Australia. 10-14 September, 1995.

ABSTRACT OF THE PAPER

During the last 10 years Australia exported over 17 million tonnes of wheat to Iran, Pakistan and India. Considerable research has been directed towards flat breads of the Middle East. However, Tandoori breads has received far less attention although they represent a substantial share of wheat-based product consumption in these countries and also in Arabian Gulf countries. Tandoori breads differ from other flat breads with flour type used, baking conditions, specifics quality attributes and variations in regional quality expectations.

Research will be carried out in developing a test baking and evaluation procedure for Tandoori breads, and determining the wheat and flour properties that effect the Tandoori bread quality. An over view of the research is presented here. Findings of the project will provide valuable technical marketing support to assist in expanding sales of Australian wheat to the markets of Pakistan and India and expand the sales to Iran breads are widely consumed and there is always a potential to develop an increased manufacture of such products in Australia.

2. Hashmi, I.A. & Wootton, M. Test Baking Procedure for Tandoori Breads. Paper presentation at the 81st AACC annual meeting in Baltimore, USA. 15-19 September, 1996.

ABSTRACT OF THE PAPER

Although Tandoori breads have been manufactured for centuries in Iran, Pakistan and India, they have not been the subject of much systematic research as is the case with other flat breads. In particular, there are no generally accepted test baking and loaf evaluation procedures currently available. In order to rectify this situation, it was necessary to develop test baking equipment and procedures. This is complicated in the case of Tandoori breads by the differing raw materials and consumer preferences between these regions. This paper reports on the results of a survey of commercial practices within each of these regions, the designing and installation of a gas-fired Tandoori oven and the establishment of test baking and loaf evaluation protocols for the three different Tandoori bread types. Operating parameters for the oven which were specified include temperature, gas flow and air supply. Processing and quality parameters for the oven were derived extensively from the results of the survey. As a result of this research, a standardised procedure for Tandoori bread production and a scoring and evaluation system were developed.

(This Abstract was published in Cereal Foods World 604/July 1996, Vol.41, No.7)

B. PAPERS GENERATED FROM THIS STUDY AS OF DECEMBER 1996.

1. Hashmi, I.A. & Wootton, M. (1995) Tandoori Bread Production and Quality. *Food Australia.* 47:366-368. (See page 157 for details).

2. Hashmi, I.A. & Wootton, M. (1996) Test Baking Technique & Evaluation of Tandoori Bread. (Draft of this paper is ready to be published. See page 160 for details).

TECHNICAL REVIEW

Tandoori bread production and quality

I. Hashmi and M. Wootton

The Indian subcontinent and the Middle East are important markets for Australian wheat. During the last 10 years Australia exported over 17 mt to Iran, India and Pakistan. In 1992/93 alone, Australian wheat exports to these regions exceeded 4 mt (AWB 1994). These markets are somewhat sporadic and opportunistic for Australia and in order to develop more consistent sales to these regions it will be necessary not only to meet pricing requirements but also to expand background knowledge as to the products and wheat quality attributes specific to these markets. Of major importance are flat breads of various types and considerable research has been directed towards those of the Middle East, eg by Faridi & others 1982, Qarooni& others 1987; Qarooni 1988 and Quail & others 1990. An earlier review of flat bread production (Quail & others 1991) refers to the situation in Australia. However, the Tandoori breads (so called because they are baked in a Tandoori oven or Tandoor) of Iran, Pakistan and India have received less attention although they represent a substantial share of wheat-based product consumption in these countries and have potential for increased consumption in non-traditional markets in other parts of the world.

The most common Tandoori breads are Taftoon (synonyms Tanoor, Tanoori) of Iran, Roti of Pakistan and Naan of India. These differ from other flat breads in terms of flour type used, baking conditions, specific quality attributes and variations in regional quality expectations. The most obvious distinction between Tandoori bread and some other flat bread types is that it has only a single layer and is not pocketed. In addition, it is normally consumed while still hot from the oven and is generally dipped into foods containing gravy. This product may be freshened the day after baking by moistening with water and reheating. In Australia, Tandoori breads of various types are produced on a relatively small scale for retail sale. They are also baked in some Indian, Pakistani and Middle Eastern restaurants as ordered by customers, the doughs generally being prepared beforehand. Some imported dry mixes, especially for Naan, have recently become available through supermarkets and Asian grocery stores in Australia for domestic preparation. As a prelude to a research program into wheat quality requirements for Tandoori breads, a survey of commercial Tandoori bread baking operations in the Middle East and Indian sub-continent has been carried out and a general review on this topic is presented here.

Dr Michael Wootton FAIFST is Research Leader and Irfan Hashmi Research Associate at the Academy of Grain Technology, 260 Princes Highway, Werribee Vic 3030.

Formulation and flour types

The basic ingredients of Tandoori breads are flour, water, yeast, baking soda and salt. Optional ingredients include milk, sugar, yoghurt, eggs and cardamom powder. These latter are often selected to suit the types of food being served. The following basic formulation is widely used for Tandoori bread in Iran, Pakistan and India:

Flour	100 parts
Salt	1.25-1.50 parts
Dry yeast	0.3-0.5 parts
Baking soda	0-0.30 parts
Water	63-64 parts

The major differences between Tandoori breads produced in the different regions arise from the different flour types used in their production. In India, Naan, the most common type, is made from straight run flour of about 72% extraction, whereas in Pakistan Tandoori bread is made from brown flours with extraction rates in the region of 88%. Iranian Tandoori bread is most commonly produced from a blend of these two flour types. The different flour types lead to variations in the characteristics of Tandoori bread between the regions. The Indian product is chewy with a glossy appearance, compared to the Pakistani bread which is soft and tender in texture but of duller appearance due to the level of bran present. Iranian Tandoori bread is intermediate in texture and appearance between the Indian and Pakistani products

Table 1. Characteristics of typical flours for Tandoori bread production

Characteristic	Straight run flour	Brown flour
Extraction (%)	72	88
Moisture (%)	13.9	13.1
Ash (%, dry basis)	0.53	0.92
Wet gluten (%)	32.1	25.3
Protein (%)	11.0	10.6
FARINOGRAPH DATA		
Water abs (%)	62.5	63.0
Development time (min)	10.5	3.5
Stability (min)	25.0	6.0
Breakdown (BU)	20	80
Valorimeter value	80	48
EXTENSOGRAPH DATA		
Extensibility (cm)	16	16
Max. resistance (BU)	630	220
Energy	140	49

but is also made with a much thinner dough sheet. It becomes hard more rapidly than the others, possibly because it dries out faster. Tandoori breads from India (Naan), Pakistan (Roti) and Iran (Taftoon) are shown in Figures 1, 2 and 3. The sizes indicated vary somewhat within and between individual Tandoors largely because of reliance on manual dough dividing, sheeting and docking.

The straight run and brown flours used in Tandoori breads would typically have the characteristics shown in Table 1, with the blend for Iranian product intermediate between these two. These data are based on information obtained from flour mills and Tandoors in the regions as part of the survey. Wheats milled to produce these flours may be from various sources including domestically grown varieties and those imported from Australia, North America and Saudi Arabia. Quality of the wheats in terms of hardness, protein content and screenings, is highly variable depending on the region involved and seasonal and economic factors, although they are generally of high Falling Number (>400 seconds). The straight run flour falls into the range of protein and gluten contents, Farinograph water absorption, and Extensograph characteristics generally associated with the Australian Hard class. However, it has longer development time, higher stability and is less extensible than generally found for Australian Hard wheat flour. The brown flour is similar to straight run flour from Australian Hard wheat in protein and gluten contents and water absorption, but is markedly lower in development time, stability and Extensograph characteristics. Data for brown flour from Australian wheats are not available to allow precise comparison.

Commercial Tandoori bread production

The procedure normally follows the sequence below:

1. Mixing: The ingredients described above are combined and mixed either by hand or slow speed spiral mixer for approximately 25-30 min to achieve the desired level of dough development. Dough temperatures are generally in the 30-40°C range

2. Fermentation: This normally takes place for 80-120 min at the ambient temperature in the bakery (normally 25-45°C).

3. Dividing: Dough pieces of 200-300g are scaled off depending on the type of bread.

4. Resting: The dough pieces are allowed to rest under a plastic sheet for 5-10 min prior to sheeting in the bakery (25-45°C).

5. Sheeting: The dough pieces are initially rolled to a thickness of 8-15 mm using a rolling pin. Final dough thicknesses of 3-10 mm are achieved by stretching manually.

6. Docking: Dough sheets are docked using plastic or metal dockers, or sometimes the baker may use his fingers, to prevent pocket formation.

7. Baking: Loaves are baked at 380-450°C for 50-90 seconds. Traditionally this is done in a Tandoori oven of clay or steel construction and fired by gas, diesel, charcoal or wood fuel . The loaf adheres to the wall of the oven when placed in position by the baker using a moistened cloth cushion and is removed with specially designed metal rods when baking is complete.

The word Tandoor, derived from the Persian, Urdu and Hindi languages, means "keep your body away". It reflects the nature of the oven which is very hot with the potential to burn the hands and other body parts if they make contact. A diagram of a Tandoor is shown in Figure 4.

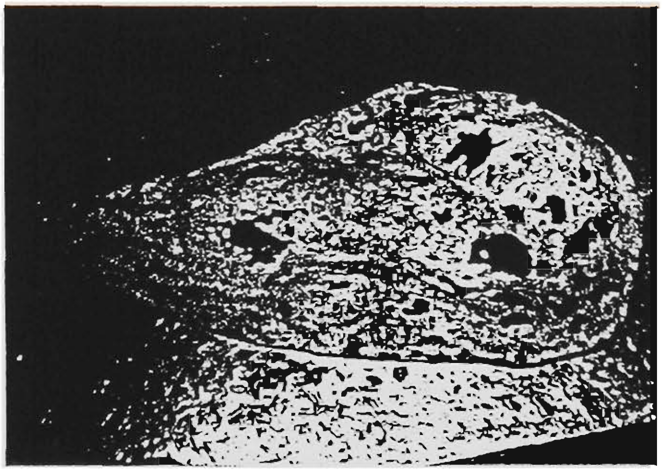


Figure 1. Naan from India (oval, approx 15cm X 20cm).

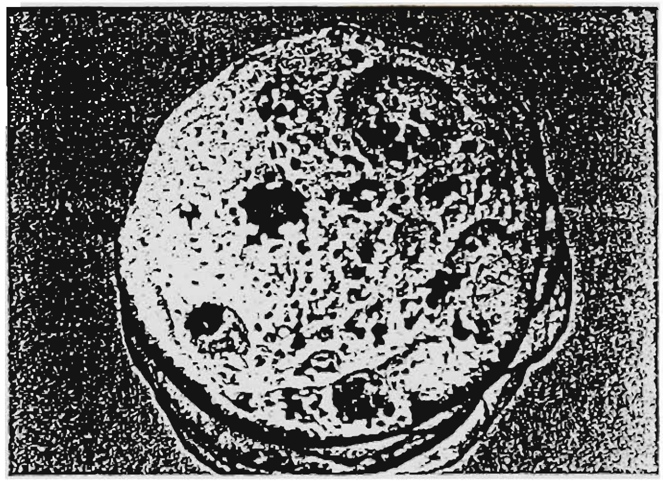


Figure 2. Roti from Pakistan (circular, approx 20cm diameter).

Figure 3. Taftoon from Iran (circular, approx 25cm diameter).

Tandoori bread quality

There has been considerable research relating to test baking, evaluation and scoring systems for flat breads of the Middle East, eg by Faridi& others 1982, Qarooni & others 1987, Qarooni 1988 and Quail & others 1991. However, there has been little corresponding work specifically dedicated to Tandoori breads. Qarooni & others

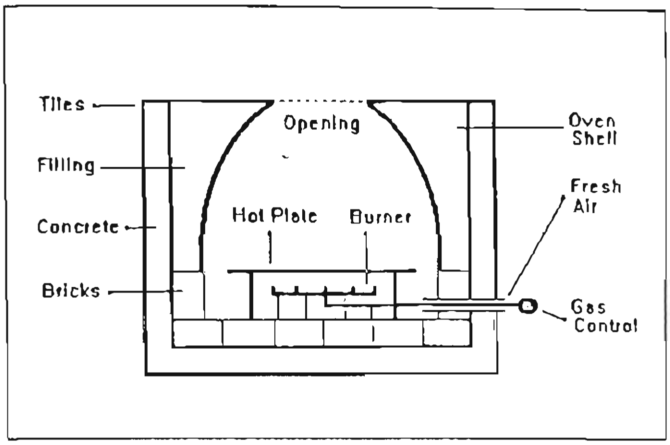


Figure 4. Diagram of a Tandoori oven.

(1993) used a test baking and scoring procedure to evaluate high extraction flours from several hard and soft American wheats in Middle Eastern Tandoori bread production. They concluded that optimum quality Iranian Tandoori bread was obtained from 85% extraction flours with 11-13% protein. Faridi & others *(1982)* included Taftoon, an Iranian Tandoori bread, in their study of the performance of US wheats in five Iranian flat breads and found that soft Western white wheats were generally best suited to this product. Rahim & others (1993) described a laboratory method for the production of Naan bread using flours from Indian wheats. None of this research examined the issue of straight run/brown flour blends as used for Tandoori breads in Iran.

This earlier work on flour quality, test baking and evaluation of Tandoori bread has been focussed on the Middle Eastern products and must be expanded to include those of India and Pakistan. In particular, the differing blends of straight run and brown flours used between India, Pakistan and Iran necessitate further work on flour properties and the impact of blending on product quality. In addition, previous work has been carried out with Indian and North American wheats only and, with the exception of research by Rahim & others (1993), represents extensions of research into other flat bread types rather than being dedicated to Tandoori breads which have distinct quality, formulation and baking requirements. For example, in loaf scoring, second day evaluation of Tandoori bread is likely to be of less importance than for most other flat breads since it is normally consumed soon after baking. Crumb texture is also likely to be less important owing to the nature of the foods with which Tandoori bread is eaten. Product evaluation and scoring systems must also take account of differing quality expectations between the regions, where texture and appearance criteria are affected by the flour blends used and must match expectations of specific consumers.

At present there is no general test baking and scoring procedure for Tandoori breads. Such a procedure is crucial to any meaningful research into wheat quality requirements and must allow assessment of the different quality requirements of the three principal regions. Scoring of Tandoori breads will however reflect appearance, texture, mouthfeel and rolling ability and will no doubt be similar to systems designed for other flat breads, such as those described by Quail & others (1991).

References

AWB 1994. Exports of bulk wheat (ASW) by destination 1982-1993. Australian Wheat Board, Melbourne.
Faridi,HA, Finney,PL& Rubenthaler,GL 1982. Microbaking evaluation of some US wheat classes for suitability in Iranian breads. Cereal Chem. 58: 471-4.
Qarooni,J, Posner,ES & Ponte Jr,JG. 1993. Production of Tanoor bread with Hard White and other US wheats. Association of Operative Millers Bulletin, September: 6288-94.
Qarooni,J. 1988. Factors governing the quality of bread in the Middle East. PhD thesis, the University of New South Wales.
Quail,K, Mcmaster,GJ, Tomlinson,JD & Wootton,M. 1990. Effect of baking temperature/time conditions and dough thickness on Arabic bread quality. J. Sci. Food Agric. 53: 527-40.
Quail,K, McMaster,G & Wootton,M. 1991. Flat bread production. Food Australia 43:155-7.
Rahim,A, Vatsala,CN & Shurpalekar,SR. 1993. Development of a laboratory method for the production of Naan. J. Food Sci. Technol. 30: 114-7.

Test Baking Technique & Evaluation of Tandoori Bread

I. Hashmi and M. Wootton

Dr. Michael Wootton FAIFST is Associate Professor of Food Science & Technology, University of NSW & I. Hashmi is Research Fellow at the Academy of Grain Technology 260 Princes Hwy Werribee 3030

As no systematic test baking procedure for reproducible measurement of Tandoori bread quality exists that is relevant to commercial practice, it was therefore necessary to undertake a survey of current commercial practices (Hashmi et al. 1994) in the regions where these breads are most popular for clearly documented data on the ranges in parameters commonly used. These parameters include the flour extraction rates, ingredient formulations, dough mixing timing and intensity, proofing conditions (such as temperature and humidity), dough dividing, moulding, sheeting, docking and the Tandoori oven design and construction and operating conditions such as baking temperatures. The results of the survey provided a rational basis for selecting the experimental conditions and establishing meaningful ranges for the parameters studied.

Development of a Test Baking Method

The following test baking equipment was designed and manufactured or modified especially for this project: (1) Intermediate Resting Tray: This is a wooden box similar to the one described by Qarooni (1988), with a sliding lid in which the dough pieces were rested for 5 minutes. (2) Space Guide: This is made of a wooden platform as described by Qarooni (1988), except the wooden strips on both sides were of 8 mm in height rather than 10 mm. Dough pieces were placed at the centre of the platform and were hand rolled with the help of a rolling pin that rolls on top of the strips. Hence the initial dough thickness was always at 8 mm. (3) Italian Pasta Sheeting Machine: An "Impreria" Italian motorised pasta machine (model R220) was purchased and its dial (that indicates the distance between the two rolls) was redesigned to 0-4 mm scale with the subdivisions of 0.1 mm. (4) Plastic Docker: A plastic docker was designed and made with 3 flat heads (10 mm x 2 mm) as a replacement of the tips of human fingers that are used in commercial practice for docking purposes.

Each wheat variety used in this project was milled to produce flours at three different extractions levels for the three different types of Tandoori breads (88% for Pakistani Roti, 72% for Indian Naan and 80% for Irani Taftoon) which were produced using the following test baking procedure:

Mixing 100 parts of wheat flour was taken with flour weight correction at 14% moisture basis. All the other dry ingredients (1.5 parts salt, 0.5 parts dry yeast and 0.2 parts baking soda) were weighed and initially mixed together in a Hobart mixer (model N50) for one minute. Water at 38^{0}C was then added according to the Farinograph water absorption (at 500 BU line) and further mixing was carried out for 3 minutes at speed 2 and 2 minutes at speed 3 for a well developed homogenous dough of desired consistency. Final dough temperature was also recorded (which is desired at 29^{0}C).

Fermentation Dough was kept in a sealed container in an APV prover at 34^{0}C for 80 minutes which resulted in a non sticky and adequately leavened dough with desired softness.

Dividing and Rounding After degassing the dough by hand it was divided manually into twelve 40 g dough pieces (using a digital weighing balance at $\pm$ 0.5 g), which were then hand moulded into balls.

Resting These dough balls were then kept for 5 minutes in the intermediate resting tray which was dusted with the same flour as used in test baking. This tray was covered with a sliding lid to avoid skinning on the dough balls.

Sheeting Two dough balls were taken out from the intermediate resting tray at a time and were initially hand rolled to 8 mm thickness using the space guide and a rolling pin and then passed twice through the rollers of the sheeting machine (rotating at 50 rpm). The gap between the rolls was adjusted to 2 mm for the first sheeting and then (with a turn of 90^0 of the sheeted dough or simply first out first in basis) they were finally sheeted at 1.5 mm. Final sheeted dough pieces were oval in shape.

Docking Sheeted dough pieces were docked with the plastic docker three times to get nine holes on the surface.

Baking Sheeted and docked dough pieces were kept on a moist cushion and then were placed on the wall of the test Tandoor operating at 330^{0}C. Baked breads were taken out after 55 sec from the Tandoor with the help of two steel rods and were cooled for 10 minutes at room temperature on the cooling racks. They were then kept in sealed plastic bags for 30 minutes before quality assessment was carried out by the sensory panel.

Design and Installation of a Tandoor

In order for reliable and repeatable small scale manufacture of Tandoori breads, it was necessary to design, install, commission and evaluate a test Tandoor which could be precisely and reproducibly set to a range of parameters controlling gas flow and air supply to the Tandoor. This Tandoor was used for all the test baking and it is also useful as an standard tool for Tandoori bread baking in commercial practice, because at present commercial Tandoors do not have control on the above mentioned factors resulting in variations of the end products even from the same mixing batch.

One steel oven shell, two hot plates, burner and gas-air controller were designed and made to order in Pakistan and purchased and imported form the United Arab Emirates to Australia especially for this project. A local supplier of commercial clay Tandoors in Melbourne was involved to assemble all the parts as per the specification provided to him. Australian gas and fuel department was also involved in certifying the design according to their standards for the use of natural gas in test baking. This newly designed test Tandoor is presented in Figure 1 and is based on the following steps: (1) Base: Fire proof bricks were fixed on top of the stainless steel plate at the base of the Tandoor. (2) Oven shell: Oven shell was fixed on top of the fire proof bricks 420 mm from the base (breads were placed horizontally on the oven wall at an approximate distance of 180 mm from the hot plates). (3) Burner: A burner was fixed on the base having gas and air inlets (to get the desired amount of gas with 1 kPa pressure). A push button spark igniter was attached to the burner for convenience. (4) Hot Plates: Two removable hot plates with six adjustable steel legs were placed on the base of the Tandoor and the distance between the hot plates and the burner was kept at 100 mm to maintain even burning. (5) Temperature: A digital thermometer was installed and connected to the main gas supply with an auto cut off and on switch. The thermometer probe was fixed in the baking chamber to control the temperature at the oven wall (for test baking purposes the temperature was set at 330^{0}C on the digital dial of the thermometer. However, it was interesting to note that because of the intensity of the flames the temperature at the top opening of the Tandoor was measured at around 430^{0}C). (6) Body: Stainless steel outer body on all four sides was bolted (810 mm x 820 mm) to the bottom. (7) Insulation: Heat and fire resistant fibreglass insulation was placed on all four sides along the stainless steel body as well as on the top except on the opening. The remaining empty space was filled with scoria (pieces of volcanic rocks having inside air bubbles which act as insulation). (8) Top: A stainless steel top was also bolted to the baking chamber (with a round opening of 250 mm diameter at the centre). A steel ring was fixed at the top opening. A steel lid with a handle was especially manufactured to cover the top opening when the Tandoor is not in use or to partially cover the top opening before the baking starts to get to the desired Tandoor temperature. (9) Position: Four wheels were fixed at the bottom of the Tandoor for easy movement (if required). (10) Loading and unloading: A moist cushion was used to load the bread in the Tandoor and two steel rods were used to remove the bread. One of the rod is the scraping rod while the other is a piercing rod to hold the bread while unloading.

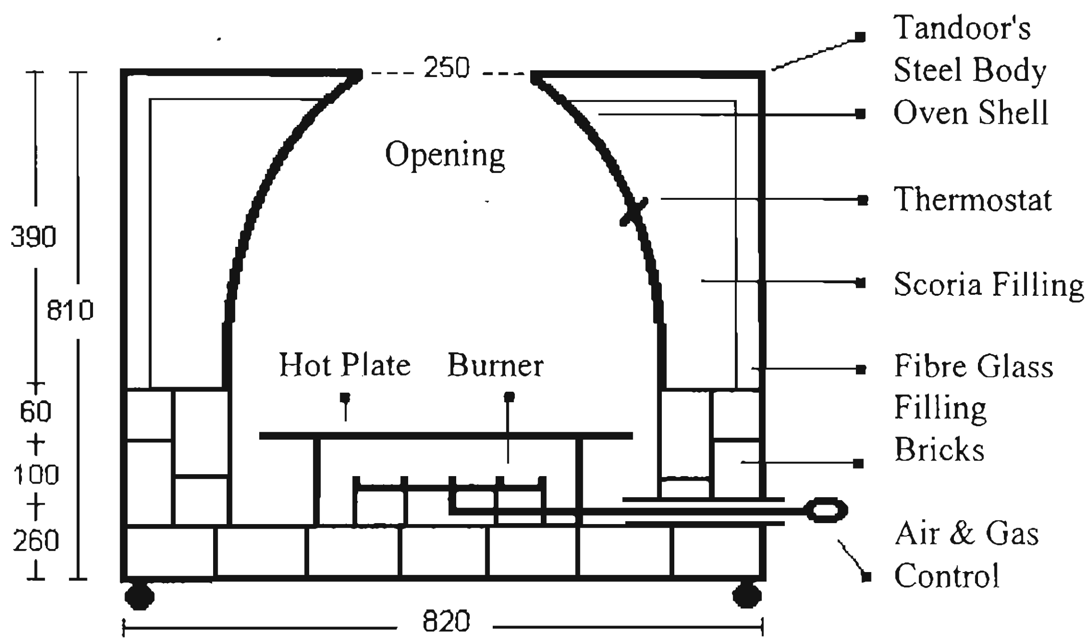


Figure .1 Diagram of the newly designed Tandoor (All dimensions are in mm)

Comparison of the New Test Baking Method with Commercial Baking

Comparison of the test baking method with the commercial baking method is described in the following sections:

Mixing In commercial Tandoori bread baking, ingredients mixed either by hand or by slow speed spiral mixer for approximately 25-30 minutes to achieve the desired level of dough development on the other hand the same dough development was achieved in only 5 minutes using a small Hobart spiral mixer.

Fermentation Test baking dough was kept in sealed container in a prover at 34^{0}C compared to the dough in commercial practice which is either taken out form the mixer and kept on a table or remains in the mixer and is covered with a plastic sheet to prevent skinning for 80-120 minutes at the variable ambient temperature in the bakery (20-40^{0}C).

Dividing & Rounding Size of the test dough piece was much smaller (40 g) than the commercial dough (150-250 g) mainly because of the amount of flour available for testing and also because of the use of the mechanical sheeting machine.

Resting Intermediate resting in the test method was carried out using intermediate wooden tray (covered with a lid) for 5 minutes than resting the dough pieces conveniently under a plastic sheet for 5-10 minutes before sheeting in the commercial method.

Sheeting In the commercial practice the dough pieces are initially rolled to a thickness of about 10-15 mm using a rolling pin. Final dough thickness of 3-10 mm is achieved by stretching them manually when they are placed on the moist cushion after docking. On the other hand a space guide with a rolling pin was used to get the initial dough thickness of 8 mm and then a sheeting machine was used to get the desired accurate shape at a final 1.5 mm thickness.

Docking In the test method docking was always carried out after final sheeting with the help of the precise plastic docker while in commercial practice docking is mostly done by finger tips or some times with a metallic docker, but as mentioned in the previous section that dough is stretched after docking.

Baking In commercial practice loaves are baked at 300-450^{0}C for 60-120 sec in a Tandoor where the bread adheres to the wall of the Tandoor's shell when positioned by the baker using a moistened cushion and are removed with special metal rods when baking is completed. Test baking was exactly the same expect that all the breads were baked at 330^{0}C for 55 sec.

Comparison of the Test Tandoor with the Commercial Tandoor

The test Tandoor is more scientifically designed than the commercial Tandoors. It has absolute controls over air, gas and temperature. Its insulation is also much effective as its outer body never gets hot, therefore the heat loss is minimum. Due to constant baking temperature, no variations occur in the bread qualities when many loaves are baked. It can also be relocated if the setting of the baking room is changed. Comparison of the commercial Tandoors and the Test Tandoor designed for this study is presented in Table 1.

Table 1. Comparison of the test Tandoor with the commercial Tandoor

#	Parts of Tandoor	Commercial Tandoor	Test Tandoor
1	Tandoor shell	Steel/Clay	Steel
2	Source of fire	Gas, coal, wood, diesel	Gas
3	Burner	Manual	Spark igniter
4	Hot plate	Fixed height	Adjustable legs
5	Air-inlet	Angular (no control)	Vertical (controlled)
6	Gas-inlet	Manual control	Controlled pressure
7	Temperature	No control	Digital thermostat with auto cut-off
8	Filling	White sand & concrete	Scoria & fibreglass insulation
9	Base	Fire proof bricks	No change
10	Body	Ceramic tiles	Stainless steel
11	Position	Stationary	On-wheels

EVALUATION OF TANDOORI BREAD

Tandoori bread evaluation is based on a scoring system carried out by a sensory penal and is described in the following paragraphs.

A simple and easy to understand scoring system to evaluate the bread quality was developed. This system is capable of discriminating between wheat varieties and was used to investigate the effect of different variables such as milling, baking and ingredients on the quality of Tandoori bread. This scoring system was designed for all the three types of Tandoori breads and is based on a survey of several Tandoori bread shops of the Middle East and the Pakistan-India

Sub-Continent (Hashmi et al. 1994). In this survey a questionnaire was given to the bakers to get their opinion about the customers' preferences for the Tandoori bread quality. In the light of the responses form the bakers, a preferred scoring system was developed and is presented in Table 2. Maximum possible scores were given according to the bakers' and their customers' preferences and choices for each quality parameter. For example the "Tearing Quality" of the bread was given a share of 20 points out of the total 100 points, but on the other hand "Blisters" were assigned only 5 points because of its less importance.

Table 2. Tandoori bread scoring system according to bakers' preferences.

Quality Parameter	Max Score
Shape	15
Crust Colour	15
Crust Smoothness	10
Blisters	5
Rolling Quality	10
Tearing Quality	20
Chewing Quality	15
Aroma & Taste	10
TOTAL SCORE	100

These quality parameters are described as follows:

Shape Tandoori bread should be of oval shape. Points being deducted for lack of symmetry.

Crust Colour The three types of Tandoori breads differ in crust colours due to the different extraction rates of the flours used (Pakistani Roti is brown, Indian Naan is cream & the Irani Taftoon is light brown in colour). Points being deducted for crust colours which were different from the required crust colour for each bread type.

Crust Smoothness Tandoori bread should have even and smooth crust without wrinkles and cracks. Points being deducted for lack of smoothness.

Blisters Tandoori breads should have evenly distributed small blisters. Marks to be deducted for very large, black and uneven distribution of blisters.

Rolling Quality Tandoori bread should withstand rolling without cracks on the crust. Marks are deducted if the bread is difficult to tear or if cracks appear while rolling the bread.

Tearing Quality Tandoori bread should be easy to tear. Marks are deducted if the bread is difficult to tear.

Chewing Quality Tandoori breads should be easy to chew, but the level of chewing differs for each of the three bread types. Roti is very easy to chew while Taftoon is moderate, but Naan is bit tougher than the two. Marks are deducted if the bread id too difficult to chew for its own type.

Taste Tastes of three types of Tandoori breads differ due to the type flour used and are as follows: Pakistani Roti (Taste of Bran), Indian Naan (No taste of Bran) and Irani Taftoon (Slight taste of Bran). There are some differences in the final product quality of the three types of Tandoori breads used in this project and are given in Table 3.

Table 3. Quality Characteristics Of Three types of Tandoori Breads

Product	Characteristics
Pakistani Roti	soft in texture, but duller in appearance
Indian Naan	bit chewy, but glossy in appearance
Irani Taftoon	moderate to soft in texture, but glossy to dull in appearance

Development of Sensory Evaluation Techniques

To produce reliable and valid data a sensory panel must be treated as a scientific instrument. It was therefore necessary that the panellist was free from any psychological errors and physical conditions which might otherwise affect human judgements. Panellist must have an ability to perform the task and to repeat their judgements. Based on this a sensory penal was chosen and trained among the staff at the research and development section of the Academy of Grain Technology to evaluate the bread qualities produced from different types of Australian wheat varieties.

As the majority of the available panellists had no experience in Tandoori breads before they were chosen, it was therefore necessary to train them about the products first and then to take into account of differing quality expectations between three principal regions, where texture and appearance criteria were affected by the flour extraction rates used and must match expectations of specific consumers. Tandoori breads from the three principal regions were baked again and again for the sensory panel to taste while explaining them the basic difference between the Tandoori breads and other flat breads of the Middle East and also the differences between the three different types of Tandoori breads. Once they started developing the taste, product oriented triangular tests were carried out for them among the three different types of Tandoori breads and in between each type.

Sensory Evaluation of Tandoori Breads

Tandoori bread evaluation is based on the scoring system of Table 2. which is carried out according to a five point scale given in Table 4.

Table 4. Tandoori bread evaluation (point scale).

Max Points	Poor	Fair	Satisfactory	Good	Excellent
5	1	2	3	4	5
10	2	4	6	8	10
15	3	6	9	12	15
20	4	8	12	16	20

As shown in the above table a panellist could grade each Tandoori bread quality parameter according the his or her choice based on the five point scale. For example, if a panellist thought that the Crust Smoothness of the bread was satisfactory then he or she had to give 6 points based on the maximum 10 points assigned to the Crust Smoothness. During this sensory evaluation work each panellist was presented with one bread sample that was evaluated in comparison to the control sample (also provided) and was rated as per the performance of each individual quality parameter shown in Table 2. in accordance to the rating given in Table 4.

Conclusion

(1) Establishment of processing formulations and conditions were also carried out. (2) A test baking procedure for Tandoori breads has been developed which has adequate precision and is relevant to commercial baking methods. It is reliable to the extent that repeatable small scale manufacture of Tandoori breads was made possible. (3) A test Tandoor was designed, installed, commissioned that was precised and reproducibly set to a range of parameters controlling temperature, gas flow and air supply. Currently there are no standards or appropriate specifications for such an oven. (4) A system for evaluation of product quality was developed for use with the test baking procedure and simple and easy to understand Tandoori bread scoring system based on the quality criteria was also developed. (5) Selection of sensory panel staff, their screening and training was also carried out for the subjective evaluation of Tandoori breads. The above procedures can be adopted for routine use in cereal testing laboratories.

References

Faridi, H.A., Finney, P.L. & Rubenthaler, G.L. (1981) Micro baking evaluation of some U.S. wheat classes for suitability in Iranian breads. *Cereal Chem.* 58:428-432.

Faridi, H.A., Finney, P.L. & Rubenthaler, G.L. (1983) Effect of soda leavening on phytic acid content and physical characteristics of Middle Eastern breads. *Jr. Fd. Sc.* 48:1654-1658.

Hashmi, I.A., Khan, M.A. & Ali, A. (1994) In UAE, Pakistan and India, a survey was carried out for this project between the people of different nationalities about their eating habits of the wheat based end products. This also includes a survey of Tandoor shops on types of flours and the composition of other ingredients used in Tandoori breads of Pakistani, Indian and Irani Origin. National Flour Mills, Dubai, UAE, (unpublished data).

Hashmi, I.A. & Wootton, M. (1995) Tandoori bread production and quality. *Food Australia*. 47 (8):366-368.

Meilgaard, M., Civille, G., & Carr, B. (1991) Sensory evaluation techniques. 2nd Ed. CRC Press Inc., Boca Raton, USA.

Qarooni, J. (1988) Factors governing the quality of breads in the Middle East. PhD thesis. University of NSW, Australia.

Qarooni, J. and Posner, E.S. (1993) Production of Tanoor bread with hard white and other US wheats. *AOM Bulletin.* Sep:6288-6294.

Rahim, A. and Vatsala, C.N. (1993) Development of a laboratory method for preparation of Nan. *Jr. Fd. Sc. & Tech.* 30/2:144-177.

Saxena, D.C. and Rao, P.H. (1995) Survey of quality characteristics of Tandoori Dough and Tandoori Roti. *Jr. Fd. Sc. & Tech.* 32/1:74-76.

7. BIBLIOGRAPHY

AACC (1994) American Association of Cereal Chemists approved methods 8th Ed. AACC, St. Paul, Minnesota, USA.

Ahmed, M. (1996) Bread Making in the Gulf. Gulf Air's monthly In-flight magazine *Golden Falcon* January 26:27.

AWB (1991-96) Exports of bulk wheat by destination Australian Wheat Board. AWB, Australia.

AWB (1994) Quality control procedures manual" Australian Wheat Board. Australia.

AWB (1995) Wheat Receival Standards-1994/95 Season. Australian Wheat Board, Australia.

Boyle, G.J. & Langley, P.D. (1989) Elementary Statistical Methods. Pergamon, Sydney, Australia.

BRI (1989) Australian Breadmaking Handbook. Tafe Educational Books. Kensington, NSW, Australia.

Buhler (1991) Operation manual for Buhler laboratory mill number MLL-202. Bhuler, Switzerland.

Falling Number (1988) Operation manual for Falling Number 1600 unit. Falling Number, Sweden.

Faridi, H.A. & Finney, P.L. (1980) Technical and nutritional aspects of Iranian breads. *Baker's Dig* 54:14-22.

Faridi, H.A., Finney, P.L. & Rubenthaler, G.L. (1981) Micro baking evaluation of some U.S. wheat classes for suitability in Iranian breads. *Cereal Chem.* 58:428-432.

Faridi, H.A., Finney, P.L., Rubenthaler, G.L. & Hubbard, J.D. (1982) Functional (bread making) and compositional characteristics of Iranian flat breads. *Jr. Fd. Sc.* 47:926-929.

Faridi, H.A., Finney, P.L. & Rubenthaler, G.L. (1983) Effect of soda leavening on phytic acid content and physical characteristics of Middle Eastern breads. *Jr. Fd. Sc.* 48:1654-1658.

Hashmi, I.A., Khan, M.A. & Ali, A. (1994) In UAE, Pakistan and India, a survey was carried out for this project between the people of different nationalities about their eating habits of the wheat based end products. This also includes a survey of

Tandoor shops on types of flours and the composition of other ingredients used in Tandoori breads of Pakistani, Indian and Irani Origin. National Flour Mills, Dubai, UAE, (unpublished data).

Hashmi, I.A. & Wootton, M. (1995) Tandoori bread production and quality. *Food Australia*. 47 (8):366-368.

International Association for Cereal Chemistry 1995 Standard Methods of the ICC. Vienna, Austria.

Levin, R.I & Rubin, D.S. (1994) Statistics for Management. 6th Ed. Prentice-Hall Inc., Englewood Cliffs, N.J, USA.

McCabe. W.L., Smith, J.C. & Herriott, P. (1985) Unit operations of chemical engineering, 3rd Ed. McGraw-Hill, NY, USA.

Meilgaard, M., Civille, G., & Carr, B. (1991) Sensory evaluation techniques. 2nd Ed. CRC Press Inc., Boca Raton, USA.

Minitab (1994) Minitab reference manual. Release 10. Minitab Inc. State College, Pennsylvania, USA.

Minolta. "Chroma Meter CR-300" Minolta. Japan 1992.

Moses, K.S. (1981) Breads of other lands. *Proceedings of Australian Society of Baking*. Sydney, Australia 1-7 Nov 1981.

Perry, R.H. & Green, D. (1984) Perry's chemical engineering handbook. 6th Ed. McGraw-Hill, NY, USA.

Pyler, E.J. (1973) Baking Science & Technology. Vol 1. Siebel Publishing Co. Chicago, ILL, USA.

Qarooni, J. (1988) Factors governing the quality of breads in the Middle East. PhD thesis. University of NSW, Sydney, Australia.

Qarooni, J., Posner, E.S. (1993) Production of Tanoor bread with hard white and other US wheats. *AOM Bulletin.* Sep:6288-6294.

Qarooni, J. (1994) Historic and present state of wheat production, milling and baking industries in the countries of the Middle East and North Africa. Kansas State University, Manhatan, USA.

Qarooni, J. (1996) Flat Bread Technology. Chapman & Hall, NY, USA

Quail, K.(1990) Factors affecting Arabic bread quality. PhD thesis. University of NSW, Sydney, Australia.

Quail, K., McMaster. G. & Wootton, M. (1991) Flat bread production. *Fd. Australia*. 43:155-157.

Quail, K.(1995) Sensory evaluation techniques. Seminar conducted at the 45th RACI conference in Adelaide, Australia. 10-14 September, 1995

Quail, K. (1996) Arabic Bread Production. AACC, St.Paul, MN, USA

Rahim, A. and Vatsala, C.N. (1993) Development of a laboratory method for preparation of Nan. *Jr. Fd. Sc. & Tech.* 30/2:144-177.

Rashid, J. (1983) Effect of wheat type and extraction rate on quality of Arabic type leavened flat bread. PhD thesis. Kansas State Univ., Manhattan, Kansas, USA.

Sanders, D., Murph, A. & Eng, R. (1980) Statistics a fresh approach. McGraw-Hill Kogakusha Ltd. Tokyo, Japan

Saxena, D.C., Rao, P.H. (1995) Survey of quality characteristics of Tandoori Dough and Tandoori Roti. *Jr. Fd. Sc. & Tech.* 32/1:74-76.

Saxena, D.C., Rao, P.H. & Rao. K.S.M. (1995) Analysis of modes of heat transfer in a Tandoor oven. *Jr. Fd. Eng.* 26:209-217.

Symes, K.J. (1961) Classification of Australian wheat varieties based on the granularity of their wheat meal. *Aust. Jr. Exp. Agri.* 1:18-22.

Tecator (1985) Numigral seed counter manual. Tecator, Hoganas, Sweden.