EVALUATION OF EFFECTIVENESS OF PRE-GELATINIZATION, FORCE –GELATINIZATION AND POST-GELATINIZATION TECHNIQUES IN MANUFACTURING OF HIGH QUALITY RICE BREAD

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DECLARATION

The work described in this thesis was carried out by me at Harischandra Mills Plc. and Faculty of Applied Sciences under the supervision of Dr S.B Navaratne and Prof. K.B. Palipane. A report of this has not submitted to any other University for another degree.

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AFFECTIONATELY DEDICATED

TO

MY PARENTS AND TEACHERS

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First I wish to express my deepest gratitude to my external supervisor Mr. S.B. Navarathne, Quality Assurance Manager, Harischandra Mills Limited for his advice, encouragement and guidance through the study for sparing his valuable time in bringing this study to a successful completion and given me a chance to carryout this project at Harischandra Mills Limited with all facilities.

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ABSTRACT

Study was focused to incorporate more than 60% of rice flour in manufacturing of rice bread using pre-gelatinization, force-gelatinization and post-gelatinization techniques concerning rice's availability and nutrient significant. Other specific objectives of this study were maintaining of high quality bread crumb structure and an attractive crust similar to wheat bread, maintaining of leavening index of rice bread to par with wheat bread and maintaining of orgonoleptic properties to meet same with wheat bread.

The study was carried out by resorting 2^4 factorial design with 4 factors such as initial moisture content (12% & 15.4%), gelatinization method (no gelatinization & force gelatinization), method of soaking (cold soaking & hot soaking) and particle size (150 μm & 300 μm). 20 kg of white raw rice was taken and divided in to 2 equal portions and moisture content of one portion was adjusted to get 12%. The rest portion was taken as it is at 15.4% moisture content. There after the rice at 12% moisture content was divided in to 2 equal portions and one portion was subjected to force gelatinization process at 90-95 ^{0}C at 3 minute. The rest portion was kept untreated. These two portions were divided in to 2 equal portions again and one portion of each was subjected to cold soaking and hot soaking process for 24 hours and 3 hours respectively. 4 treatments obtained from above treatments were divided in to 2 equal portions and each of which was subjected for grinding process to get particle size 150 μm and 300 μm. Similar process was adopted to get 8 treatment combinations from raw rice at 15.4% moisture content too.

Rice flour obtained from 16 treatment combinations were subjected for leavening index test by substituting 50:50, 60:40 and 70:30 rice flour, wheat flour respectively. As leavening index is related to increment volume divide by initial volume, leavening index of all treatments were measured and best treatments with respect to 60:40 and 70:30 rice flour, wheat flour combinations were selected in terms of high leavening index. The treatments that have shown high leavening index (15.4% of moisture, force gelatinization, cold soaking, 150 μm particle size) were subjected for bread manufacturing process and physical, chemical and orgonoleptic properties of these breads were compared as against same properties of wheat bread.

As in the case of organoleptic properties, statistical test (kruskal-wallis) review that taste, texture, appearance and overall acceptability of rice bread (60:40) are significantly better than wheat bread. However crusts of all breads are same in each other. As in the case of physiochemical properties, statistical test (one way ANOVA) review that pH, moisture and bulk density of rice breads (60:40 and 70:30) are closer to the values of wheat bread.

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ABBREVIÀTIONS

Fig. : Figure
ADD : Activated Dough Development
App. : Appendix
Avg. : Average
Eg. : Example
et al. : And others
i.e. : That is
Min. : Minute
USA : United States of America

CHAPTER 01

INTRODUCTION

1.1 Background:

Bread is the most popular and palatable food item in Sri Lanka as which is more convenient, economical and easy food in terms of money time and energy servings for busy housewife especially for working class.

Because the working housewife whenever strive hard to earn spare time from her busy time schedule because they waiting to utilize spare time for other family related activities such as entertainment with children, with the media and other social activities. Hence bread can play a significant role by cutting down a cooking time and which impart a real mental relief for busy house wife.

Sri Lanka is a third world developing economy and compel to import a substantial amount of wheat flour from foreign sources as no wheat cultivating done at all in our country. Bakery industry is the major consumer of wheat flour and considerable amount of these imported wheat flour is being used in manufacturing of breads. Because bread is a most popular food product across the whole social profile of the society. Therefore importation of wheat flour is a real burden for national coffer and substitution of wheat flour with rice is a national service in order to prevent foreign exchange drain from the country.

Rice (*Oriza sativa*) is one of the oldest and most important food crops and staple food of over half the world population. Harvested area of the rice land has fluctuated between about 350 and 360 million acres during the last few years. Annual world production of rough rice probably approached 475 million metric tons. (Cauvain and Young, 1999)

Rice is nutritionally important cereal. Milled rice contains 91.5% of carbohydrates, 7.6% of protein, 0.5% of ash, 0.3% of fat and 0.4% of crude fiber. (Board, 1999). Instead of direct eating of rice, use in cookies and crackers, because of its mild flavour, white colour and neutral textural qualities.

Rice flour is far from ideal as the structural component of leavened bread. It does not contain the gluten proteins that give wheat flour its unique, ability to form highly expanded, tender, white and flavorful yeast-leavened baked products.

Understanding the above circumstances Harischandra Mills Limited wanted to develop and formulate rice bread. Therefore the study was focused to incorporate more than 60% of rice flour in manufacturing of rice bread using pre-gelatinization, force-gelatinization and post-gelatinization methods by overcoming above disadvantages.

1.2 Objectives:

1.2.1 Overall Objective:

Manufacturing of high quality rice bread by incorporation of as much rice flour as possible, preferably more than 60%.

1.2.2 Specific Objectives:

- Maintaining of high quality bread crumb structure similar to wheat bread.
- Maintaining of attractive crust structure similar to wheat bread.
- Maintaining of leavening index of rice bread to par with wheat bread.
- Maintaining of orgonoleptic properties to meet same with wheat bread.

CHAPTER 02

LITERATURE REVIEW

2.1 The product of bread

2.1.1 Introduction

Bread in its many forms is one of the most staple foods consumed by humanity. Traditionally bread is based on flour derived from the cereal wheat. Many other types of cereals, pulses and even legumes can be milled to give'flour' but the ability of the proteins present in wheat to transform a gruel of flour and water into a glutinous mass which becomes bread is currently limited to wheat and a few other commonly used cereal seeds. Genetic manipulation may yet combine the special protein characters of wheat with other more conveniently grown and processable seeds.

Many consider bread to be one of the oldest, if not the oldest 'processed'- food. It is likely that the place of discovery was in the Middle East where the origins of cereal farming also lie in antiquity. In its earliest forms bread would have been very different from how see it in industrialized countries today and it would probably be closest in character to the modern flat breads of the Middle East. (Cauvain and Young, 1999).

The move to improve the digestibility of the wild grass seed forerunners of early wheat types, by cooking or baking represent a major step in the evolution of human food production. To make this step requires an appreciation, but not necessarily a scientific understanding, of the unique properties of the proteins in the grass seeds we call wheat, namely their ability to form a cohesive mass of dough once the grains have been crushed (milled) and the resultant product wetted (hydrated) and subjected to the energy of mixing, even by hand. This cohesive mass is called as 'gluten' and once formed it has the ability to trap gases during resting (fermentation and proof) and baking and this allows the mass to expand to become a softer, lighter and even more palatable food after the final heat processing.(Cauvain and Young, 1999).

Another important event in the production of bread the discovery that, it left long enough. The dough mass would increase in volume without being subjected to the high temperatures of cooking or baking. There is no doubt that the changes in the rheological character of the dough – the way in which it behaved in handing- would also have been keenly observed by those in charge of food production. The combined effect of these changes is for the subsequent baked mass to be further increased in volume and give a product with an even softer, more digestible character and different flavour.

Bread is a staple foodstuff and today there are few countries in the world where bread is not made and eaten, bread products have evolved to take many forms, each based on quite different and very distinctive characteristics. Today, scientific study and technical development provide faster and more cost effective ways of making bread, but even so bakers still have to use their collective knowledge, experience and craft skills to integrate the available raw materials and processing methods to satisfy their customer demands for fresh, wholesome and flavoursome fermented products.

In some countries the nature of breadmaking has retained its traditional form while in others it has changed dramatically. The flat breads of the Middle East and the steamed breads of china are example of traditional bread forms which still remain an essential part of the culture of the countries where they are still produces in large quantities. On the other hand in North America the arrival of wheats along with settlers and farmers from Western Europe was to lead eventually to production of new wheat varieties and the rapid industrialization of breadmaking in a country where the maize-bases products of the native Americans had previously been the main cereal-bases foods. (Cauvain and Young, 1999).

2.1.2 Quality characteristics of bread

The proliferation of bread varieties derives from the unique properties of wheat proteins to form gluten and from the baker' ingenuity in manipulating the gluten structures formed within the dough. The rubbery mass of gluten with its ability

to deform, stretch, recover shape and trap gases is very important in the production of bread and all fermented products.

With such a long history of production and such diversity of form, breadmaking is almost always an emotive subject. Whenever the subject of quality is raised amongst bakers and consumers, that there will be a diversity of opinion, with different bakers extolling the virtue of different breads, different processes, different doughmaking formulae and different ingredients. (Cauvain and Young, 1999).

To be able to make our particular bread type must have an understanding of the complex interactions between our raw materials and the methods use in the conversion processes from ingredients to baked product. Our raw materials will change and our processes are time and temperature sensitive. Given the intricate nature of the process, it is a wonder that we manage to make bread at all.

2.1.3 Bread flavour

Nothing will provoke more debate in discussions on bread characteristics than that related to the flavour of fermented products. The judgement of what constitutes the 'right' flavour is another highly personal and emotionally charged issue. Sometimes bread products are eaten alone, but more often they will be eaten as an accompaniment to other foods in a meal or part of a composite product, so that bread flavours tend to be more subtle than we would encounter in many other foods.

The development of flavour in fermented products comes from a number of different sources and includes contributions from the ingredients and the processing methods which are used. Many of the ingredients which are used in the production of fermented products make a significant contribution to the flavour of the product. Flour tends to have a fairly bland flavour with most of its contribution coming from the oils of the germ (embryo) and bran particles present. Since this is the case, can reasonably expect that wholemeal, wholewhat and bran and germ-enriched white flours will yield bread with more flavour than white flours. (Cauvain and Young, 1999).

Breadmaking around the world has evolved many dough formations which use ingredients to confer special flavours which have now become an essential part of that product character. The addition of salt (sodium chloride) to bread is the most obvious of those flavour modifiers, imparting both its own characteristic 'salty' taste and working in the mouth to increase our perception of other flavours which may be present. Since salt levels vary in many products so will our perception of flavour between products. Other common additions include fat, sugar, milk and malt products. Each contributing its own special flavour. The level of yeast used in the recipe also makes its own unique contribution to bread flavour. (Cauvain and Young, 1999).

During the natural fermentation processes which occur in breadmaking new flavour products are generated within the dough. Both the intensity of those flavours and the particular flavour 'notes' which are developed change with increasing fermentation time. The most commonly observed flavour changes are those associated with the development of acid flavours from microbial activity in the dough, which are readily derected in the flavour of the bread crumb. Not all of this flavour activity will come from the addition of bakers' yeast; some will come from wild yeast and bactiria. Especially lactic acid bacteria, which are present naturally in the flour. Usually several hours of fermentation are required before there are significant changes to the flavour profile of the bread crumb. Where the breadmaking process being used has no provision for lengthy fermentation times. It is often the practice to develop flavour in a 'pre–ferment', 'brew' or 'sponge' which is later mixed with the remaining ingredients to form the dough for final processing. (Cauvain and Young, 1999).

By far the most important contribution to bread flavour comes from the process of baking. During this heat-setting stage many of the flavour compounds present undergo major changes; some old ones are lost and many new ones are formed. This phenomenon sees in the formation of a dark, mostly brown crust on the outer surfaces of the dough. These changes are associated with the complex processes commonly referred to as 'maillard browning' and many of the compounds are highly flavoured. These compounds are very important to perception of flavour in many baked foods and views have been expressed that as much as 80% of bread flavour is derived from the product crust. (Cauvain and Young, 1999).

2.1.4 Assessing bread quality

The process by which bread quality determined still relies to a significant extent on subjective assessments by experts because of the difficulties associated with objective measurements of some assessment problems we face are those characters related to flavour and eating quality because of the diverse preferences of individual consumers. Various scoring techniques are usually employed to try and standardize subjective assessment. (Cauvain and Young, 1999).

The techniques for assessing bread quality usually fit into there broad categories: external, internal and texture/eating quality, which includes flavour.

2.1.4.1 External character

Among the characters most often assess under this heading are product dimensions, volume, appearance, color and crust formation.

The critical dimensions for most breads are their length and height, with breadth being of lesser importance. A large number of bread types are characterized by their length. Devices for measuring product dimensions off-line can be simple and include graduated rulers and tapes. It is possible to measure product height and shape on-line using image analysis techniques. Measurement of height will often be used together with width (breadth) as a basis for an estimation of volume where the product shape makes such estimates meaningful.

The most common method of assessing whole product volume is by using a suitable seed displacement method. Which has previously been calibrated with a suitable seed, usually rape seed or pearl barley in to which the product is introduced. The seed is reintroduced and the product displaces a volume of seed equivalent to its own volume. It is important to keep such apparatus regularly calibrated with suitable 'dummy' products of known volume since the bulk density of seeds may change with time because of frictional attrition.

Image analysis techniques have been applied to the measurement of product volume. One such method is based on the measurement of the cross-sectional areas of several slices from selected places along the length of the loaf and then integrating these with the known length of the product. This method may be preferable where uncut loaves are not available and samples are being taken straight from the production line.

The external appearance of the product will often be a major factor which attracts the eye of the consumer. To this end, cutting or marking of the surface, both in terms of the number and direction of the cuts, must be consistent with the product 'norm'. Any quality assessment of this character can be carried out by comparing the product with a standard illustration of the accepted product norm.

Crust colour is commonly assessed using descriptive techniques. Objective methods can be used based on comparison with standard colour charts, such as the Munsell system (Munsell, undated), or direct measurement with tristimulus type instruments, but commonly crust colour is uneven on bread surfaces and this reduce the effectiveness of such measurements. (Cauvain and Young, 1999).

2.1.4.2 Internal character

Our major concerns with internal character are normally limited to the sizes, number and distribution of cells in the crumb (crumb grain), the crumb colour and any major quality defects, such as unwanted holes or dense patches, visible in a cross-section of the product. As discussed above, each bread type has its own special cell structure requirements and therefore there is no single standard which can be applied to all products. Because of this, subjective assessment of product crumb cell structure is still the most common method being used with some form of standard reference material, such as photographs. The assessment of crumb cell structure may well include an evaluation of the thickness of cell wall material.

While being among the most important of bread characters, crumb cell structure remains the most difficult to quantify to quality in a way which correlates

well with the human perception of quality. Techniques employing photographs, or scanning quantitative data on the cell structure and have been correlated with expert assessors.

2.1.4.3 Texture/eating quality and flavour

Texture and eating quality are important properties of bread products and are different from one another. In assessing the texture of bread crumb, concerned with its mechanical properties such as firmness and resiliency, and often we try to relate such properties to eating quality by adaptation of more fundamental physical testing methods.

Crumb softness or firmness is the texture property which has attracted most attention in bread assessment because of its close association with human perception of freshness. In the subjective 'squeeze' test simultaneously and subconsciously measure a number of product properties. The most obvious of these is the resistance of the product to deformation. Less obvious are how much the product recovers after the deforming force is removed and how much force we need to apply to compress the product to our 'standard squeeze'. Collectively, our subjective assessment will be recorded in degrees of softness or hardness, and sometimes as recovery or springiness. (Cauvain and Young, 1999).

2.1.5 Nutritional qualities of bread and its consumption

Bread and other cereal based products have become 'staple' foods throughout the world and are now established as an integral part of many modern diets. The nutritional qualities of cereals are well established, with most of the nutritional input from this category coming from wheat-based products. Although there will be some small changes in the nutritional qualities as a result of the milling and baking processes, wheat-based breads continue to provide significant sources of protein, complex carbohydrates (mainly statch), fibre, vitamins and minerals. The nutritional contributions are greatest in wholemeal (wholewheat) breads since they require conversion of 100% of the grain into flour. In lower-extraction white flours the removal of some of the bran and germ components from the wheat grain changes the

overall nutritional qualities of the resultant product, although in spite of this, white breads continue to make significant contributions to the diet. Typical nutritional compositions for breads are given in table 2.1.

Table 2.1 Composition of bread (per 100g)

Nutrient	White	Brown	Wholemeal
Carbohydrate	49.3	44.3	41.6
Protein	8.4	8.5	9.2
Dietary fibre	2.7	4.7	7.1
Fat	1.9	2.0	2.5

(Source: Cauvain and Young, 1999)

2.2 Breadmaking process

In the same way that different bread varieties have evolved with the passage of time so have different methods which allow the conversion of flour and other ingredients into bread. In reality each baker uses a breadmaking process which is unique, in that the combinations of ingredient qualities, formulations, processing conditions and equipment reflect the qualities of the products seeking to achieve.

2.2.1 Functions of the breadmaking process

All of processes which have evolved for the manufacture of bread have a single, common aim, namely to convert flour into an aerated and palatable food. In achieving this conversion there are a number of largely common steps which are used.

- The mixing of flour and water together with yeast and salt, and other specified ingredients in appropriate ratios.

- The development of a gluten structure (hydrated proteins) in the dough through the application of energy during mixing, often referred to as 'kneading'
- The incorporation of air bubbles within the dough during mixing.
- The continued 'development' of the gluten structure created as the result of kneading, in order to modify the rheological properties of the dough and to improve its ability to expand when gas pressures increase because of the generation of carbon dioxide gas in the fermenting dough. This stage of dough development may also be referred to as 'ripening' or 'maturing' of the dough.
- The creation or modification of particular flour compounds in the dough.
- The subdivision of the dough mass into unit pieces.
- A preliminary modification of the shape of the divided dough pieces.
- A short delay in processing to modify further the physical and rheological properties of the dough piece.
- The shaping of the dough piece to achieve their required configurations.
- Further expansion of the dough pieces and fixation of the final bread structure during baking. (Cauvain and Young, 1999).

The main difference between individual or groups of breadmaking processes are usually associated with mixing and kneading, air incorporation, and the creation and development of the gluten structure, in summary all of those operation which in practice deal with the formation of a large dough bulk. The subdivision of the bulk dough and processing stage for individual dough pieces do contribute to the modification of product quality but tend to build on the dough development created before subdivision of the bulk dough. The processing stages at the end of the sequence, proving and baking, are common to most breadmaking processes and differences between individual bakeries tend to be in the type of equipment used and small variations in conditions which are applied in the bakery equipment, e.g. time and temperature. (Cauvain and Young, 1999).

2.2.2 Cell creation control

The production of a defined cellular structure in the baked bread depends entirely on the creation and retention of gas bubbles in the dough. After mixing has been completed, the only 'new' gas which becomes available is the carbon dioxide gas has many special properties and at this point, concerned with two: its high solubility and its relative inability to form gas bubbles. As the yeast produces carbon dioxide gas, the latter goes into solution in the aqueous phase within the dough. Eventually the solution becomes saturated and unable to hold any further carbon dioxide which may be produced. The rate at which saturation occurs depends on the fermentation conditions, but is fairly fast in all breadmaking processes, as shown by rapid dough expansion as gas is retained within the developing or developed dough structure. (Cauvain and Young, 1999).

Two other gases are available in significant quantities within the dough as a result of mixing, oxygen and nitrogen, both of which are derived from any quantities of air trapped within the dough mamatrix as it forms. In the case of oxygen, its residence time within the dough is relatively short since it is quickly used up by the yeast at scavenging oxygen that in some breadmaking processes no oxygen from mechanically developed doughs has been illustrated previously for a wide range of nitrogen ration. (Cauvain and Young, 1999).

With the removal of oxygen from the dough, the only gas which remains entrapped is nitrogen and this plays a major role by providing bubble nuclei into which the carbon dioxide gas can diffuse as the latter comes out of solution. The number and sizes of gas bubbles available in the dough at the end of mixing will be strongly influenced by the mechanism of dough formation and the mixing conditions in a particular machine. (Cauvain and Young, 1999).

2.2.3 Major breadmaking process groups

The methods by which dough development is achieved in the bakery may be fitted into four broad processing groups, although there are numerous variations and also elements of overlap between each of the individual groups. For discussion purposes we can name and characterize the groups as follows:

- Straight dough bulk fermentation, where resting periods (floortime) for the dough in bulk after mixing and before dividing are the norm
- Sponge and dough, where a part of the dough formulation receives a prolonged fermentation period before being added back to the remainder of the ingredients for further mixing to form the final dough.
- Rapid processing, where either a very short or no period of bulk fermentation is given to the dough after mixing and before dividing.
- Mechanical dough development, where a primary function of mixing is to impart significant quantities of energy to facilitate dough development, and the dough moves without delay from mixer to divider.

2.2.4 Straight dough bulk fermentation

To many, the application of bulk fermentation for dough development is probably the most traditional and most 'natural' of the breadmaking processes. This process group is the most homogenous of all the groups we shall be discussing since the variations within it tend to be confine to different period of bulk fermentation tie, with variations in some other aspect of controlling fermentation, such as those associated with temperature or yeast level. There are only a few essential features of bulk fermentation processes and can be summed up as follows:

- Mixing of the ingredients to form a homogeneous dough;
- Resting of the dough so formed in bulk for a prescribed time (floortime), depending on flour quality, yeast level, dough temperature and the bread variety being produced;

- Part way through the prescribed bulk fermentation period there may be a remixing of the dough (a 'knock-back').

The formulations bulk fermentation need only contain a few ingredients as shown in table 2.2.

Table 2.2 Recipes for bulk fermented doughs

	3 h (%)	1 h (%)
Flour	100	100
Yeast	1	2
Salt	2	2
Water	57	58

(Source: Cauvain and Young, 1999)

2.2.4.1 Yeast level

The different in yeast levels in the two examples of recipes given in table 2.1 occur because more yeast is required with shorter bulk fermentation periods in order to achieve full dough development in the shorter time. This relationship between dough development time and yeast level probably comes from the contribution that enzymes present in the yeast cells, viable or dead, make to modification of the protein structures which are forming with increasing dough resting time.

2.2.4.2 Flours

The 'strength' of the flour which can be used in bulk- fermented dough is closely linked with thee length of the bulk fermentation period which employ. In general, the stronger the flour, the longer the fermentation period require in order to achieve optimum dough development and better the final bread quality will be (i.e. with a larger volume finer crumb structure and softer crumb). Flour strength is largely

related to its protein content and quality, so that higher protein flours require longer bulk fermentation times than lower protein flours.

The level to which bran is present in the flour will also affect the length of bulk fermentation times, with wholemeal (wholewheat) flours requiring shorter bulk time than white flours. A typical white flour protein content for bulk fermentation would be 12% or greater.

Failure to match flour and bulk times will result in a number of quality defects in both the dough and the baked product. In the dough insufficient bulk time gives one which is 'underfermented' and will exhibit a tough, rubbery gluten, not easily given to being moulded and which, in turn, will yield loaves of small volume, a dense cell structure and firm crumb. Too long a bulk time will result in the dough becoming 'overfermented', readily giving up its gas at the slightest touch and liable to collapse under its own weight. (Cauvain and Young, 1999).

2.2.4.3 Water levels

One of the most obvious manifestations of the changes taking place when the dough ferments in bulk is a progressive softening of the dough with increasing time. In breadmaking, bakers aim to achieve a 'standard' dough consistency for dividing and moulding. They accomplish this by adjusting the water level added during dough mixing according to the water absorption capacity of the flour. During bulk fermentation progressive enzymic action is responsible for the softening of the dough which occurs. Since enzymic actions are time and temperature dependent, can reasonably expect that dough softening will vary according to the bulk fermentation conditions, and in these circumstances adjustment of added water levels will have to be made to compensate for these changes. The recipes given in table 2.2 show how a reduction in added water is required with longer bulk fermentation times in order to maintain a standard dough consistency for dividing. (Cauvain and Young, 1999).

2.2.4.4 Optional ingredients

While the only essential ingredients required are those given in table 2.1, other ingredients are sometimes added for making bread by bulk fermentation. Typical rates of addition for these optional ingredients and the properties they confer to the dough and the bread are given in table 2.3.

In addition to those optional ingredients identified in table 2.3, 'improvers' may be added to bulk-fermented doughs. Usually the levels of addition are much lower than would be seen in no-time doughmaking processes. In some cases the 'improver' may consist of a small quality of an oxidizing material added at the flour mill in order to assist in dough development. (Cauvain and Young, 1999).

Table 2.3 Optional ingredients in bulk fermentation

	Percentage of Flour weigh	Improvement
Fat	1.0-2.0	Gas retention Crumb softness
Emulsifiers	0.1-0.3	Gas retention Crumb softness
Enzyme-active malt flour	0.1-0.2	Gas production Gas retention Crust colour
Enzyme-active soya flour	0.2-0.5	Crumb whiteness
Skimmed milk powders	up to 2.0	Crust colour

(Source: Cauvain and Young, 1999)

2.3 Functional ingredients

The most basic bread dough one might use to produce a baked product would of necessity contains the following minimum ingredients: flour, water, yeast and salt. However, even those most skilled in the art of baking would agree that at the very least it would be difficult to make bread of a high, consistent quality from only these raw materials. The baker has always, where expedient, added small amounts of extra ingredients to enhance dough performance during processing or to improve the quality of finished bread. In the past these materials would usually be foodstuffs in their own right, such as fat, sugars, honey and malt flour. Although the principal benefits were probably considered to be related to the eating properties of the final baked article, it must have become apparent that it was possible to produce modifications to the dough itself during processing which might be equally beneficial in the finished product. (Cauvain and Young, 1999).

2.3.1 Fats

The 'rules' for fat in the dough making systems can be summarized as follows.

- The ideal functional fat is a fully saturated one, with a chain length of C_{16} -C_{18}, i.e. tripalmin and tristearin with a melting point in the region of 50-60 ^{0}C(130-140 ^{0}F).
- Short-chain triglycerides, such as C_{12} and C_{14}, are much less efficient on a weight for weight basis and require more rigid control of dough and proof temperatures.
- Fully hydrogenated fats based on fish and whale oils, even those with high melting points, are less efficient than fully hydrogenated animal and vegetable oils, presumably because the fatty acid chains are branched rather than straight.
- The fully saturated triglycerides must be in a highly dispersed form in the dough. A wide range of ingredients and techniques are capable of successfully dispering the high melting point fat.

- The fat effect is not linear; too little fat produces bread of the same poor quality as bread without fat. There is then a dramatic increase in bread quality over a narrow range of increasing fat, after which there is little more to be gained in bread qualityterms by further increases in the level of fat addition. (Cauvain and Young, 1999).

2.3.2 Additives

2.3.2.1 Emulsifiers

1. Diacetylated tartaric acid esters of mono and diglycerides of fatty acids{ DATA esters, E 472(e)}.

The legal status of DATA esters in the EC is that they are permitted at a QS (quantum satis) level in all types of bread and fine bakers' wares. (Cauvain and Young, 1999).

The function of DATA esters in yeast-raised wheat flour dough can be readily demonstrated by practical baking tests and by a number of standard dough rheology methods. The most basic description of the function of DATA esters is that they enhance gas retention then incur ported into almost any yeast- raised wheat flour-based bough. There is a fairly direct relationship between the level of addition and the enhancement of gas retention up to an optimum level, after which there is a plateau followed by a slight reduction of effect at excessive levels of use. The final level of bread quality enhancement is far greater than that of fat.

There is strong evidence that when DATA esters are incorporated into bread dough they bond rapidly and totally to the hydrated gluten strands. The resultant gluten network is not only stronger but is more extensible and has a more resultant character. This product a dough which has a gas bubble network with small – sized , strong and extensible gas cell walls.(Cauvain and Young, 1999).

2. Sodium stearoyl-2-lactyl (SSL, E482)

This is a less complex material than DATA esters, although the number of lactic acid residues may vary, usually between 2 and 5 per molecule. SSL is a white solid with a comparatively high melting point and can be added to doughs in power form, either alone or as part of a compound dough conditioner. It is miscible with fat and therefore is an ideal compound of fat-based concentrates, particularly for semi-rich and rich fine bakers' wares, including rich buns and doughnuts.

SSL has some of the properties of DATA esters. It enhances gas retention in the dough but weight for weight it is less efficient in this function. At the same time it does demonstrate genuine soft-eating shelf life extension. It is capable of binding to amylose in a manner similar to that of distilled monoglyceride, which must account for its crumb softening effect.

The ideal mode of use for SSL is as part of a compound fat-based dough conditioner together with salt, sugar and flour treatment agents. The range of the end products to which it is best suited is that containing both fat and sugar. These 2 factors combine to make SSL an attractive emulsifier in quite a wide range of baked goods, which is why its use continuous to grow in the market. (Cauvain and Young, 1999).

3. Distilled monoglyceride (E471)

In the EC this category of emulsifiers is permitted at a QS level in all breads and fine bakers' wares. It is used as a crumb softener and functions by binding to the amylose fraction of the wheat starch at the elevated temperatures typical of baking. In doing so it retards retrogradation of the starch during cooling and subsequent storage, hence it can be claimed that it actually retards staling.

There is no doubt that incorporation of monoglyceride in to a recipe does extend the softness of the crumb of yeast-raised products, particularly during the first 3 days after baking. The different is sufficient to be appreciated by the average customer in a wide range of products. For this reason they may be used cost

effectively as partial fat replaces. The distilled monoglycerides function extremely well in this role but there is a temptation, particularly in semi-rich and rich fermented goods, totally to replace the fat by what is considered to be an appropriate level of monoglyceride. Such actions can result in products in which the crumb is indeed very soft immediately after baking, but over the next 24 hours becomes weak, dry and crumbly.

The most functional fatty acid base for crumb softening is stearic acid which for baking ingredients has a relatively high melting point, 55-60 ^{0}C, and therefore to be functional it must be made water dispersible in someway and must be in the correct crystalline state. For these reasons, distilled monoglycerides are offered to bakers in 2 distinct forms as hydrates in water and emulsions, and as water-dispersible powders. (Cauvain and Young, 1999).

4. Lecithins (E 322)

The legal status within the EC for lecithins is that they are permitted QS in all types of bread and fine bakers' wares. The term lecithin covers a group of complex phospholipids found naturally in a wide range of animals and plants. The most usual source of lecithin used in the baking industry is soya. It is extracted as a viscous liquid which is approximately 65% phospholipids and 35% soya oil. The liquid is blended with gypsum or wheat flour to produce a free –flowing power which can then form the base of a composite dough conditioner.

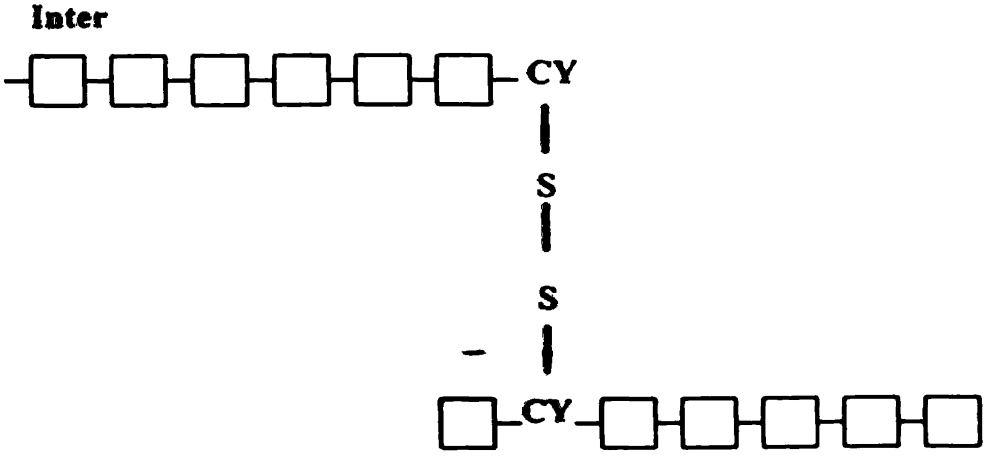
It is capable of enhancing gas retention in dough to some degree, although in this respect it is far less efficient than DATA esters or SSL. At the same time it has a very s different effect on crust character. DATA esters in particular produce crusty baked goods with a thin, 'egg cell' crust which can have an 'exhibition' appearance but which tends to become leathery during storage. Lecithins give a thicker denser crust which may not look as attractive but tends to retain its crispness qualities for longer. (Cauvain and Young, 1999).

2.3.3 Flour treatment agents

The 2 significant additives, or flour treatment agents, likely to be retained in this group which are relevant to yeast-raised products are the oxidizing agent ascorbic acid and the reducing agent L-cysteine.

1. Ascorbic acid (vitamin C, E300)

To understand the beneficial effects of oxidants in the bread making process it is necessary to describe briefly the basic structure of wheat flour-based dough. The key factor is the wheat protein. When mix with water, wheat protein has a properly unlike almost any other plant protein to form a viscoelastic sheet. The hydrated wheat starch granules are embedded in this structure which forms at the surface of minute gas bubbles produced in the dough from occluded air present on the flour particles prior to mixing. The 2 major components of wheat protein are usually described as glutenin and gliadin. Glutenin consists of high molecular wheat proteins in which individual polypeptides chains are cross linked by the disulphide bonds of the amino acids cysteine. Gliadines are composed of intra-rather than intermolecular (Fig 2.1). (Cauvain and Young, 1999).



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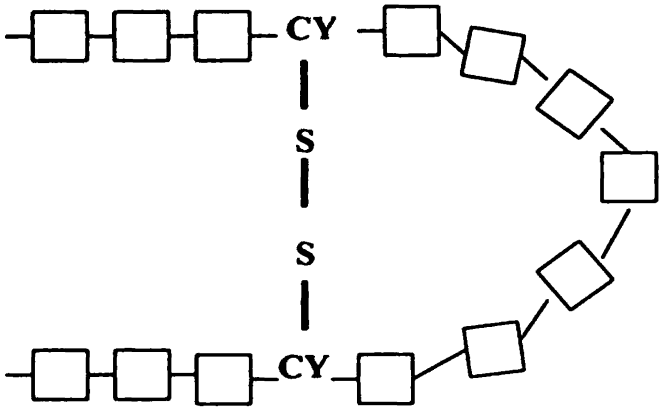

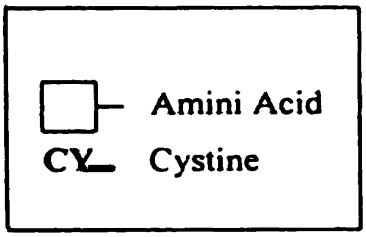

Fig 2.1 Representation of cystein cross links in gluten
(Source: Cauvain and Young, 1999)

Once hydrated both classes of protein are to a high degree in the form of either alpha-helix or random helix. In addition to the crosslinked cysteine present in wheat protein there are a number of cysteine amino acids present in the reduced form as shown in figure 2.2. The ratio of –S-H groups to –S-S- bonds is approximately 1:20. The reactions which occur between –S-S- and –S-H links during mixing bulk fermentation or mechanical dough development are varied and complex.

At this stage need consider only the most basic change which occurs in the dough, which is a reduction in the stresses and experienced in the gluten network and is commonly referred to as the disulphide-sulphydryl interchange. This exchanged is illustrated in figure 2.2. It occurs to some degree during conventional mixing, but at much more rapid rate during mechanical dough development or spiral mixing. Introducing an oxidizing agent in to the system complicates matters further. It is now possible to oxidize the –S-H group, either to form new cross links between protein

chains or to oxidize the –S-H group to SO_3H, which is no longer capable of undergoing disulphide-sulphydryl interchange. (Cauvain and Young, 1999).

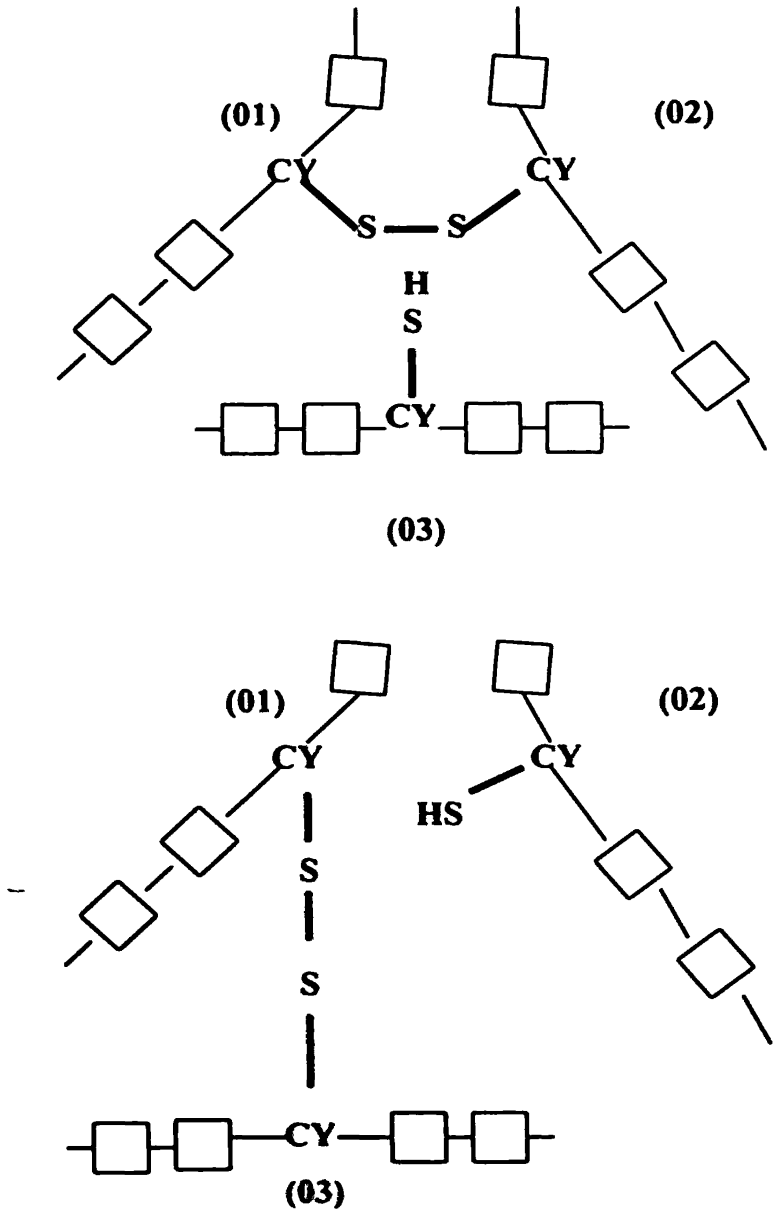

Fig 2.2 Representation of disulphide-sulphydryl interchanges
(Source: Cauvain and Young, 1999)

The possible effects of ascorbic acid in mechanically developed dough can be listed as follows.

1. Oxidation of water soluble –S-H groups to remove them from the system. This would benefit the dough structure by preventing them from preferentially reacting with the –S-H groups of the glutenin molecules exposed during the development period.
2. Causing an –S-S- bond to be formed between a water-soluble protein –S-H groups. This might well weaken the dough structure.
3. Causing an –S-S- bond to be formed between 2 of the glutenin –S-H groups exposed during the development period. This would increase the elasticity of the dough structure.
4. The direct oxidation of an –S-H group in a glutenin molecule to a stable form which is then unable to take part in further interchange reactions.
   (Cauvain and Young, 1999).

2. L-cysteine (920)

This is an amino acid which due to its –S-H group can act as a reducing agent directly on the disulphide bonds in the gluten structure of the dough. It is commonly use in hydrochloride form.

It is used as a component of the Activated Dough Development (ADD) process as a mixed oxidant in conjunction with ascorbic acid and potassium bromate. The ADD process allowed bakers to obtain some of the processing advantages of no-time dough with low speed mixtures. L-cysteine relaxes the gluten structure during the mixing processing, enhancing dough development. (Cauvain and Young, 1999).

2.4 Proving and Baking

2.4.1 Introduction

Proving and baking are the stages of bread making that convert fermenting dough into a stable product ready for consumption. The two operations proving and baking have been essentially the same ever since, relying on the properties of the raw materials and the way they behave when heated to produce a staple product that is both nutritious and good to eat. Proving or proofing, allows time under favorable conditions for the yeast and enzymes in the flour to be active. Then, during baking, the rate of heat transfer is increased so that the outside of the loaf dries to a crust and inside, the starch swells and the protein coagulates. (Cauvain and Young, 1999).

2.4.2 The proving process

Proving, or proofing, is the name given to the dough resting period, after the moulded pieces have been put into tins, during which fermentation continues in a controlled atmosphere. To understand proving, a simpler model is sufficient. Starch is converted into sugars by enzyme action. The sugars feed the yeast and the breakdown products are carbon dioxide and alcohol. As carbon dioxide is produced it is retained in the tiny cells formed in the protein matrix during mixing, causing the cells to grow and the dough to expand. The number of cells cannot be increased during proving, but the structure can be coarsened, and if the dough is over proved then the cell walls will start to collapse. Other products of yeast activity, mainly acids, are also formed during proving and they can contribute significantly to flavor development.

When the dough enters the prover, it will be at a temperature of 28-30 ^{0}C (82-86 ^{0}F), which is the maximum at which the moulding equipment will work efficiently – any hotter and the dough will be so sticky that problems of product transfer will outweigh the advantage of any possible reductions

The dough expands by a factor of three or four during proving, to almost its final volume, and it is important that the skin remains flexible so that it does not tear

as it expands. A flexible skin is one which has not been allowed to dry out, so that controlled humidity is essential. A humidity atmosphere is also required to minimize weight loss during proving. (Cauvain and Young, 1999).

2.4.3 The baking process

2.4.3.1 Crumb structure

For the centre of the dough piece, the move into the oven is undramatic. It is so well insulated by surrounding dough that it is completely insensitive to any change for the first several minutes of baking and continues at peak gas production. Effectively, the centre of the loaf gets additional proof time which compensates for its slower start at the beginning of proof. Eventually the centre of the loaf does start to warm up and as the temperature rises, it goes through a complex progression of physical, chemical and biochemical changes which are independent of the precise conditions in the oven and, therefore outside the control of the oven operator.

Thermodynamically, the situation in the centre is fairly simple. The driving force for heat transfer is the temperature gradient from the region near the crust, where the temperature is limited to the boiling point of water, to the center. The heat transfer mechanism is conduction along the cell walls and the center temperature will rise independently of the oven temperature and approach boiling point asymptotically. (Cauvain and Young, 1999).

2.4.3.2Yeast activity

Yeast activity decreases as the dough warms and the yeast is inactivated by the time the temperature has reached 55°C (131°F). Stability of the structure is maintained because the trapped gases expand as they warm and maintain the positive internal cell pressure.

2.4.3.3 Starch gelatinization

Gelatinization of wheat starch starts at about 60°C (140°F) and initially the starch granules absorb any free water in the dough. The gelatinized starch will eventually be self-supporting and will take over from the protein membranes which, by their gas-retaining properties, have established the form of the loaf but have little intrinsic strength. There is insufficient water in the dough to gelatinize fully the starch, and water will transfer from the protein membranes to the starch as baking proceeds. Starch has remarkable water-retaining capacity and the ease with which gelatinization continues is affected both by starch damage, deliberately imparted during milling and by enzyme activity during baking. (Cauvain and Young, 1999).

2.4.3.4 Crust formation

Formation of a satisfactory crust is one of the most important aspects of baking the crust provides most of the strength of the finished loaf and the greater part of the flavour. The thickness and characteristics of the crust to a large extent define the product.

In contrast to the crumb, where changes during baking are largely chemical and biochemical, though initiated by the rising temperature, in the region of the crust very complicated physical mechanisms are at work. (Cauvain and Young, 1999).

2.5 Properties of Rice

2.5.1 Chemical Composition

The rice grain (rough rice) consists of an edible portion, the rice caryopsis and its covering structure, hull or husk .The rice fruit is the caryopsis in wish the single seed is fused with the wall of the ripened ovary (pericarp) a seed like grain (Fig.2.3).The grain is tightly enclosed by the lemma and palea (hull or husk). The colour of the grain is usually that of the pericarp. The pericarp consists of six layers

and is further classified in to outer epicarp, mesocarp and cross layers. Next to the pericarp are two layers of cells representing the tegmen or seed coat. (Juliano, 1972).

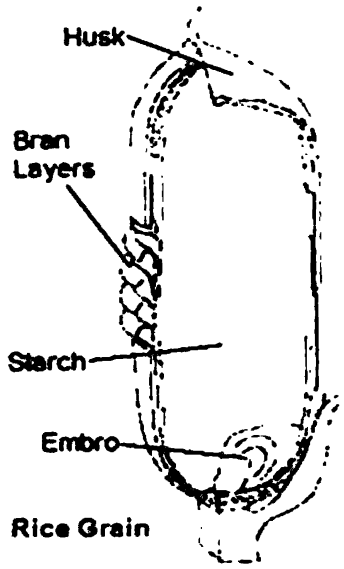

Fig. 2.3 Structure of rice grain
(Source: Juliano, 1972).

The aleurone layer lies beneath the tegmen and encloses both the endosperm and the embryo. It is composed of cells filled with small, protein- rich aleurone grains enclosed in a sheath of fat containing material. The embryo or germ is extremely small and located near the base towards the lemma side of the grain. The cells of the germ are filled with minute protein and oil particles. The weight distribution of the various parts of rough rice and brown rice is given in table 2.4.

Table2.4 Parts of rice grain

Parts of the grain	percentage by weight	
	In Brown Rice	In Rought Rice (paddy)
Hull or Husk	-	18-25
Pericarp	1-2	
Aleurone plus testa	4-6	72-82
Germ (Embryo)	2-3	
Endoosperm	89-94	

(Source: Adapted from Juliano, 1972)

The starchy endosperm consists of thin-walled cells heavily loaded with compound starch granules and some protein bodies. Rice starch granules are polygonal and range in size from 2-10μ. Up to 95 per cent of endosperm protein has been observed to be in the from of discrete particles (1-4 μ in size) called protein bodies and are found more along the periphery than in the centre of each cell.

Opaque or chalky regions appear in the starchy endosperm of non-waxy varieties. When the chalky regions extends to the center of the endosperm and the edge of the ventral side (embryo side), it is called white core. An opaque regions occurring in the middle of the ventral side is called white belly or abdominal white. The opaque portion may be structural in nature and is generally softer than the translucent regions, thereby contributing the grain breakage during milling. Waxy rice varieties have an opaque endosperm which may be due to the presence of microspores absent in non-waxy starch granules. (Juliano, 1972).

2.5.2 Proximate Analysis of Rice and its Milling Fraction

The composition of rice and the products in different stages of milling has been complied from the values reported in the established bibliographies (Tables 2.5 and 2.6). The range of values has only been included for ease of comparison and ready reference. Variations in compositions of a cereal grain are due to mainly varietals and environmental conditions, and also to the differences in analytical techniques used by the different investigators. The degree of milling introduces further variation in the composition due to the difficulty of milling equally rice samples that differ in grain hardness, size and shape, and number of cell layers of the aleurone. (Elizabeth et al., 1970).

Table2.5 composition of rice

Form	Water %	Protein %	Fat %	Fibre %	Ash %
Rough Rice	9.0-12.0	6.7-9.9	1.4-2.6	7.9-11.5	3.3-5.5
Brown Rice	9.3-12.6	6.7-10.5	1.5-2.4	0.5-1.1	1.0-1.4
Milled Rice	9.4-13.2	5.4-10.3	0.4-1.0	0.1-0.6	0.3-1.0

(Source: Elizabeth et al., 1970).

Table2.6 composition of milling fraction of rice

Component	Rice bran %	Embryo %	Polish %
Water	8.9-.14.7	10.5-12.3	9.5-10.0
Protein	10.6-13.4	10.5-11.8	11.9-12.7
Fat	10.1-22.4	10.7-13.4	9.1-11.5
Fibre	6.3-14.1	3.3-3.9	1.9-3.0
Ash	9.3-14.3	7.4-8.0	4.8-8.0

(Source: Elizabeth et al., 1970).

2.5.2.1 Carbohydrates

Carbohydrates of rice are predominantly starch with small portions of peosans, hemicelluloses and starch constitutes on an average 90 percent of milled rice by weight.

The pentosan content is reported as about 1 to 2 percent of milled rice and 2 to 25 percent to brown rice. The corresponding distribution of pentosans is 43 percent in bran, 8 percent in germ, 7 percent in polish and 42 percent in milled rice. The distribution of cellulose in brown rice is 62 percent in bran, 4 percent in germ, 7 percent in polish and 27 percent in milled rice.

Sugars comprise some 0.3 to 0.5 percent of milled rice and about 0.6 to 1.4 percent of brown rice. Free sugars are predominantly sucrose, with small amounts of reducing sugar glucose and fructose. The embryo is reported to have 11.6 per cent reducing sugars and 9.1 per cent no reducing sugars.

Rice starch in common with most other starches, contain both amylose (linear fraction) and amylopection (branched fraction). The amylose content of nonwaxy milled rice may constitute 7 to 33 percent of its dry weight, whereas, waxy (glutinous) rise has an apparent amylose content of 0.8 percent. Amylopectin is the

major starch constituent and is the only starch fraction of waxy (glutionous) rice. Waxy rice starch stains red or brown with iodine, whereas non waxy starch stains purple-blue to blue.

Rice starch granules are the smallest of commercial starches. The size of the granule is commonly 3-8 μ although the large granules may be from 8 to 10 μ. In a starch granule the amylose and amylosepectin moleclule are associated by hydrogen bonding, either directly or through water hydrate bridges to from radially oriented crystalline areas (micelle). An interconnected three dimensional micellar lattic is formed by the participation of segments of individual molecules in several micellar areas. The overall strength of micellar network controls the behaviour of starch in water. (Elizabeth et al, 1970).

2.5.2.2 Protein

Next to starch protein is the second most abundant constituent of rice. Protein content is usually calculated from kjeldahl nitrogen multiplied by the factor 5.95. This factor is based on the average nitrogen content of the major rice protein of 16.8 percent. The major protein is the alkali soluble (glutenin) type called oryzenin, with proportions of water soluble (albumin), salt soluble (globulin) and alcohol soluble (prolamin) proteins. The amino acid compositions of brown and milled rice in table 2.7.

Table 2.7 Amino acid composition of brown and milled rice

Amino acid	Milled Rice (g/16 g N)	Brown rice (g/16 g N)
Isoleucine	4.6	4.6
Leucine	8.0	7.9
Lysine	3.5	3.6
Phenylalanine	4.9	4.7
Tyrosine	5.2	5.1

Total sulphur amino acid	5.4	5.3
Methionine	2.9	2.8
Threonine	2.9	2.8
Tryptophan	1.3	1.4
Valine	6.5	6.4

(Source: Adapted from Houston and Kohler, 1970)

2.5.2.3 Lipids

Major portion of the lipids of rice is in the bran (containing the germ) and the polish and milled rice contain only about 0.3 to 1 per cent fat. When the oil is extracted from the fresh bran with hexane and refined light coloured stable oil with high grade edible qualities is obtained. The crude oil from the bran has a some what green chlorophyll colour.

Oleic linoleic and palmitic acid are the major constituents of bran oil. The stability of bran oils reportedly due to the low content of the relatively unstable linolenic acid and natural antioxidants mainly tocopherols. Tocopherols have vitamin E activity. Significant proportions of sterols are present in the unsaponifiable water to the extent of 25 percent.

The total lipids of rice contain 3-9 percent wax which is mainly an ester of lignoceric acid, $C_{23}H_{47}CO_2H$ and myricyl alcohol $C_{30}H_{61}OH$. The wax is not extracted by hexane below 10^0C. The purified wax has a melting point of 75-76 ^0C. The properties of refined and bleached wax are similar to those of carnauba wax. (Elizabeth et al., 1970).

2.5.2.4 Vitamins

Vitamins are present mostly in brown rice and located in the aleurone layers. Calculations show that 65 per cent of the thiamine of brown rice is in the bran (58 percent in embryo) 13 percent in polish and the rest in milled rice. Riboflavin is

distributed as 39 percent in bran (24 per cent embryo) 8 percent in polish and 53 percent in milled rice The distribution of niacin is 54 percent in bran (18 per cent in embryo), 13 percent in polish and 33 percent in milled rice these calculations are confirmed by actual histological studies. (Elizabeth et al., 1970).

2.5.2.3 Minerals

The mineral composition of rice varies largely in view of the difference of the soil composition and in analytical methods. The ash distribution in rice is reported to be 51 percent in bran, 10 percent in germ, 11percent in polish and 28 percent in milled rice. Iron, Phosphorous and potassium show a similar distribution. (Elizabeth et al., 1970).

2.5.3 Enzymes of rice

There are various enzymes in the rice seed, taking part in syntheses and breakdown of starch during ripening and germination stages. There are 2 different enzyme proteins present either in a soluble form or particular form.

There are 2 amylases present, an alpha amylase with optimum activity at pH 4.6. A starch-liquefying enzyme is also present. During the ripening process both enzymes become gradually inactivate, but become active during germination. The pure alpha and beta amylases are transformed during germination in to the amylase system which is characteristics of malt. (Elizabeth et al., 1970).

2.5.4 Use of rice in the Bakery Industry

The use of whole or broken rice kernels in baked products is certainly of minor importance. Rice flour made by impact milling of the broken grains does have some applications. There is no theoretical reason why roller milling can not be applied to rice, but this would not be an efficient use of the complex roller milling system. The simpler method of pearling, then impact milling works very well for rice. (Board, 1999).

Rice flour is far from ideal as the structural component of leavened bread rollers or loaves. It does not contain the gluten proteins that give wheat flour its unique, ability to form highly expanded, tender, white and flavorful yeast-leavened or chemically leavened baked products. (Board, 1999).

Understanding the above circumstances study was focused to incorporate more than 60% of rice flour in manufacturing of rice bread using pre-gelatinization, force-gelatinization and post-gelatinization methods by overcoming above disadvantages.

CHAPTER 03

MATERIAL AND METHODOLOGY

3.1 Materials

3.1.1 Preparation of rice flour

Materials	Apparatus
White rice	Mill FAB moisture meter
Water	Thermometer
	Gas cooker
	Blender
	150 µm and 300 µm mesh size sieves
	Clock
	Trays
	Bowls
	Laminated bags

3.1.2 Preparation of dough samples and determination of the leavening index

Materials	Apparatus
Rice flour	Electronic balance
Wheat flour	Measuring cylinders (100ml)
Salt	Glass rod
Sugar	Stainless steal mixing pan
Yeast	Stainless steal spoon
Corn flour	Petridish (Borosil)
Shortening agent	Clock
Water	

3.1.3 Preparation of rice breads

Materials	Apparatus
Rice flour	Electronic balance
Wheat flour	Dough mixing machine
Salt	Oven
Sugar	Metal plates

Yeast	Metal trays
Corn flour	Clock
Shortening agent	
Water	

3.1.4 Sensory Evaluation

Materials	**Apparatus**
Coded bread samples	Sensory evaluation ballet papers
	Serviette
	Glasses of portable water

3.1.5 Determination of the moisture content

Materials	**Apparatus**
Bread samples	Electric balance
	Automated moisture detector

3.1.6 Determination of the pH

Materials	**Apparatus**
Bread samples	PH meter
Distilled water	Beaker
	Funnel
	Filter paper (Whatman No: 1)
	Blender
	Gas cooker

3.1.7 Determination of the bulk density

Materials	**Apparatus**
Bread samples	Polythene sheet
Water	Bowl
	Measuring cylinder
	Knife
	Electric sealer

3.2 Methodology

3.2.1 Preparation of rice flour

In preparation of rice flour for the study 2 factor factorial designs with 4 variables, namely moisture content, method of gelatinization, method of soaking and particle size of the rice flour at two levels were selected. 16 treatments combinations were prepared with respect to the design of the experiment given in fig 3.1 and table 3.1.

20 kg of 80% polished, white rice was taken and initial moisture content of which was measured using mill fab moisture meter (Fig 3.2) and divided in to 2 equal portions. One portion (10 kg) was dried in the sun drying yard to get the moisture content 12%, while drawing sample intermittently to confirm the moisture content. The rest portion was kept as it is (15.4%); as the treatment for high level moisture content.

The portion at low moisture level was divided in to two equal portions again and one portion was subjected for force gelatinization process (Dextrinization) by giving a heat treatment at 95-100 ^{0}C for 3 minutes. The rest portion was kept untreated.

These 2 portions were divided in to equal 2 portions as per design and one portion of each was subjected to overnight cold soaking process. The rest two portions were subjected for hot soaking for 3 hours at 70 ^{0}C.

4 portions generated out of these 3 treatments were divided in to 2 equal portions again and one portion of each treatment was subjected for grinding process to get coarse particles at 300 µm. The rest 4 portions were again ground to get fine particles at 150 µm.

The same procedure was adapted to the rice portion at high moisture content (15.4%).

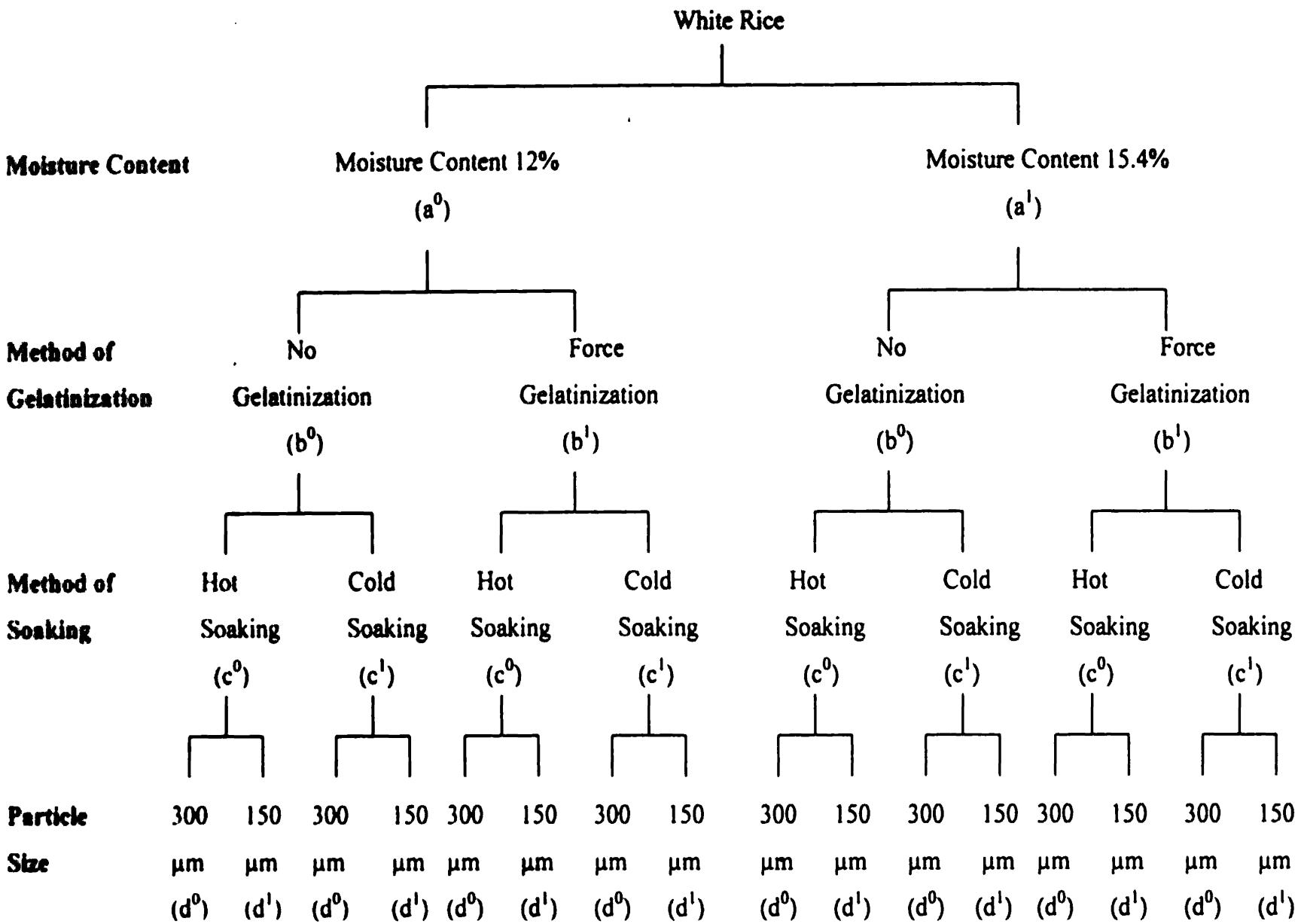

Fig 3.1 Flow diagram of rice flour preparation

Table 3.1 Different combinations of rice flour

Treatment No:	Combinations
1	1 = $a^0 b^0 c^0 d^0$
2	a = $a^1 b^0 c^0 d^0$
3	b = $a^0 b^1 c^0 d^0$
4	ab = $a^1 b^1 c^0 d^0$
5	c = $a^0 b^0 c^1 d^0$
6	ac = $a^1 b^0 c^1 d^0$
7	bc = $a^0 b^1 c^1 d^0$
8	abc = $a^1 b^1 c^1 d^0$
9	d = $a^0 b^0 c^0 d^1$
10	ad = $a^1 b^0 c^0 d^1$
11	bd = $a^0 b^1 c^0 d^1$
12	abd = $a^1 b^1 c^0 d^1$
13	cd = $a^0 b^0 c^1 d^1$
14	acd = $a^1 b^0 c^1 d^1$
15	bcd = $a^0 b^1 c^1 d^1$
16	abcd = $a^1 b^1 c^1 d^1$

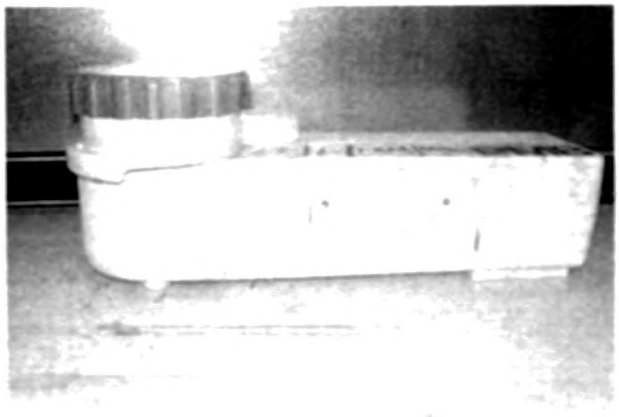

Fig 3.2 Mill FAB moisture meter

3.2.2 Preparation of the dough samples

Rice flour prepared out of 16 treatments was subjected for preparing of dough samples with respect to the following ratios of rice flour and wheat flour.

Rice flour	:	Wheat flour
50	:	50
60	:	40
70	:	30
(From 16 treatment combinations)		(Pure wheat flour)

16 dough samples with respect to each rice flour and wheat flour ratios were prepared with respect to the recipes given in table 3.2.

Table 3.2 Recipes used to form the dough

Ingredients	**Rice flour : Wheat flour ratio**		
	50:50	**60:40**	**70:30**
	Weight %	**Weight %**	**Weight %**
Rice flour	50	60	70
Wheat flour	50	40	30
Salt	1.5	1.5	1.5
Sugar	1	1	1
Yeast	1	1	1
Corn flour	2	2	2
Shortening agent	3	3	3
Water	58	58	58
No: of treatments	16	16	16

In preparation of the dough samples quantity of rice flour and wheat flour were taken as per the ratio and incorporate other constituents; salt, sugar, yeast, corn flour and water and mix well for 5 minutes. There after the shortening agent (hyco) was also added to the dough and mixed well for another 5 minutes in order to get dough of suitable consistency. Prepared dough was subjected for leavening index test in order to measure the efficiency of the treatment.

3.2.3 Determination of the leavening index of the dough

Prepared dough according to the above recipes (Table 3.2) was put in to measuring cylinder (100ml) up to 10 ml level (Fig 3.3). Thereafter increase of the volume; as a result of leavening action was measured by every 10 minutes; until the action was seized (Fig 3.4) (See App. I). This procedure was replicated for all 48 treatments while replicating thrice.

As leavening index is related to increment volume divide by initial volume,

$$\text{Leavening index} = \frac{\text{Volume increased}}{\text{Initial Volume}}$$

Fig 3.3 Before Leavening action

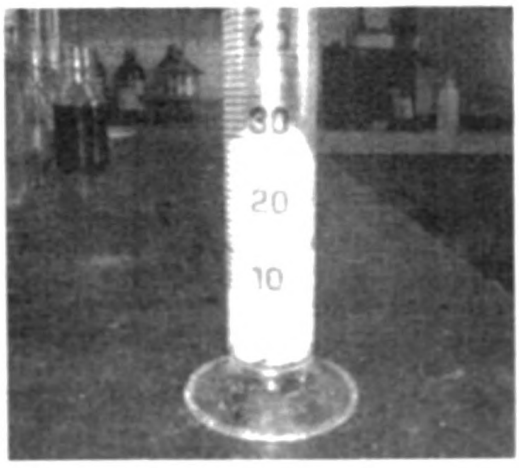

Fig 3.4 After Leavening action

3.2.4 Determination of best treatment combinations

The best combinations of 16 treatments subjected for 3 ratios of rice flour: wheat flour (50:50, 60:40, 70:30) were selected in terms of leavening index.

Results obtained from the study were analyzed using computer aided MINITAB Statistical Analysis package according to One-way ANOVA (See App. III) after confirming normal distribution by normality test at 5 % significant level. (See App. II).

3.2.5 Preparation of rice bread samples

The best treatment combination in terms of leavening index with respect to each rice flour: wheat flour ratios (60:40 and 70:30) was selected and subjected for commercial scale bread manufacturing process at the bakery of Harischandra Mills Limited; using the recipe given in the table 3.3. All the treatments were replicated 3 times and loaf of a wheat bread was used as a control treatment for comparison purpose.

Table 3.3 Ingredients for bread manufacturing

Ingredients	Rice flour : Wheat flour ratio	
	60:40	70:30
	Weight	Weight
Rice flour	240 g	280 g
Wheat flour	160 g	120 g
Salt	6 g	6 g
Sugar	4 g	4 g
Yeast	4 g	4 g
Corn flour	8 g	8 g
Shortening agent	12 g	12 g
Water	232 g	232 g

All ingredients given in the recipe were put in to the dough mixing machine (Fig 3.5) except shortening agent and mixed well for 5 minutes. There after the shortening agent was added in to the dough and kneaded for another 5 minutes in order to get dough of suitable consistency.

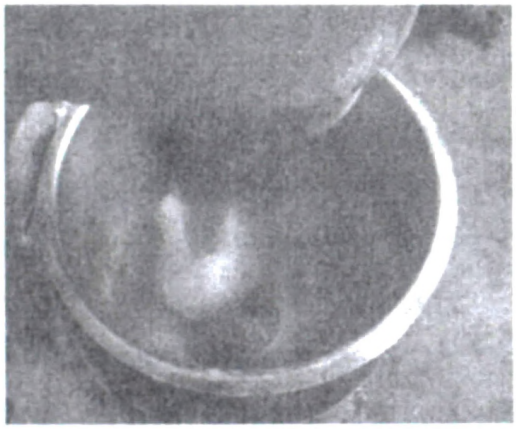

Fig 3.5 Dough mixing machine

Prepared dough was divided in to desirable portions, molded in to bread shape and placed in the trays for one hour fermentation process (Fig 3.6). The top of the dough in the trays exposed to open environment was applied a thin layer of shortening agent in order to prevent escaping of carbon dioxide bubbles during fermentation. Well fermented dough (Fig 3.7) was placed in the oven at 260-270 ^{0}C for 30 minutes to get baked breads.

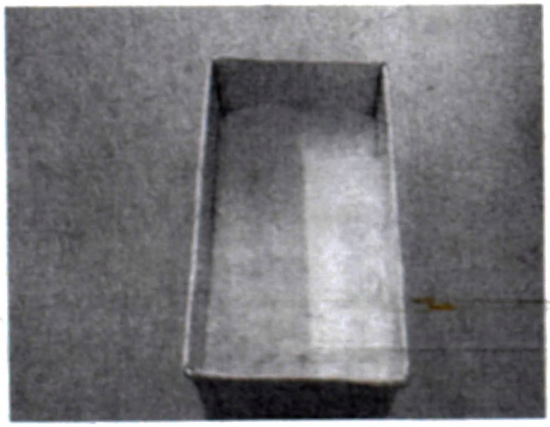

Fig 3.6 Before fermentation

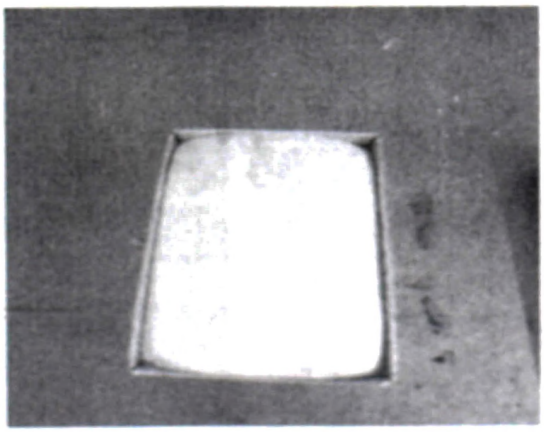

Fig 3.7 After fermentation

3.2.6 Evaluation of Organoleptic properties of breads

The bread samples were coded in 3 digits numbers as 574, 328 and 936 for 60% and 70% of rice breads and wheat bread respectively. Thirty trained sensory panelists of Harischandra Mills Limited were used to sense them for taste, smell, texture, crumb cell distribution, bread crust and overall acceptability of 3 bread samples. Ballot papers and water glasses were given for each and every panelist.

Acceptability of 3 samples was evaluated using 9 – point hedonics scale subjectively (Heymann and Lawless, 1999). (See App. IV). Results were analyzed using computer aided MINITAB Statistical Analysis package according to non parametric test of kruskal-wallis test (See App. VI) after confirming data do not follow the normal distribution by normality test at 5 % significant level. (See App. V).

3.2.7 Analysis of physiochemical properties

3.2.7.1 Determination of moisture content of the breads

About 5 grams of bread crumb was taken from the middle of a bread loaf and placed in the automated moisture detector (Fig 3.8). Switch of the meter was on and drying process was carried out until the meter was giving the moisture content of the bread crumb piece automatically. Procedure was replicated each and every sample for 3 times.

Fig 3.8 Automated moisture detector

3.2.7.2 Determination of pH of the breads

20 grams of bread sample was taken in to a dry volumetric flask and 200 ml of cool recently boiled water added. Then it was shaken well until obtained even suspension that should be free from lumps. Then the suspension was kept for 30 minutes. Thereafter it was shaken again and kept for additional 10 minutes. Then suspension was filtered (Whatman No: 1 filter paper) in to another flask and measured pH value by pH meter. Procedure was replicated each and every sample for 3 times.

3.2.7.3 Determination of bulk density of breads

A slice of bread from middle portion was cut off and weighted. Slice was wrapped with a polythene sheet and placed in a bowl and poured water until overflow. Slice was taken off from the container and volume left was refilled with water in a measuring cylinder. The volume left in the measuring cylinder to refill the bowl was recorded which approximately equal to the volume of the bread slice. Procedure was replicated each and every sample for 3 times.

$$\text{Hence, Bulk density} = \frac{\text{weight of the slice}}{\text{volume of the water}}$$

3.2.7.4 Statistical analysis of physiochemical properties

Physiochemical properties were analyzed using computer aided MINITAB Statistical Analysis package according to One-way ANOVA (See App. VIII) after confirmed normal distribution by normality test at 5 % level of significant level. (See App. VII).

CHAPTER 04

RESULTS AND DISCUSSION

4.1 Results of leavening index measurements

16 treatment combinations formulated with respect to the design of experiment were subjected for leavening index test for 50:50, 60:40, and 70:30 rice flour: wheat flour ratios and results are given in the table 4.1.

Table 4.1 Leavening index measurements of 50:50, 60:40 and 70:30 rice flour to wheat flour dough combinations

Treatment combinations	Leavening Index		
	50:50 (Rice flour: Wheat flour)	60:40 (Rice flour: Wheat flour)	70:30 (rice flour: Wheat flour)
1 - $a^0 b^0 c^0 d^0$	1.17	1.03	0.97
2 - $a^1 b^0 c^0 d^0$	1.27	1.20	1.03
3 - $a^0 b^1 c^0 d^0$	1.87	1.57	1.47
4 - $a^1 b^1 c^0 d^0$	1.84	1.67	1.60
5 - $a^0 b^0 c^1 d^0$	1.47	1.37	1.23
6 - $a^1 b^0 c^1 d^0$	1.57	1.43	1.30
7 - $a^0 b^1 c^1 d^0$	2.13	1.80	1.66
8 - $a^1 b^1 c^1 d^0$	2.37	2.27	1.93
9 - $a^0 b^0 c^0 d^1$	1.27	1.23	0.96
10 - $a^1 b^0 c^0 d^1$	1.37	1.27	1.07
11 - $a^0 b^1 c^0 d^1$	1.87	1.67	1.57
12 - $a^1 b^1 c^0 d^1$	1.87	1.73	1.67

13 - a^0 b^0 c^1 d^1	1.50	1.43	1.20
14 - a^1 b^0 c^1 d^1	1.64	1.47	1.34
15 - a^0 b^1 c^1 d^1	2.17	2.00	1.77
16 - a^1 b^1 c^1 d^1	2.57	2.43	2.03

To further elaborate the effectiveness of the study, the data were used to plot a graph as leavening index versus treatment combinations, which is given in fig 4.1.

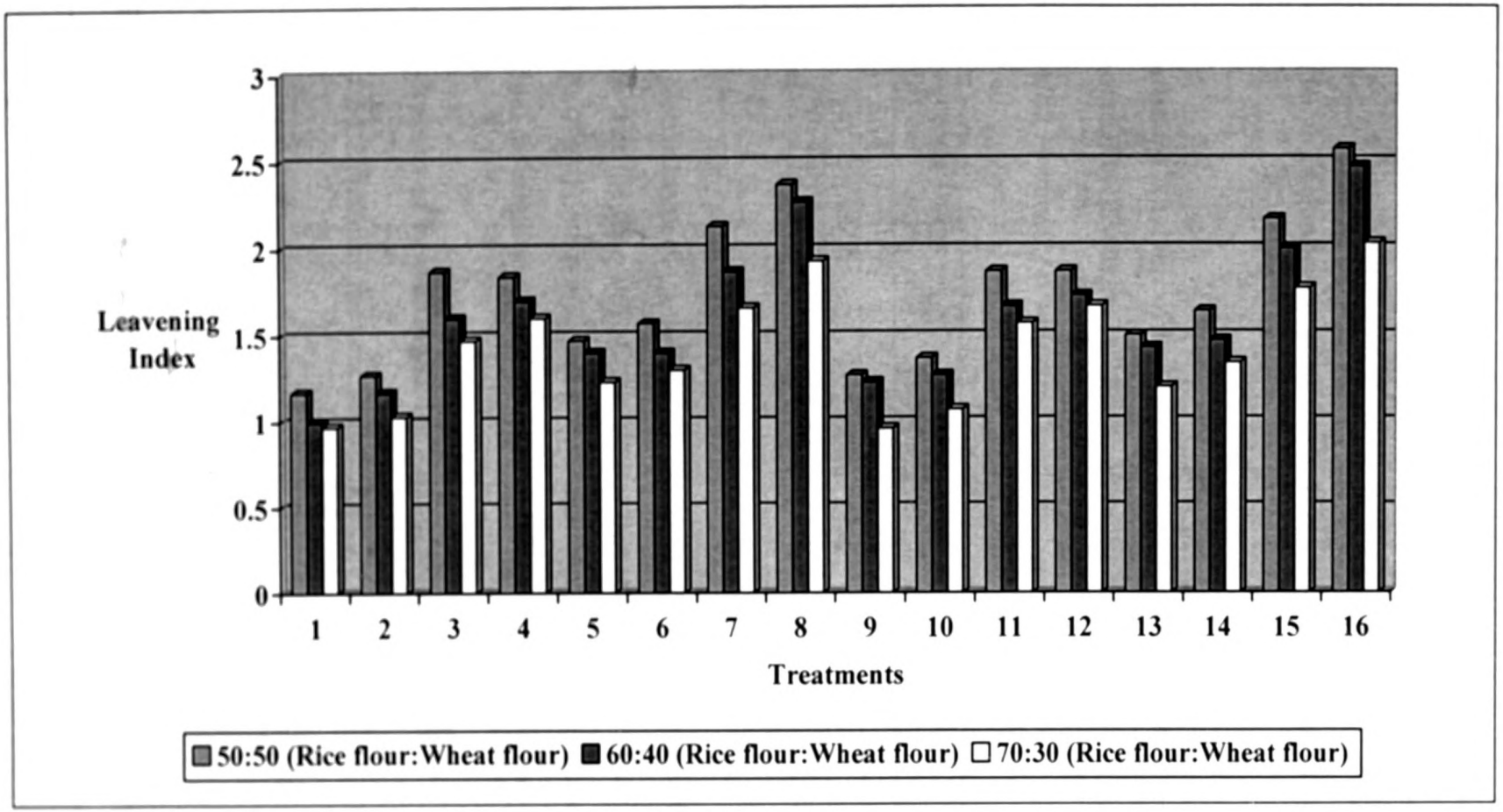

Fig 4.1 Graphical representation of leavening index of different ratios of rice flour to wheat flour dough combinations

The data obtained from the study pertain to the leavening index reveled that best treatment combination for 50:50, 60:40 and 70:30 rice flour: wheat flour ratios is a^1 b^1 c^1 d^1 (16). Because this treatment was capable to accomplish highest leavening index of 2.57, 2.47 and 2.03 for 50:50, 60:40 and 70:30 rice flour: wheat flour ratios respectively. To further scrutinized these results a statistical analysis was performed using one way ANOVA and result are given below.

4.2. Statistical Analysis of Leavening Index Measurements

4.2.1 Normality P values

Table 4.2.1 Normality p values

Leavening Index	Mean	Standard Deviation	P-Value
50 : 50	1.744	0.4073	0.073
60 : 40	1.608	0.3929	0.059
70 : 30	1.425	0.3361	0.056

Normality test's p-value indicates that, at 5% levels less than p-value, there is evidence that the data follow the normal distribution. According to table 4.2, alls P-values (0.073, 0.059, 0.056) are greater than alpha (0.05), which mean all data, follow the normal distribution. (See App. II).

4.2.2 Results of Leavening Index measurements

Table 4.2.2 Determine the best treatment

Dough combinations (Rice flour : Wheat flour)	P- value	Best treatment
50 : 50	0.000	a^1 b^1 c^1 d^1 -16
60 : 40	0.000	a^1 b^1 c^1 d^1 -16
70 : 30	0.000	a^1 b^1 c^1 d^1 -16

4.2.2.1 Best treatment for dough combination (50:50 rice flour : wheat flour)

The P-value (0.000) obtained for treatment no: clearly indicates that there is sufficient evidence that not all the means are equal when alpha at 0.05. To explore the differences among the means, examine the multiple comparison results. Best 50:50 rice flour to wheat flour combination was selected as treatment no. 16 (a^1 b^1 c^1 d^1) by Hsu's multiple comparisons procedure.(See. App. III).

4.2.2.1 Best treatment for dough combination (60:40 rice flour : wheat flour)

The P-value (0.000) obtained for treatment no: clearly indicates that there is sufficient evidence that not all the means are equal when alpha at 0.05. To explore the differences among the means, examine the multiple comparison results. Best 60:40 rice flour to wheat flour combination was selected as treatment no. 16 (a^1 b^1 c^1 d^1) by Hsu's multiple comparisons procedure. (See. App. III).

4.2.2.1 Best treatment for dough combination (70:30 rice flour : wheat flour)

The P-value (0.000) obtained for treatment no: clearly indicates that there is sufficient evidence that not all the means are equal when alpha at 0.05. To explore the differences among the means, examine the multiple comparison results. Best 60:40 rice flour to wheat flour combination was selected as treatment no. 16 (a^1 b^1 c^1 d^1) by Hsu's multiple comparisons procedure. (See. App. III).

4.3 Reasons for high performance of the treatment No: 16 (a^1 b^1 c^1 d^1)

Reason for having best performance of this treatment a^1 b^1 c^1 d^1 (high moisture rice grain, force gelatinization, cold soaking and fine particles) is, high moist rice grain would facilitate to have well gelatinized rice flour during the process of bread baking. When rice grain at high moisture subjected for force gelatinization process a considerable amount of starch granules in the rice grain would attempt to gelatinize with free water available in the voids of the grain itself. These water molecules would be compelled to couple with starch granules (force gelatinization) at a high thermal

conduction environment. When starch granules coupled with more water, more starch granules would be gelatinized (Fig 4.2)

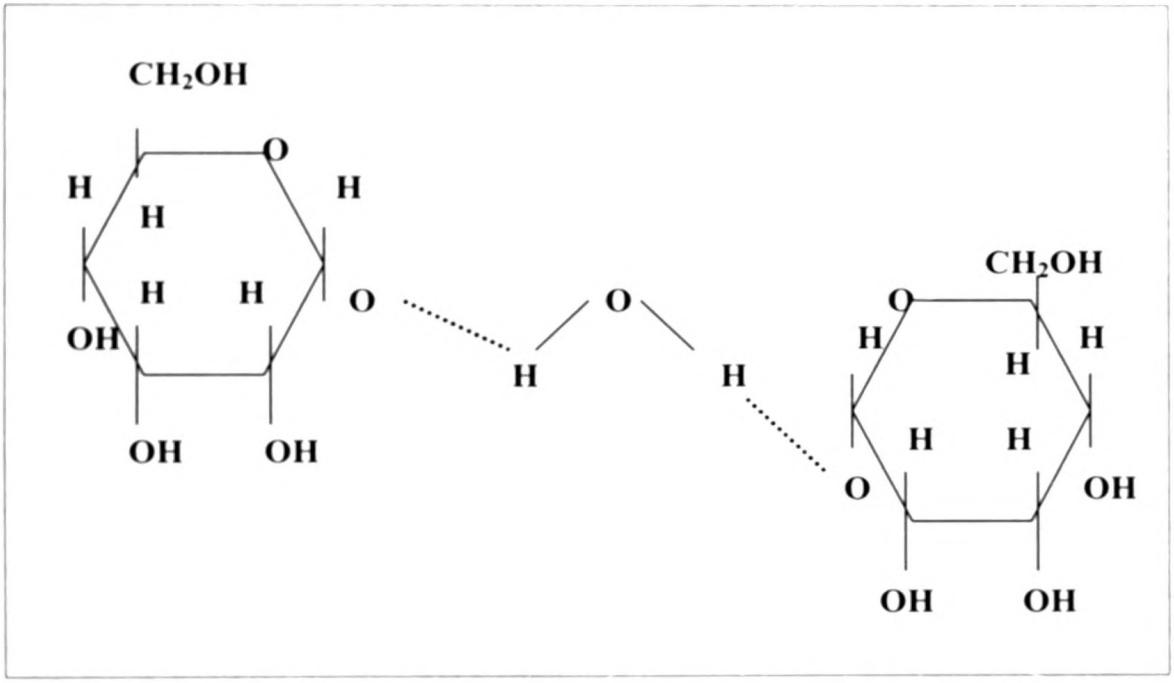

Fig 4.2 Starch gelatinization

If starch granules coupled with more water molecules sticky property of the starch granules would concurrently be increased. Hence, if rice grain subjected for a heat treatment with high amount of free water; the sticky nature among starch granules is also enhanced.

In the case of cold soaking process, which would facilitate to absorb water molecules in to the rice grain, while does not contributing denaturing of the protein matrix in the rice grain itself. However the high temperature at hot soaking process would somewhat badly affect in the denaturing of protein in the rice grain. The protein content in the rice grain is also contributing a little to enhance sticky property of rice flour.

As far as fineness of the rice flour is concerned, fineness is small particles with a more surface area. If flour particles having some what more surface area, the

area itself facilitate to have more stickiness than the rice flour particles having with less surface area (Coarse particles).

Hence combined effect of these 4 factors would greatly facilitate to enhance stickiness of rice flour comparatively other treatments. Therefore rice flour with high degree of stickiness would be capable to arrest more carbon dioxide bubbles during the period of fermentation.

Treatment $a^1 b^1 c^1 d^1$ is the treatment having enriched with all these properties. Therefore rice prepared with this treatment is significantly different to the other 15 treatment combinations. Thus, 70% of rice flour prepared with respect to above treatment ($a^1 b^1 c^1 d^1$) can maximally be incorporated in manufacturing of 70:30 rice bread without significantly disturbing to the loaf volume.

4.4 Preparation of rice bread samples

Figure 4.3, 4.4 and 4.5 shows the external and internal structure of rice breads and wheat bread samples.

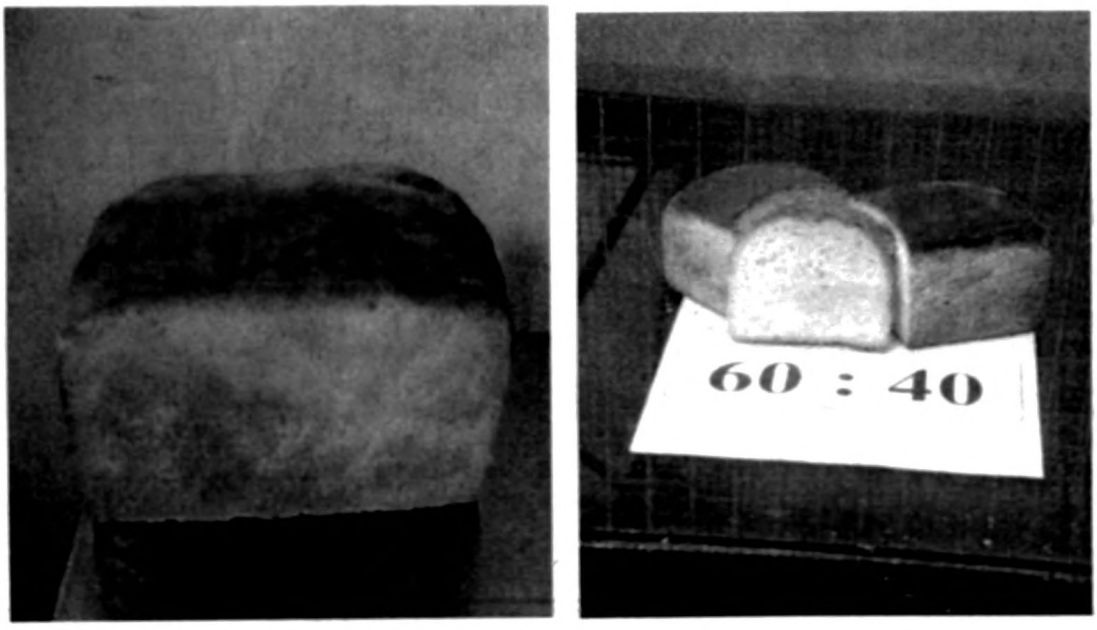

Fig 4.3 External and internal structure of rice bread (sample code 574)

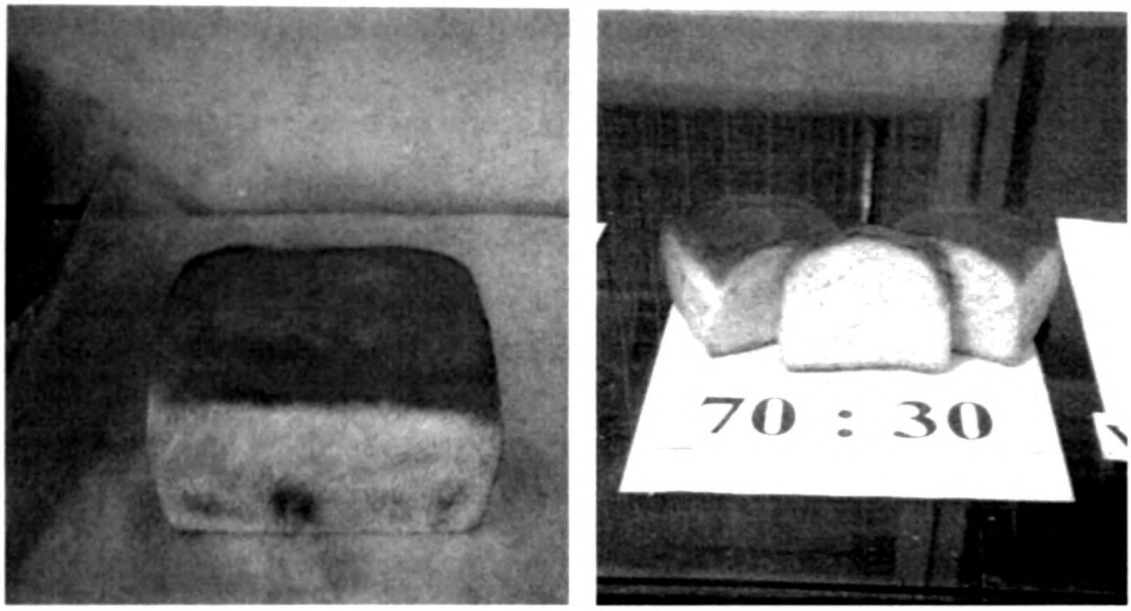

Fig 4.4 External and internal structure of rice bread (sample code 328)

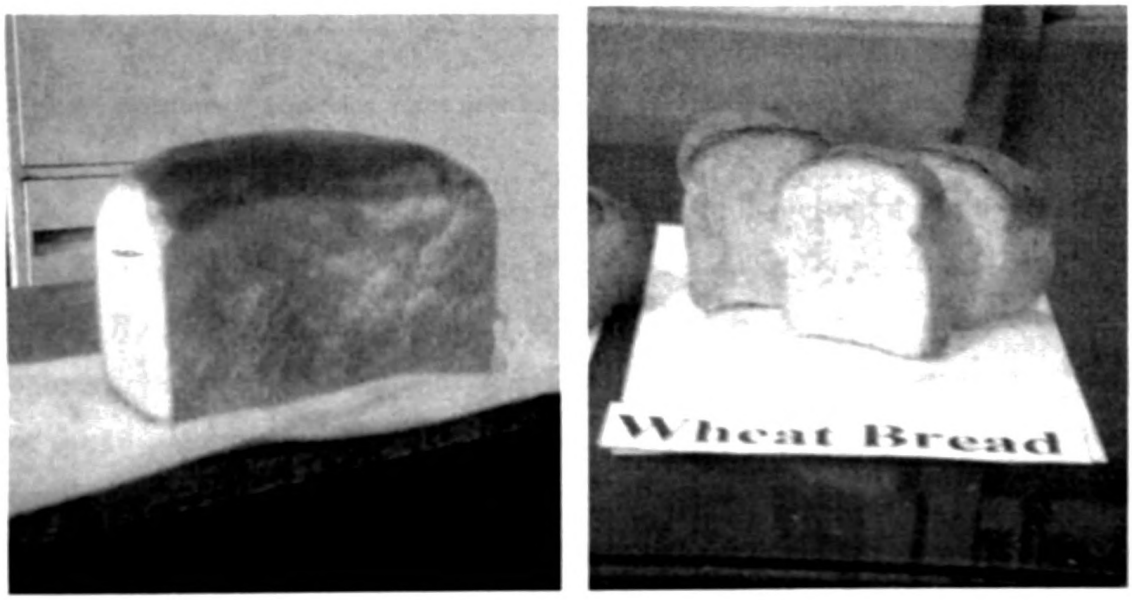

Fig 4.5 External and internal structure of wheat bread (sample code 936)

4.5 Maintaining of high quality bread crumb structure similar to wheat bread

Bread crumb structure of rice bread prepared with respect to $a^1b^1c^1d^1$ treatment for 60:40 and 70:30 rice flour: wheat flour were evaluated in terms of bulk density and results relevant to the study is given in the table 4.4 alones with wheat bread.

Table 4.3 Bulk density of rice breads against with wheat bread

Treatment ($a^1b^1c^1d^1$)*											
Bulk Density (gml^{-1})											
60:40(Riceflour:Wheat flour) Bread				**70:30(Riceflour:Wheat flour) Bread**				**Wheat Bread**			
R_1	**R_2**	**R_3**	**Avg**	**R_1**	**R_2**	**R_3**	**Avg**	**R_1**	**R_2**	**R_3**	**Avg**
0.14	0.16	0.15	0.150	0.16	0.15	0.16	0.156	0.15	0.15	0.14	0.140

* 15.4% moisture of white rice, force gelatinization, cold soaking and 150 µm particles.

The results given in the table 4.4 clearly indicate that mean bulk density of the rice breads prepared with respect to $a^1b^1c^1d^1$ treatment for 60:40 and 70:30 rice flour: wheat flour combinations are 0.150 gml^{-1} and 0.156 gml^{-1} respectively. These 2 values are closer to the value of wheat bread (0.140 gml^{-1}). However rice bread crumb of 60:40 combinations is somewhat softer than 70:30 combinations, because 60:40 combinations cited less bulk density; which figure is closer to wheat bread. Reason for having with low bulk density of these 2 treatments is high degree of leavening effectiveness as described under the sub tropic of 4.3.

4.6 Physical and chemical properties of rice breads as against wheat bread

Physical and chemical properties of rice bread was evaluated in terms of moisture content and pH value of the bread prepared with respect to $a^1b^1c^1d^1$ treatment for 60:40 and 70:30 rice flour: wheat flour combinations. Results are given in the table 4.5 and 4.6.

Table 4.4 Moisture of rice breads against with wheat bread

Treatment ($a^1b^1c^1d^1$)*											
Moisture (percentage)											
60:40(Riceflour:Wheat flour) Bread				70:30(Riceflour:Wheat flour) Bread				Wheat Bread			
R_1	R_2	R_3	Avg	R_1	R_2	R_3	Avg	R_1	R_2	R_3	Avg
41.36	40.25	40.16	40.59	39.02	39.37	40.01	39.46	40.04	39.05	39.52	39.50

* 15.4% moisture of white rice, force gelatinization, cold soaking and 150 µm particles.

Table 4.5 pH value of rice breads against with wheat bread

Treatment ($a^1b^1c^1d^1$)*											
pH Value											
60:40(Riceflour:Wheat flour) Bread				70:30(Riceflour:Wheat flour) Bread				Wheat Bread			
R_1	R_2	R_3	Avg	R_1	R_2	R_3	Avg	R_1	R_2	R_3	Avg
5.04	5.08	5.10	5.07	5.15	5.10	5.16	5.13	5.05	5.02	5.06	5.04

* 15.4% moisture of white rice rice, force gelatinization, cold soaking and 150 µm particles.

The data given in the table 4.5 and 4.6 clearly indicate that moisture and pH value of bread samples prepared with 60:40 and 70:30 ratios are similar to each other including values of control treatment (wheat bread) too.

4.6.1. Moisture content of the bread

Around 58% of water was used in preparation of dough for all treatments including wheat dough. The whole scenario of this process can be depicted by resorting the principal material balance indicates in fig 4.6.

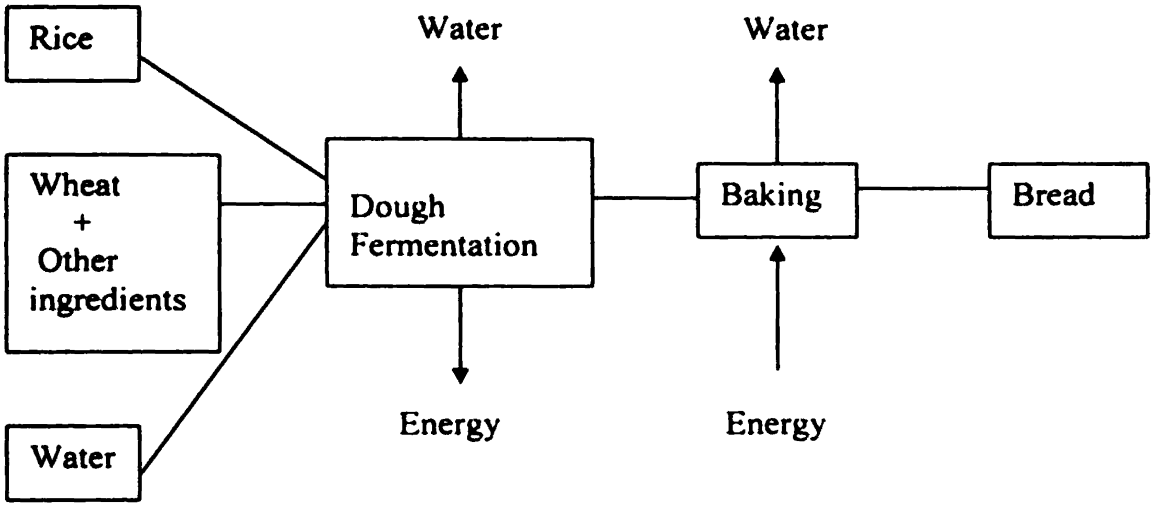

Fig 4.6 Material balance for water in bread preparation

In accordance with material balance figure, initially 58% of water was used in preparation of the dough of all treatments. During the period of fermentation and baking equal amount of water being liberated and evaporated as a result of microbial and thermal activities. Hence baked bread having somewhat equal amount of moisture for all treatments, including control treatment too.

4.6.2 PH value of the bread

PH value of bread is governed by the acetic acid formation process of bread dough during the fermentation. There in the yeast (leavening agent) secreted α and β amylases and these 2 enzymes convert starch in to simple sugar and thereafter in to alcohol. A considerable amount of formulated ethyl alcohol was subjected for further oxidation process and resultant product would be acetic acid. This acetic acid imparts low pH value for baked bread.

In case of these 2 treatments, fermentation time (1 hour) and fermentation process (dough place in the trays and keep in normal in-house environmental condition) are similar to each other including control treatment too. Hence, formation of acetic acid of these two treatments is similar to each other and as a result of which

both treatments impart somewhat similar pH values: which also falling with the regulations value of bread (pH 5.3 - 6).

To further scrutinize these results a statistical analysis was carried out.

4.7 Statistical Analysis of Physiochemical Properties

4.7.1 Results of Normality Test

Table 4.6.1 Normality P values

Physiochemical Property	Mean	Standard Deviation	P-Value
PH	5.074	0.04157	0.486
Moisture	39.86	0.7301	0.377
Bulk Density	0.1511	0.007817	0.056

Normality test's p-value indicates that, at 5% levels less than p-value, there is evidence that the data follow a normal distribution. According to table 4.7, alls P-values (0.486, 0.377, 0.056) are greater than alpha (0.05), which means all data, follow the normal distribution. (See App. VII).

4.7.2 Result of Physiochemical Properties

Table 4.6.2 P values for the physiochemical properties

Physiochemical Property	P-Value
PH	0.180
Moisture	0.087
Bulk Density	0.317

4.7.2.1 PH

The P-value (0.180) obtained for pH clearly indicates that there is not a statistical significant difference between samples coded as 328, 574 and 936 when alpha at 0.05. (See App. VIII).

4.7.2.2 Moisture

The P-value (0.087) obtained for moisture clearly indicates that there is not a statistical significant difference between samples coded as 328, 574 and 936 when alpha at 0.05. (See App. VIII).

4.7.2.3 Bulk Density

The P-value (0.317) obtained for moisture clearly indicates that there is not a statistical significant difference between samples coded as 328, 574 and 936 when alpha at 0.05. (See App. VIII).

According to the above results, statistical analysis revealed that mean variations of pH, moisture and bulk density of bread samples are similar to each other.

4.8 Statistical Analysis of Sensory Attributes

4.8.1 Results of Normality Test

Table 4.7.1 Normality P values

Sensory Attribute	Mean	Standard Deviation	P-Value
Taste	6.567	1.290	0.005
Smell	6.956	0.9934	0.005
Texture	7.156	0.9934	0.005
Crumb cell distribution	7.511	0.9025	0.005
Bread crust	7.122	0.8187	0.005
Overall acceptability	6.767	1.290	0.005

Normality test's p-value indicates that, at 5% levels less than p-value, there is evidence that the data follow a normal distribution. According to table 4.9, alls P-values (0.005) less than alpha (0.05), which means all data, do not follow the normal distribution. (See App. V).

4.8.2 Result of Sensory Evaluation

Table 4.7.2 Sensory Evaluation Records

Sensory Attribute	P-Value	Mean Rank			Median			Best Sample
		328	574	936	328	574	936	
Taste	0.001	38.0	60.1	38.5	6	7.5	6.5	574
Smell	0.000	54.5	52.9	29.1	7	7	6	328
Texture	0.000	27.3	58.2	51.0	6.5	8	7	574
Crumb cell distribution	0.000	44.0	61.8	30.7	7.5	8	7	574
Bread crust	0.287	40.3	50.2	46.0	7	7	7	-
Overall acceptability	0.000	36.1	65.4	35.1	6	8	6.5	574

4.8.2.1 Taste

The P-value (0.001) obtained for taste clearly indicates that there is a statistical significant difference between samples coded as 328, 574 and 936 when alpha at 0.05. Based on corresponding rank means and medians, it is possible to say that sample code 574 is the best sample in taste attribute because it bears the highest rank mean (60.1) and highest median (7.5). (See App. VI).

4.8.2.2 Smell

The P-value (0.000) obtained for smell clearly indicates that there is a statistical significant difference between samples coded as 328, 574 and 936 when alpha at 0.05. Based on corresponding medians, 328 and 574 samples have highest

and same median value (7). Based on corresponding rank means, it is possible to say that sample code 328 is the best sample in smell attribute because it bears the highest rank mean (54.5). (See App. VI).

4.8.2.3 Texture

The P-value (0.000) obtained for texture clearly indicates that there is a statistical significant difference between samples coded as 328, 574 and 936 when alpha at 0.05. Based on corresponding rank means and medians, it is possible to say that sample code 574 is the best sample in texture attribute because it bears the highest rank mean (58.2) and highest median (8). (See App. VI).

4.8.2.4 Crumb cell distribution (Appearance)

The P-value (0.000) obtained for crumb cell distribution (Appearance) clearly indicates that there is a statistical significant difference between samples coded as 328, 574 and 936 when alpha is set at 0.05. Based on corresponding rank means and medians, it is possible to say that sample code 574 is the best sample in crumb cell distribution (Appearance) attribute because it bears the highest rank mean (61.8) and highest median (8). (See App. VI).

4.8.2.5 Bread crust

The P-value (0.287) obtained for bread crust clearly indicates that there is not a statistical significant difference between samples coded as 328, 574 and 936 when alpha is set at 0.05. (See App. VI).

4.8.2.6 Overall acceptability

The P-value (0.000) obtained for overall acceptability clearly indicates that there is a statistically significant difference between samples coded as 328, 574 and 936 when alpha at 0.05. Based on corresponding rank means and medians, it is possible to say that sample code 574 is the best sample in overall acceptability attribute because it bears the highest rank mean (65.4) and highest median (8). (See App. VI).

4.6 Drawing a sensory profile for best treatment as against wheat bread

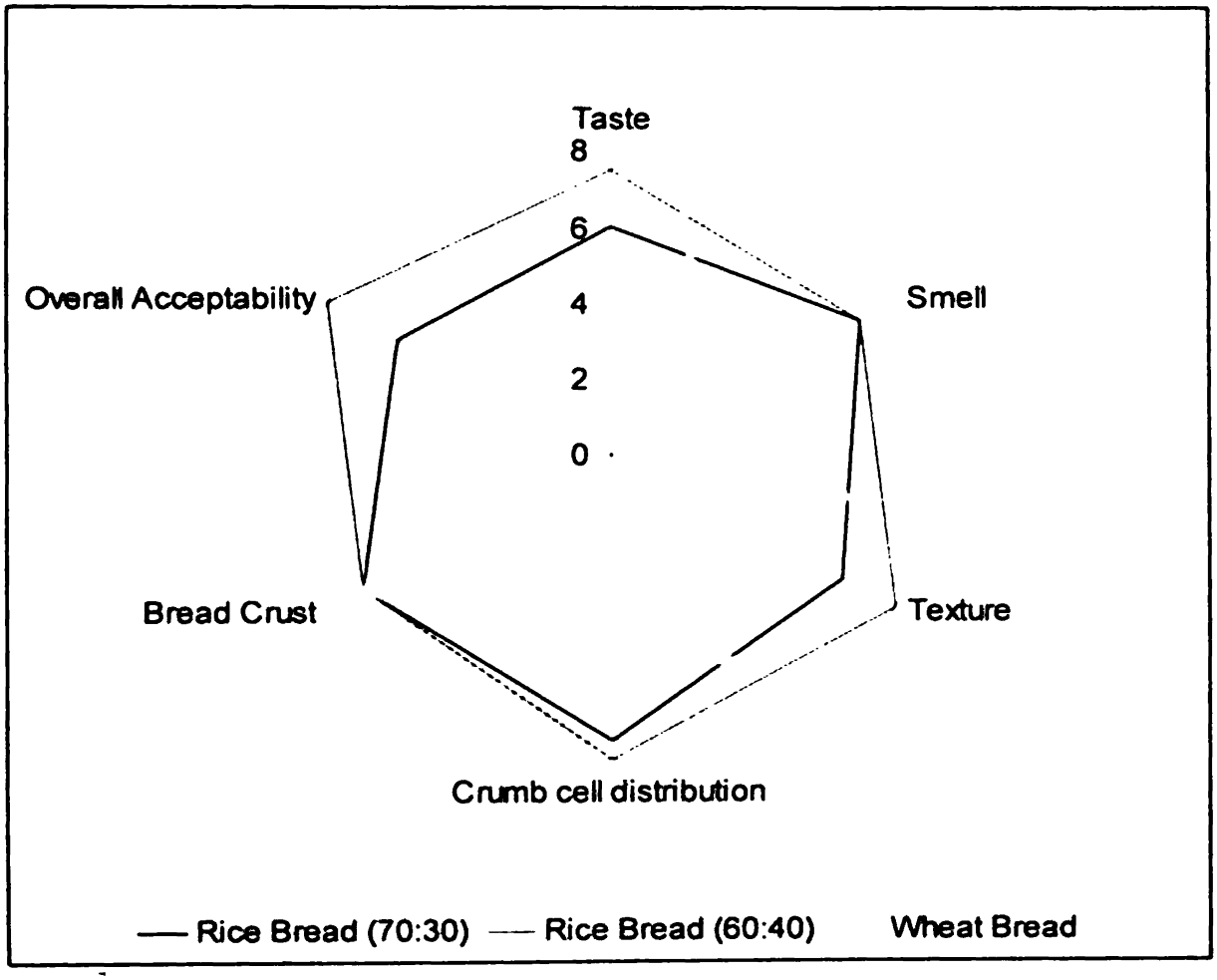

Fig 4.7 Sensory profile for best treatment as against wheat bread

Sensory profiles also clearly indicate that best treatment in manufacturing of rice bread is $a^1b^1c^1d^1$ with 60:40 rice bread as against same treatment of 70:30 rice bread. Almost all sensory stimuli (taste, texture, crumb cell distribution, overall acceptability) of 60:40 rice bread are significantly better than wheat bread. On the other hand, 70:30 rice bread appears to have the best smell; in fact both rice bread samples have highest median value for smell. However crusts of all breads are same in each other.

CHAPTER 05

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

01. In manufacturing of rice bread moisture content of raw rice shall be maintained some what above ordinary rice, preferably at 15.5%. Thereafter rice grain shall be subjected for force gelatinization process by giving a heat treatment at 90-95 ^{0}C for 3 minutes. Heat treated rice shall be subjected for over night cold soaking process, preferably 10-12 hours and to be ground to get 150 µm particle size after carrying out of 2-3 shade drying process. Rice prepared from that treatment (a^1 b^1 c^1 d^1) is suitable to manufacture rice bread with 60% rice flour and 40% wheat flour.

02. The best leavening index measurements were reported as 2.57, 2.47 and 2.03 for (a^1 b^1 c^1 d^1) treatment of 50:50, 60:40 and 70:30 rice flour to wheat flour dough combinations respectively.

03. 60:40 rice bread was selected as the best sample through the sensory attributes of taste, texture, crumb cell distribution and overall acceptability by sensory evaluation test.

04. Baked rice breads having somewhat equal amount of pH, moisture and bulk density for all treatments, including wheat bread.

5.2 Recommendations

01. This study revealed, if particle size of rice flour can be made as minimum as possible (less than 150 μm), the magnitude of rice flour incorporation can be increased up to a certain limit preferably around 70-75%, whereas rice flour prepared from a^1 b^1 c^1 d^1 treatment.

02. If it is blended with plant base gum or mucilaginous material, magnitude of rice flour incorporation in to bread can also be increased.

03. Finally, consumer shall be educated on merits of rice bread as against wheat bread and how to make use rice bread for their daily menu.

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APPENDIX I

Reading for leavening index test (50:50 rice flour to wheat flour combination)

Treatment No:	Replicates	Initial Volume	Final Volume	Leavening Index	Average Leavening Index
1 = 1	1	10 ml	22 ml	1.2	
	2	10 ml	21 ml	1.1	1.17
	3	10 ml	22 ml	1.2	
2 = a	1	10 ml	22 ml	1.2	
	2	10 ml	23 ml	1.3	1.27
	3	10 ml	23 ml	1.3	
3 = b	1	10 ml	28 ml	1.8	
	2	10 ml	29 ml	1.9	1.87
	3	10 ml	29 ml	1.9	
4 = ab	1	10 ml	28 ml	1.8	
	2	10 ml	28 ml	1.8	1.84
	3	10 ml	29 ml	1.9	
5 = c	1	10 ml	25 ml	1.5	
	2	10 ml	25 ml	1.5	1.47
	3	10 ml	24 ml	1.4	
6 = ac	1	10 ml	25 ml	1.5	
	2	10 ml	26 ml	1.6	1.57
	3	10 ml	26 ml	1.6	
7 = bc	1	10 ml	32 ml	2.2	
	2	10 ml	31 ml	2.1	2.13
	3	10 ml	31 ml	2.1	
8 = abc	1	10 ml	34 ml	2.4	
	2	10 ml	34 ml	2.4	2.37
	3	10 ml	33 ml	2.3	
9 = d	1	10 ml	22 ml	1.2	
	2	10 ml	23 ml	1.3	1.27
	3	10 ml	23 ml	1.3	
10 = ad	1	10 ml	23 ml	1.3	
	2	10 ml	24 ml	1.4	1.37
	3	10 ml	24 ml	1.4	
11 = bd	1	10 ml	29 ml	1.9	
	2	10 ml	29 ml	1.9	1.87
	3	10 ml	28 ml	1.8	
12 = abd	1	10 ml	29 ml	1.9	
	2	10 ml	28 ml	1.8	1.87
	3	10 ml	29 ml	1.9	

13 = cd	1	10 ml	26 ml	1.6	
	2	10 ml	24 ml	1.4	1.50
	3	10 ml	25 ml	1.5	
14 = acd	1	10 ml	27 ml	1.7	
	2	10 ml	26 ml	1.6	1.64
	3	10 ml	26 ml	1.6	
15 = bcd	1	10 ml	32 ml	2.2	
	2	10 ml	31 ml	2.1	2.17
	3	10 ml	32 ml	2.2	
16 = abcd	1	10 ml	35 ml	2.5	
	2	10 ml	36 ml	2.6	2.57
	3	10 ml	36 ml	2.6	

Reading for leavening index test (60:40 rice flour to wheat flour combination)

Treatment No:	Replicates	Initial Volume	Final Volume	Leavening Index	Average Leavening Index
1 = 1	1	10 ml	21 ml	1.1	
	2	10 ml	20 ml	1.0	1.00
	3	10 ml	19 ml	0.9	
2 = a	1	10 ml	21 ml	1.1	
	2	10 ml	23 ml	1.3	1.17
	3	10 ml	21 ml	1.1	
3 = b	1	10 ml	26 ml	1.6	
	2	10 ml	25ml	1.5	1.60
	3	10 ml	27 ml	1.7	
4 = ab	1	10 ml	27 ml	1.7	
	2	10 ml	28 ml	1.8	1.70
	3	10 ml	26 ml	1.6	
5 = c	1	10 ml	23 ml	1.3	
	2	10 ml	25 ml	1.5	1.40
	3	10 ml	24 ml	1.4	
6 = ac	1	10 ml	25 ml	1.5	
	2	10 ml	24 ml	1.4	1.40
	3	10 ml	23 ml	1.3	
7 = bc	1	10 ml	28 ml	1.9	
	2	10 ml	28 ml	1.8	1.87
	3	10 ml	28 ml	1.9	
8 = abc	1	10 ml	33 ml	2.3	

	2 3	10 ml 10 ml	32 ml 33 ml	2.2 2.3	2.27
9 = d	1 2 3	10 ml 10 ml 10 ml	22 ml 22 ml 23 ml	1.2 1.2 1.3	1.23
10 = ad	1 2 3	10 ml 10 ml 10 ml	23 ml 22 ml 23 ml	1.3 1.2 1.3	1.27
11 = bd	1 2 3	10 ml 10 ml 10 ml	27 ml 27 ml 26 ml	1.7 1.7 1.6	1.67
12 = abd	1 2 3	10 ml 10 ml 10 ml	27ml 28 ml 27 ml	1.7 1.8 1.7	1.73
13 = cd	1 2 3	10 ml 10 ml 10 ml	24 ml 24 ml 25 ml	1.4 1.4 1.5	1.43
14 = acd	1 2 3	10 ml 10 ml 10 ml	25ml 25 ml 24 ml	1.5 1.5 1.4	1.47
15 = bcd	1 2 3	10 ml 10 ml 10 ml	30 ml 31 ml 29ml	2.0 2.1 1.9	2.00
16 = abcd	1 2 3	10 ml 10 ml 10 ml	35 ml 34 ml 35 ml	2.5 2.4 2.5	2.47

Reading for leavening index test (70:30 rice flour to wheat flour combination)

Treatment No:	Replicates	Initial Volume	Final Volume	Leavening Index	Average Leavening Index
1 = 1	1 2 3	10 ml 10 ml 10 ml	20 ml 19 ml 20 ml	1.0 0.9 1.0	0.97
2 = a	1 2 3	10 ml 10 ml 10 ml	21 ml 20 ml 20 ml	1.1 1.0 1.0	1.03
3 = b	1 2	10 ml 10 ml	25 ml 25ml	1.5 1.5	1.47

	3	10 ml	24 ml	1.4	
4 = ab	1	10 ml	27 ml	1.7	
	2	10 ml	25 ml	1.5	1.60
	3	10 ml	26 ml	1.6	
5 = c	1	10 ml	23 ml	1.3	
	2	10 ml	22 ml	1.2	1.23
	3	10 ml	22 ml	1.2	
6 = ac	1	10 ml	22 ml	1.2	
	2	10 ml	23 ml	1.3	1.30
	3	10 ml	24 ml	1.4	
7 = bc	1	10 ml	27 ml	1.7	
	2	10 ml	27 ml	1.7	1.66
	3	10 ml	26 ml	1.6	
8 = abc	1	10 ml	29 ml	1.9	
	2	10 ml	30 ml	2.0	1.93
	3	10 ml	29ml	1.9	
9 = d	1	10 ml	19 ml	0.9	
	2	10 ml	20 ml	1.0	0.96
	3	10 ml	20 ml	1.0	
10 = ad	1	10 ml	21 ml	1.1	
	2	10 ml	20 ml	1.0	1.07
	3	10 ml	21 ml	1.1	
11 = bd	1	10 ml	26 ml	1.6	
	2	10 ml	25 ml	1.5	1.57
	3	10 ml	26 ml	1.6	
12 = abd	1	10 ml	27ml	1.7	
	2	10 ml	27 ml	1.7	1.67
	3	10 ml	26 ml	1.6	
13 = cd	1	10 ml	22 ml	1.2	
	2	10 ml	22 ml	1.2	1.20
	3	10 ml	22 ml	1.2	
14 = acd	1	10 ml	23ml	1.3	
	2	10 ml	23 ml	1.3	1.34
	3	10 ml	24 ml	1.4	
15 = bcd	1	10 ml	28 ml	1.8	
	2	10 ml	27 ml	1.7	1.77
	3	10 ml	28ml	1.8	
16 = abcd	1	10 ml	30 ml	2.0	
	2	10 ml	30 ml	2.0	2.03
	3	10 ml	31 ml	2.1	

APPENDIX II

Normality test for leavening index measurements

Generates a normal probability plot and performs a hypothesis test to examine whether or not the observations follow a normal distribution. For the normality test, the hypotheses are,

H_0: Data follow a normal distribution

H_1: Data do not follow a normal distribution

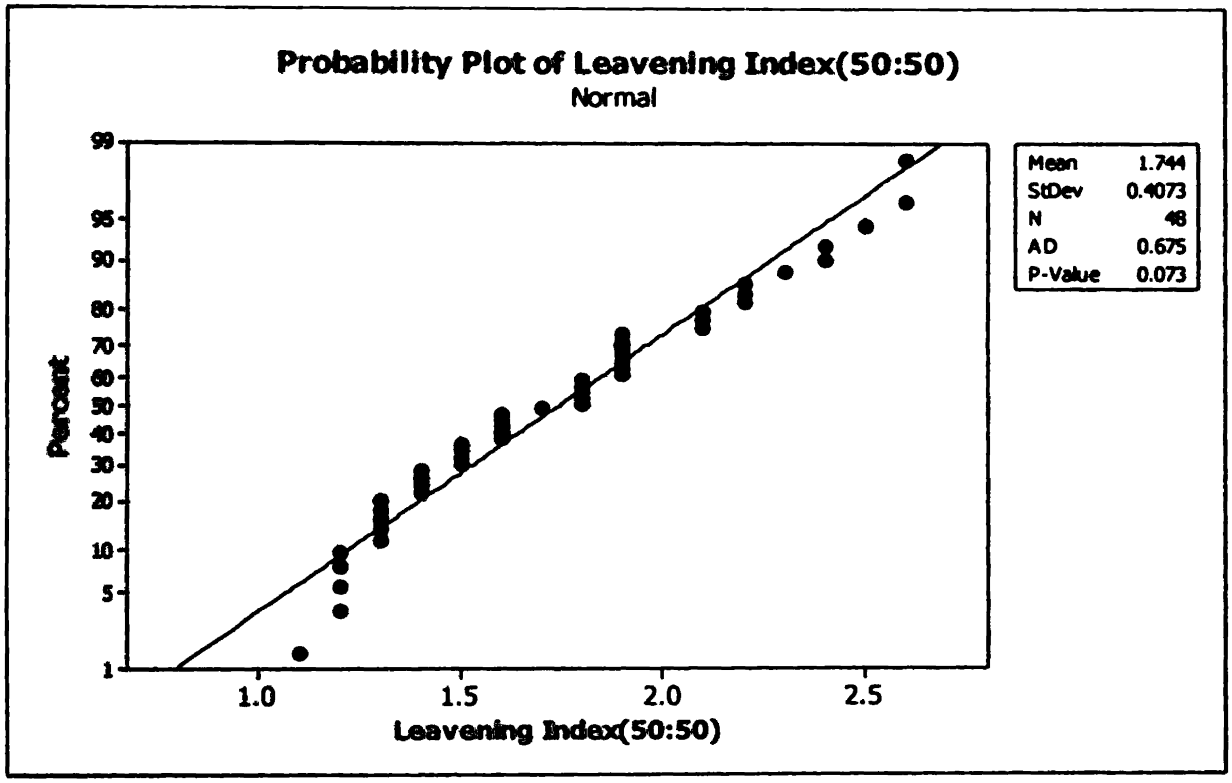
$\alpha = 0.05$, If P value < α

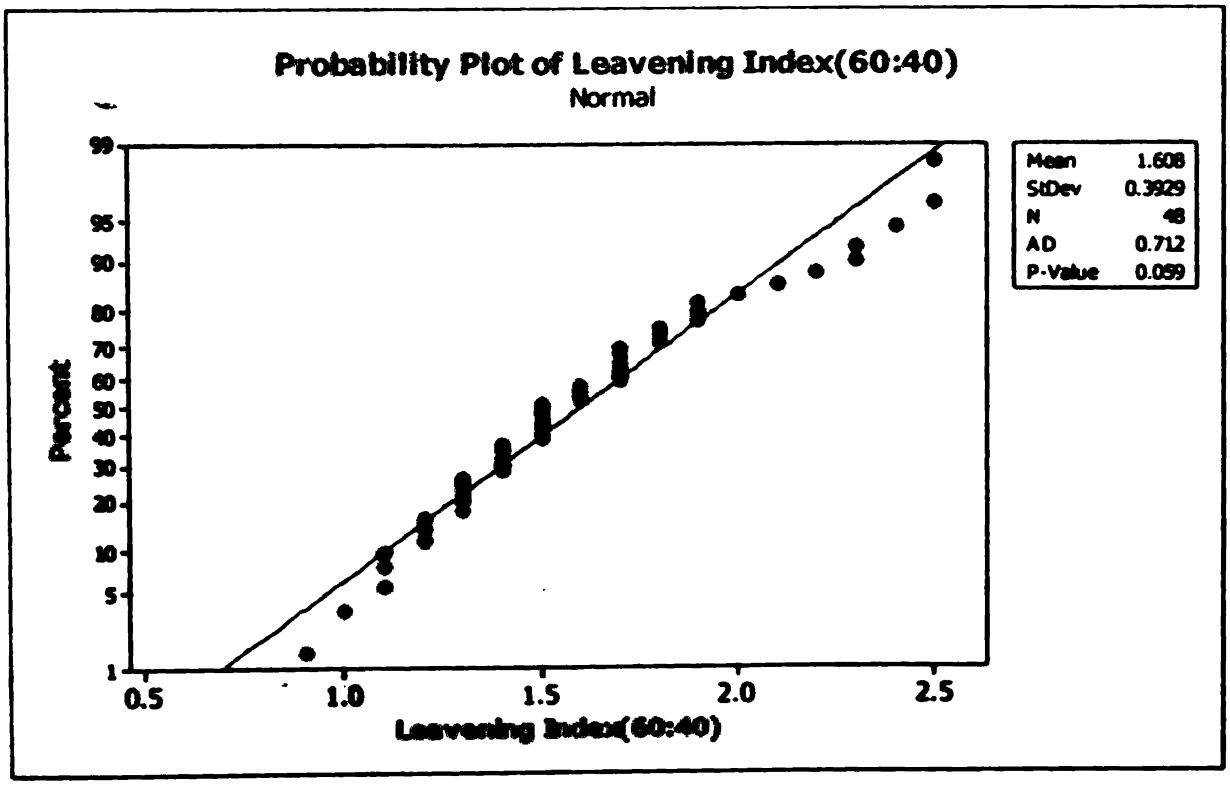
Ho: Rejected

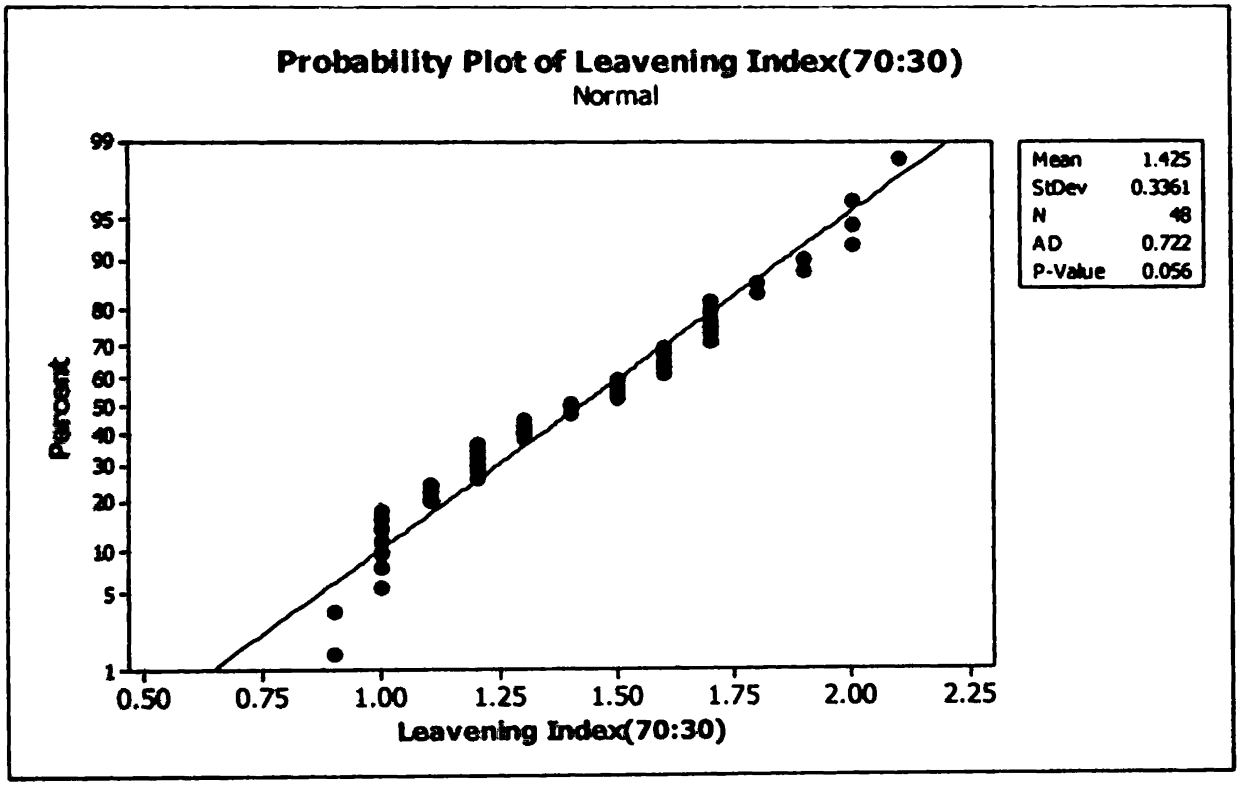
The Anderson-Darling test's p-value indicates that, at 5% levels less than p-value, there is evidence that the data follow a normal distribution. According to following tables, alls P-values (0.073, 0.059 and 0.056) greater than alpha (0.05), which mean following all data, follow the normal distribution

Result of Normality Test

Leavening Index	Mean	Standard Deviation	P-Value
50 : 50	1.744	0.4073	0.073
60 : 40	1.608	0.3929	0.059
70 : 30	1.425	0.3361	0.056


Probability Plot of Leavening Index(50:50)
Normal
Mean 1.744
StDev 0.4073
N 48
AD 0.675
P-Value 0.073
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
1.0
1.5
2.0
2.5
Leavening Index(50:50)


Probability Plot of Leavening Index(60:40)
Normal
Mean 1.608
StDev 0.3929
N 48
AD 0.712
P-Value 0.059
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
0.5
1.0
1.5
2.0
2.5
Leavening Index(60:40)


Probability Plot of Leavening Index(70:30)
Normal
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
Leavening Index(70:30)
Mean 1.425
StDev 0.3361
N 48
AD 0.722
P-Value 0.056

APPENDIX III

One-way ANOVA: Leavening Index (50:50) versus Treatment No

Source	DF	SS	MS	F	P
Treatment No	15	7.67813	0.51188	136.50	0.000
Error	32	0.12000	0.00375		
Total	47	7.79813			

S = 0.06124 R-Sq = 98.46% R-Sq(adj) = 97.74%

Hypothesis:

H_0: There is sufficient evidence that all the means of leavening indexes are equal.

H_1: There is sufficient evidence that not all the means of leavening indexes are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value < α ,

H_0 - rejected

P value = 0.000

Statistical decision:

Reject H_0

At 5% significant levels, there is sufficient evidence that not all the means of leavening indexes are equal.

Multiple comparisons procedure

Hsu's MCB (Multiple Comparisons with the Best

Family error rate = 0.05
Critical value = 2.69

Intervals for level mean minus largest of other level means

Level	Lower	Center	Upper
1	-1.5347	-1.4000	0.0000
2	-1.4347	-1.3000	0.0000
3	-0.8347	-0.7000	0.0000
4	-0.8680	-0.7333	0.0000
5	-1.2347	-1.1000	0.0000
6	-1.1347	-1.0000	0.0000
7	-0.5680	-0.4333	0.0000

```
 8      -0.3347   -0.2000   0.0000                                (--*---)
 9      -1.4347   -1.3000   0.0000        (--*-------------------------)
10      -1.3347   -1.2000   0.0000          (--*-----------------------)
11      -0.8347   -0.7000   0.0000                    (--*-------------)
12      -0.8347   -0.7000   0.0000                    (--*-------------)
13      -1.2013   -1.0667   0.0000              (--*-------------------)
14      -1.0680   -0.9333   0.0000                 (-*-----------------)
15      -0.5347   -0.4000   0.0000                          (--*-------)
16       0.0000    0.2000   0.3347                                  (---*--)
                                    -+---------+---------+---------+--------
                                   -1.50     -1.00     -0.50      0.00
```

One-way ANOVA: Leavening Index (60:40) versus Treatment No:

Source	DF	SS	MS	F	P
Treatment No:	15	7.06333	0.47089	77.94	0.000
Error	32	0.19333	0.00604		
Total	47	7.25667			

S = 0.07773 R-Sq = 97.34% R-Sq(adj) = 96.09%

Hypothesis:

H_0: There is sufficient evidence that all the means of leavening indexes are equal.

H_1: There is sufficient evidence that not all the means of leavening indexes are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value $< \alpha$,

H_0 - rejected

P value = 0.000

Statistical decision:

Reject H_0

At 5% significant levels, there is sufficient evidence that not all the means of leavening indexes are equal.

Multiple comparisons procedure

```
Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.05
Critical value = 2.69

Intervals for level mean minus largest of other level means

Level     Lower    Center    Upper  -------+---------+---------+---------+--
 1      -1.6376   -1.4667   0.0000  (--*-----------------------)
 2      -1.4709   -1.3000   0.0000    (--*-----------------------)
 3      -1.0376   -0.8667   0.0000             (--*-------------)
 4      -0.9376   -0.7667   0.0000              (--*------------)
 5      -1.2376   -1.0667   0.0000         (--*-----------------)
 6      -1.1709   -1.0000   0.0000          (--*----------------)
 7      -0.7709   -0.6000   0.0000                  (--*---------)
 8      -0.3709   -0.2000   0.0000                        (--*--)
 9      -1.4042   -1.2333   0.0000       (-*--------------------)
10      -1.3709   -1.2000   0.0000       (--*-------------------)
11      -0.9709   -0.8000   0.0000              (--*------------)
12      -0.9042   -0.7333   0.0000               (--*-----------)
13      -1.2042   -1.0333   0.0000          (--*----------------)
14      -1.1709   -1.0000   0.0000          (--*----------------)
15      -0.6376   -0.4667   0.0000                   (--*-------)
16       0.0000    0.2000   0.3709                            (--*--)
                                  -------+---------+---------+---------+--
                                      -1.20     -0.60      0.00      0.60
```

One-way ANOVA: Leavening Index (70:30) versus Treatment No:

```
Source          DF       SS        MS       F      P
Treatment No:   15  5.18333  0.34556  87.30  0.000
Error           32  0.12667  0.00396
Total           47  5.31000

S = 0.06292   R-Sq = 97.61%   R-Sq(adj) = 96.50%
```

Hypothesis:

H_0: There is sufficient evidence that all the means of leavening indexes are equal.

H_1: There is sufficient evidence that not all the means of leavening indexes are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value < α ,

H_0 - rejected

P value = 0.000

Statistical decision:

Reject H_0

At 5% significant levels, there is sufficient evidence that not all the means of leavening indexes are equal.

Multiple comparisons procedure

```
Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.05
Critical value = 2.69

Intervals for level mean minus largest of other level means

Level     Lower    Center    Upper      +---------+---------+---------+---------
 1      -1.2050   -1.0667   0.0000     (--*-------------------------)
 2      -1.1383   -1.0000   0.0000       (--*-------------------------)
 3      -0.7050   -0.5667   0.0000                 (---*-------------)
 4      -0.5717   -0.4333   0.0000                    (--*----------)
 5      -0.9383   -0.8000   0.0000           (--*--------------------)
 6      -0.8717   -0.7333   0.0000            (---*-----------------)
 7      -0.5050   -0.3667   0.0000                     (---*--------)
 8      -0.2383   -0.1000   0.0383                           (---*--)
 9      -1.2050   -1.0667   0.0000     (--*-------------------------)
10      -1.1050   -0.9667   0.0000       (---*-----------------------)
11      -0.6050   -0.4667   0.0000                  (--*-----------)
12      -0.5050   -0.3667   0.0000                   (---*--------)
13      -0.9717   -0.8333   0.0000           (--*--------------------)
14      -0.8383   -0.7000   0.0000              (---*----------------)
15      -0.4050   -0.2667   0.0000                        (--*------)
16      -0.0383    0.1000   0.2383                              (---*--)
                                    +---------+---------+---------+---------
                                  -1.20     -0.80     -0.40      0.00
```

APPENDIX IV

SABARAGAMUWA UNIVERSITY OF SRI LANKA

Department of Food Science & Technology

Questionnaire for Sensory Analysis (Nine Point Hedonoic Test)

Name: ..... Product: **Rice bread**
Date: ..... Time : .....

- Assess the sample individually.
- Indicate how much you preferred each sample after testing.
- Rinse you mouth with water after tasting each sample.
- Give numerical values ranking from Like Extremely to Dislike Extremely.

Point Scale	Points
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Sensory Aspects	Sample code		
	574	328	936
Taste			
Smell			
Texture			
Crumb cell distribution			
Bread crust			
Overall Acceptability			

Comments:
.....

.....
Signature

Thank you

APPENDIX V

Normality test for sensory evaluation

Generates a normal probability plot and performs a hypothesis test to examine whether or not the observations follow a normal distribution. For the normality test, the hypotheses are,

H_0: Data follow a normal distribution

H_1: Data do not follow a normal distribution

$\alpha = 0.05$, If P value $< \alpha$

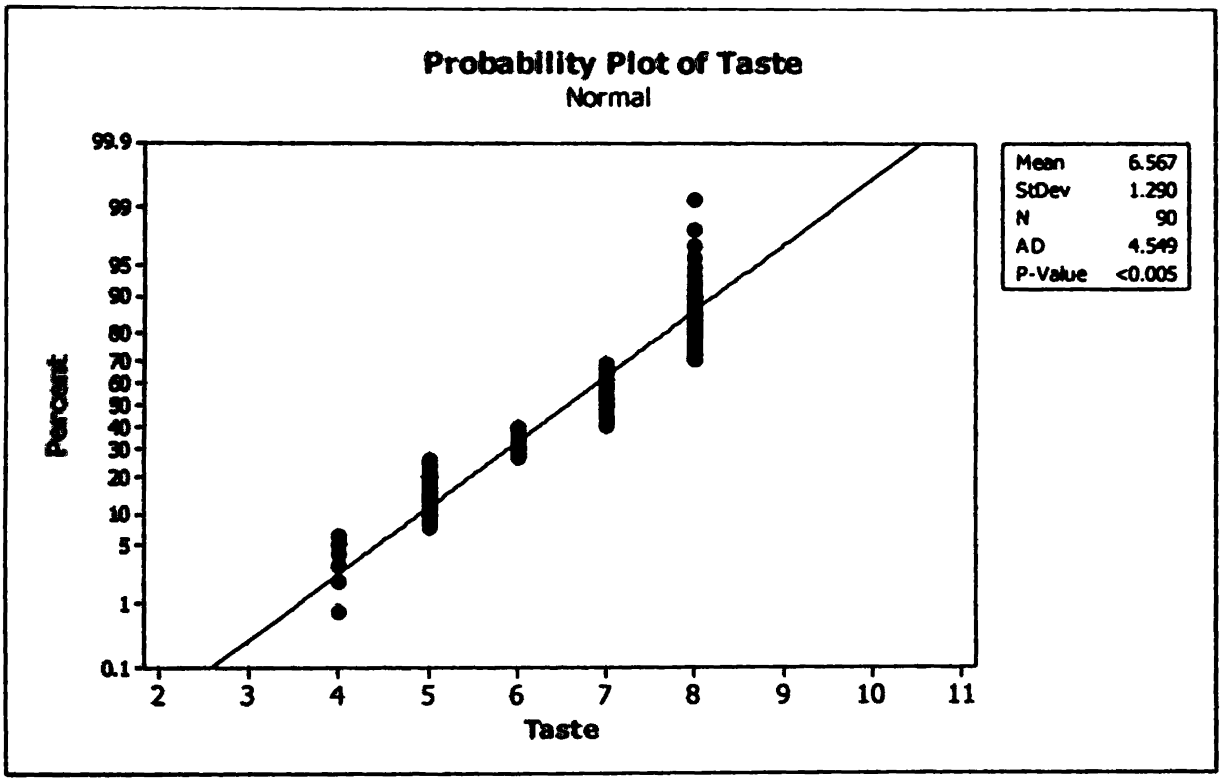
Ho: Rejected

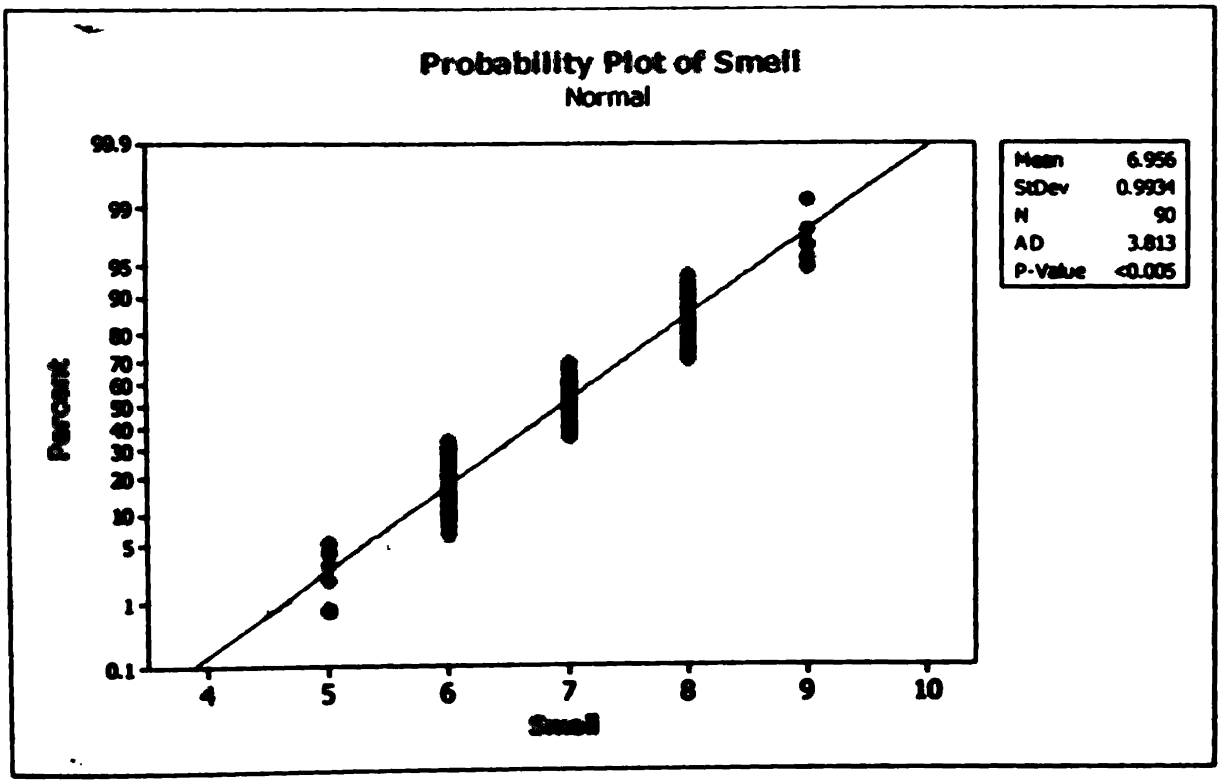
The Anderson-Darling test's p-value indicates that, at 5% levels less than p-value, there is evidence that the data follow a normal distribution. According to following tables' alls P-values equal to 0.005, which mean following all data, do not obey the normal distribution.

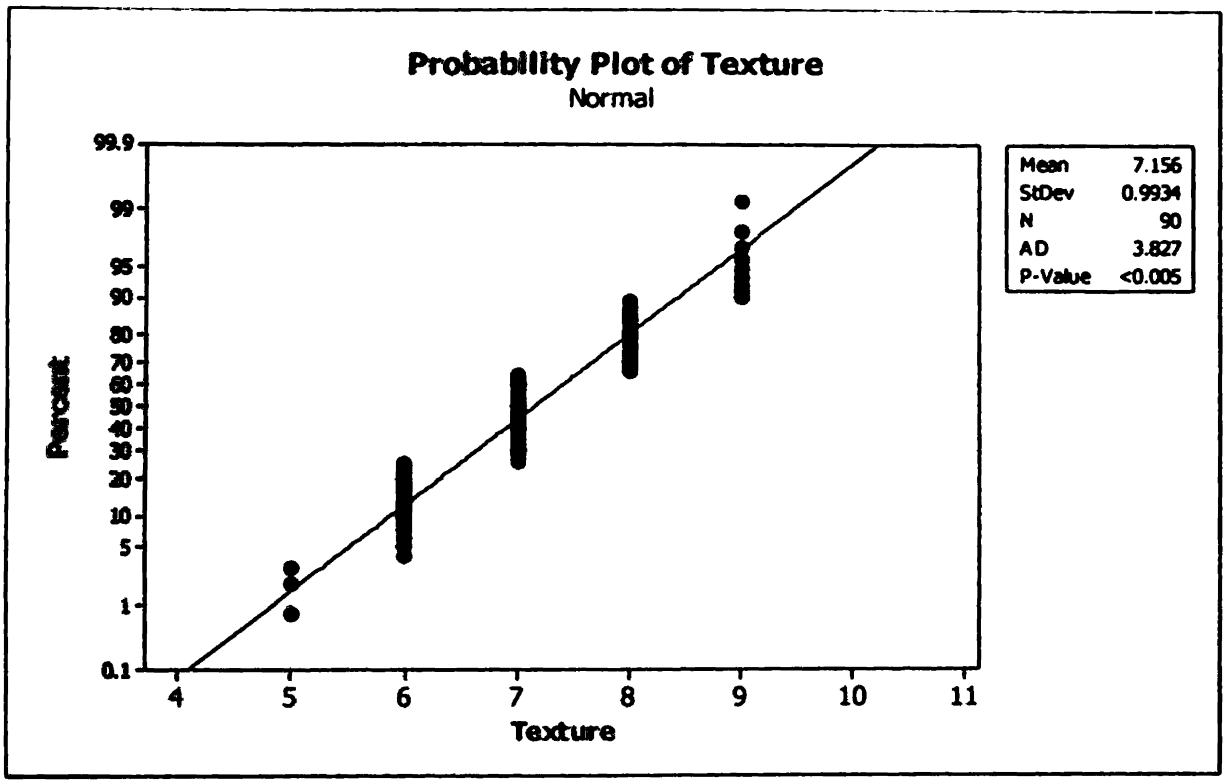
Result of Normality Test

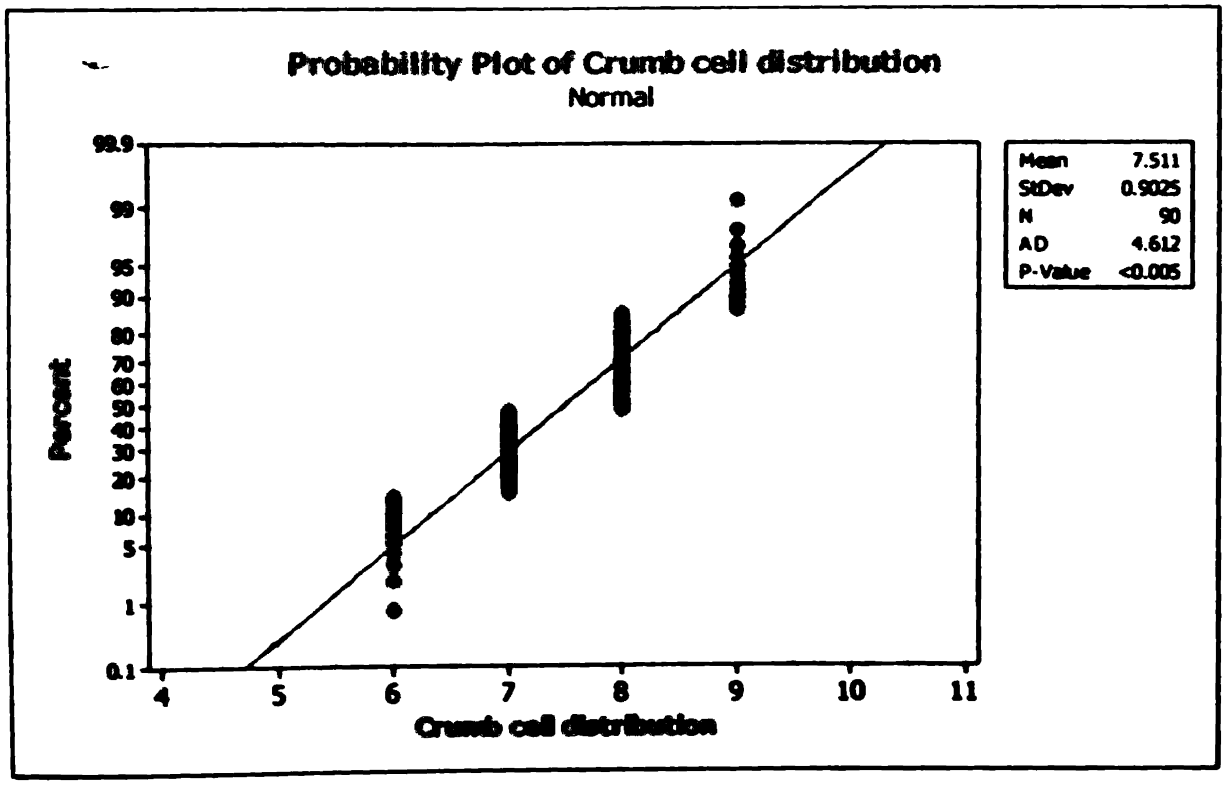
Sensory Attribute	Mean	Standard Deviation	P-Value
Taste	6.567	1.290	0.005
Smell	6.956	0.9934	0.005
Texture	7.156	0.9934	0.005
Crumb cell distribution	7.511	0.9025	0.005
Bread crust	6.633	1.054	0.005
Overall acceptability	6.767	1.290	0.005

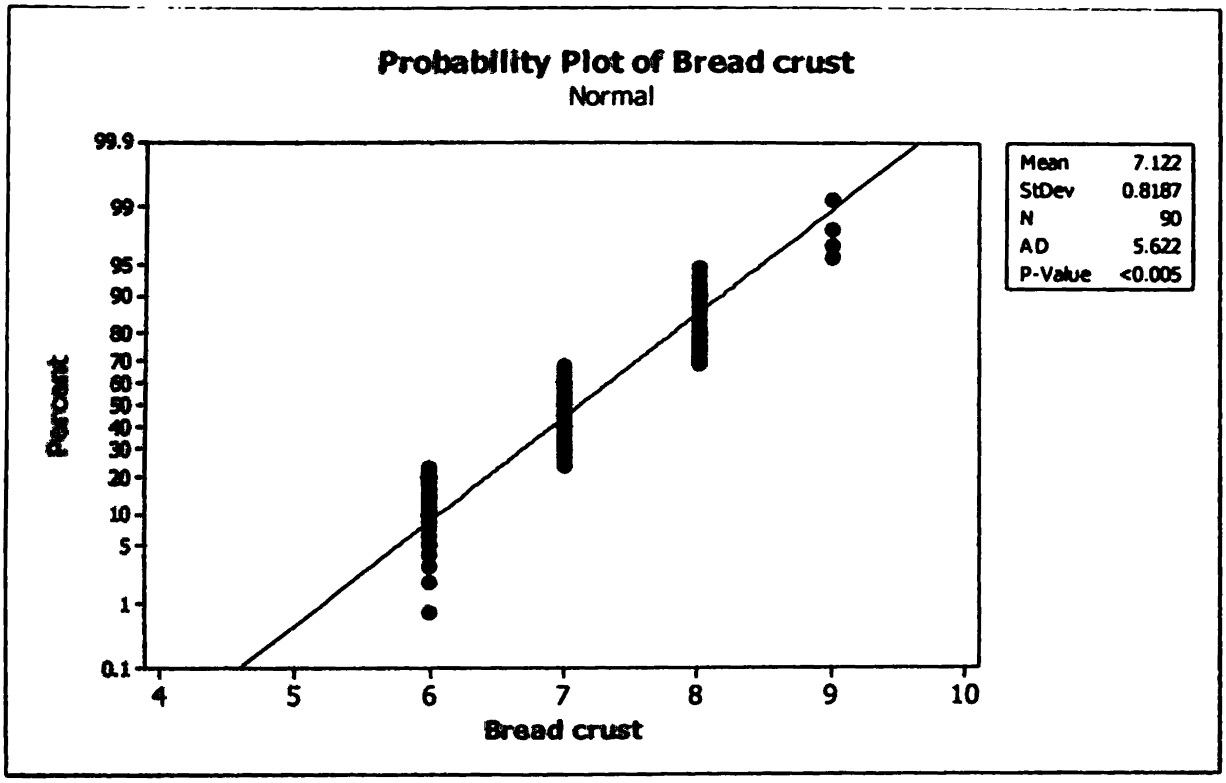
Normal Probability Plots of Sensory Attributes

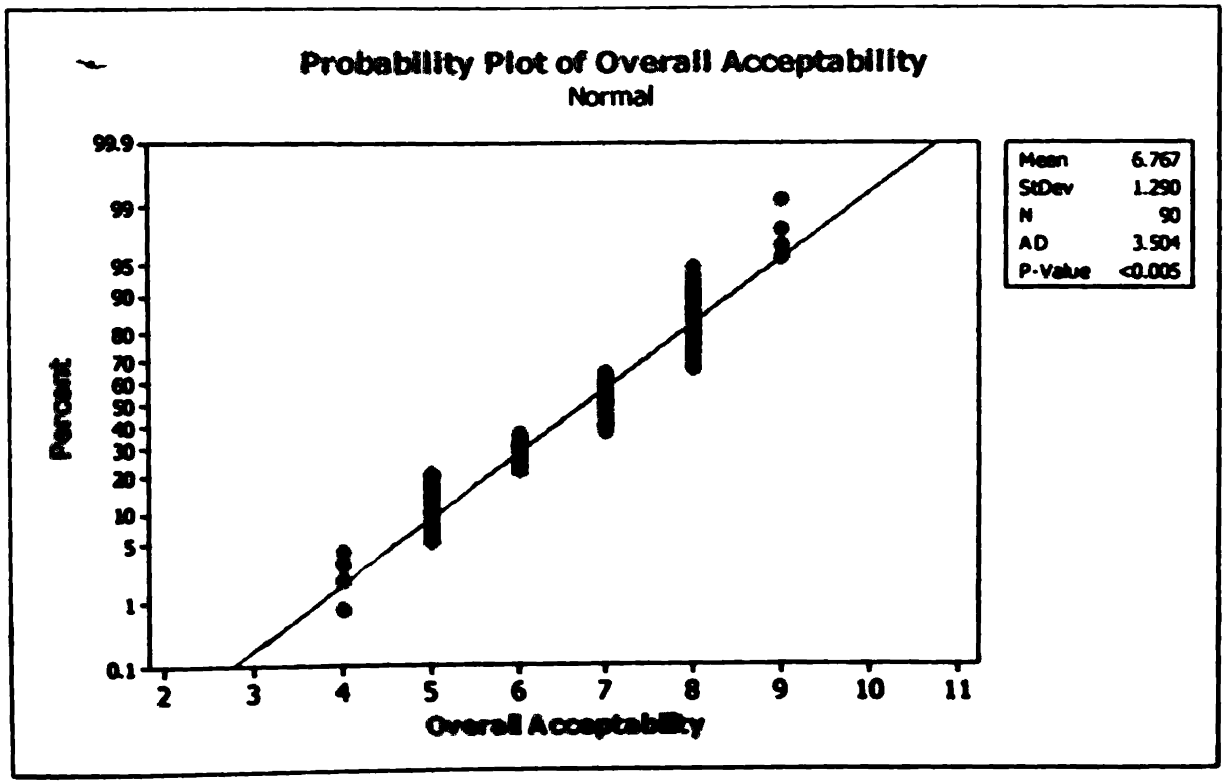





Probability Plot of Texture
Normal
Mean 7.156
StDev 0.9934
N 90
AD 3.827
P-Value <0.005
Percent
Texture


Probability Plot of Crumb cell distribution
Normal
Mean 7.511
StDev 0.9025
N 90
AD 4.612
P-Value <0.005
Percent
Crumb cell distribution


Probability Plot of Bread crust
Normal
Mean 7.122
StDev 0.8187
N 90
AD 5.622
P-Value <0.005
Percent
Bread crust


Probability Plot of Overall Acceptability
Normal
Mean 6.767
StDev 1.290
N 90
AD 3.504
P-Value <0.005
Percent
Overall Acceptability

Appendix VI

Kruskal-Wallis Test: Taste versus sample code

```
Kruskal-Wallis Test on Taste

sample code   N  Median  Ave Rank      Z
328          30   6.000      38.0  -1.93
574          30   7.500      60.1   3.74
936          30   6.500      38.5  -1.81
Overall      90               45.5

H = 13.96  DF = 2  P = 0.001
H = 14.93  DF = 2  P = 0.001  (adjusted for ties)
```

Hypothesis:

H_0: There is sufficient evidence that all the medians of taste are equal.

H_1: There is sufficient evidence that not all the medians of taste are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value < α ,

H_0 - rejected

P value = 0.001

Statistical decision:

Reject H_0

At 5% significant levels, there is sufficient evidence that not all the medians of taste are equal.

Kruskal-Wallis Test: Smell versus sample code

```
Kruskal-Wallis Test on Smell

sample code   N  Median  Ave Rank      Z
328          30   7.000      54.5   1.31
574          30   7.000      52.9   1.05
936          30   6.000      29.1  -4.36
Overall      90               45.5

H = 17.76  DF = 2  P = 0.000
H = 19.38  DF = 2  P = 0.000  adjusted for ties
```

Hypothesis:

H_0: There is sufficient evidence that all the medians of smell are equal.

H_1: There is sufficient evidence that not all the medians of smell are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value $< \alpha$,

H_0 - rejected

P value = 0.000

Statistical decision:

Reject H_0

At 5% significant levels, there is sufficient evidence that not all the medians of smell are equal.

Kruskal-Wallis Test: Texture versus sample code

```
Kruskal-Wallis Test on Texture

sample code   N  Median  Ave Rank      Z
328          30   6.500      27.3  -4.67
574          30   8.000      58.2   3.26
936          30   7.000      51.0   1.41
Overall      90              45.5

H = 22.94  DF = 2  P = 0.000
H = 25.23  DF = 2  P = 0.000  (adjusted for ties)
```

Hypothesis:

H_0: There is sufficient evidence that all the medians of texture are equal.

H_1: There is sufficient evidence that not all the medians of texture are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value $< \alpha$,

H_0 - rejected

P value = 0.000

Statistical decision:

Reject H_0

At 5% significant levels, there is sufficient evidence that not all the medians of texture are equal.

Kruskal-Wallis Test: Crumb cell distribution versus sample code

```
Kruskal-Wallis Test on Crumb cell distribution

sample code    N  Median  Ave Rank      Z
328           30   7.500      44.0  -0.38
574           30   8.000      61.8   4.17
936           30   7.000      30.7  -3.80
Overall       90              45.5

H = 21.31  DF = 2  P = 0.000
H = 23.71  DF = 2  P = 0.000  (adjusted for ties)
```

Hypothesis:

H_0: There is sufficient evidence that all the medians of crumb cell distribution are equal.

H_1: There is sufficient evidence that not all the medians of crumb cell distribution are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value < α ,

H_0 - rejected

P value = 0.000

Statistical decision:

Reject H_0

At 5% significant levels, there is sufficient evidence that not all the medians of crumb cell distribution are equal.

Kruskal-Wallis Test: Bread crust versus Sample code

```
Kruskal-Wallis Test on Bread crust

Sample code    N  Median  Ave Rank      Z
328           30   7.000      40.3  -1.34
574           30   7.000      50.2   1.21
936           30   7.000      46.0   0.13
Overall       90              45.5

H = 2.18  DF = 2  P = 0.336
H = 2.49  DF = 2  P = 0.287  (adjusted for ties)
```

Hypothesis:

H_0: There is sufficient evidence that all the medians of bread crust are equal.

H_1: There is sufficient evidence that not all the medians of bread crust are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value < α ,

H_0 - rejected

P value = 0.287

Statistical decision:

Do not reject H_0

At 5% significant levels, there is sufficient evidence that all the medians of bread crust are equal.

Kruskal-Wallis Test: Overall Acceptability versus sample code

```
Kruskal-Wallis Test on Overall Acceptability

sample code    N  Median  Ave Rank      Z
328           30   6.000      36.1  -2.41
574           30   6.000      65.4   5.11
936           30   6.500      35.5  -2.68
Overall       90              45.5

H = 26.00  DF = 2  P = 0.000
H = 27.65  DF = 2  P = 0.000  adjusted for ties
```

Hypothesis:

H_0: There is sufficient evidence that all the medians of overall acceptability are equal.

H_1: There is sufficient evidence that not all the medians of overall acceptability are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value $< \alpha$,

H_0 - rejected

P value = 0.000

Statistical decision:

Reject H_0

At 5% significant levels, there is sufficient evidence that not all the medians are equal.

Appendix VII

Normality test for Physiochemical Properties

Generates a normal probability plot and performs a hypothesis test to examine whether or not the observations follow a normal distribution. For the normality test, the hypotheses are,

H_0: Data follow a normal distribution

H_1: Data do not follow a normal distribution

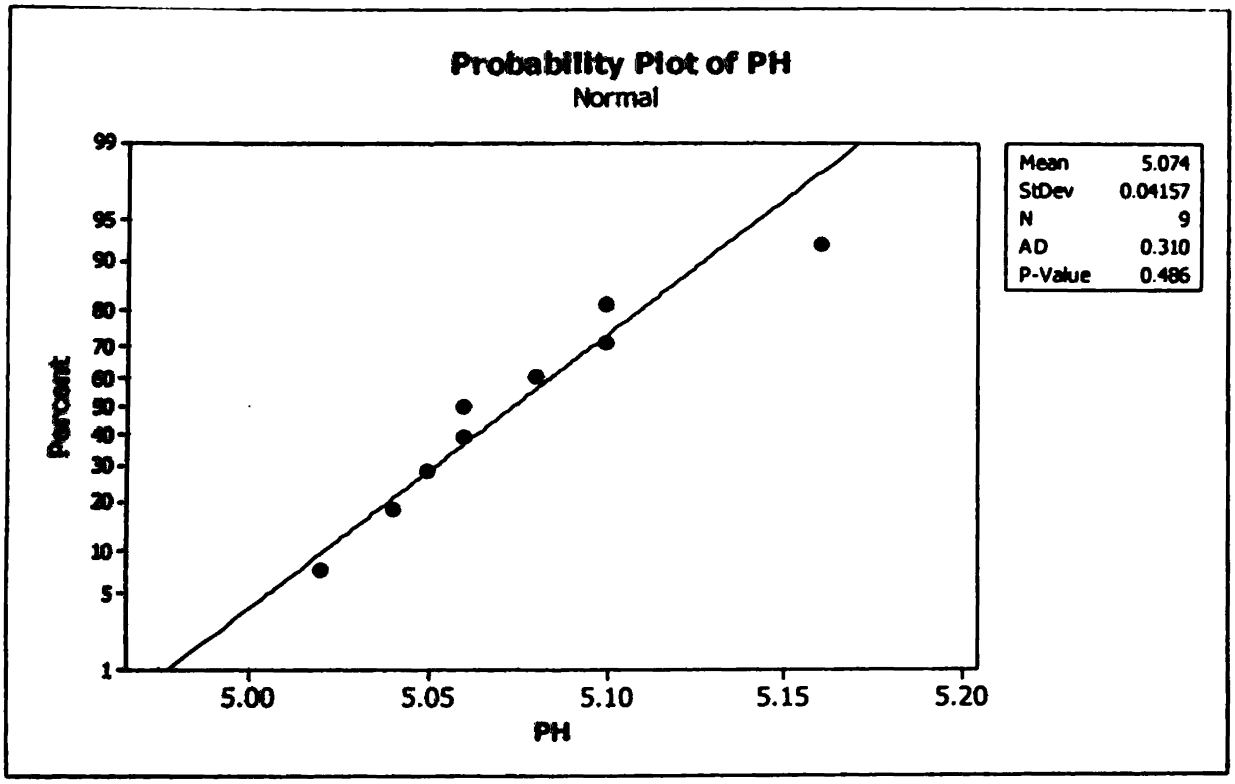
$\alpha = 0.05$, If P value < α

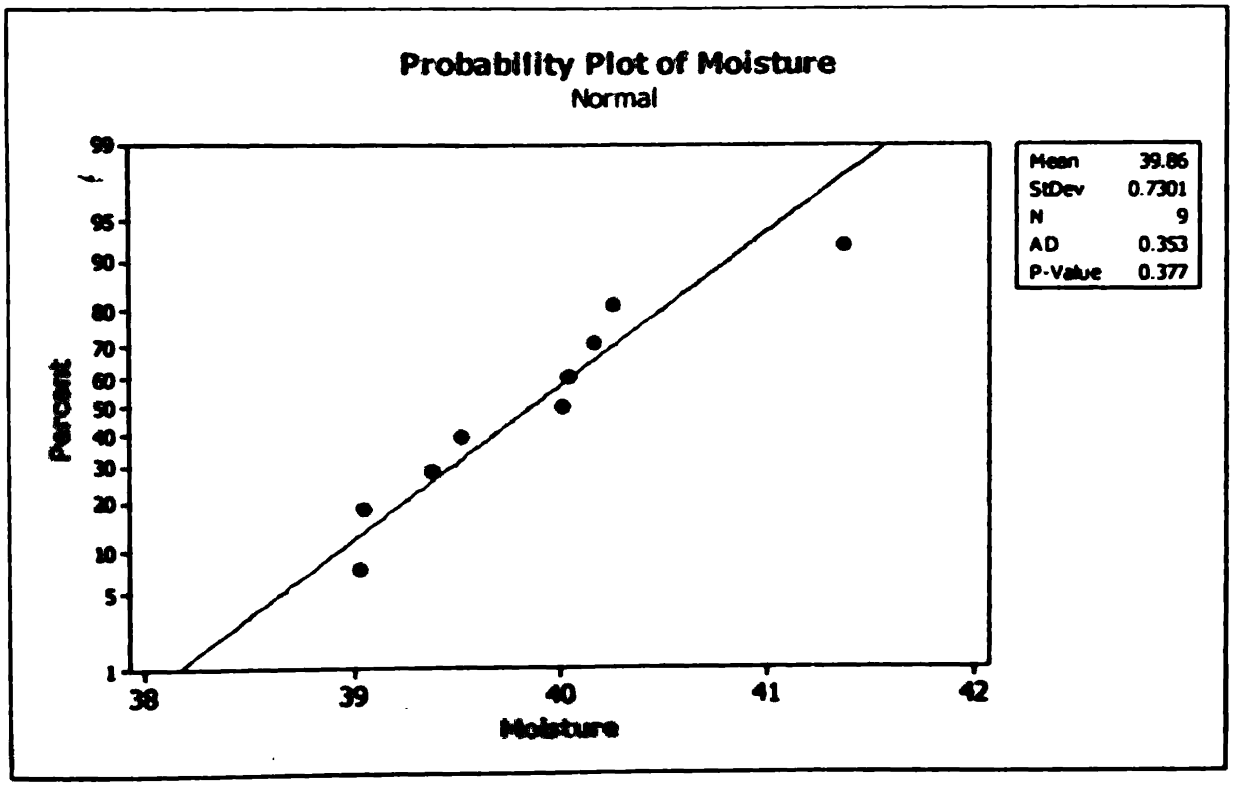
Ho: Rejected

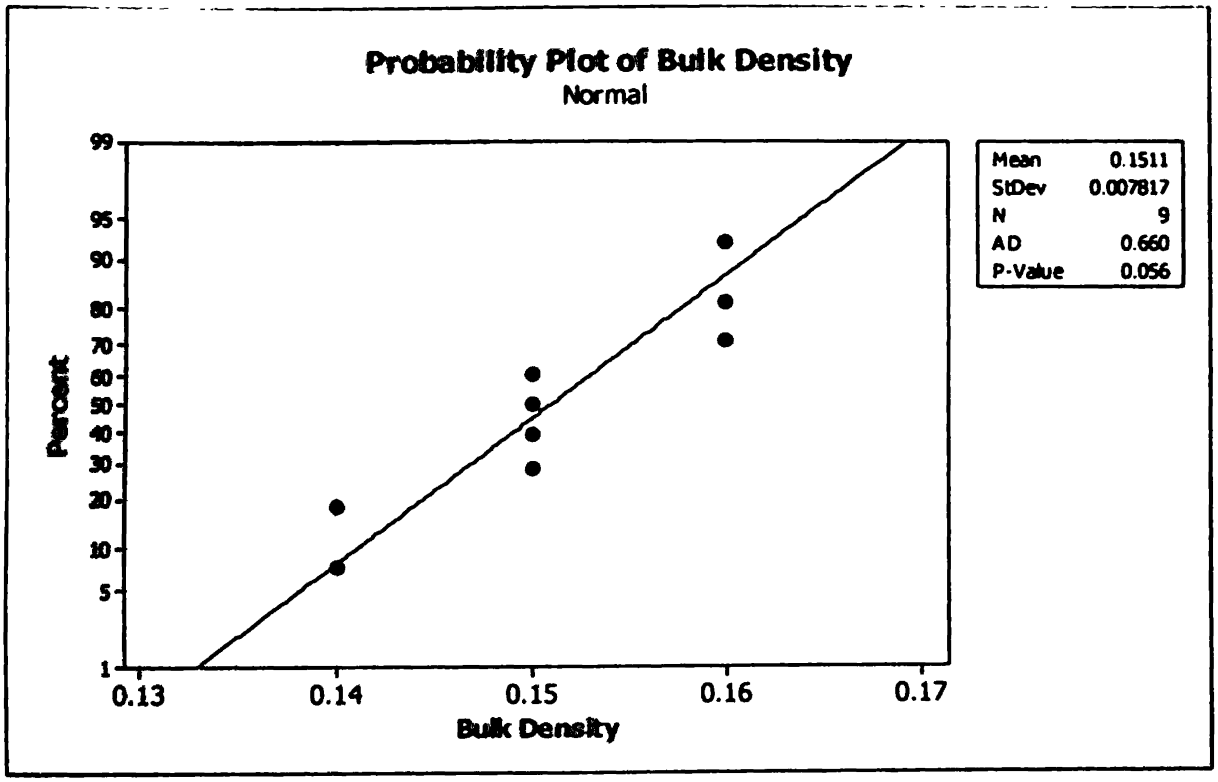
The Anderson-Darling test's p-value indicates that, at 5% levels less than p-value, there is evidence that the data follow a normal distribution. According to following tables, alls P-values (0.486, 0.377 and 0.056) greater than alpha (0.05), which mean following all data, follow the normal distribution

Result of Normality Test

Physiochemical Property	Mean	Standard Deviation	P-Value
PH	5.074	0.04157	0.486
Moisture	39.86	0.7301	0.377
Bulk Density	0.1511	0.007817	0.056


Probability Plot of PH
Normal
Mean 5.074
StDev 0.04157
N 9
AD 0.310
P-Value 0.486
Percent
PH
5.00
5.05
5.10
5.15
5.20


Probability Plot of Moisture
Normal
Mean 39.86
StDev 0.7301
N 9
AD 0.353
P-Value 0.377
Percent
Moisture
38
39
40
41
42


Probability Plot of Bulk Density
Normal
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
0.13
0.14
0.15
0.16
0.17
Bulk Density
Mean 0.1511
StDev 0.007817
N 9
AD 0.660
P-Value 0.056

Appendix VIII

One-way ANOVA: PH versus Sample code

```
Source        DF       SS       MS     F      P
Sample code    2  0.00602  0.00301  2.32  0.180
Error          6  0.00780  0.00130
Total          8  0.01382

S = 0.03606   R-Sq = 43.57%   R-Sq(adj) = 24.76%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level  N    Mean   StDev  --+---------+---------+---------+-------
328    3  5.1067  0.0503                (---------*---------)
574    3  5.0733  0.0306       (---------*---------)
936    3  5.0433  0.0208  (---------*---------)
                           --+---------+---------+---------+-------
                           5.000     5.050     5.100     5.150

Pooled StDev = 0.0361
```

Hypothesis:

H_0: There is sufficient evidence that all the means of pH are equal.

H_1: There is sufficient evidence that not all the means of pH are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value $< \alpha$,

H_0 - rejected

P value = 0.180

Statistical decision:

Do not reject H_0

At 5% significant levels, there is sufficient evidence that all the means of pH are equal.

One-way ANOVA: Moisture versus Sample code

```
Source        DF      SS      MS      F      P
Sample code    2   2.376   1.188   3.78  0.087
Error          6   1.888   0.315
Total          8   4.264

S = 0.5609   R-Sq = 55.73%   R-Sq(adj) = 40.97%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
328     3  39.467   0.502  (-----------*----------)
574     3  40.590   0.668                    (----------*----------)
936     3  39.537   0.495   (-----------*----------)
                           --------+---------+---------+---------+-
                                39.20     39.90     40.60     41.30

Pooled StDev = 0.561
```

Hypothesis:

H_0: There is sufficient evidence that all the means of moisture are equal.

H_1: There is sufficient evidence that not all the means of moisture are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value $< \alpha$,

H_0 - rejected

P value = 0.087

Statistical decision:

Do not reject H_0

At 5% significant levels, there is sufficient evidence that all the means of moisture are equal.

One-way ANOVA: Bulk Density versus Sample code

```
Source        DF          SS          MS      F      P
Sample code    2   0.0001556   0.0000778   1.40  0.317
Error          6   0.0003333   0.0000556
Total          8   0.0004889

S = 0.007454   R-Sq = 31.82%   R-Sq(adj) = 9.09%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level   N     Mean    StDev     +---------+---------+---------+---------
328     3  0.15667  0.00577                  (-----------*-----------)
574     3  0.15000  0.01000        (-----------*-----------)
936     3  0.14667  0.00577     (-----------*-----------)
                                +---------+---------+---------+---------
                               0.1360    0.1440    0.1520    0.1600

Pooled StDev = 0.00745
```

Hypothesis:

H_0: There is sufficient evidence that all the means of bulk density are equal.

H_1: There is sufficient evidence that not all the means of bulk density are equal.

Significant level and decision rule:

At 5% significant levels, $\alpha = 0.05$

If P value < α,

H_0 - rejected

P value = 0.317

Statistical decision:

Do not reject H_0

At 5% significant levels, there is sufficient evidence that all the means of bulk density are equal.

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