CHAPTER ONE

INTRODUCTION

Cereal-based foods play an important role as a source of dietary energy and nutrients in human nutrition. The use of microorganisms by humans has a long tradition. Besides beer and wine production, bread making is one of the oldest arts known to man. For example, Egypt, Greece and Italy were early places of discovery of leavened breads (Kulp and Lorenz, 2003).

Wheat falls under the grass family Gramineae, which include the cereal grains. Other popular cereal grains that fall under this category are corn, rice, barley, oats, sorghum and pearl millet. All of this can be milled into flour, but only wheat flour has the ability to be transformed into glutinous dough, together with water and other ingredients. The uniqueness of wheat flour to be transformed into a cohesive, viscoelastic mass is due to the hydration of gluten proteins in the wheat together with the application of mixing energy. After the dough is formed, the gluten structure entraps the gasses produced during the fermentation stage. This allows the dough mass to expand and to be baked into a soft, light and palatable product, which is known as bread (September, 2007).

Fermented foods, particularly those produced under controlled conditions, have a good record of safety and are implicated in outbreaks of diseases relatively infrequently (Adams and Nout, 2001).

Bread is a staple foodstuff made and eaten in most countries around the world (Owens, 2001). Bread is the most popular yeast leaved product made from wheat flour. The bread making process is one of the oldest applications of biotechnology. The term bread defines a great variety of baking products, which vary in formulation, ingredients, and processing conditions (Shetty *et al.,* 2006). Bread products have evolved to take many forms, each based on quite different and very distinctive characteristics. In some countries the nature of bread making has retained its traditional form while in others it has changed dramatically. Of all the cereals wheat is almost unique in this respect. The aim of the bread making process is quite simple: namely to convert wheat flour and other ingredients into a light, aerated and palatable food (Owens, 2001).

In Sudan, the consumption of wheat bread is increasing in both rural and urban areas as a consequence of changing taste, convenience and consumer subsidies (Abdelghafor *et al.,* 2011).

The basic ingredients in bread-making are flour, water, salt, and yeasts. In modern bread making however a large number of other components and additives are used as knowledge of the baking process has grown. These components depend on the type of bread and on the practice and regulations operating in a country. They include ‘yeast food’, sugar, milk, eggs, shortening (fat) emulsifiers, anti-fungal agents, anti-oxidants, enzymes, flavoring, and enriching ingredients. The ingredients are mixed together to form dough which is then baked (Okafor, 2007).

Nowadays, the use of additives has become a common practice in the baking industry. The need for their use arises due to the fact that numerous benefits are associated with their use. With this objective, a large number of these substances of various chemical structures have been used. Some additives are focused on improving dough machinability.

Food hydrocolloids are high-molecular weight hydrophilic biopolymers used as functional ingredients in the food industry. In the baked goods, hydrocolloids have been used for retarding the staling and for improving the quality of the fresh products. Emulsifiers are commonly added to commercial bakery products to improve bread quality and dough handling characteristics (Kohajdová *et al.,* 2009). Emulsifiers have become highly functional ingredients in the food industry. They are used at very low amounts in foods, many times at fractions of a percent, yet can greatly affect the final products' performance. For example, emulsifiers can aerate foams and batters, extend shelf-life, promote fat agglomeration, and improve texture in foods. The functionality of emulsifiers depends on the particular emulsifier used and the concentration, formulation, and processing the final food product has experienced (Baker, 2010).

Gum arabic (GA, E-Number 414) is an edible, dried, gummy exudate from the stems and branches of *Acacia senegal* and *A. seyal* that is rich in non-viscous soluble fiber, It is defined by the FAO/WHO Joint Expert Committee for Food Additives (JECFA) as 'a dried exudation obtained from the stems of *A. senegal* (L.) Willdenow or closely related species of Acacia (family Leguminosae)' (Ali *et al.,* 2009).

Generally, bread quality faces many problems like deterioration of flavor, color, texture and taste after few hours from production time, so what the effect of gum arabic on this problem? What amount of gum arabic that gives desired function on wheat flour? In addition, what about effect of gum arabic in fermentation process, baking process, color measurement, shelf life and as antistaling agent?

Objectives:

The ultimate goal of this study was to investigate the effect of gum arabic on the quality of bread. To achieve the goal, there were some minor objectives should be included:

1) To study the characteristics of the dough (fermentation and baking) and bread organoleptics.
2) To evaluate bread quality after 8 hours.
3) To determine the optimum percentage of gum arabic that to be used in the bread making.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cereal grains:

Cereals are the fruits of cultivated grasses, members of the monocotyledonous family *Gramineae*. Most of the 195,000 species of flowering plants produce edible parts which could be utilized by man; however less than 0.1% or fewer than 300 species are used for food. Approximately 17 plant species provide 90% of mankind's food supply, of which cereal grains supply far and away the greatest percentage (Cordain, 1999). Grain crops, or cereals, are by far the most important sources of plant food for the human race. On a worldwide basis, they provide almost half of the energy and protein of the diet (Vaughan and Geissler, 2010).

Eight cereal grains: wheat, maize, rice, barley, sorghum, oats, rye, and millet provide 56% of the food energy and 50% of the protein consumed on earth. Three cereals: wheat, maize and rice together comprise at least 75% of the world's grain production. It is clear that humanity has become dependent upon cereal grains for the majority of its food supply. As Mangelsdorf has pointed out, 'cereal grains literally stand between mankind and starvation'; therefore, it is essential that we fully understand the nutritional implications of cereal grain consumption upon human health and well being (Cordain, 1999). Cereals represent an important food category as they contribute a large portion of our daily calorie supply. Besides energy, cereal products are important for nutrition because of their contents of dietary fiber and a wide range of micronutrients and bioactive components including minerals, vitamins, antioxidants, and other bioactive compounds (Hamaker, 2008).

2.1.1 Origin of cereals:

The genealogy of the cereals begins with wild grasses (*Poaceae*), Barley (*Hordeum vulgare*), probably one of the first cereals grown systematically, was known as early as 5000 B.C. in Egypt and Babylon (Belitz *et al.,* 2009). Although the first anatomically modern humans (Homo sapiens) appeared in Africa 90,000 years ago, humans prior to the mesolithic period (~15,000 years ago) like other primates rarely if ever utilized cereal grains (Cordain, 1999).

The cultivation of wheat (*Triticum spp.*) reaches far back into history, and the crop was predominant in antiquity as a source of human food. It was cultivated particularly in Persia (Iran), Egypt, Greece and Europe (Kent and Evers, 1994).

2.1.2 Historical perspective of cereals:

Widespread consumption of cereal grains began in the Middle East about 10,000 years ago, when agriculture first began. It was then that wheat was first planted and cultivated (Figoni, 2008). Wheat became so important that at one time its export from Greece was prohibited, and bread was such a staple and important food that its weight and price were fixed in law (Cauvain and Young, 2006). The status of the baker began to change during the years of the Roman Empire. It became a profession for men, and baking acquired a respectable and significant status as a trade. During this period the first guilds, or trade unions, of bakers began to form, reflecting the respectable nature of the trade (Cauvain and Young, 2006).

The traditional baked products with which we are all familiar have a long history of development through trial and error rather than systematic study. The origins of many baked products can be assigned to the error category. Indeed, the discovery of leavened bread has been ascribed to the error of leaving dough overnight before baking, and the discovery of laminated pastry to the apprentice who forgot to add fat to the bread dough and tried to recover the situation by folding the missing ingredient into the dough after mixing (though there can be no absolute proof of either story). More recently, systematic studies have been applied to the development of new baked products but most commonly the rule sets applied have tended to be limited and confined by the traditional definition of baked products (Cauvain and Young, 2006).

2.1.3 Cereal production, utilization and stocks:

The latest FAO world cereal production in 2014 now stands at 2542 million tones. Word cereal utilization in 2014/15 is expected to reach 2475 million tonnes, 8 million tonnes more than projected in February with most of the revision resulting from greater anticipated feed use of sorghum and barley. At the current forecast level, world cereal utilization in 2014/15 would grow by 2.6 percent (62 million tonnes) from the previous season. Total feed use of cereals is projected at 877 million tonnes, up 4 percent (34 million tonnes) from 2013/14, led by a 3.6 percent (nearly 20 million tonnes) expansion in maize feed utilization. The FAO forecast for world cereal stocks by the close of the crop seasons ending in 2015 has been lifted by 1.3 percent (8 million tones)

2.1.4 Importance of cereals:

Cereal products are amongst the most important staple foods of mankind. Nutrients provided by bread consumption in industrial countries meet close to 50% of the daily requirement of carbohydrates, one third of the proteins and 50–60% of vitamin B. Moreover, cereal products are also a source of minerals and trace elements (Belitz *et al.,* 2009). In some countries of Southern Asia, Central America, the Far East and Africa cereal product consumption can comprise as much as 80% of the total caloric intake, and in at least half of the countries of the world, bread provides more than 50% of the total caloric intake. In countries where cereal grains comprise the bulk of the dietary intake, vitamin, mineral and nutritional deficiencies are common place (Cordain, 1999). The major cereals are wheat, rye, rice, barley, millet and oats. Wheat and rye have a special role since only they are suitable for bread-making (Belitz *et al.,* 2009). Cereal grains are predominantly composed of starch; nonstarch polysaccharides composed of glucose (β-glucan), fructose (polyfructan), xylose, and arabinose (arabinoglycan), some of these polysaccharides, like starch, are partially digested, and others are believed to be dietary fiber, such as arabinoxylan. In addition to polyfructan, wheat and rye flours contain kestose, nystose, and other FOS of the inulin type (Shetty *et al.*, 2006).

2.1.5 Applicability of cereals to make bread:

Only milled grain products from wheat and rye can be used to make bread. No other cereal is capable of retaining gas to the same extent as wheat during fermentation and baking (Brennan, 2006). Milled products from other types of cereal such as rice, barley, oat or corn will not yield proper dough when combined with liquid. These results in products with a low increase in volume, hardly any browning and which, in addition, are hard to cut, spread and chew. On the other hand, milled wheat and rye products in combination with liquid will yield visco-elastic doughs which retain the gas from the yeast fermentation (CO2) in the form of tiny bubbles. In wheat dough, the so-called gluten is responsible for that. This protein absorbs water and forms an extensible and elastic membrane which encloses the gas bubbles. In rye doughs, the gas is retained due to the high viscosity of swollen gum-like substances (pentosanes) present in the dough. However, the gas permeability of the mass surrounding the gas bubbles is higher in rye dough than in wheat dough. Therefore, rye-containing baked goods have a lower specific volume than wheat dough products (Wassermann, 2009). While staple food, such as corn and wheat flours are usually fortified with iron, rice grains present much hard problems and challenges. In addition, whole brown rice is barely consumed, and its commercial milling (polishing) produces considerable loss of micronutrients, up to 30% and 67% for zinc and iron, respectively, by eliminating its outer layers where these metals are accumulated (Shetty *et al.,* 2006).

2.2 Wheat grain:

Wheat (*Triticum spp.*) is a cereal grain, originally from the Levant region of the Near East and Ethiopian Highlands, but now cultivated worldwide (Belitz *et al.,* 2009). The principal wheats of commerce belong to the botanical species *Triticum aestivum* and *Triticum durum*; *Triticum compactum* or Club Wheat is not widely grown now, but in the USA it is milled to produce soft flour for the manufacture of confectionery and biscuits (Ranken *et al.*, 1997)**.** Wheat is the most popular cereal grain for use in baked goods. Its popularity stems mainly from the gluten that forms when flour is mixed with water. Without gluten, raised bread is hard to imagine. Wheat is also preferred because of its mild, nutty flavor. Both factors, no doubt, contribute to wheat being the most widely grown cereal grain in the world (Figoni, 2008). Wheat grains are the fruit of the wheat plant, which is able to grow in most kinds of soil and under widely differing climatic conditions (Ranken *et al.*, 1997).

2.2.1 Production of wheat:

More wheat is produced annually than any other cereal crop and it is probably the world's foremost food plant (Vaughan and Geissler, 2009). Wheat is a product of the natural environment, and while breeding and farming practices can modify aspects of wheat quality, we millers and bakers still have to respond to the strong influences of the environment (Cauvain and Young, 2007). Some 80 per cent of the world's wheat production takes place in Russia, the United States of America, China, India, France, Canada, Australia, Turkey, Pakistan, and Argentina (Vaughan and Geissler, 2009). since February, to 631 million tonnes. (FAO, 2015).

FAO's first wheat production forecast for 2015 stands at 720 million tonnes, including an early projection for the Southern Hemisphere countries that will begin planting in August. At this level, production would be 1 percent below the record output of 2014, predominantly reflecting an expected decline in *Europe*. (Figure 1).

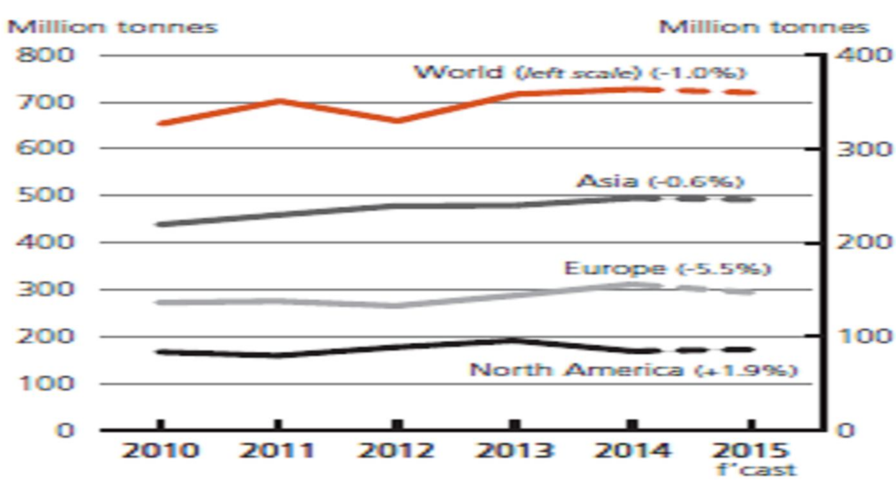

Figure 1: Wheat production in 2015 forecast to contract slightly below the record of 2014. Note: The regional aggregations refer only to the top fifteen producing countries. Percentages refer to year-on-year changes.

Source: (FAO, 2015)

2.2.2 Wheat classification:

Today, thousands of different wheat varieties are grown throughout the world.While certain varieties will grow within the Arctic Circle and others will grow near the equator in the Andes Mountains, most varieties of wheat require moderate growing conditions (Figoni, 2008). Millers and wheat farmers have devised a classification system in North America to help them predict the likely performance characteristics of wheat shipped to market. The system comprises three factors that are correlated with a particular crop before it is sold or turned into flour, Protein content, Kernel color, and harvest season (DiMuzio, 2010).

The climatic features in countries where spring pedigree and are grown under varied conditions of soil and climate, show wide variations in characteristics (Kent and Evers, 1994). Before wheat is marketed, it might acquire a label like hard red winter, soft white winter, or hard red spring (Table 1). Artisan bread bakers favor hard winter wheat flour (10–15% protein) the most, and it is grown in both red and white varieties (DiMuzio, 2010). The two most important species are bread wheat, *Triticum aestivum* (*T. vulgare*) and durum or macaroni wheat (*Triticum durum*) (Vaughan and Geissler, 2009).

Table 1: *Wheat classification*

Variety	Protein Content	Kernel color	Planting season	harvesting season	Typical use
Soft red winter	8–11%	Red	Fall	Early summer	Cake, pastry flour
Soft white winter	8–11%	White	Fall	Early summer	Cakes, pastry flour
Hard red winter	10-15%	Red	Fall	Early summer	Bread Flour
Hard white winter	10–15%	White	Fall	Early summer	Bread flour
Hard red spring	12–18%	Red	Spring	Fall	Bread flour, high-protein flour
Durum Spring	14–16%		Spring	Fall	Semolina, durum flour

Source: DiMuzio (2010)

Hard wheat is required for inclusion in bread making and a soft texture is required for biscuit making (Owens, 2001). Soft wheats alone do not make good breads, hard wheats alone are inappropriate for (sweet) biscuit and cake making, and durum wheat must be used for high-quality pasta (Belton, 2007). Bread wheat *Triticum aestivum (T. vulgare)*. On a worldwide basis, bread wheat constitutes about 90 per cent of the wheat grown; the remainder is devoted essentially to durum wheat (Vaughan and Geissler, 2010).

2.2.3 The Wheat berry:

A grain of wheat is ovoid in shape and bears at one end a number of short fine hairs, the beard. Down one side of the grain runs a deep longitudinal crease. The grain consists of three main parts, the enveloping skins (bran), the embryo (germ) and the endosperm. The relative proportions of these parts vary with the plumpness of the grain, but the average composition of wheat is 83% endosperm, 2.5% embryo, 14.5% enveloping skins (Ranken *et al.,* 1997). An understanding of the structure is necessary to developing an understanding of the interactions that may be present in the isolated cell-wall components. The aleurone layer of wheat, rye, and oat grain is one cell thick (Eliasson *et al.,* 2006).

Wheat grain is a seed that is designed to protect the embryonic plant from the rigours of the outside world until conditions are right for its germination and subsequent growth. A representation of the structure of the wheat grain is given in. The outer bran coat with its unique physical structure which folds the seed in on itself to form the characteristic crease protects the seed (Cauvain and Young, 2007).

2.2.4 Composition of wheat grain:

The composition of wheat varies quite widely, which is not unexpected in view of the many varieties that are grown and the very different conditions under which they are cultivated (Table 2). Bran consists of the pericarp, the testa, the nucellar layer and the aleurone layer. The components of bran are fiber (comprising hemicelluloses, b-glucans, cellulose and glucofructans,), minerals, enzymes, vitamins and globulin storage proteins. The embryo contains lipids, enzymes (lipases and lipoxygenase), vitamins and globulin storage proteins. The largest proportion of the wheat seed is the endosperm, which contains the nutrients necessary for germination (Edward, 2007).

Table: 2 *Composition of wheat (The ranges of data normally encountered for commercially traded wheats) are as follows:*

Component	Percentage %
Moisture	10.0-16.0
Protein	8.5-15.0
Fat	2.0-2.5
Fiber	2.0-2.5
Mineral matter	1.5-2.0
Sugars	2.0-3.0
Starch	63.0-71.0%

Source: Ranken *et al.,*(1997)

2.2.5 Grain attributes for specific market:

Grain attributes which determine its suitability for a specific market include its chemical, physical and biological properties. All sectors of the market have a basic requirement for sound grain free from impurities, insect damage and moulds. Other standards are more market specific and will vary in importance according to species and end product. For wheat these may include protein quality and quantity, endosperm texture, flour yield and color, water adsorption capacity, α-amylase activity and specific weight.

2.3 Baked products:

The term ‘baked products’ is applied to a wide range of food products, including breads, cakes, pastries, cookies and crackers and many other products, and it can be difficult to identify a common thread linking the members of such a diverse group (Cauvain and Young, 2006). Baked products are foods manufactured from recipes largely based on or containing significant quantities of wheat or other cereal flours which are blended with other ingredients, are formed into distinctive shapes and undergo a heat-processing step which involves the removal of moisture in an oven located in a bakery (Cauvain and Young, 2006). Making baked products, particularly bread, is one of the oldest human activities (Edward, 2007).

Some products that are similar to baked products are either fried or boiled instead. Strictly, these products are outside the scope (Edward, 2007). Baked products (Table 3) are made from milled wheat, rye and, to a lesser extent, other cereals by the addition of water, salt, a leavening agent and other ingredients (shortening, milk, sugar, eggs, etc.) (Belitz *et al.,* 2009).

Table 3: *Classification of baked products*

Bread including small baked products (rolls, buns)	Made entirely or mostly from cereal flours; moisture content on average 15%. Addition of sugar, milk and/or shortenings amounts to less than 10%. Small baked products differ from bread only by their size, form and weight.
Fine baked goods, including long term or extended shelf life products such as biscuits crackers, cookies etc.	Made of cereal flours with at least 10% shortening and/or sugar, as well as other added ingredients. In baked goods for long shelf life the moisture content is greatly reduced.

Source: Belitz (2009)

2.3.1 Traditional basis for classifying baked products:

Despite (or because of) its long history, baking still has strong and deep roots in the craft and still struggles to develop its scientific credibility. Until it truly graduates to being a science a common taxonomy remains impossible. Common English dictionary definitions for groups of baked products include:

• Bread – *n.* food made of flour or meal (and) baked
• Cake – *n.* baked, sweetened bread
• Biscuit – *n.* dry, small, thin variety of cake
• Pastry – *n.* article of food made chiefly of flour, fat and water.

All of the above definitions illustrate the difficulties associated with defining the various groups of baked products (Cauvain and Young, 2006).

2.4 Bread:

Bread is an important staple food in both developed and developing countries. Bread is made by baking a dough which has for its main ingredients wheaten flour, water, yeast and salt. Other ingredients which may be added include flours Of Other cereals fat, malt flour, soya flour, yeast foods, emulsifiers, milk and milk products, fruit, gluten (Kent and Evers, 1994). Wheat (*Triticum aestivum Desf.*) flour of both hard and soft wheat classes has been the major ingredient of leavened bread for many years because of its functional proteins (Abdelghafor *et al.*, 2011). Bread is a bakery product priced for its taste, aroma and texture (Malomo *et al.*, 2011). Bread is baked aerated dough, the primary ingredients of which are flour, salt and water. The aeration is normally obtained by fermentation with yeast but may be obtained by other means (Ranken *et al.,* 1997).

Bread has affected politics more recently in Russia and Eastern Europe. Former communist governments in these regions sometimes put a hold on bread prices, or even rolled them back, to keep their citizens from revolting (DiMuzio, 2010).

2.4.1 Definition of bread:

Bread is baked dough product made from cereal grains (mostly commonly wheat) ground into flour, moistened and kneaded into dough and then baked, Often leavened by the action of bakers yeasts or by addition of sodium bicarbonate (Merryweather *et al.,* 2005). Bread is produced by making dough from wheat flour and aerating this with carbon dioxide produced by yeast fermentation. The proportion of water in the dough mixture varies with the type of equipment used but is normally within the range 55-65% of the flour weight (Ranken *et al.,* 1997).

In wheat-producing countries or areas, baked yeast bread is a major staple in people's diet. This is common in the major developed countries. In other countries, other forms of bread may be the major staple.

The fact is that we can never form a concise definition of bread since it is characterized by all of the ingredients we use to make it, and more besides (Cauvain and Young, 2007).

2.4.2 Physical characteristics of bread:

Bread is characterized by a crust, a dry thin layer that encloses a soft, sponge-like cellular structure. The crust will usually have a light golden-brown color. In some bread products the color may be darker, as when whole meal (whole wheat), brown or non-wheat flours are used in its production. Rye breads, which are especially popular in Scandinavia, eastern and northern Europe, tend to produce darker crust colors. Many different factors affect crust color, which appears during baking because of the Maillard reaction (Cauvain and Young, 2006).

2.4.3 A Brief history of bread making:

Historical records have been found in ancient Egyptian tomb carvings dating from 3000 BC, which show fermented bread being made from wheat flour and baked in clay ovens (Brennan, 2006). The ancient Hebrews distinguished between the leavened and unleavened forms of bread. Even today the unleavened bread is reserved for certain ceremonial occasions. Bread quickly took its place in the psyche of humankind in the ancient world, and the technology spread rapidly wherever wheat and other cereal grains could be grown. Later, as wheat and other grains began to be imported and exported around the ancient world, the art of baking either spread with the grain or was discovered in different locations. No doubt three thousand years ago bakers were developing their own distinctive style of bread based on their cultural beliefs or just for the simple reason of wanting to be different from their competitors(Cauvain and Young, 2006).

References to bread and baking begin to appear in Greek literature from the seventh century BC. Wheat became so important that at one time its export from Greece was prohibited, and bread was such a staple and important food that its weight and price were fixed in law. The place of wheat and bread in religion remained pivotal and the Greeks built temples to the goddess Demeter, who has remained associated with agriculture since those ancient times. The importance of bread was not lost on successive Roman emperors either, and the goddess Ceres was high on the list of important gods. So important was the provision of bread to the Romans, that it is considered that much of the expansion of their empire was driven by the need to acquire control of more wheat-growing areas to feed her armies and growing homeland population. Indeed, it is claimed by some that the Roman invasion of the British Isles was mostly about acquiring control of the large wheat and barley growing areas that existed at that time (Cauvain and Young, 2006).

2.4.4 Bread types:

Baked bread may come in different forms such as regular yeast breads, flat breads, and specialty breads. Today, even retarded (chilled or frozen) doughs are available to meet consumers' preferences for a semblance of home-cooked food. For countries or areas with less available energy, other forms of bread such as steamed bread and boiled breads are available. Fried breads are consumed mainly as breakfast or snack items (Hui *et al.,* 2007). Many different bread types have been evolved with the passage of time and all require their own individual bubble structures, processing techniques, processing equipment and process control mechanisms. To the environmental and cultural differences which have influenced the type of bread which is predominant in a particular country has been added the consequences of the various waves of refugees and immigrants which have moved between countries (Cauvain and Young, 2007). The main bread types can be divided into four broad categories:

- ☑ Pan breads – that is, products based on placing a piece of dough in a metal pan for the proving and baking stages. Commonly the pan will be rectangular, though round pan shapes are known. Sometimes the pan may have a separate lid fitted to more tightly control product shape. Examples are the sandwich loaf (lidded), open-top pan breads, pan coburgs (round، unlidded), milk rolls (round, lidded) and malt loaves (baked under inverted pans.
- ☑ Free-standing breads – that is where the dough product is proved and baked without the aid of a pan to constrain and support the sides of the dough. This approach leads to a crustier product. Examples of this type of product include bloomers, cottage loaves and coburgs.

- ☑ Baguettes, pain Parisien and other products made as long, stick-shaped loaves. Sometimes placed on indented trays for proving and baking. Typically these products will have a high degree of crust formation and characteristic surface markings.
- ☑ Rolls and other small fermented breads baked on trays or indented pans. These products will have higher levels of sugar and fat in the recipe and so typically will have a sweeter flavor and softer eating character.

This movement of bread types between countries and cultures can pose problems for bakers. For example, the manufacture of French bread may be considered a challenge to bakers outside France. This is a challenge which can be overcome but does need an understanding of what makes French bread what it is.

2.4.5 The difference between bread and other baked products:

Bread is regarded as a staple food and as such attracts regulation of its composition and sometimes price. Biscuits, cakes, pastries and pies are regarded as discretionary purchases and avoid regulation. Bread production is an extremely competitive business while the production of other baked goods is not quite so competitive (Edward, 2007). Bread products are not highly flavored by comparison with other baked products and many other foods (Cauvain and Young, 2000). The character of bread and other fermented products then depends very heavily on the formation of a gluten network in the dough, not just for trapping gas from yeast fermentation but also to make a direct contribution to the formation of a cellular crumb structure which after baking confers texture and eating qualities quite different from other baked products (Cauvain and Young, 2007).

2.4.6 Bread baking process:

Baking is at heart a process: the conversion of some relatively unpalatable ingredients (starch, gluten, bran, in the case of most cereals) into the aerated, open cell sponge structure we know as bread has taken millennia to develop (Brennan, 2006). The bread making process are related to the ability of the dough to retain gas bubbles (air) and permit the uniform expansion of the dough piece under the influence of carbon dioxide gas from yeast fermentation during proof and baking. Bread is produced by making a dough from wheat flour and aerating this with carbon dioxide produced by yeast fermentation. The proportion of water in the dough mixture varies with the type of equipment used but is normally within the range 55-65% of the flour weight (Ranken *et al.,* 1997).

Each country has its own particular methods of baking, but in essence bread is made by simply mixing flour, water, yeast (and air) into a dough, allowing the yeast to ferment for some time to produce an expanding aerated foam and then setting the structure at high temperature in an oven to produce bread (Brennan, 2006).

2.4.7 The basic bread recipe:

Formulations for baked products will vary from country to country and from company to company. Many companies guard their formulations assiduously (Cauvain and Young, 2000). The basic bread recipe is the "lowest common denominator" of bread recipes—the simplest one possible (Table 4). It gives new bread makers a simple recipe to use and illustrates that all recipes are derived from the same place. There is no secret to them—they all have basically the same percentages of water, yeast, and salt, adjusted to account for the other ingredients (Buehler, 2006).

Table 4: *The basic bread recipe for a one kilogram (about two pound) loaf of bread*

	Percent	**Weight**
White flour	100%	0.580 kg
Water	70%	0.406 kg
Instant yeast	0.7%	0.004 kg
Salt	2%	0.012 kg
Total	172.7%	1 kg

Source: Buehler (2006)

2.4.7.1 Wheat flour:

Flour can be defined as the powder or particles that result from the crushing or milling of starchy seeds, grains, tubers, or legumes (DiMuzio, 2010). Flour is the primary product obtained from the milling of wheat by the gradual reduction system (Ranken *et al.,* 1997). Flour performs a number of functions in baked goods: It provides structure; it binds and absorbs; it affects keeping qualities; it affects flavor; it imparts nutritional value.

Wheat flour's ability to capture the gases from fermentation and thereby leaven bread is the reason it has become the preferred grain for bread making in so many cultures. In fact, today it's almost always a given that, when we refer to flour in a recipe, with no other descriptors, we're talking about flour made from wheat only (DiMuzio, 2010).

Many bread labels include "wheat flour" as an ingredient. Wheat flour is not the same as whole wheat flour. The names are similar, but the flours are different. Whole wheat flour is a whole grain, milled from the whole wheat kernel. Wheat flour is another name for white flour, milled from the endosperm. It is called wheat flour to distinguish it from rye flour, corn flour, oat flour, or rice flour. This is a helpful distinction for those with allergies to wheat products, but it can mislead consumers into thinking that wheat flour contains all the health benefits of whole wheat flour (Figoni, 2008).

In the Stone Age, flour that came from grains crushed by hand using rocks would have been quite coarse and mealy. Ancient Egyptians used stones that were chiseled and shaped purposely for milling to enable them to produce flour that was much finer in consistency. For approximately the next 6,000 years, this was the basic method used to mill flour (DiMuzio, 2010).

Wheat flour is used for bread making as a result of the viscoelastic properties of the dough when water is added. There are two principal types of wheat flour: whole meal and white. In the case of whole meal flour, the whole of the wheat grain is crushed to yield flour. Wheat flour's ability to capture the gases from fermentation and thereby leaven bread is the reason it has become the preferred grain for bread making in so many cultures (DiMuzio, 2010).

In general the higher the protein content in the wheat the higher the protein content of the flours produced from it. The higher the protein content of flour the better is its ability to trap carbon dioxide gas and the larger can be the bread volume (Owens, 2001).

2.4.7.1.1 The wheat flour milling process:

The object of this milling process is to separate, as cleanly as possible, the endosperm of the grain from the enveloping skins and embryo. How effectively this separation can be performed in a given mill is a measure of its efficiency (Ranken *et al.,* 1997). The term 'coarse grains milling' is a very broad one that refers to the combination of the berries of the wheat, barley and other coarse grain crops. This is the definition of milling as interpreted by an engineer or process manager. However, a cereal chemist or quality assurance manager might interpret the term milling as the transformation of raw material into a primary product for secondary processing. This definition encompasses every aspect of the transformation, from raw material purchasing to quality assurance and product testing (Owens, 2001). During milling of wheat to produce sifted white flour, about 30% of the wheat kernel is removed (70% extraction rate) (Hamaker, 2008).

Milling methods and mixing technology didn't change significantly for several millennia, but by the early twentieth century, bakers began to consider the possibility of incorporating more advanced milling and mixing methods into their production (DiMuzio, 2010). The cultivation of wheat for bread making has played a key role in the development of modern civilization. The object of the milling process is to remove the endosperm from the wheat grain with the minimum contamination of bran powder and germ (Ranken *et al.,* 1997).

2.4.7.1.2 Why we do mill wheat grain:

Because bakers demand flours that meet stricter specifications. The procedure for getting from whole grain to white powder has become more technical and controlled. Initially, turning grain into flour, or milling it, was done solely to create a meal or powder that more readily absorbed water (DiMuzio, 2010).

2.4.7.1.3 Flour composition:

The specific composition of flour is critically important because it has a major influence on the fermentation as well as the physical structure of the dough and finished bread. In the case of wholemeal flour, the whole of the wheat grain is crushed to yield flour (Table 5). White flour is the ultimate product of flour milling. The aim of white flour milling is to extract a maximum amount of endosperm from the wheat berry in as pure a form as possible (Owens, 2001).

Table 5: *General composition of wholemeal and white flour:*

Flour component (%)	Wholemeal	White
Moisture	13.0–14.0	13.0–14.5
Starch and other carbohydrates	67.0–73.0	71.0–78.0
Protein	10.0–15.0	8.0–13.0
Lipid	~2.0	1.0–1.5
Crude fibre	~2.0	~2.0

Source: Cauvain and Young (2006)

2.4.7.1.3.1 Protein:

The protein content of wheat grain varies widely, but for bread making a value of at least 11% is required. In practice high grain protein levels are achieved through the application of nitrogen fertilizer above the optimum for yield (Owens, 2001). Higher-protein wheat is generally considered suitable for flour to be made into bread and bagels by the retail baking industry. Lower-protein varieties are usually considered appropriate for cakes, pastry, cookies, and crackers. The protein level of wheat and its potential gluten levels in flour are certainly related, but they are not precisely the same thing (DiMuzio, 2010). Protein quality is strongly influenced by genotype, although husbandry and environmental factors can also play an important role (Owens, 2001). Wheat proteins were clearly defined by Osborne

(1924) and his broad classification still remains in use today. Of the four main types of protein defined by Osborne, two have attracted greatest interest – the prolamins (gliadins) and the glutelins (glutenins) – because they comprise the gluten-forming proteins so essential in baking. Gluten encloses the gas-containing pores in the dough and is thus responsible for the gas retention capacity of the dough and therefore for the volume of the baked good. The quality of the gluten dictates how much gas is retained in the dough (Wassermann, 2009). The other proteins that are present are the albumins and the globulins. The main wheat proteins of interest in baking are classically divided into two fractions, referred to as gliadins and glutenins and both contribute to flour quality and dough rheological properties. Variations in the ratio of gliadins to glutenins arise largely from wheat genetics and are therefore quite specific to an individual wheat variety. Inevitably, such differences are carried through to the flour milled from the wheat and thus contribute greatly to the bread making potential of the material. The glutenins are largely responsible for the elastic properties of gluten once it is formed in wheat flour. The molecular basis of wheat proteins and the formation of gluten in dough are complex. Recent work has shown that the glutenin may be divided into high-molecular weight (HMW) and low-molecular-weight (LMW) sub-units.

High-protein flours that develop strong gluten networks require longer fermentation times than those with lower proteins (Cauvain and Young, 2000).

2.4.7.1.3.2 Carbohydrates:

The composition of wheat flour is dominated by the carbohydrate known as starch. The starch is contained within the cells of the endosperm, which is located inside the outer bran skins of the grain. The individual starch granules are enveloped in a protein matrix and provide a food source for the grains when germination starts. In the manufacture of bread, the function of starch is mostly concerned with the absorption of water, which leads to swelling as the temperature rises, particularly during baking. The ability of the starch granules to absorb water is limited, but is increased during the milling process that converts the wheat grains to flour (Cauvain and Young, 2000). The contribution of starch is related to its three important properties: water absorption, gelatinization, and retrogradation (Cui, 2005). During the milling process, a proportion of the starch granules are physically damaged and this increases their ability to absorb water five-fold (Cauvain and Young, 2000). High levels of starch damage in white flours can lead to the loss of bread volume (Cauvain and Young, 2000). The damaged starch will absorb a greater amount of liquid during dough preparation and can be attacked by amylases (Wassermann, 2009).

Starch comprises two polymers – amylase and amylopectin. The former is essentially a linear polymer, apparently amorphous, while the latter has a branched structure. Much of the soft crumb of freshly baked bread is from gelatinized starch. As with protein structure, however, too much starch produces toughness and dryness (Figoni, 2008).

2.4.7.1.3.3 Fiber:

Cereals also contain polysaccharides other than starch. In endosperm cells their content is much less than that of starch. They include pentosans, cellulose, β-glucans and glucofructans. These polysaccharides are primarily constituents of cell walls, and are more abundant in the outer portions than the inner portions of the kernel, from a nutritional and physiological viewpoint, soluble and insoluble polysaccharides other than starch and lignin are also called dietary fiber (DiMuzio, 2010). A significant impact of fiber is to reduce dough gas retention and thus bread volume. As the level of fiber increases so does the adverse effect on bread volume. The volume loss may be overcome with recipe adjustment to augment the gas retention properties of the dough. The impact of particle size is similar to wheat bran, namely that fine particles tend to have a greater impact on the loss of bread volume than coarse ones (Wassermann, 2009). The addition of fibers also has an impact on the mouth-feel and, to a lesser extent, the flavor of baked products, but such changes are usually considered more acceptable. Fibrous materials from sources other than wheat may be added to baked-product recipes in order to confer particular nutritional or sensory properties (Cauvain and Young, 2006).

Flour also contains water-insoluble hemicelluloses originating from the walls of the grain cell. By adding xylanase these materials can be converted into soluble, gum like substances which bind water resulting in an increase in dough strength as well as improved dough processability. The risk of dough sticking to machine parts and causing production problems can be minimized in this way. The absorbed water migrates into the starch during the baking process causing a decrease in viscosity and resulting in an improved oven spring and higher volume for the baked goods (Wassermann, 2009).

2.4.7.1.3.4 Fats:

Fats are esters of fatty acids and glycerol, which commonly form triglycerides in which three fatty acids are attached to the glycerol molecule. The variation in fat chemistry has a profound effect on its physical form.

The outer portions of wheat grain contain considerably are oil than the rest, so that the whitest flours contain the least (about 1 percent). The germ is quite plastic owing to its high oil content and is easily flattened into a single plug on the first couple of passes. It is usually removed by the third break roll (despite its high nutritive content of lipids or fats) because it easily becomes rancid and will cause spoilage in the resulting flours (Amendola and Rees, 2003).

Cereal- and pulse-based diets of the third world generally tend to be considerably lower in both total fat, saturated fat and cholesterol than the meat-based diets of western countries (Cordain, 1999).

2.4.7.1.3.5 Mineral content/ ash:

Minerals are the inorganic substances present in wheat that are derived from the soil. Wheat flour contains anywhere from 1 to 2 percent minerals. Ash content is affected by the soil itself, rainfall, type and amount of fertilizer, and so on. Once again, during milling most of the wheat kernel that contains significant proportions of minerals is removed with the bran and germ. The minerals that remain in white flour are actually in excess of what minerals occur in the endosperm. Thus, the ash content of the flour is directly related to the amount of bran particles in the flour (Amendola, and Rees, 2003).

2.4.7.1.4 Different flours for different requirements:

Not every flour is going to do the same job well, so over the years "flour" has become many, many "flours." Pastry chefs today are presented with a bewildering array of flours tailored to meet specific requirements in different products. The big variable at the heart of this proliferation is protein content (and quality) and its consequences for gluten development. Modern milling practices can further modify the inherent ability of a specific wheat through choices in blending, milling, and processing (Amendola, and Rees, 2003).

There are two principal types of wheat flour are whole meal and white (Cauvain and Young, 2000). Flour of course is the main ingredient in baked goods. Flour is normally supplied to meet a specification. In some cases the specification is very wide or it is very tight. Some specifications ensure that the flour is fit for making a specific product, e.g. bread. The description of flour types required for baked products varies and can be confusing (Cauvain and Young, 2006).

2.4.7.1.4.1 Bread flour:

Bread flour is milled from either hard red spring or hard red winter wheat. It is high in protein—typically 11.5–13.5 percent proteins that forms good-quality gluten, essential for high volume and fine crumb in yeast-raised baked goods. Because it is from hard wheat kernels, bread flour is more difficult for the miller to grind into flour. This is why bread flour is coarser in texture than pastry flour, and why it contains a higher percentage of broken and fragmented starch granules. These damaged starch granules absorb more water than intact granules, which is generally considered desirable in bread-making. Damaged granules are also more susceptible than intact ones to breakdown by amylase, making more sugar available to yeast for fermenting into carbon dioxide gas and alcohol. Bread flour can be purchased unbleached or bleached. Sometimes it contains added malted barley flour to provide for better yeast fermentation, dough handling, and shelf life. Bread flour is typically used for pan breads, rolls, croissants, and sweet yeast doughs. The circle graph in (Figure 2) illustrates the major components in flour and the relative amounts of each in typical bread flour (Figoni, 2008).

Flour quality should be judged by its intended use. Often, however, certain flours, typically those high in gluten-forming proteins, are described as high quality. While bread bakers rightfully describe flour as high quality when it forms strong, cohesive gluten, this does not mean that so-called high-quality flour is best for all baked goods, or even for all breads (Figoni, 2008).

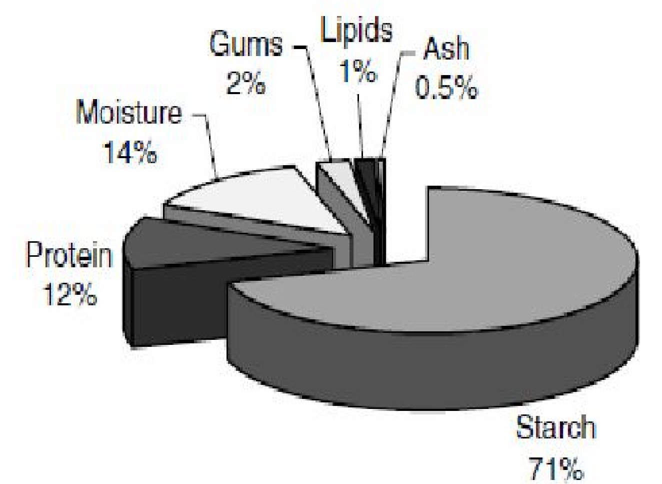

Figure 2: The makeup of bread flour.
Source: Figoni (2008).

Bread making flour in the UK is milled from selected home grown wheats alone or blends containing a proportion of strong wheat from North America, and has a protein content of 10.5-12.5% (Ranken *et al.,* 1997). In general, an increase in the protein content leads to an increase in the gas-retention properties of the dough and therefore an increase in bread volume. The extent to which the product volume will increase depends on a number of recipe and process factors. It also depends on the ability of the wheat proteins to form a gluten network with the appropriate rheological properties. Such properties are strongly influenced by protein-quality attributes, which are notoriously difficult to define measure and, to some extent, standardize. As a general rule, wheat flours with higher protein contents have more appropriate protein qualities than those with lower protein contents and are therefore better suited to bread making (Cauvain and Young, 2000).

Wheat for different purposes may be selected according to protein content. Hard wheat with 11.5–14.0% protein is desirable for white bread and some whole wheat breads require even higher protein levels, 14–16%. In contrast, soft or weak flours with lower protein contents are suited to chemically leavened products with a lighter or tenderer structure. Hence protein levels of 8–11% are adequate for biscuits, cakes, pastry, noodles and similar products. Varieties of wheat for processing are selected on this basis; and measurement of protein content would be a good guide to process suitability (Table 6) (Brennan, 2006).

Table 6: *Flour types used in the manufacture of baked products.*

Flour type	Protein content range (%) (based on 14% moisture)	Special features and other specified properties
CBP	10.0–12.0	Starch damage, Hagberg Falling Number, color
Bakers' grade	11.5–12.5	Starch damage, Hagberg
Bread	12.0–13.5	Starch damage, Hagberg Falling Number, color, gluten strength
Strong	12.5–13.5	Starch damage, Hagberg Falling Number, color, gluten strength
Medium	11.0–12.0	Limited gluten strength
Soft	10.0–11.0	Made from softer milling wheats
Weak	9.0-10.0	Made from softer milling wheats with poor gluten-forming properties
Biscuit	9.5–10.5	Low resistance high extensibility gluten often specified
Whole meal	12.0–14.0	Bran particle size may be specified
Cake	8.0–10.0	Particle size often specified. May be treated with chlorine gas.
Cake–heat treated	8.0–10.0	Particle size often specified

Source: Cauvain and Young (2006)

2.4.7.1.4.1.1 Grades of bread flour:

According to (Ranken *et al.,* 1997) the term flour extraction rate is used to denote the proportion of flour obtained from wheat during the milling process. Most millers supply a range of flours to bakers. Some millers specialize in producing niche products. A typical range of bread flours would look as follows:

2.4.7.1.4.1.1.1 Top grade:

This would have a substantial proportion of Canadian wheat and would be suitable for any long process. It can be used to make ordinary bread but is more likely to be used to make Viennas or rolls. The protein content could be as high as 14% with water absorption of 62–64%. This product would have a high tolerance in the bakery. One use would be with a suitable improver to produce very well blown up rolls.

2.4.7.1.4.1.1.2 Baker's extra grade:

This grade has less imported wheat and lower protein content than the top grade but more than the baker's grade. The protein content might be 13%.

2.4.7.1.4.1.1.3 Baker's grade:

This is the standard grade used by small bakers to make bread. There will be sufficient third country wheat, probably Canadian, for it to work in a long process such as bulk fermentation. The protein content would be around 12%.

2.4.7.1.4.1.1.4 Euro baker's grade:

This product is really a creature of the EU's Common Agricultural Policy (CAP). It would be a baker's flour similar to the standard baker's Raw Materials grade but without any non-EU wheat. As it would match the protein content of baker's grade, dried vital wheat gluten would be used to make up the protein content. This product would only be suitable for quick processes like the spiral mixer. Not all millers would produce this grade. Changes to the CAP may destroy the commercial viability of this product.

2.4.7.2 Common salt (sodium chloride):

Common salt, or simply salt, refers to sodium chloride which is a white, crystalline product, consisting of the elements sodium and chlorine and has the chemical formula NaCl (Hashmi, 1996). Salt is used for a variety of purposes in the manufacture of baked products. First and foremost it makes a major contribution to product flavor. It is also important, because of its ionic nature, in the control of product water activity and therefore mould-free shelf-life, in the manufacture of fermented products, salt limits the activity of yeast in dough and so recipes should be balanced to take this into account. The lower the level of salt in the dough the lower the yeast level will be to maintain a given proof time. There is also some impact of salt on gluten formation in the dough-making stage (Cauvain and Young, 2000).

Salt levels vary in fermented products according to local tastes. Too little salt and the bread taste insipid, too much and it tastes too salty. The more salt we use in a given recipe the more yeast will be needed to achieve a given proof time (Owens, 2001). The quantity used is usually 1.8-2.1 % on flour wt, giving a concentration of 1.1-1.4 % of salt in the bread. Salt is added as an aqueous solution (brine) or as the dry solid (Kent and Evers, 1994).

2.4.7.3 Yeast (*Saccharomyces cerevisiae*):

Yeasts are fungi that grow vegetatively as single-celled organisms; the distinction between yeasts and other fungi is sometimes murky; fungi such as rusts and smuts grow as single cells during part of their life cycle and as typical mold-like mycelia during other parts.

All yeasts grow vegetatively by budding or by binary fission. *Ascomycetous* yeasts are distinguished by the fact that during sexual reproduction spores are produced inside a specialized structure known as an *ascus*, whereas *basidiomycetous* yeasts produce external spores on a structure known as a *basidium*. Although a yeast lifestyle has been adopted by members of three of the four the major fungal groupings (*Basidiomycetes, Ascomycetes*, and *Fungi imperfect*, but not *Phycomycetes*), most yeasts of interest to the baking industry are biologically members of the *Ascomycetous* genus *Saccharomyces*. However, because fungal taxonomy relies on the identification of reproductive structures, yeasts that have lost the capacity for sexual reproduction are automatically classified among the *Fungi imperfecti*. In 1983, *Saccharomyces minor* and *Saccharomyces cerevisiae* were found by Kazanskaya *et al*. in spontaneous sourdoughs from Russian bakeries (Kulp and Lorenz, 2003).

Baker's yeast, *Saccharomyces cerevisiae*, is used to produce carbon dioxide in the manufacture of bread, rolls and other fermented products. Instant dry yeast combines the ease of use of fresh yeast with the convenient storage of active dry yeast. There is no need to dissolve it first in warm water; in fact, the manufacturer prefers that you mix it first with the flour before adding any liquids (DiMuzio, 2010). *Saccharomyces cerevisiae* hydrolyzes maltotriose, although trisaccharides are fermented to a lesser extent. The yeast does not ferment malto-oligosaccharides with degree of polymerization (DP) 4 to 8, nor did the presence of glucose stimulate their fermentation, probably due to a lack of the appropriate transport system for these oligosaccharides (Kulp and Lorenz, 2003). It acts on simple sugars to produce both carbon dioxide and alcohol; the alcohol is driven off during baking and so is of limited relevance to baked products. The carbon dioxide is an important part of the expansion of baked products and contributes significantly to changes in texture and eating quality (Wassermann, 2009).

There is no rule of thumb for how much yeast to use, since that is determined by the length of fermentation time desired (for development of complex flavors) and whether lots of sugar and fat are in the dough (Amendola and Rees, 2003).The higher level of yeast presents in the recipe, the faster the rate at which carbon dioxide will be produced. The reaction is very temperature sensitive and increases as the temperature rises to 40–43°C. Thereafter, the rate of evolution of carbon dioxide falls until the yeast is inactivated at 55°C. This temperature profile is critical in the manufacture of bread and fermented products (Wassermann, 2009).

Too much sugar will damage yeast by an osmotic dehydration mechanism. This is why volume expansion is always a problem for sweet bread bun. Similarly, salt can inhibit yeast growth, and too much salt will slow down the proving process (Hui *et al.,* 2007).

Baker's yeast is marketed in different forms, i.e., compressed yeast (CY), cream yeast (CmY), and instant yeast (IADY). The chemical parameters describing these products are moisture, protein, and phosphorus. Using the strain typified as no. 7752 of the American Type Culture Collection for ADY, it is reported that higher yields of yeast on a sugar basis are achieved, but these are lower in proteins and phosphorus than the CY. However, they generate less carbon dioxide, indicating a lower activity than that in CY which needs to be compensated for by a higher level of yeast solids in order to achieve an equivalent leavening power in bread fermentations (Kulp and Lorenz, 2003). Active dry yeast was created to help solve the storage and shelf life limitations of fresh yeast. By surrounding live, active cells with dead cells and removing most of their moisture, yeast manufacturers were able to provide a reliable source of yeast activity that could be kept in sealed packages for a year or more after manufacture. Another possible plus is that the dead yeast cells in the product produce a type of protein called glutathione, which can act as a natural relaxer in bread dough that is otherwise too tight and inextensible (DiMuzio, 2010).

Bakers' yeast (*S. cerevisiae*) has a facultative metabolism, meaning that it can use glucose by either aerobic (i.e., via the tricarboxylic acid or TCA cycle) or anaerobic pathways the former pathway yields much more cell mass and more ATP per glucose than the anaerobic pathway (Hutkins, 2006). Maximum fermentation rates for commercial baker's yeasts range from 0.3 to 0.7 g carbohydrate consumed per gram yeast solids per hour.This rate is reached only gradually. Yeast fresh from the manufacturer is in a resting state and requires time to revive and adjust to its new environment. The time required depends primarily on fermentation temperature and ranges from 30 min at 107^0F to 150 min at 84^0 F. Thus, a baker's yeast added to dough will not reach maximal activity until well after the dough is mixed (Kulp and Lorenz, 2003).

Yeast cells possess a variety of transport enzymes to bring sugars from the environment into the cell where they can be metabolized. The monosaccharides glucose and fructose, molecules consisting of a single sugar unit, can be used directly, whereas the disaccharides sucrose (glucose plus fructose) and maltose (glucose plus glucose) must be broken down to their component monosaccharides before they are metabolized. Glucosesensing molecules (receptors) in the cell membrane monitor the presence of glucose and signal the cell to synthesize hexose transporters and begin importing glucose for energy production. The sensor molecules themselves, though closely related to transporters, are specialized for signaling and do not transport glucose themselves. Glucose and maltose are naturally present in flour, and additional amounts are released by the action of flour and bacterial amylases on broken or damaged starch granules. Sucrose or fructose may be added by the baker as table sugar or syrup (Kulp and Lorenz, 2003).

Baker's yeasts in general are capable of utilizing a variety of sugars present in flour: glucose, fructose, mannose, maltose, and sucrose. On the other hand, they do not utilize the pentoses xylose or arabinose, and consume raffinose only partially (Kulp and Lorenz, 2003).

2.4.7.4 Water:

Water is a critical component in carbohydrate systems because it interacts with all components of the bread. It facilitates intra- and inter-molecular association of the protein, solvates small molecules such as sugar and salt, and is a key component in the transformation of starch crystalline structure to amorphous. As a result, many of the dough‘s physicochemical properties are related to the amount and state of water (Crockett, 2009).

Chemically, water is the simplest ingredient used in baking (two atoms of hydrogen and one of oxygen), but because of its special properties it plays many significant roles in baking, final product quality and product shelf-life (Cauvain and Young, 2000). Water is present in many ingredients that are used in baking, such as liquid egg, or it may be added as a separate ingredient. It has key roles associated with the solubilising and dispersion of ingredients during the mixing process and in the formation of complexes such as gluten in bread and fermented doughs. In the final product, the water (moisture) content makes major contributions to eating quality and shelf-life. The level of water used in a given product recipe needs to be optimized in order to achieve the required handling properties of the intermediate (dough, batter, paste) and final product character. In the case of bread dough, optimum water levels are associated with the ability to handle the dough during processing and the actual levels used should be as high as possible while remaining consistent with processing requirements. The temptation to reduce added water levels in bread dough should be avoided, because of the contribution it makes to dough development. Often, the stickiness that bakers associate with too much water comes instead from under-development of the dough: that is, the dough has not achieved its full potential. Improvements in the underlying dough development often allow an increase in added water levels (Cauvain and Young, 2000).

2.4.7.5 Optional ingredients:

The bread making quality of freshly milled white flour improves with age due to the action of atmospheric oxygen; the gluten is rendered more stable and stronger and also more elastic. At one time millers never despatched flour to a baker until it had been stored for several weeks and thus had undergone this natural 'ageing'. Natural aging has a few disadvantages. First, it requires time, often several weeks or months. During this time, the four takes up valuable silo space and is not paying the bills (Figoni, 2008).

Millers often add small amounts of additives to flour. Some of these additives are also available to bakers for mixing directly into dough. The types and amounts of additives that are allowed are strictly regulated by government agencies (Figoni, 2008). By law, millers must label flour with the additives it contains. There are several different types of flour additives. Some improve the nutrient content of flour and are required by law. Others improve dough handling or baking properties, or whiten the color of flour. A few of the main flour additives are described in the following (Figoni, 2008).

2.4.7.5.1 Sugar:

Similarly to fat, sugar also functions to reduce dough viscosity and relaxation time, as well as to delay the effect of chemical leavening agents during baking. Moreover, sugar could increase the temperature of the starch phase transition. To reduce the sugar content in bakery products, sugar replacers might be used. Sucrose confers sweetness and color to baked products, but also has a key function in structure formation. In particular, the concentration of sucrose solution in a recipe has a significant effect on the gelatinization characteristics of wheat and other starches – the higher the sucrose concentration, the more significant the delay in the gelatinization temperature of the starch (Cauvain and Young, 2000).

2.4.7.5.2 Ascorbic acid:

Ascorbic acid has a number of uses in the manufacture of baked products, but by far its main use is as an oxidizing agent in the production of bread and fermented products. In the strict chemical sense, ascorbic acid is a reducing agent and sometimes described as an anti-oxidant, in the breadmaking process, the availability of oxygen allows for its conversion to dehydroascorbic acid, which then acts as an oxidizing agent and plays an essential part in the development of gluten in modern bread making processes. Ascorbic acid may be used at low levels of addition (<50 ppm flour weight) in the manufacture of laminated products to increase their lift. The list of other oxidizing agents permitted for breadmaking is quite small. Commonly, in many parts of the world, ascorbic acid is the only one, but the use of potassium bromate, azodicarbonamide and calcium peroxide as bread improvers is retained in the USA and some other countries. While several bromate replacers are available, ascorbic acid is one of the most popular (Figoni, 2008).

2.4.7.5.3 Alpha-amylases:

The source of amylase—more specifically called alpha-amylase—added by the miller makes a surprising difference in the quality of baked bread. This is because not all amylase is alike. Different amylase enzymes are inactivated at different oven temperatures. Since amylase can have its greatest activity on bread dough during baking, its heat stability is extremely important. Fungal amylase, for example, typically is inactivated before starch granules gelatinize, which is when the granules are most susceptible to its action (Figoni, 2008).

Saccharomyces cerevisiae lacks a-amylases, but in dough systems, flour and/or exogenous amylases split starch molecules into fermentable sugars and malto-oligosaccharides (Kulp and Lorenz, 2003). Flour naturally contains small amounts of enzymes called amylases and diastases that can break down starch into simple sugars needed by yeast (Amendola, and Rees, 2003). Amylase —also known as diastase—breaks down starches into sugars and other molecules. A certain amount of starch breakdown is desirable because this softens bread and keeps it from becoming stale too quickly (Figoni, 2008).

2.4.7.5.4 Emulsifiers:

Many different emulsifiers provide a wide range of functions in baked goods .In all cases, emulsifiers function by interacting with other ingredients. For example, emulsifiers interact with fats and oil droplets, helping to disperse them more evenly throughout batters and dough (Figoni, 2008). The addition of fat or emulsifiers directly aids the incorporation of air bubbles into the dough, or if they do then their contribution is small by comparison with that of the gluten network. However, fats and emulsifiers certainly do play a role in the stabilization of the air bubbles once they have been incorporated into bread dough and during subsequent processing (Cauvain and Young, 2001).

2.4.7.5.5 Hydrocolloids:

Food gums/hydrocolloids are often the determinants of texture, other quality attributes, stability, and applicable processing methods, even when naturally occurring and not added as ingredients. Often gum/hydrocolloid producers reduce the average molecular weights of their products in order to have available different viscosity grades; such depolymerization increases the polydispersity. Additional analytical difficulties result from the generally low concentrations (0.01 to 1%), the range of use levels in foods, and the increased use of blends of gums to extend functionalities.These factors complicate determination of the types and amounts of polysaccharides in a food product (Eliasson *et al.*, 2006).

2.4.8 Methods of bread production:

The manufacture of all baked products is based on complex interactions between ingredients, formulation and processing methodologies and capabilities – change one aspect of the relationship and the nature of the interaction changes, resulting in one or more changes in product quality. The processing methodologies used in the manufacture of baked products today are the result of many years of, mainly, trial and error research (Cauvain and Young, 2000). Generally, the production of bread and bakery products consists of several common steps, including:

1) Prepare basic and optional ingredients.
2) Prepare yeast or sourdough for inoculation.
3) Mix proper ingredients to make dough.
4) Ferment.
5) Re-mix dough (optional).
6) Sheet.
7) Mold and pan.
8) Proof in a temperature- and relative-humidity-controlled chamber.
9) Decoratively cut the dough surface (optional).
10) Bake, steam, fry, or boil.
11) Cool.
12) Pack.
13) Store.

Each step plays an important role in achieving high and consistent product quality (Hui *et al.,* 2007).

2.4.9 The steps of baking process:

The baking process can be divided into three main processes: mixing, fermentation (or proof), and baking according to (Brennan, 2006).

2.4.9.1 Mixing:

Mixing can be done either by hand or by machine (Edward, 2007). The first significant process in the manufacture of any baked product is the blending together of the ingredients used in the recipe. Mixing of bread dough has three main functions:

(a) To blend and hydrate the dough ingredients.

(b) To develop the dough and.

(c) To incorporate air into the dough.

In the production of doughs, the nature of the mixing action develops the viscoelastic properties of gluten and also incorporates air, which has a major effect on their rheology and texture (Brennan, 2006). There is an intimate relationship between mixing, aeration and rheology, the design and operation of the mixer develops texture, aeration and rheology to different extents; and conversely the rheology of the food affects the time and energy input required to achieve optimal development. This is seen in the great variety of mixers used in the baking industry, where certain mixers are required to produce a desired texture or rheology in the bread (Brennan, 2006). The most common way to increase energy transfer during mixing is to increase mixing time. However, this does not change the rate at which energy is transferred and only applies until the resistance of the dough decreases as its temperature rises above 35°C or so (Cauvain and Young, 2000). Optimum work input or mixing time has been related to optimum bread making performance, which varies depending on mixer type, flour composition and ingredients (Brennan, 2006).

The strong relationship between mixing and handling and baking properties has resulted in a large number of commercial force-recording dough mixers, such as the Farinograph and Mixograph, which are used to determine the optimum in mixing speed and energy. Mixing doughs by elongational flow in sheeting to achieve optimum development requires only 10–15% of the energy normally used in conventional high-speed shear mixers, suggesting that much higher rates of work input can be achieved due to the enhanced strain hardening of doughs under extension (Brennan, 2006).

First add water. Then add the flour. Add the yeast on top of the flour and swirl to disperse it into the flour. Use your hand or a spoon to mix the poolish, squashing any flour lumps. At first you will feel stringy flour globs throughout the mixture. When these are gone, you will find smaller lumps to squash. Mix until there is no dry flour left (Buehler, 2006).

In the case of such products, the end of mixing was defined as being that moment during mixing at which the dough mass reached 40–42°C, if sodium metabisulphite (SMS) was present as a reducing agent, and 44–46°C if SMS was not present. This approach to defining the end point of mixing has largely been confined to this one area of baking (Cauvain and Young, 2000).

Mixing beyond the optimum (overmixing) is thought to damage the dough, causing the gluten network to break down, resulting in more fragile bubble walls and less gas retention and lower baking volume, Over mixing can also result in sticky, difficult to handle doughs which causes production problems (Brennan, 2006).

2.4.9.2 Fermentation (Proof):

Fermentation, or proof, is the critical step in the bread making process, where the expansion of air bubbles previously incorporated during mixing provides the characteristic aerated structure of bread, which is central to its appeal (Brennan, 2006). Fermentation involves allowing yeast in dough to convert sugars into carbon dioxide. It typically occurs in two separate stages—bulk fermentation and final proofing and can take several hours to complete (Figoni, 2008). The yeast used in bakery products is *Saccharomyces cerevisiae*. Various yeast strains have been developed to have different tolerances to osmotic dehydration and therefore suit different types of bread (Hui *et al.,* 2007). During proof, the gas content within the dough increases from around 4–8% to approximately 80%. The growth and stability of the gas bubbles during proof determine the ultimate expansion of the dough and its final baked texture and volume (Brennan, 2006). In the initial stages of bread-making, the CO_2 produced stays in solution until the water phase becomes saturated. At this point, all further CO_2 diffuses into the existing gas cells produced during mixing (Rosa and Péter, 2006). Dough is normally proved at 38^0 C, as yeast is most active within the temperature range of 25–40^0C. Proving time is dependent on the yeast level, proving temperature, and humidity. Increasing the yeast level is likely to speed up the proving process (Hui *et al.,* 2007).

The fermentation conditions should be controlled in order to get optimum and consistent results. The precise length of fermentation time depends on a number of factors, including the level of yeast and salt in the recipe and the temperature at which the fermentation is carried out. There is a close relationship between flour strength and the length of fermentation time. High-protein flours that develop strong gluten networks require longer fermentation times than those with lower proteins (Cauvain and Young, 2000). When the dough enters the prover, it will be at a temperature of 28 to 30ºC. Bakers' yeast is at its most active at 35 to 40º C and so running the prover around 40ºC minimizes the time required for proof. It is important that the skin of the dough remains flexible so that it does not tear as it expands. Since the dough relative humidity is around 90–95% a moist atmosphere is required to maintain that skin flexibility (Owens, 2001).

2.4.9.3 Dividing/scaling/depositing:

After mixing the bulk dough is divided to generate the shape and size of product required (Owens, 2001). On the commercial scale no baked products are mixed to deliver a single unit size. This means that in practice the large bulk of the mix must be divided into smaller units for further processing. The main aim of all dividing/scaling/depositing processes is to deliver the unit size product for further processing without significant change in the intrinsic properties of the matrix concerned. The dividing process is commonly achieved by filling a chamber of known dimensions with a dough, batter or paste of known and fixed density. This relationship between chamber volume and matrix density is important, because most bakery products need to be manufactured to a given weight. In some cases this is for legal weight-control reasons while in others it is so that variations between individual products will be limited (Cauvain and Young, 2000).

2.4.9.4 Forming/moulding/shaping:

After the bulk of material from the mixer has been divided into unit sized pieces, it is common for the individual pieces to undergo some change in form or shape to fit the particular product concept (Cauvain and Young, 2000). The most common shaping is by rounding, an action which mimics that carried out by hand in the craft bakery. The action of mechanical first moulding places the dough under stress and strain which may lead to damage to the existing gas bubble structure in the dough (Owens, 2001).

The shaping of a dough piece in bread manufacture is typically a two-stage process, often separated by a short rest. It is not unusual for the dough piece to be moulded first into a round ball shape and later into some form of cylinder. There may be a short rest period, known as first or intermediate proof, between the two moulding stages. In both moulding stages the rheological properties of the dough are very important in deciding the final product quality (Cauvain and Young, 2000). During rounding the dough piece is rotated on its axis between the two inner surfaces of a V- or U-shaped trough, where one side is driven and the other fixed or moving at a lower speed. The dough piece quickly forms the shape of the trough as it moves under the force of the driven side. The key functions of the final moulder are to shape the dough to fit the product concept and to re-orientate the cell structure (Owens, 2001).

It is especially important that the relatively delicate bubble structure in the dough piece is not damaged during moulding otherwise loss of quality may occur. Damage to the gluten membrane that separates the gas bubbles allows them to coalesce more readily before baking and can lead to the formation of large holes and discolored, firm-eating patches in the crumb (Cauvain and Young, 2000).

2.4.9.5 Expansion and relaxation:

In many cases, usually bread dough and pastes, the passage of baked products from mixer to oven is interrupted by a stage of limited activity. A common aim of this interruption is to modify the rheological properties of the material to prepare it for baking and to obtain improved product quality. In the manufacture of bread, the moulded dough pieces are transferred to a warm and moist environment in which the yeast continues to produce carbon dioxide gas and inflate the nitrogen gas-bubble nuclei. Provided the gas is retained in the dough, it will expand and may more than double its original size in a defined time period. The process employed is commonly referred to as proof (Cauvain and Young, 2000).

The limit of expansion of these bubbles is related directly to their stability, due to retardation of coalescence and loss of gas when the bubbles fail. The rheological properties of the expanding bubble walls are therefore important in maintaining stability in the bubble wall and promoting gas retention (Brennan, 2006).

2.4.9.6 Baking:

Baking is a complex unit operation involving simultaneous heat and mass transfer mechanisms. Heat is supplied to the dough through radiation, convection, and conduction. Thermal reactions including starch gelatinization and protein denaturation are activated (Hui *et al.,* 2007). Within the first few minutes of baking, the volume of the dough increases rapidly and reaches the maximum size of the loaf; and this period is called oven rise or oven spring. At the end of oven spring, there is a sharp increase in the rate of gas lost from the loaf, which is due to the rapid coalescence or rupture of the bubble cell walls (Brennan, 2006). At the temperature of starch gelatinization (~ 65^0 C), there is a transfer of water from the protein to the starch, leading to a swelling of the starch granules and a rapid increase in viscosity of the dough, which sets the sponge structure. These physical changes lead to a change from a closed cell foam structure to an open cell sponge structure (Brennan, 2006).

Ovens can be heated by gas, oil, coal, coke, wood or steam. If an oven is steam heated there has to be a steam boiler elsewhere to generate the steam. This should not be confused with steam baking where steam is introduced into the oven to give a particularly crisp crust. A low technology way of doing this is to put a tray of water in the bottom of the oven. While there are small bakers who are using old ovens that consist merely of a heated box most modern ovens fall into one of three classes:
They are either deck ovens, rack ovens or travelling ovens. Travelling ovens are also known as tunnel ovens (Edward, 2007).

The Maillard reaction is a complex set of chemical reactions in which the amino acids in proteins react with reducing sugars such as glucose and fructose and which are very important to our perception of flavor in baked bread (Brennan, 2006).

Generally, the important mechanisms that operate during bread baking may be summarized as follows:

• Carbon dioxide gas is released from solution in the dough, and from the final burst of activity of the yeast, until the temperature reaches 55° C.

• As the temperature of the batter increases the starch granules begin to swell and gelatinization occurs around 60°C.

• Alpha-amylase activity increases and may attack the gelatinizing starch. This activity will continue until the amylase is inactivated at 60–90° C, depending on the form used.

• Other enzymes which may be present are inactivated

• The gluten proteins in the dough coagulate at 70–80°C

• Gases (including water vapor/steam) trapped in the dough expand with heat.

• Moisture is lost.

• Maillard reactions contribute to crust-color formation.

2.4.9.7 Cooling:

After leaving the oven, most baked products require a period of cooling before further processing and wrapping. Heat transfer to the surrounding atmosphere involves mainly convection and radiation. Heat is also lost through moisture evaporation but usually such losses are minimized. Most of the cooling in bakeries is carried out without refrigeration and relies on a flow of cool air across the product (Cauvain and Young, 2000). Bread leaves the oven with the centre of the crumb at a temperature of about 96°C and cools rapidly (Kent and Evers, 1994). When removed from the oven, a baked good continues to cook until its temperature cools to room temperature. This is called carryover cooking. Because of carryover cooking, baked goods must be watched carefully during the last few minutes of baking, and they must be removed before—not when—they are baked to perfection (Figoni, 2008).

Cooling of baked goods between baking and packaging requires an intermediate storage space and is a stage in processing during which there is a chance that the product will become contaminated with mould spores. It is also a time during which the collapse of some products occurs and in which the warm product is more susceptible to damage (Ranken *et al.,* 1997).

The length of time taken for baked products to cool will vary according to size and shape but commonly takes from 30 minutes for small-cross-section products to several hours for large cross-section and dense products (Cauvain and Young, 2000).

2.4.9.8 Packaging:

Packaging bread in polyethylene bags is an almost universal method of bread packaging (Yam, 2009). In the case of product destined for sale on the store shelf, it must also present the product in an attractive manner to appeal to the consumer (Hui *et al.,* 2007). There are many factors to be considered in choosing the optimal packaging form and material for any particular product, including the product characteristics, processing considerations, shelf-life required and overall cost (Kilcast and Subramaniam, 2000). The function of bread packaging for Western-style breads can be described as:

- To contain the slices and crusts together in a single unit for handling purposes;
- To maintain product quality by reducing crumb drying, minimizing the risk of contamination;
- To present an appealing and informative package to the consumer.

The most common material now used in Western countries is a low-density polyethylene, usually in the form of bags. This product provides a good barrier to water vapor, thus inhibiting drying, is easy to handle, and provides a clear background through which the consumer can see the product being purchased (Cauvain and Young, 2007).The new polyethylene bagging and closing equipment. Tape was neither convenient for the consumer nor fast and dependable for the bakers. Two types of closures and automatic equipment systems have emerged as the standards of the baking industry. Developed simultaneously, these are the wire tie and the plastic-clip closure (Yam, 2009).

In the world of food manufacturing, this is not a small matter, because the FDA has rigid control over the materials used in food packaging. To obtain a longer shelf-life, packaging has to be carefully designed. As far as the FDA is concerned, any packaging material is considered a food additive. All packaging materials used to contain food must comply with rigid regulations for the use of a food additive (Hui *et al.,* 2007).

Traditional bread is still a very important part of the total bread market. Central European and Scandinavian influence is bringing new ideas to the Baltic bread market, but the strong tradition will remain (Kulp and Lorenz, 2003). Normal Polypropylene (PP) films have limited food packaging applications (e.g., packaging of bread) because of their low cold temperature resistance (Piringer and Baner, 2008).

2.4.9.9 Bread weights:

From 1980, enforcement of bread weight regulation in the U.K. has taken place at the point of manufacture rather than, as formerly, at the point of sale, and is based on the average weight of a batch rather than on the weight of an individual loaf (Kent and Evers, 1994).

2.4.9.10 Freshness of bread:

Bread is the most important staple food in the Western world and it is recognized as a perishable commodity, which is at its best when consumed ‘fresh’. Unfortunately, bread remains truly ‘fresh’ for only a few hours after it leaves the oven. During storage it is subjected to a number of changes which lead to the loss of its organoleptic freshness (Cauvain and Young, 2007).

When we collect our bread from the baker and it is still warm to the touch we have no doubt as to its freshness but when we purchase it cold from the store shelf we need convincing of its freshness. The pursuit of fermented products which retain their ‘oven-fresh’ character for an extended period of time after they have left the oven has been one of the great challenges facing bakers, technologists and scientists for many years, and many different strategies have been evolved to meet this challenge. Whether they have been successful can really only be judged by consumers (Cauvain and Young, 2007).

2.4.9.11 Nutritional qualities of bread:

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 starch), fiber, vitamins and minerals. The nutritional contributions are greatest in wholemeal (wholewheat) breads since they require conversion of 100% of the grain into flour. Typical nutritional compositions for UK breads are given in (Table 7) (Cauvain and Young, 2007).

Table 7: *Composition of bread (per 100g)*

	WHITE	BROWN [a]	WHOLEMEAL
Carbohydrate	49.3	44.3	41.6
Protein	8.4	8.5	9.2
Dietary fiber	2.7	4.7	7.1
Fat	1.9	2.0	2.5

a= In the UK the term ‘brown’ denotes bread made from flour which consists of a mixture of white flour and a proportion of the bran component of the wheat.
Source: Cauvain. and Young (2007)

2.4.9.12 Bread flavor:

Freshly baked bread has a delectable flavor that is most appealing to the public. The flavor, however, is not stable, for bread loses much of its appeal after relatively short storage time (Gould, 1966). Sometimes bread products are eaten alone, but more often they will be eaten as an accompaniment to other foods in a meal or as part of a composite product, so that bread flavors tend to be more subtle than we would encounter in many other foods (Cauvain and Young, 2007). The oven exhaust from baking industries releases water vapor, CO_2, VOC, and various combustion products. The VOCs are primarily ethanol produced by the yeast during the fermentation process. It should be noted, however, that many individuals find the odor of fresh baked bread very desirable (Nicolay, 2006). The extremely complex nature of bread flavor is illustrated by the fact that more than 70 compounds have been identified or implicated (Gould, 1966). The development of flavor in fermented products is derived from the ingredients and the processing methods which are used. Flour tends to have a fairly bland flavor with most of its contribution coming from the oils of the germ (embryo) and any bran particles present. Since this is the case wholemeal, wholewheat and bran and germ enriched white flours will yield bread with more flavor than white flours. The addition of salt (sodium chloride) to bread is the most obvious of those flavor modifiers, imparting both its own characteristic 'salty' taste and working in the mouth to increase our perception of other flavors which may be present (Owens, 2001).

During the dough fermentation process new flavor products are generated within the dough. Not all of this flavor activity will come from the addition of bakers' yeast; some will come from wild yeasts and bacteria, especially lactic acid bacteria, which are present naturally in the flour (Owens, 2001).

2.4.9.13 Color of bread:

The brown color of the crust of bread is probably due to melanoidins formed by a non-enzymic 'browning reaction' (Maillard type) between amino acids, dextrins and reducing carbohydrates. Addition of amino acids to flours giving pale crust color results in improvement of color. The perceived color of bread crumb is influenced by the color, degree of bleach, and extraction rate of the flour; the use of fat‹ milk powder, soya flour or malt flour in the recipe; the degree of fermentation; the extent to which the mixing process disperses bubbles within the dough and the method Of panning- cross-panning and twisting to increase light reflectance (Kent and Evers, 1994).

2.4.9.14 Deterioration of bread quality:

Baked goods manufacturers are concerned with physical spoilage (staleness), chemical spoilage (rancidity), and microbiological spoilage (bacterial, yeast, and mold spoilage) (Zagozewski, 2008). Bread is a short-life product that is neither sold nor consumed continuously. The need with bread is to get the product to the retail outlet in time to sell it (Edward, 2007). Fresh bread is a product with a short shelf-life and during its storage a number of chemical and physical alterations occur, known as staling. As a result of these changes, bread quality deteriorates gradually as it loses its freshness and crispiness while crumb firmness and rigidity increase (Kohajdová *et al.*, 2009).

The baking process is similar to pasteurization in that both enzymes and micro-organisms are destroyed by the heat. Thus, bread may be stored at room temperature in spite of its high water activity. The various modes by breads deteriorate include:

2.4.9.14.1 Microbial growth:

The a_w of breads is normally low enough (0.75 to 0.9) to prevent growth of bacteria (Ray, 2004). The most common source of microbial spoilage of bread is mould growth. Less common, but still causing problems in warm weather, is the bacterial spoilage condition known as 'rope' caused by growth of *Bacillus* species (Cauvain and Young, 2007). The spores, coming from flour or equipment, survive baking and then germinate and grow inside within 1 to 2 d. They also produce extracellular amylases and proteases and break down the bread structure (Ray, 2004). Least common of all types of microbial spoilage in bread is that caused by certain types of yeast, There are mainly two types of yeasts involved in the spoilage of bread, fermentative yeasts and Filamentous yeasts (Cauvain and Young, 2007). By the time microbial growth begins to be a problem, the bread has usually been consumed or other modes of deterioration have already limited shelf life (The Office of Technology Assessment (OTA), 1979). Mould spoilage of bread is due to post-processing contamination. Bread loaves fresh out of the oven are free of moulds or mould spores due to their thermal inactivation during the baking process (Cauvain and Young, 2007).

Yeast and moulds are more tolerant of low water activity and low pH than bacteria. Subsequently they typically spoil foods such as fruit and vegetables and bakery products. Bread is spoiled by *Rhizopus nigricans* ('bread mould', black spots), *Penicillium* (green mould), *Aspergillus* (green mould) and *Neurospora sitophila* ('red bread') (Forsythe, 2000). In wheat-breads a wide range of spoilage moulds including *Penicillium, Aspergillus, Cladosporium, Mucorale*s and *Neurospora* have been observed (Cauvain and Young, 2007).

Aside from the possibly toxic effects of consuming large amounts of moldy bread, there are little or no safety considerations in determining the shelf life of fresh bakery products. Most people, in fact, would reject moldy bread even when one colony forms (OTA, 1979).

In addition to spoilage, some moulds present a severe risk to public health because they can produce mycotoxins. Exposure to mycotoxins can occur either directly by eating bread spoiled by mycotoxigenic moulds or indirectly as a result of people consuming the products of animals fed contaminated bread. Mycotoxins are very resistant and can survive the heating process designed to kill moulds. It has been reported that 10% of *Aspergillus spp*. and *Penicillium spp*. are toxic to mice (Cauvain and Young, 2007).

The anti-microbial activity of propionates is mainly against moulds and the bacteria responsible for the development of rope in bread. The addition of ethanol at levels between 0.5 and 3.5% of loaf weight leads to a substantial extension of the shelf-life of bread (Cauvain and Young, 2007). Calcium propionate is often added to bread as a mold inhibitor to slow this process (OTA, 1979).

2.4.9.14.2 Nutritional losses:

Proteins, fats, carbohydrates, vitamins, and minerals are examples of nutrients in food. Heat changes certain nutrients in very important ways. For example, proteins and starches in flour are more digestible once they are heated. This means that baked foods containing flour are often more nutritious than raw foods (Figoni, 2008). Not all the effects of heat on food are positive, however. Heat destroys some nutrients, such as vitamin C (ascorbic acid). Nutrient loss is of minor consideration since it occurs much more slowly than sensory quality losses caused by staling. Vitamin losses occur very slowly in bakery products. Loss of available lysine through nonenzymatic browning occurs more quickly but is not a significant problem, since bread is not a significant source of lysine in the diet (OTA, 1979).

2.4.9.14.3 Moisture loss:

During the storage of bread, the moisture content of the crust increases as a result of moisture migration from the crumb to the crust. With an initial moisture content of only 12%, the crust readily absorbs moisture from the interior crumb, which has a moisture content about 45%. It has been reported, that during a storage period of 100 h, the crust moisture increased from 15 to 28%, while the crumb moisture loss was only from about 45 to 43.5%. In a zone near the crust the decrease was much more pronounced, from about 45 to 32% (Cauvain and Young, 2007). For intermediate moisture products such as bread and cake, the physicochemical change is normally associated with starch retrogradation. Water distribution among the high-molecular-weight substances such as protein and starch causes the water to transform from strongly bound to weakly bound. Therefore, staling can be observed (Hui *et al.,* 2007). Moisture loss can be kept to a minimum by use of moisture-proof packages (OTA, 1979).

There is no legal standard for the moisture content of bread in the U.K. The moisture content of American and of Dutch bread must not exceed 38%. In Australia the maximum permitted moisture content in any portion weighing 5 g or more is 45% for white bread, 48% for brown and wholemeal. In New Zealand, 45% is the maximum moisture content similarly permitted in any bread (Kent and Evers, 1994).

It is not possible to stop migration of moisture since this obeys physical laws that cannot be changed. However, product design can help minimize this effect so that the breadcrumb remains more moist and soft during storage (Smith, 2004).

2.4.9.14.4 Flavor loss:

During the degradation of organic matter, volatile organic compounds (VOC) are formed as intermediate metabolites. Under aerobic conditions, microbial degradation will lead to the formation of

VOC, which are rapidly oxidized to carbon dioxide and water (Nicolay, 2006). Bread quality changes rapidly during storage. Due to moisture adsorption, the crust loses its crispiness and glossyness. The aroma compounds of freshly baked bread evaporate or are entrapped preferentially by amylose helices which occur in the crumb. Repeated heating of aged bread releases these compounds (OTA, 1979). Very labile aroma compounds also contribute to the aroma of bread, e. g., 2-acetyl-1-pyrroline. They decrease rapidly on storage due to oxidation or other reactions (Belitz *et al.,* 2009).

2.4.9.14.5 Staling:

The term ‘staling’ refers to the gradually decreasing consumer acceptance of bread due to all the chemical and physical changes that occur in the crust and crumb during storage excluding microbial spoilage. Staling is detected organoleptically by the changes in bread texture, as well as in taste and aroma. (Cauvain and Young, 2007). Baked products are perishable. They undergo physicochemical changes, generally referred as ‘‘staling’’ and microbial degradation. The term staling designates the loss of consumer acceptability due the storage changes other than those caused by the microbiological action. The main change that reduces the bread quality during aging is crumb firming, which is attributed to starch retrogradation (Kulp and Lorenz, 2003). Staling of wheat bread is often experienced as a firming of the bread crumb during storage. This process can be retarded by the inclusion of monoglycerides of fatty acids, stearoyllactylate and/or water binding/swelling agents such as guar gum or locust bean gum. (Freshkeeping agents) (Wassermann, 2009).

Starch gelatinizes during baking and the amylose component leaches out from the granules. Upon cooling the amylose crystallizes and determines the firmness of fresh bread crumbs; amylopectin crystallizes (retrogrades) at a slower rate than amylose and causes gradual firming during storage. This change is highly correlated with the consumers’ perceived freshness as determined organoleptically. Other factors that affect freshness judgment are a the loss of moisture due to simple drying out, which can be controlled by moisture proof wrapping, or moisture migration from the high moisture crumb phase to the dry crust. The latter change is minimized by production of thin-crust breads. Two types of reactions affect flavor deterioration associated with aging of breads:

(1) Transfer of certain flavor components from the crust to the crumb region and.

(2) Loss of some flavor compounds by formation of complexes with amylose. The crust of wrapped products loses its fresh crispness due to equalization of moisture (Kulp and Lorenz, 2003).

Bread tends to stale—i.e., obtain a harder and shorter texture—during storage at room temperature. Keeping the bread in a refrigerator enhances staling rate, but storage in a freezer greatly reduces staling, slow rate of staling at a temperature of, say, -20^0 C is due to the system being near the glassy state, where the molecular mobility of amylopectin molecules is already greatly reduced, forming of starch microcrystallites, which make the matrix much stiffer (Walstra *et al.,* 2003). Although no additives have been specifically developed to counteract staling, emulsifiers such as glyceryl monostearate (GMS) are proven to be very effective, probably because they help complex starch, which inhibits retrogradation (Smith, 2004). In contrast, increased temperatures can reduce the development of staling in bread, although the situation with other baked foods can be complex and unpredictable (Kilcast and Subramaniam, 2000).

2.5 Food additives:

A food additive is a substance (or a mixture of substances) which is added to food and is involved in its production, processing, packaging and/or storage without being a major ingredient (Belitz *et al.,* 2009). A food additive is any substance added to food. Legally, the term refers to "any substance the intended use which results or may reasonably be expected to result, directly or indirectly, in its becoming a component or otherwise affecting the characteristics of any food." This definition includes any substance used in the production, processing, treatment, packaging, transportation, or storage of food (Hui *et al.,* 2007). Food additives play a vital role in today's bountiful and nutritious food supply. They allow our growing urban population to enjoy a variety of safe, wholesome, and tasty foods, year round. Also, they make possible an array of convenience foods without the inconvenience of daily shopping. Although salt, baking soda, vanilla, and yeast are commonly used in foods today; many people tend to think of any additive added to foods as being a complex and sometimes harmful chemical compound. All food additives are carefully regulated by federal authorities and various international organizations to ensure that foods are safe to eat and are accurately labeled (Hui *et al.,* 2007).

2.5.1 European community policy regarding additives:

Additives will only be included in a permitted list if a reasonable technological need is demonstrated, and if this need cannot be achieved by other means that are economically and technologically practicable. Furthermore, the additives must present no hazard to health at the levels of use proposed, and they must not mislead the customer. 'Need' is understood to mean preservation of nutritional quality; the meeting of special dietary requirements; enhancement of keeping quality, stability and organoleptic properties; or providing aid in manufacture, processing, preparation, treatment, packaging, transport or storage. Specified additives are to be allowed only in specified foods, and at levels not exceeding those required to achieve the desired effect (Kent and Evers, 1994).

2.5.2 Why are additives used in foods?

According to (Hui *et al.,* 2007) additives perform a variety of useful functions in foods that are often taken for granted. As most people no longer live on farms, additives help keep food wholesome and appealing while en route to markets sometimes thousands of miles away from where it is grown or manufactured. Additives also improve the nutritional value of certain foods and can make them more appealing by improving their taste, texture, consistency, or color. Some additives could be eliminated if we were willing to grow our own food, harvest and grind it, spend many hours on cooking, or accept increased risks of food spoilage. However, most people today have come to rely on the many technological, aesthetic, and convenience benefits that additives provide in food. Additives are used in foods for five main reasons.

i. To Maintain Product Consistency. Emulsifiers give products a consistent texture and prevent them from separating. Stabilizers and thickeners give smooth uniform texture. Anticaking agents help substances such as salt to flow freely.

ii. To Improve or Maintain Nutritional Value. Vitamins and minerals are added to many common foods such as milk, flour, cereal, and margarine to make up for those likely to be lacking in a person's diet or lost in manufacturing. Such fortification and enrichment have helped reduce malnutrition in the U.S. population. All products containing added nutrients must be appropriately labeled.

iii. To Maintain Palatability and Wholesomeness. Preservatives retard product spoilage caused by mold, bacteria, fungi, yeast, or air. Bacterial contamination can cause foodborne illness, including the life-threatening botulism. Antioxidants are preservatives that prevent fats and oils in baked goods and other foods from becoming rancid or developing an off-flavor. They also prevent cut fresh fruits such as apples from turning brown when exposed to air.

iv. To Provide Leavening or Control Acidity/Alkalinity. Leavening agents, which release acids when heated, can react with baking soda to help cakes, biscuits, and other baked goods to rise during baking. Other additives help modify the acidity and alkalinity of foods for proper flavor, taste, and color.

v. To Enhance Flavor or Impart Desired Color. Many spices and natural and synthetic flavors enhance the taste of foods. Colors, likewise, enhance the appearance of certain foods to meet consumer expectations.

2.5.3 Evaluation of safety of food additives:

The World Health Organization (WHO) and Food and Agricultural Organization (FAO), joint expert committee on food additives has the responsibility of proposing Acceptable Daily Intakes. The Committee divided food additives into three categories:

- Fit for use in food.
- Need to be evaluated.
- Should not be used in foods.

After evaluation, detailed specifications for the food additives include identity and purity. Typically, WHO provides data on biological aspects such as ingestion, calorific availability, and digestibility, an on toxicology. Toxicological evaluation includes short term and long term evaluation using a range of different animals.

Since 1958, FDA and USDA have continued to monitor all prior-sanctioned and GRAS substances in light of new scientific information. If new evidence suggests that a GRAS or prior-sanctioned substance may be unsafe, federal authorities can prohibit its use or require further studies to determine its safety (Hui *et al.,* 2007).

In addition, FDA operates an Adverse Reaction Monitoring System (ARMS) to help serve as an ongoing safety check of all additives. The system monitors and investigates all complaints by individuals or their physicians that are believed to be related to specific foods, food and color additives, or vitamin and mineral supplements (Hui *et al.,* 2007).

2.5.4 Bread improvers:

This term covers any ingredient added to 'improve' the bread making potential of flour (Owens, 2001). The term 'dough conditioner': any material or combination of materials which are added to yeast-raised doughs to enhance and control gas production or gas retention, or both. Dough conditioners are also called dough improvers (Figoni, 2008). The range and level of use of these substances is controlled by legislation in most countries (Cauvain and Young, 2007).

The use of improvers in the production of baked goods is common practice today. It is also part of the technological effort to produce baked goods from wheat and rye flour that have high sensory, practical and nutritional value. Besides the use of machines for dough and batter make up, processing and baking, improvers are used specifically to improve production methods and the quality of bakery products. According to the definition laid down in the German Guidelines for Bread and Small Baked Items, improvers are mixtures of food including additives intended to facilitate or simplify the production of baked goods, to compensate for changes in processing properties due to fluctuations in raw materials and to influence the quality of baked goods (Wassermann, 2009).

In Austria, improvers are similarly defined by the BMSG (Federal Ministry for Social Security, Generations and Consumer Protection) in decree 31.901/25-IX/B/12/01 of July 3, 2001.

"Improvers" are preparations intended to simplify the production of baked goods, to compensate changes in processing properties due to fluctuations in raw materials and to improve the quality of bakery products. They are made from food (cereal products such as starch, malt… different sugars, dairy products such as powdered milk, soy flour,...) with or without additives (preservatives, fruit acids, phosphates, thickening agents,...), depending on the relevant application. The substances used for improvers are often also components found in the food product that is being made with these improvers (Wassermann, 2009).

2.5.5 Classification of improvers:

According to (Wassermann, 2009) Improvers can be composed differently depending on the product to be used in or on the intended production method. They belong to either one of the following groups:

1) Improvers for small yeast-raised items (rolls).
2) Improvers for bread with more than 10 % rye flour content (Acidifier).
3) Improvers for toast bread and wheat bread.
4) Improvers for yeast-raised fine bakery wares.
5) Improvers for retarded and interrupted proofing.
6) Improvers for prolonged shelf life (staling retarder).
7) Improver for production of pound and sponge cakes (Batter enhancing agent).

Improvers are generally used at an amount of no more than 10 % calculated on flour. Depending on the purpose, they contain an optimum amount of components. They are commercially available as powder, in granular form, as liquid or as a paste (Wassermann, 2009).

2.6. Hydrocolloids:

Hydrocolloids are defined as “a macromolecular substance such as a protein or polysaccharide which swells by absorption of water, in some cases forming a stiff gel” Food hydrocolloids, or food gums, have high molecular weights when compared to carbohydrate ingredients, such as sugar or corn syrup, Food gums are usually added to food systems/products for specific purposes, such as thickening agents, stabilizers, emulsifiers, gelling, etc (Sadar, 2004). One group of the most extensively used additives in the food industry are hydrocolloids (or gums) (Kohajdová *et al.,* 2009). A hydrocolloid is a noncrystalline substance with very large molecules which dissolves in water to give a thickened (viscous) solution (Shetty *et al.,* 2006). They are derived from seeds, fruits, plant extracts, seaweeds, and microorganisms, being of polysaccharide or protein nature (Table 8). They are generally polysaccharides, but gelatin (a protein) is included because its functionality is very similar to that of the polysaccharide-based gums (Hui *et al.,* 2007).

Table 8: *Guideline quantities of substances used to improve the baking of products made using milled wheat or rye expressed as a percent, of the dough weight*

Substances	**Quantities**
Hydrocolloids (pregelatinized flour, guar gum, soya flour)	approx. 1 %
Lecithin	0.1–0.3 %
diacetyl tartaric ester of mono- and diglycerides (dawe, datem)	0.2 %
monoglycerides of fatty acids, stearoyl lactylate	0.2 %
ascorbic acid	100–200 (ppm)
Cysteine	50 mg/kg (ppm)
Acids (citric, lactic, acetic acid)	1 %
sugars (sucrose, glucose, malt extract)	1 %

Source: Wassermann (2009).

2.6.1 Types of hydrocolloids:

The scientific and academic classification of food hydrocolloids is divided along functional properties or raw material origins. For example gelling agents vs. thickening agents or seaweed extracts vs. seed gums vs. plant exudates vs. fermentation polymers (Williams and Phillips, 2002). The polysaccharide gums come from a wide variety of sources and are used extensively in the food industry. The origins of these gums are varied ranging from bacterial (xanthan gum), algal (alginate and carrageenan) to arborial (gum arabic) (Williams and Phillips, 2004). Not only can hydrocolloids perform numerous functions, but there is a wide selection of hydrocolloids available for manufacturers. The function of each gum varies and certain ones are chosen for particular reasons. Decisions may be based on solution clarity, solubility at various temperatures, suspension ability, natural versus not natural, ability to stabilize proteins at a low pH, acid stability, or relative cost per pound (Sadar, 2004).

2.6.2 Basic Structure of food hydrocolloid:

Hydrocolloids or gums are substances consisting of hydrophilic long-chain, high-molecular-weight molecules, usually with colloidal properties, which in water-based systems produce gels, that is, highly viscous suspensions or solutions with low dry-substance content (Hui *et al.,* 2007). The typical structure of a food hydrocolloid includes a sugar backbone with protruding substituents. The backbone can vary in length from several hundred to several thousand sugar units long. These sugar units are most commonly linear in form, but branched backbones have been seen. The backbone provides pertinent information such as the acid stability of the particular hydrocolloid. The type, number, and distribution of substituents protruding from the backbone determine whether a gum is a thickening agent or a gelling agent (Sadar, 2004).

2.6.3 Factors Influencing behavior of food hydrocolloids:

The four major factors influencing food gum properties include molecular weight, the monosaccharide backbone, type of side chains, and distribution of side chains the molecular weight of the food gum is basically the chain length... If the chain length is doubled, the chain will now occupy eight times the volume it did before, thus it is eight times more likely to collide with an adjacent chain. These collisions and restrictions are referred to as resistance to flow, which is measured as viscosity. The composition of the backbone also indicates gum properties. The monosaccharide composition influences properties such as pH stability, ability to thicken or gel in food systems. Therefore the molecular weight and monosaccharide composition affects the final behavior of the food hydrocolloid (Sadar, 2004).

In addition to those two factors, the type of side chains or substituents also plays a part in determining gum behavior. The main influence of side units is whether the gum will become a thickening or a gelling agent. Side chains can vary drastically in size. In the case of pectin and carrageenan, the side units are small in size and are simply a carboxyl or a sulfate group respectively. Side units can be an additional sugar protruding off the backbone as is the case with both guar gum and locust bean gum, the final factor that influences food gum properties is the distribution or uniformity of these side chains (Sadar, 2004).

The distribution of side chains can determine cold water solubility and synergistic effects with other gums. Substituents are distributed either evenly or unevenly on the sugar backbone. Uneven substitution results in smooth and hairy regions. Smooth areas are defined by areas on the backbone that do not contain any side units. In contrast, hairy regions contain a cluster of side units projecting from the backbone. An example of distribution of side units is seen by locust bean gum and guar gum. Both hydrocolloids have the same galactomannan backbone, but locust bean gum is unevenly distributed and guar gum is evenly distributed. Due to the substitution difference, they both possess different cold water solubility properties as well as synergistic relationships with other gums (Sadar, 2004).

2.6.4 Use of hydrocolloids in food industries:

Hydrocolloids are widely used as additives in the food industry because they are useful for modifying the rheology and texture of aqueous suspensions; hydrocolloids are used in food products as thickeners, stabilizer, gelling agent and emulsifier. They improve the texture of the products, retard starch retrogradation during storage, increase water retention, while enhancing lower energy value; they are often employed in low-calorie foods (Hemeda and Mohamed, 2010).

2.6.5 Role of hydrocolloids in manufacture of baked goods:

1) Hydrocolloids are used either alone or in combination to achieve specific synergies between their respective functional properties. At a lower level of incorporation, hydrocolloids have served as additives to improve the quality of baked goods (Kohajdová *et al.,* 2009).

2) Hydrocolloids or gums serve two basic functions in food systems: They stabilize the product, and they affect the texture of the product, and are widely used in the food industry for these functional properties These functional properties lead to the improvement of food texture, they retard starch retrogradation, increase moisture retention, and extend the overall quality of the product over time (Hui *et al.,* 2007).

3) In the baking industry, hydrocolloids are of increasing importance as bread improvers, they can induce structural changes in the main components of wheat flour systems along the bread making steps and bread storage (Kohajdová *et al.,* 2009).

4) Hydrocolloids such as pregelatinized cereal flours and starches as well as guar gum and soya flour can also be used to improve the hydration capacity of doughs. These substances take up water during dough preparation making the doughs much drier and more easily processed. Besides that, the increased moisture contributes to optimum starch gelatinization which, in turn, improves the fresh keeping properties (Wassermann, 2009).

5) Hydrocolloids when used in small quantities (<1% (w/w) in flour) are expected to increase water retention and loaf volume and to decrease firmness and starch retrogradation (Kohajdová *et al.,* 2009). Hydrocolloids affected in different extent to the fresh bread quality, and concentrations of 0.1% (w/w, flour basis) were sufficient for obtaining the observed effects (Guardaa *et al.*, 2004).

6) The presence of hydrocolloids influenced melting, gelatinization, fragmentation, and retrogradation starch processes. These effects were shown to affect pasting properties, dough rheological behavior bread staling. It is generally accepted that each hydrocolloid affects the pasting and rheological properties of starch in a different way (Kohajdová *et al.,* 2009).

7) Hydrocolloids have a neutral taste and aroma which permits a free flavor release of all recipe components. They provide an unctuous body to fat-reduced products, in which compensate for the low fat content with their water-binding ability and texturising properties. These compounds have been used as gluten substitutes in the formulation of gluten – free breads due to their polymeric structure (Kohajdová *et al.,* 2009).

8) Hydrocolloids have been found to affect dough rheological performance, as they mimic the viscoelastic properties of gluten in bread doughs and also swelling, gelatinization, pasting properties, and staling of starch.

2.7 Emulsifiers:

Emulsions are two-phased systems in which one phase (disperse) is suspended as small droplets in the second phase (continuous). Substances that promote stability in emulsions are known as emulsifiers and they work by providing a bridge between the two phases. The two common types of emulsion are oil in water (salad dressings) and water in oil (margarines). Batters and doughs are complex emulsions and a number of different emulsifiers are used successfully to aid oil and, more critically, air dispersion and their stability during all stages of baking processes. Emulsifiers have become highly functional ingredients in the food industry. The functionality of emulsifiers depends on the particular emulsifier used and the concentration, formulation, and processing the final food product has experienced (Wassermann, 2009). Emulsifiers contain both hydrophilic and lipophilic parts, resulting in their ability to be useful in foods at very low levels (Baker, 2010).They are used at very low amounts in foods, many times at fractions of a percent, yet can greatly affect the final products' performance. For example, emulsifiers can aerate foams and batters, extend shelf-life, promote fat agglomeration, and improve texture in foods. In addition to potential interactions with oils, liquids and gases, emulsifiers may play a role in starch-complexing (anti-staling) and interact with proteins (Cauvain and Young, 2000). Natural surfactants (emulsifiers) do occur in nature but many are the result of manufacturing technologies available today. In such cases the emulsifier is more powerful than the fat on a weight -for- weight basis at promoting many of the required properties, for example batter aeration and gas-bubble stability. Gum arabic is widely used for emulsifying the flavor bases used in beverages (Williams and Phillips, 2004).

2.7.1 Emulsifiers as bread improver:

These emulsifiers improve the gas impermeability of the membrane that encloses the gas bubbles. This makes the dough less susceptible to mechanical stress during dividing, moulding and handling. Proofing stability as well as oven spring will also increase (Wassermann, 2009). Although bread dough does not ordinarily require emulsification, emulsifying agents may improve the functional properties of the dough by increasing water absorption and gas retention, decreasing proofing times، and reducing the staling rate (Hutkins, 2006). The anti-staling ability of emulsifiers is mainly due to their interaction with starch but the exact mechanism is still unexplained. Emulsifiers complex with linear amylose, and they may do some complexing with the outer linear branches of amylopectin (Cauvain and Young, 2007). Dough conditioners or stabilisers and emulsifiers reduce the necessity for resting times and improve tolerance towards dough handling in the bakery equipment. The bread volume is increased and the crumb structure becomes finer and more uniform. In addition, dough conditioners emulsify any fat in the recipe (Smith, 2004). Gums may be used in reduced-fat baked goods to improve texture and prevent moisture loss (Amendola and Rees, 2003).

2.7.2 Exudate gums:

Plant family *Leguminosae* belong to the order *Rosales* which includes 9 sub-families. *Gummiferae* is one of the series of the sub family *mimosoideae*. The species from which gum exudation is obtained are referred to belong to the series *Gummiferae*. The series have only fifteen species which are regarded as a source of the gum where as the plant family *Leguminosae* includes 550 genera and 13000 species which grow in varied soil and climate condition but most abundantly in temperate and warm climate. The plants of this family range from herbs, shrubs, and trees and show great diversity in their habitat (Jilani, 1993).

Acacia is the common name for the plants of genus *Acacia* of the plant family *Leguminosae*. *Acacia* is a large genus with 900 species, approximately 700 of which are native to Australia. The remainder occurs mainly in tropical and sub-tropical regions of Africa, Asia and America. The name acacia is derived from the Greek AKAZO which means "l Sharpen." (Jilani, 1993). The genus *Acacia* is the second largest within the *Leguminosae* family and contains at least 900 species (Verbeken *et al.*, 2003). With their extensive root system, Acacia trees can be found in semi-arid areas in Australia, India, and America, but mainly in the Sahelian region of Africa. They are multipurpose trees, not only producing gum, but also preventing desert encroachment, restoring soil fertility, and providing fuel and fodder. Almost all commercial gum comes from the so-called gum belt of Africa, a vast area which extends over Mauritania, Senegal, Mali, Burkina Faso, Benin, Niger, Nigeria, Chad, Sudan, Eritrea, Ethiopia, Somalia, Uganda, and Kenya (Verbeken *et al.,* 2003).

There is no agreement as to the origin of gums exudates. Some thought that they are a product of normal plant metabolism and some suggest that they are arising from a pathological condition (Jilani, 1993). Exudate gums have been used for centuries in a variety of fields: they have retained their importance despite the many alternative gums, with similar typical performances, which have since come into existence. Natural gums exude from trees and shrubs in tear-like, striated nodules or amorphous lumps, and then dry in the sun, forming hard, glassy exudates of different colors, from white to pale amber for gum arabic, pale gray to dark brown for karaya gum, and white to dark brown for tragacanth (Nussinovitch, 2010). Exudates are fluids that ooze out of wounds in injured trees and harden upon exposure to air. This designation includes all types of natural exudates, including many water-insoluble materials such as resins, latex, chicle, etc., which accounts for the erroneous use of the term gum for many of the water-insoluble resins used in the paint and chemical industry today (Nussinovitch, 2010). The term gum is applied to a wide varity of substances with "Gummy" characteristics and cannot be precisely defined (Jilani, 1993).

2.7.3 Gum arabic: gum acacia E414

Gum arabic is produced from two acacia varieties, which are found to a varying intensity in the gum belt of Sub-Saharan Africa. These varieties are *Acacia senegal* and *Acacia seyal*. Gum from *A. senegal* aqueous solutions are levorotatory Gum from *A. seyal* aqueous solutions are dextrorotatory (Table 9).

Table 9: *Some information about Gum arabic*

Synonyms	CAS 9000-01-5/ EINECS 232-519-5/ E414/ Acacia gum/ Sudan gum/ Gum arabica/ Gum hashab/ Kordofan gum/ Arabic gum/ Kami.
Synergists	None known
Antagonists	None known
Food safety issues	Non-toxic. The powder is combustible
Legislation	**USA:** FDA 21CFR § 169.179, 169.182 184.1330, GRAS **UK and EUROPE:** UK: approved. Europe: listed **AUSTRALIA/PACIFIC RIM:** Japan: approved for use as a natural thickener and stabilizer
Food use	All food products/ Edible films/ Coatings

Source: Smith and Hong-Shum (2003).

2.7.3.1 Definition of gum arabic:

Gum arabic is defined by the FAO/WHO Joint Expert Committee for Food Additives (JECFA) as: "a dried exudate obtained from the stems and branches of *Acacia senegal (L.)* Willdenow or *Acacia seyal* (Fam. *Leguminosae*)" In a wider sense, the name gum arabic is also used to denominate gums produced by other Acacia species, like for example *A. karroo*, and is sometimes referred to as gum acacia (Verbeken *et al.,* 2003). Gum arabic accoding to the Codex Alimentarius Commission at its 23rd Session in Rome, 28 June - 3rd July 1999 adopted the following substantive definition:

"Gum arabic is a dried exudation obtained from the stems and branches of *Acacia senegal* (L) or *Acacia seyal* (fam. Leguminosae)."

Previous attempts (by JECFA) to set analytical parameters included a specified range of optical rotation. In 1990 it was decided that the specific optical rotation should be within -26 to -34^0 (Williams and Phillips, 2004).

Gum arabic is traditionally defined as a 'substance, which exudes from *Acacia senegal* or related species'. This definition encompasses a variety of species, which, from a taxonomy point of view, are not related. To date, though, only the gum from *A. senegal* has been effectively demonstrated as an innocuous food additive (Touré, 2008).

Gum arabic has proven to be difficult to define unequivocally. One reason is that there are gum exudates from Acacia species other than *A. senegal* and the closely related *A. seyal,* such as *A. laeta* (related to *A. senegal), A. kamo* (related to *A. seyal* and *A. polyacentha*. Another reason is that there can be numerous variations within a single species. A study of 1500 gums from *A. senegal* demonstrated significant variations in properties, such as molecular weight, specific optical rotation and viscosity (Williams, and Phillips, 2004).

2.7.3.2 Plant taxonomy of gum arabic:

There are close to 900 acacia species capable of producing gum. These are primarily located in tropical climates, with about 130 of them located specifically on the African continent (Touré, 2008).

Acacia senegal (L) Wild.

Family: *Mimosaceous* Legumes (*Leguminosae – Mimosoideae*) Synonyms : Acacia vérek Guill et Perrott; *Mimosa senegal* L. (1753), Acacia rupestris Stokes. Vernacular names: White gum tree, Vérek (French); Gum arabic tree, gum tree, threethorned acacia (English); Kittir (Arab).

***Acacia seyal Del*.**

Family: *Mimosaceous* Legumes (*Leguminosae – Mimosoideae*)
Synonyms: Acacia stenocarpa Hochst; Acacia hockii De Wild.
Vernacular names: Mimosa épineux (French); Talha (Arabe).

2.7.3.3 Hashab tree:

Acacia senegal is widely distributed and shows a remarkable adaptability to both drought and frost. *Acacia senegal* is found in Africa across a belt extending from Senegal to Ethiopia, passing through Mali, Nigeria, Chad, Somalia, and Sudan. *Acacia senegal* is a species that can sustain very dry conditions, can grow with anything from 100 to 800 mm of rain but preferring 300 to 400 mm of rain and a dry period of 8 to 11 months. It can survive very high daily temperatures but not frost. The species may grow on a range of topographic conditions but grows well in sandy soils (red-brown sub-arid soils and ferruginous tropical soils). It also grows well in fossil dunes, slightly silty soils, brown clay soils, clay sandstone and even in litho soils although a good drainage is required (Touré, 2008).

2.7.3.4 Appearance of gum arabic:

Gum arabic is a solid of a pale to orange brown color which, when ruptured, secretes a vitreous substance. Gum arabic of excellent quality is tear-shaped, round, with an orange-brown color and a surface with a matte texture. After it is crushed or shattered, the pieces are paler in color and have a vitreous appearance.

2.7.3.5 History and origin of gum arabic:

Gum arabic is certainly the most ancient and the most well known of all gum types. The term 'Gum Arabic' was coined by European merchants who imported it from Arab ports such as Jeddah and Alexandria. Egyptians referred to it as 'kami' and allegedly used it from the third dynasty onwards (around 2650 BC) to secure bandages around mummies. This gum was supposedly also used to fix pigments into hieroglyphic paintings (Touré, 2008).

According to a Sudanese researcher, the word 'mana' (manna) mentioned in the Koran (Surah Al baquarah) as the best food available to man is, in fact, a direct reference to gum arabic. The word 'mana' seemingly also refers to gum arabic in the Torah where it is described as an essential food and designated by Moses to the Israelis as God-given bread.

Introduced in Europe through various Arabian ports, it was called gum arabic after its place of origin. During the middle Ages, gum arabic trade was controlled by the Turkish Empire, giving rise to the name turkey gum (Verbeken *et al.,* 2003). In the 15th century, European navigators discovered gum arabic on the coasts of modern-day Senegal and Mauritania. In the 18th century, following a bloody and determined 'gum war' France acquired the monopoly of gum trade along the West African coast (Touré, 2008).

At the beginning of the 20th century, England opened up access to the other primary source of gum arabic by building a railroad between Eloubeid, in the heart of the Kordofan region, and the Sudanese port. England and France, aboard their merchant fleet, would transport the gum from the trading post back to Europe to be processed. Consequently, gum arabic became a prized commodity given its popularity with these two colonial powers (Touré, 2008).

2.7.3.6 Production of gum arabic:

The most important forest in the Sudan may be the gum arabic belt. The "belt" refers to a zone of approx. 520,000 km2 that expands across Central Sudan between latitudes 10° and 14° N, accounting for one-fifth of the country's total area (Nussinovitch, 2010). Statistical information on production and exportation are difficult, virtually impossible, to obtain because few producing countries release customs information (Touré, 2008). Sudan is historically known to be a major exporter, however, during the past 30 years production in Sudan shows alarming signs of overall decrease and also a substantial year–to-year variation. The average production in Sudan has declined from 46,000 metric tons (MT) in the sixties to 28,000 MT in the nineties (Table 10). Other countries such as Chad, Senegal and Niger produce acacia gums (Edward, 2007).

Table 10: *Gum arabic production in Sudan (5-year annual averages) between 1960 and 1994*

Period	Annual average (t)
1960-1964	46,550
1965-1969	50,576
1970- 1974	35,073
1975- 1979	37,408
1980-1984	31,079
1985- 1989	23,721
1990- 1994	18,358

Source: Verbeken *et al* (2003).

The production of *Acacia senegal* and *Acacia seyal* between 1970 and 2003 in Sudan was very regular and interrupted only by three years of low production: 1992, 2000 and 2004, with less than 10,000 metric tons produced annually (Touré, 2008).

2.7.3.7 Collection of gum arabic:

The time of tapping, tapping intensity, rainfall and maximum temperature at gum collection were found to explain 85% of the total variability in gum yield per unit area (Nussinovitch, 2010). It is collected as air-dried droplets with diameters from 2–7 cm. The annual yield per tree averages 0.9–2.0 kg (Edward, 2007). When Acacia trees lose their leaves and become dormant at the beginning of the dry season, usually by the end of October or beginning of November, superficial incisions are made in the branches and bands of bark are stripped off. After 5 weeks, gum is manually collected as partially dried tears. This collection is repeated at 15-day intervals for up to five or six collections in total, depending on the weather conditions and the health of the tree (Verbeken *et al.,* 2003).

A. senegal is a thorny tree that reaches a height of 4.5–6.0 m. It is very drought-resistant and grows on sites with annual rainfall of 100–950 mm and dry periods of 5– 11 months. It is known by many different local names. Sudan is known to have a higher density of *Acacia senegal* with a uniform distribution of the tree in pure stands, making the country the most important producer of Hashab gum arabic (Rahim *et al.*, 2005).

2.7.3.8 The difference between *A. senengal* and *A. seyal* gum:

Acacia Seyal gum is sometimes encountered, which is less soluble than gum acacia and hence it is unsuitable for making sweets with a high proportion of gum acacia as it will not dissolve sufficiently (Edward, 2007). In Sudan the gum from *Acacia senegal* and *seyal* are referred to as Hashab and Talha respectively. The former is a pale to orange-brown solid which breaks with a glassy fracture and the latter is darker, more friable and is rarely found in lumps in export consignments. Hashab is undoubtedly the premier product but the lower-priced. (Touré, 2008).

2.7.3.9 Grading of gum arabic:

After collection, the gum is cleaned and graded. This is traditionally done by women, who manually sort the gum according to the size of the lumps and remove foreign matter (Verbeken *et al.,* 2003).

Commercial samples commonly contain Acacia species other than *Acacia senegal* notably *Acacia seyal*. Some typical grades of Sudanese gum available are listed in table 11. The gum from *A. seyal* (Talha) has been divided into three grades: super, standard clean, and siftings (Verbeken *et al.,* 2003).

Table 11: *Commercial grades of Acacia senegal gum from Sudan*

Type	Description
Hand-picked selected	The cleanest and largest pieces with the lightest color. The most expensive grade.
Cleaned and sifted	The material which remains after hand-picked selected and siftings are removed. This grade comprises whole and broken lumps with a pale to dark amber color.
Cleaned	The standard grade with a light to dark amber color. It contains siftings but the dust is removed.
Siftings	The residue formed by sorting the above, more choice grades. This grade contains a proportion of sand, dirt, and bark.
Dust	This grade is collected after the cleaning process and comprises very fine particles of gum, sand, and dirt.
Red	Dark red gum particles removed from other lumps.

Source: Verbeken *et al* (2003).

For several years, it was impossible for any organization apart from the Gum Arabic Company (GAC) to buy Gum Arabic in Sudan or export from Sudan. This company maintained the monopoly because it was created by the State, in order to monitor and maintain control over a resource so key to the economy (Touré, 2008). The aim of this policy was to end GAC's monopoly and gave numerous exporters' direct access to raw Sudanese Gum Arabic. Fifty-nine exporters joined the local gum arabic market and energized it in the process. This policy was very successful because the exporters generated gum arabic transformation factories in Sudan, which eventually changed local trade practices and guaranteed better revenues for farmers and internationally acceptable rates for producers (Touré, 2008).

Gum arabic manufacturing companies lack the means to promote it through the media. However, an organization like the Association for International Gum Promotion (AIPG), working in conjunction with producer countries, their exporters and financed by international partners, could achieve this (Touré, 2008).

Recently the supply of gum acacia from the Sudan was subjected to U.S. trade sanctions and embargoes. Additionally, some corn starch producers have been unable to guarantee that their products are not derived from Genetically Modified Organisms (GMO), creating a marketing problem where consumers demand products that are "GMO-free". Due to the above considerations, it would be desirable to investigate other options by evaluating polysaccharide or hydrocolloid emulsifiers that are not based on cornstarch or its derivatives, and do not have the supply problem and high cost of emulsifying grade gum acacia (Williams and Phillips, 2004).

2.7.3.10 Gum arabic processing:

After grading, the gum can be further processed into kibbled and powdered forms. Kibbling is a mechanical process which breaks up large lumps into smaller granules with a more uniform size distribution and facilitates the dissolution of the gum in water. Even better solubility characteristics are obtained with powdered gum, which is usually produced by dissolving the gum in water, removing impurities by filtration or centrifugation and spray-drying (Verbeken *et al.,* 2003).

The number of viable bacteria contained in the gum can also be reduced by treatment with ethylene oxide (no longer permitted for food use), or propylene oxide (less efficacious). Heating carried out during manufacture to reduce the microflora can lead to precipitation of the arabinogalactan-protein complex (Nussinovitch, 2010).

The drying temperature influences the gum's functional behavior. Heat in general (either from spray-drying or rollerdrying) causes the gum solutions to be slightly turbid or opalescent (Nussinovitch, 2010).

2.7.3.11 Structure of gum arabic:

Gum arabic analyzed and found that moisture content of 15%, ash content of 3.56%, nitrogen content of 0.35% protein content of 2.31% and with no tannin content. Minerals content of the gum arabic (g/100 g) are Ca 0.7, Mg 0.2, Na 0.01, K 0.95, Fe 0.001 and P 0.6 (Hemeda and Mohamed, 2010). Total dietary fiber content of gum acacia ranges from 80–90% (Hui *et al.,* 2007). The proportion varies significantly depending on the Acacia species. Gum arabic is a mixture of closely related polysaccharides, with an average molecular weight range of 260–1160 kdal. The main structural units, with molar proportions for the gum exudate *A. senegal* given in brackets, are L-arabinose, L-rhamnose, D-galactose and D-glucuronic acid. Most of the gum had a very low protein content (0.35%) and was referred to as an arabinogalactan (AG). It represented 88.4% of the total gum and was found to have a molecular mass of 3.8×10^5 Da. The second fraction represented 10.4% of the total gum and was referred to as an AG–protein complex (AGP) with a molecular mass of 1.45×10^6 Da. The protein content of the AGP was 11.8%. The smallest fraction (1.2% of total gum) was referred to as a lowmolecular- weight glycoprotein (GP) with a molecular mass of 2.5×10^5 Da and a protein content of 47.3%, (Table 12) gives an overview of some chemical characteristics of the gum from *Acacia senegal* (Verbeken *et al.,* 2003). Three principal fractions have been identified by hydrophobic affinity chromatography: a low-molecular-weight arabinogalactan (AG), a very highmolecular- weight arabinogalactan-protein complex (AGP) and a low-molecular-weight glycoprotein (GI). These components represent 88%, 10% and 1% of the molecule, respectively, and they contain 20%, 50% and 30% of the polypeptides, respectively. The protein is located on the outside of the AGP unit. The overall conformation of the gum arabic molecule is described by the 'wattle blossom' model in which approx. five bulky AG blocks, ~200,000 Daltons each, are arranged along the GI polypeptide chain which may contain up to 1,600 amino-acid residues (Nussinovitch, 2010).

Table 12: *Analytical data for the gum obtained from Acacia senegal*

PARAMETER	RANGE
Moisture content (%)	12.5–16.0
Specific rotation	From -32.7^{o} to -27.0^{o}
Nitrogen (%)	0.22–0.39
Protein (%)	1.5–2.6
Galactose (%)	39–42
Arabinose (%)	24–27
Rhamnose (%)	12–16
Glucuronic acid (%)	15–16
Equivalent mass (Da)	1,118–1,238

Source: Verbeken *et al*, (2003).

Gum arabic has a major core chain built of β-D-galactopyranosyl residues linked by 1 → 3 bonds, in part carrying side chains attached at position (Belitz *et al.,* 2009). Side branches may contain α-

Lrhamnopyranose, β-D-glucuronic acid, β-D-galactopyranose, and α-L-arabinofuranosyl units with (1→3), (1→4), and (1→6) glycosidic linkages (See figure 3) (Cui, 2005).

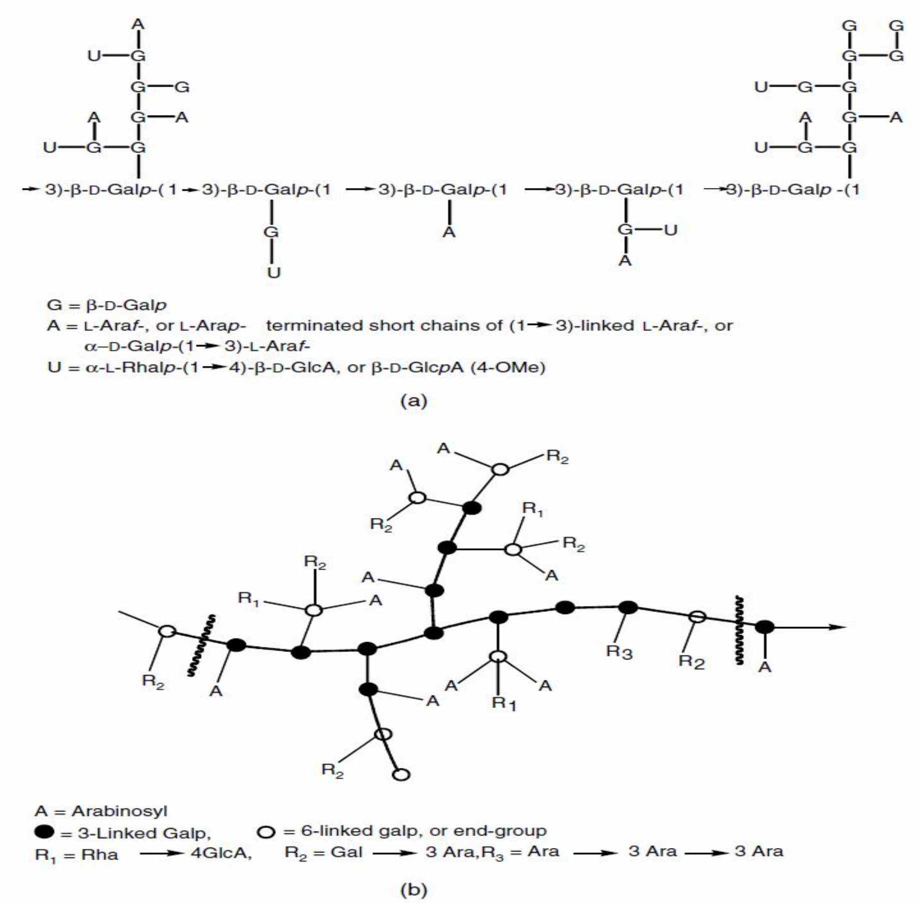

Figure 3: Typical structure feature of gum arabic.
Source: Cui (2005).

2.7.3.12 Properties of gum arabic:

The characteristics may vary significantly, depending on the geographical origin and age of the trees, climatic conditions, soil environment, and even on the place of exudation on the tree (Verbeken *et al.,* 2003).

Gum arabic is a low viscosity gum and its solutions exhibit Newtonian flow behavior even at high concentrations (Cui, 2005). It is non toxic, odorless, colorless, tasteless and completely water soluble and doesn't affect the flavor, odor or color of the food to which it is added (Jilani, 1997). Gum arabic occurs neutral or as a weakly acidic salt. Counter ions are Ca^{2+}, Mg^{2+} and K^{+}. Solubilization in 0.1 mol/l HCl and subsequent precipitation with ethanol yields the free acid (Belitz *et al.,* 2009). Another unique feature of gum arabic is its covalent association with a protein moiety. It is thought that the protein moiety rich in hydroxyproline (Hyp), serine (Ser), and proline (Pro) constitutes a core to which polysaccharide subunits are attached via Ara-Hyp linkages (the wattle blossom model). The protein moiety of gum arabic is responsible for the surface activity, foaming, and emulsifying properties of this polymer (Cui, 2005). Gum arabic exhibits marked emulsifying and film-forming properties, which are caused not only by its structure, but also by the slight admixture (ca. 2%) of a protein. The serine and threonine residues of this protein are thought to be covalently bound to the carbohydrate. The interfacial activity of gum arabic is low compared to that of proteins. The proportion of gum arabic to oil used in formulations has to be approximately 1:1. In contrast, a protein oil ratio of about 1:10 is used in an emulsion stabilized by milk proteins (Belitz *et al.,* 2009). Gum acacia is much more soluble than other gums. The viscosity of a gum solution falls with increasing temperature as well as being pH dependent (Edward, 2004). The pH of the solution is usually around 4.5 to 5.5, but maximal viscosity is found at pH 6.0 (extension of the molecule). At still higher pH, ionic strength of the solution increases until the repulsive electrostatic charges are masked, yielding a compact conformation with lower viscosity (Nussinovitch, 2010).

Gum arabic is very soluble in water and solutions of up to 50% gum can be prepared. The solution viscosity starts to rise steeply only at high concentrations (Figure 4). This property is unlike that of many other polysaccharides, which provide highly viscous solutions even at low concentrations (Belitz *et al.,* 2009).

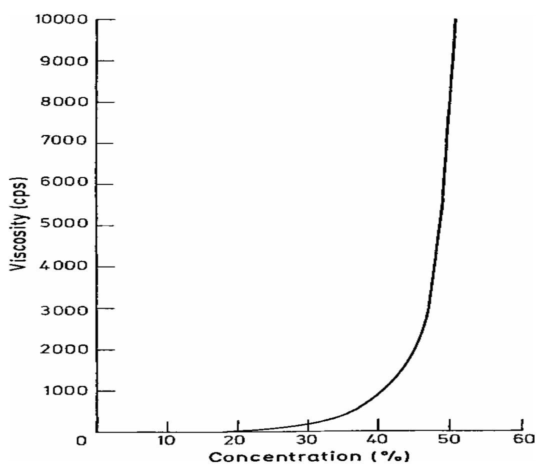

Figure 4: Viscosity curve of an aqueous gum arabic solution (25.5 ◦C, Brookfield viscometer).
Source: Belitz *et al.,* (2009).

Gum arabic is a surface active gum that is able to stabilize oil-in-water emulsions. The protein-rich high molecular weight fraction of gum arabic is preferentially adsorbed onto the surface of oil droplets while the carbohydrate portion inhibits flocculation and coalescence by electrostatic repulsions and steric forces. A wattle blossom model of the arabinogalactan–protein complexes and the stabilizing mechanism in oil-in-water emulsions is depicted in figure (5) (Cui, 2005).

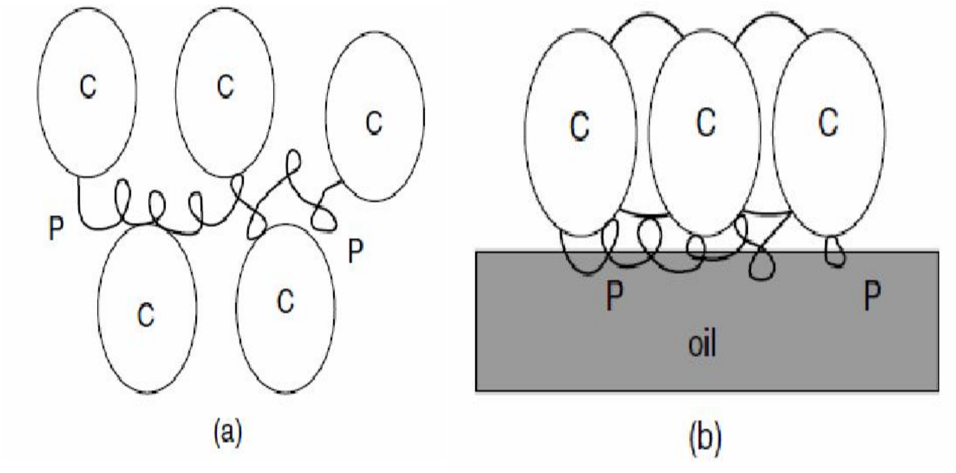

Figure 5: Models of gum arabic as an emulsifier in oil-in-water emulsions: (a) Sketch representation of gum arabic structure: c and p represent the carbohydrate and protein moieties respectively; (b) Behavior of gum arabic at the oil/water interface.
Source: Cui, (2005).

The unique property of Gum Arabic is its ability to produce oil droplets of fairly uniform 1-2 micron diameter and to stabilize the emulsion so that it neither aggregates nor coalescences in acid solutions, even over periods of several months (Nishinari, 2000).

Spray dried gum acacia has been used in pharmaceutical products for some time. The spray dried gum offers the pharmaceutical manufacturer a clean ready to use product. Instant forms of gum acacia have been offered by suppliers for some time. The instant products can be rapidly made into solution and used. Obviously the instant gum is more expensive. A manufacturer that uses gum as a minor ingredient may well find that the capital and labor cost of purifying raw gum is not cost effective. A company that uses gum acacia as a major ingredient might come to a different conclusion (Edward, 2007).

2.7.3.13 Safety of gum arabic:

In Europe, gum arabic is authorized as a food additive named E414; while in the United States it possesses the FDA GRAS (Generally Recognized as Safe) status (Touré, 2008). Moreover, its safety has been established in healthy volunteers. The estimated acceptable daily intake (ADI) for humans was set as “not specified” in 1982, and this was confirmed in 1992 **(**Nussinovitch, 2010)**.**

Clinically, it has been tried in patients with chronic renal failure, and it was claimed that it helps reduce urea and creatinine plasma concentrations and reduces the need for dialysis from 3 to 2 times per week. GA has been claimed to alleviate the adverse effects of chronic renal failure in humans. Effects of GA on lipid metabolism in humans and rats are at variance, but mostly suggest that GA ingestion can reduce plasma cholesterol concentrations in rats. GA has proabsorptive properties and can be used in diarrhea. It enhances dental remineralization, and has some antimicrobial activity, suggesting a possible use in dentistry. GA has been shown to have an adverse effect on electrolyte balance and vitamin D in mice, and to cause hypersensitivity in humans (Ali *et al.*, 2009).

Returning to the renal field of renal medicine, it is well established that supplementation of the diet with gum arabic soluble fiber lowers serum urea nitrogen in rodents and in patients with chronic renal failure. This effect is the result of increased colonic bacterial fermentation of gum arabic thus providing them with energy for growth and nitrogen incorporation, and in turn increasing faecal bacterial mass and nitrogen excretion. More recently a pilot study performed in collaboration with the Dialysis Centre in Khartoum suggests that dietary gum arabic supplementation also reduces serum creatinine. This cannot be related to alterations in colonic bacterial fermentation, but rather suggest that there may be a direct beneficial effect on renal function. The mechanism of these potentially important therapeutic observations is currently the subject of ongoing research (Williams and Phillips, 2004).

2.7.3.14 Nutrition of gum arabic:

Food manufacturers use the term "dietary fiber" to describe their products or its contents, but there is no internationally accepted legal definition or approval system to support this practice. Gum arabic, like other food fiber materials, is universally recognized scientifically as a food additive but its regulatory status remains a matter of discussion and some uncertainty. The same uncertainty also relates to the regulatory status, as dietary fiber, of other soluble and insoluble plant/algal polysaccharides (Nussinovitch, 2010).

Upon its consumption, gum arabic is fermented by the intestinal bacteria to SCFAs, particularly propionate. Using an enrichment culture of pig cecal bacteria from a selected high-molecular- weight gum arabic (MW 1.77 x 106), it was observed that a *Prevotella ruminicola*-like bacterium, as the predominant bacterium, is most likely responsible for gum arabic fermentation to propionate. On the one hand, dietary supplementation with gum arabic (SUPER GUM^{TM}) increased serum butyrate, which at least in vitro has beneficial effects on renal profibrotic cytokine generation. On the other hand, plant hydrocolloids can reduce protein digestibility and, consequently, modify the bioavailability of amino acids. In-vitro hydrolysis at 37°C of β-lactoglobulin in mixed dispersions containing gum arabic, low-methylated pectin or xylan was studied. β-lactoglobulin was almost totally resistant to pepsin digestion and the three plant hydrocolloids significantly inhibited β-lactoglobulin digestibility. The decrease in digestibility obtained with xylan was greater than that obtained with gum arabic or low-methylated pectin (Nussinovitch, 2010).

Diarrhea is a common and deadly threat to millions of infants and children worldwide. Similarly, malabsorption can aggravate the health status of the chronically ill, particularly in the elderly population.

Prompt recovery from intestinal dysfunction may have a substantial impact on many populations. The proabsorptive effects of gum arabic could directly reduce and ameliorate intestinal dysfunction. Natural proteoglycans, such as gum arabic, can reduce secretory effects induced by cathartics and, hence, are predictive of potential effectiveness in the context of diarrhea or malabsorption due to infectious or systemic causes. Stem exudates, seeds, leaves and the insides of pods are also used for skin diseases, as well as to control parasites in dogs and to treat diarrhea (Nussinovitch, 2010).

2.7.3.15 Adverse effects and toxicity of Gum arabic:

Gum arabic, gum tragacanth, gum karaya and gum ghatti are safe for human consumption based on a long history of usage as well as recent toxicological studies (Nussinovitch, 2010).

The safety of GA (5, 10, 20 or 40 g in water for 4 weeks) has recently been confirmed in healthy men. The subchronic toxicity of a new type of GA (SUPER GUM [Acacia (sen) SUPER GUM]), a naturally processed polysaccharide exudate from *A. senegal*, was studied when given to both sexes of F344 rats at dietary levels of 0 (control), 1.25%, 2.5%, and 5.0% (10 rats/sex/group). During the study, the treatment had no effect on clinical signs, survival, body weights, food and water consumption, urinalysis, ophthalmology, hematology, and blood biochemistry, and no gross pathological or histopathological alterations. Increased relative cecum (filled) weights, evident in both sexes of the 5.0% group and females of the 1.25% and 2.5% groups, were considered to be a physiological adaptation. It was concluded that, at least, up to a dietary level of 5.0%, SUPER GUM (equivalent to 3117 mg/kg body weights/day for males, and 3296 mg/kg body weights/day for females) caused no adverse effect. This confirms earlier reports that documented the safety of GA (Ali *et al.,* 2009).

2.7.3.16 Applications of gum arabic:

Gum arabic is used in five main food areas: confections, beverages and emulsions, flavor encapsulation, baked goods and brewing (Nussinovitch, 2010). Only the gum from *A. senegal* has been effectively demonstrated as an innocuous food additive (Touré, 2008). Gum arabic is the most commonly recognized hydrocolloid emulsifier which is widely used in the soft drinks industry for emulsifying flavor oils (e.g., orange oil) under acidic conditions. Gum arabic found broad applications in the confectionary and beverage industries as an emulsifier and stabilizer and flavor encapsulation agent. For example, it is used as an emulsifier in the production of concentrated citrus juices and cola flavor soft drinks (Edward, 2007). Gums have also been used to coat sensitive ingredients against both moisture and fat migration. A common example is the use of gum arabic solution, to coat nuts prior to chocolate panning or adding into multicomponent confectionery bars (Kilcast and Subramaniam, 2000).

Gum arabic has excellent emulsifying properties, particularly thanks to its AGP fraction (Verbeken *et al.,* 2003). The officially accepted value for the energy content of gum acacia has varied between zero and 100% of the bomb calorimeter value. The currently accepted value is 50% of the bomb calorimeter value (Edward, 2007).

Gum arabic is also used in candies to prevent sugar crystallization and to emulsify the fatty components in products such as pastilles, caramel, and toffee. Gum arabic is an ingredient in chewing gums and cough drops. Spray-drying of flavor oils with gum arabic solutions produces microencapsulated powders that can be easily incorporated into convenient dry food products such as soup and dessert mixes (Cui, 2005).

Gum acacia gives a lower viscosity than the other gums more has to be used. However, as this gum is more soluble it is possible to use more (Edward, 2007). Natural gums are capable of causing a large increase in solution viscosity, often even at low concentrations (Nussinovitch, 2010).

2.7.3.17 Use of gum arabic in breadbaking:

Gum arabic is unique in the very high gum concentrations which can be used to prepare solutions. Thus, large amounts of gum can be used in a variety of food products (Nussinovitch, 2010).

Gum arabic is widely used in the backing industry for its viscosity and adhesive property (Jilani, 1993). The addition of gum arabic concludes in increased loaf volume and bread characteristics. The improvement of bread external appearance and its internal characteristics such as texture, cell wall structure, color and softness were also described (Hemeda and Mohamed, 2010). Gum arabic and CMC improved loaf volume, internal and external appearance of bread, Gum Arabic gave the better results than CMC (Asghar *et al.*, 2005). Gum acacia is likely to be encountered in bakeries in small quantities when it has been used to make emulsions of citrus oils as a bakery flavor (Edward, 2007). Gums like guar, carboxy-methylcellulose, xanthan, and gum arabic improve machinability, decrease dough stickiness, delay staling, improve rollability and water holding capacity, improve freeze/thaw stability and decrease moisture loss (Gritsenko, 2009). Arabic gum is added into wheat dough to slow aging of bakery products, to improve volume of bakery products, to milder consistence in ice creams and in confectionery to stop sugar crystallization (Mikuš *et al.,* 2011). The use of gum arabic and CMC, both at 3% on a flour weight basis, improved the quality of the frozen pizza dough (Nussinovitch, 2010). The effects of different hydrocolloids on the gelatinization behavior of hard wheat flour, Gum Arabic lowers the peak viscosity, reduces breakdown during heating and thus provides increased stability during cooking (Alam *et al.*, 2009).

In general, however, it is the highly soluble fibers (those that are highly branched or are relatively short-chain polymers, such as gum arabic, isolated arabinogalactans, inulin and oligosaccharides) that have low viscosities. These low-viscosity fibers have low GI and are generally used to modify texture or rheology, manage water migration, influence the solution properties of the food system, and improve the marketability of the food product as a health-promoting or functional food product. These fiber sources can be used in food products at relatively high levels, as they typically enhance the food product's taste, mouth feel and shelf-life without significantly altering the specific application characteristics. For example, they can be used in sugar-free and fat-free products, increasing the potential for a high fiber claim (Kent and Evers, 1994).

Gum arabic can also be regarded as a source of soluble fiber, being unaffected by passage through the stomach but broken down by the large intestine (Emerton and Choi, 2008).

Flavor emulsions are flavor oils dissolved in water with the aid of a starch or gum. The starch or gum—often gum arabic or xanthan gum—acts as an emulsifier, allowing the oil to blend more easily with other ingredients. This makes flavor emulsions easier to add to batters and doughs, for example (Figoni, 2008).

The maximum % usage level of specific gums in bakery foods, based on the Code of Federal Regulations in the U.S. Gum acacia may be used at 0.8% gum level in baked goods (Williams and Phillips, 2004).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials:

3.1.1 Wheat flour:

Wheat flour was obtained from A Flour Mills – industrial zone Bahry. Main specification of flour is without any additives, that sample was taken from process line. Flour was kept in temperature below 5^0 C during period of experiment.

3.1.2 Gum arabic:

Gum arabic was obtained from Henelie Industries Ltd. Which is provide gum arabic (Spray-dried gum arabic and kibbled gum), Industrial zone – Albagair. Type of gum arabic (Hashab) gum, that gum was purchased from Alobeid market. Weights of samples of gum arabic were taken as percentage of flour (w/w %), the sample of gum arabic was kept in temperature below 5^0 C during period of experiment.

3.1.3 Other raw materials:

- Baker yeast from local market, Levure instant yeast, made in Turkey by Ozmaya San. A.S. (a Lesaffre company).
- Salt from Alrasheed factory, portsudan, local market
- Ascorbic acid, purchasing from local market.
- Alpha amylase purchasing from local market.
- Sugar from Dal group company package 1 kg
- Edible oil from Savola Company – Sudan

3.2 Methods:

Proximate analysis was carried out for samples consist of mixture of wheat flour and gum arabic.

3.2.1 Determination of moisture content:

The determination of moisture was carried out according to AACC (2000) methods.

The main steps were as follows:

Three grams of well-mixed samples were weighed accurately in clean preheated moisture dish of known weight by using sensitive balance.

The uncovered dishes with the samples were kept in an air oven provided with a fan at 130°C for 1 hour.

The dish was then covered and transferred to desiccator and weighed after cooled to room temperature.

The loss of weight was calculated as percent of sample weight and expressed as moisture content:

$$\text{Moisture content \%} = \frac{Wt_1 - Wt_2}{\text{Sample wt.}}$$

Where:

Wt_1 = Weight of sample + dish before oven dry.

Wt_2 = Weight of sample + dish after oven dry.

3.2.2 Determination of ash

The determination of ash was carried out according to AACC (2000) methods.

The steps were as follows:

Three grams were weighed in empty crucible of known weight. The sample was heated in a Muffle-Furnace at 550°C until its weight is stable. The residue is cooled to room temperature after removed from a Muffle-furnace and placed in a desiccator then weighed.

The process was repeated until constant weight was obtained.

% Ash content was calculated using the following equation:

$$\text{Ash content \%} = \frac{(Wt_1 - Wt_2) \text{ x } 100X100}{\text{Sample wt.x } (100\text{-m})}$$

Where:

Wt_1 = Weight of crucible with ashed sample.

Wt_2 = Weight of empty crucible.

m = % moisture.

3.2.3 Determination of crude protein:

The determination of crude protein was carried out on the samples according to AOAC (1984) methods.

The steps were as follows:

A 0.2 gram of sample, plus 0.4 gram catalyst mixture (potassium sulfate + cupric sulfate 10:1 by wt), and 7 ml concentrated nitrogen free sulfuric acid, were mixed in a small Kjeldahl flask (100 ml).

The mixture was digested for two hours, then cooled, diluted, and placed in the distillation apparatus.

Fifteen milliliters of 40% NaOH solution were added and mixture was heated and distilled until 50 ml were collected in a 100 ml conical flask. The ammonia evolved was received in 10 ml of 2% boric acid solution plus 3-4 drops of universal indicators (methyl red and bromo cresol green).

The trapped ammonia was titrated against 0.02N Hcl.

The percentage (g/100) of protein was calculated by using an empirical factor to convert nitrogen into protein as follows:

$$\text{Nitrogen content \%} = \frac{TV \times N \times 14.00 \times 100}{1000 \times \text{wt. of sample}}$$

Protein content % = (nitrogen content %) X F

Where:

TV = Actual volume of HCL used for titration (ml HCL – ml blank).

N = Normality of HCL.

14.00 = Each ml of HCL is equivalent to 14 mg nitrogen.

1000 = To convert from mg to gm.

5.7 = constant factor for wheat flour.

3.2.4 Determination of fat content:

Crude fat was determined according to the standard method of AOAC (1990). A sample of 3 g was weighed into an extraction thimble and covered with cotton; that was previously extracted with hexane (BP60-70°C), and then the sample and a pre-dried and weighed Erlenmeyer flask containing about 50 ml were attached to extraction unit for 45 minutes. At the end of distillation period, the solvent was recovered from the oil. Later, the flask with the remaining crude hexane extract was put in an oven at 105 °C for about an hour. Cooled in a desiccator, reweighed and dried extract was recorded as crude fat% (DM) according to the following formula:

Crude fat % (DM) = <u>Dry extract w.t (g) x 100 x 100</u>

Wt. sample (100 - % moisture)

All the analyses were replicated three times and the means were reported.

3.3 Breadmaking processes:

The breadmaking process was divided into three processes as follow:

1) Bread from A_1 flour (without any improvers).
2) Bread from A_2 flour with some improvers (Ascorbic acid and Alpha amylase as 80 ppm)
3) Bread from B flour intended use for breadmaking for comparing.

3.3.1 The bread recipes:

The bread recipes which was used in the study are just different in some additives (Ascorbic acid and alpha amylase) comparing with B flour. (See table 13)

Table 13: *Basic recipe*

Ingredient	Quantity
Wheat flour*	250 gm
Sugar	3.0 gm
Baker's yeast	2.5 gm
Common Salt	2.0 gm
Edible Oil	2 ml
Gum Arabic	0.5, 1.0, 1.5, and 2.0 % (w/w) flour
Water	165 ml

* Note: Wheat flour was A_1, A_2 and B flour. In A_2 some additives were used (Ascorbic acid and alpha amylase as 80 ppm).

3.3.2 Weighing of raw material:

All raw materials weighed by sensitive balance (6 digits) which provided by glass box protected from air current, raw materials prepared before starting the process.

3.3.3 Mixing:

Wheat flour was added in mixer bowl first and the mixer was started then baker's yeast and sugar were added after one minute of dry mixing Water was added then other ingredients were added, Mixing was running until there was no dry flour left and mixer was running for total time three minutes.

3.3.4 First fermentation (proofing):

Fermentation process was implemented in two steps:

After mixing the dough was taken out from the mixer and put on the table after that it was given code numbers and covered and kept to rest for ten minutes at room temperature.

3.3.5 Dividing:

After first fermentation, dough was transferred and scaled into three portions, and rounded into balls. Each weight of piece was 120 gm and then pieces were placed in lightly greased metal templates.

3.3.6 Second fermentation:

Dough after dividing was placed in the fermentation cabinet at 30ºC and 85% relative humidity. In this step fermentation times were done in different time in both samples of A flours, in B flour the fermentation time was maintained stable for each samples.

3.3.7 Baking process:

After fermentations process all templates were transferred to Oven at 250^0 C, provided with rotation shelf to distribute heating. Baking time of samples were different in A_1 and A_2 flour, B flour sample was maintained stable.

3.3.8 Cooling process:

Bread was transferred from the Oven to table and then were removed from the templates and kept to cool. After 15 minutes all bread reached the room temperature.

3.3.9 Measuring of specific volume:

The specific volume of bread was calculated according to AACC (2000) by dividing volume (cc) by weight (g). After bread was cooled. It was transferred to sensitive balance for weight and subsequently to bread volume tester to measure volume. Loaf Specific Volume (LSV), was calculated according to the following:

L.S.V = Loaf volume (cc) / Loaf weight (g) = cc /g

3.3.10 Color measurement:

The color of bread crumb and bread crust were determined by (Colorflex EZ Hunter l, a, b) measurements were taken. Three readings, average L, a, and b values were recorded (Table 14). Bread color results were reported in terms of 3-dimensional color values based on the following rating scale:

Table 14: *Mechanism of Colorimeter(Colorflex EZ) instrument*

Letter	Reading	Type of color
L	brightness	Dark- Bright (0-100)
a	+	Red color
	-	Green color
b	+	Yellow color
	-	Blue color

3.3.11 Slicing process:

After measuring specific volume the bread pieces sliced to carry out sensory evaluation by electric knife to obtain uniform slices of 1 cm thickness.

3.3.12 Sensory evaluation:

The bread samples were sliced with electric knife and prepared for sensory attributes evaluation after bread samples were reached room temperature. Sensory evaluation was done using Ranking method by Trained panelists. After 8 hours storage sensory evaluation was carried out by semi trained panelists, The panelists received five samples and were asked to rank them for the intensity of some specific characteristics. Panelists were presented with several blind coded samples. They are asked to assess the samples in the order provided and placed them in order of intensity for a specified attribute. The surrounding conditions were kept the same all through the panel test. All sensory evaluations were carried out individually for each experiment.

3.3.13 Statistical Analysis:

Statistical software "Minitab for Windows (Minitab, 2007)" was used to perform statistical analysis (ex. Analysis of Variance, Correlation Matrix, Principal Component Analysis and Multiple Regression).

ANOVA permits a decision maker to conclude whether or not all means of the populations under study are equally based upon the degree of variability in the sample data. In statistics, the term "population" means the total of any kind of units under consideration (N) by the statistician and a "sample" is any portion of the population selected for study (n). ANOVA is based on two hypotheses (null: H_0 and alternative: H_1). According to the "null hypotheses", all the population means are same. On the other hand, if there are significant differences among the sample means are not same, "alternative hypothesis".

Correlation coefficient is an index of the degree of relationship between two sets of measures and is always between -1.00 to +1.00. A correlation coefficient of -1.00 is indicative of a perfect negative correlation; zero is indicative of no correlation; +1.00 is indicative of a perfect positive correlation, Correlation coefficients will be determined for this study to assess the correlations between gum arabic treatment and other parameters of the experiment.

Descriptive analysis was performed, using standard statistical methods.

A five-item Likert scale was used as the highest grade was given 5 degrees, the lowest grade given one degree and the degrees sorted in descending order (1, 2, 3, 4, 5). The range was calculated for the scale as 5-1 = 4, then dividing the range by the number of categories (5) gave 4/5 = 0.80, which was the length of each category of the five scales. Finally, the length of the category was added to the lowest grade of the scale, which was 1. Thus, the first category was calculated to be 1 to 1.80. By adding the length of the highest limit for the category to produce the second category and so on for the rest of the categories, the following criteria were defined for purposes of analyzing the results:

0.00 to 1.80	Excellent
> 1.81 to 2.60	Very good
> 2.61 to 3.40	Good
> 3.41 to 4.20	Acceptable
> 4.21 to 5.00	Poor

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Proximate composition of mixture of wheat flour and gum arabic:

Gum arabic had no significant effect on proximate composition of mixture of gum arabic and wheat flour P-value is greater than the α-level (Table 15) ($P > 0.05$). Therefore, the null hypothesis failed to reject.

4.2 Effect of gum arabic on fermentation time:

Table 16 shows that the gum arabic addition has no significant effects on fermentation time (P-values: 0.651 and -0.769) in A_1 flour, A_2 flour, respectively, p-values is greater than the α-level, failed to reject the null hypothesis.

Gum arabic addition had no effect on fermentation time at significant level (0.05). Emulsifying agents may improve the functional properties of the dough by increasing water absorption and gas retention, decreasing proofing times, and reducing the staling rate as was previously found by (Hutkins, 2006). In another study, dough conditioners or stabilizers and emulsifiers reduce the necessity for resting times and improve tolerance towards dough handling in the bakery equipment (Amendola and Rees, 2003).

4.3 Effect of gum arabic on baking time:

Table 17 shows the gum addition had no significant effect on baking time (P-values: 0.162 and 0.932 in A_1 flour and A_2, respectively, p-values are greater than the a-level, fail to reject the null hypothesis.

From this result effect of gum arabic on baking time had no significant by comparison with sample of B flour (constant baking time) perhaps, due to amount of gum arabic addition compared as was previously found by Wassermann (Proofing stability as well as oven spring will also increase) (Wassermann, 2009).

Table 15: *Proximate composition (%) of mixture of flour and gum arabic*

Mixture(w/w% flour)	Moisture	Protein	Fat	Ash
0.0	12.35	12.93	0.22	0.65
0.5	12.10	12.63	1.27	0.56
1.0	11.52	12.54	1.17	0.55
1.5	11.53	12.66	1.25	0.61
2.0	12.38	12.57	1.54	0.59
Mean	11.97	12.66	1.09	0.59
SD	0.43	0.155	0.51	0.04
Pearson correlation	-0.482	-0.704	0.819	-0.262
P-Value	0.411	0.185	0.09	0.67

SD= Standard deviation

Table 16: *Effect of gum arabic on fermentation time (min.) of A flours*

Gum treatment	A_1 flour	A_2 Flour
0	40	36
0.5	35	47
1	30	42
1.5	35	38
2	45	43
Mean	37	41
SD	5.7	4.32
Pearson correlation	0.277	-0.121
P-Value	0.651	0.769

SD= Standard deviation

Table 17: *Effect of gum arabic on baking time (min.) of A flours*

Gum treatment	A_1 flour	A_2 flour
0.0	35	23
0.5	35	26
1.0	40	30
1.5	30	27
2.0	20	23
Mean	31.25	26.5
SD	7.58	2.95
Pearson correlation	-0.73	0.054
P-Value	0.162	0.932

SD = Standard deviation

4.4 Effect of gum arabic on specific volume of A_1 and A_2 breads:

Table 18 shows the gum addition had significant effects on specific volume (P-values: 0.004 and 0.043 in A_1 bread and A_2 bread respectively, p-values are less than the α-level, reject the null hypothesis in favor of the alternative hypothesis.

Gum arabic had strong decreasing effect on specific volume on A breads (Look Plate 1 and 2). Table 19 presented effect of gum arabic on specific volume of A_1 bread and A_2 bread as percentage compared with control sample.

4.5 Effect of gum arabic addition on specific volume of B bread:

Table 20 shows the gum addition has significant effects on specific volume of B bread (Fermentation and baking times were kept stable). (P-value: 0.007) p-value is less than the α-level, failed to reject the null hypothesis in favor of the alternative hypothesis. Gum arabic decreased specific volume of B bread by -20.67 % every 0.5% gum arabic (Table 21)

Gum arabic had different effect on specific volume of three types of flours, decreasing of specific volume was presented for every treatment, but the effect is less in A_1 bread, A_2 bread and B bread, respectively (Table 22).

In the results above gum arabic play as inhibition factor as was previously found by hydrocolloids when used in small quantities (<1% (w/w) in flour) are expected to increase water retention and loaf volume and to decrease firmness and starch retrogradation (Kohajdova *et al.,* 2009).

The negative effect of gum arabic was more effect by the general volume of bread, so if specific volume of bread was too high gum arabic effect was becomes high too.

Generally, comparing with the control, gum arabic addition decreased specific volume according to volume of bread, but this effect does not continue because there well reached point then become permanent. There was semi relation between A_1 bread and B bread in 0.5% and 1.5% of gum arabic.

Gum arabic had decreased specific volume of all treated breads compared with the control sample. Plate (3) shows relation between gum arabic treatment and specific volume of B bread.

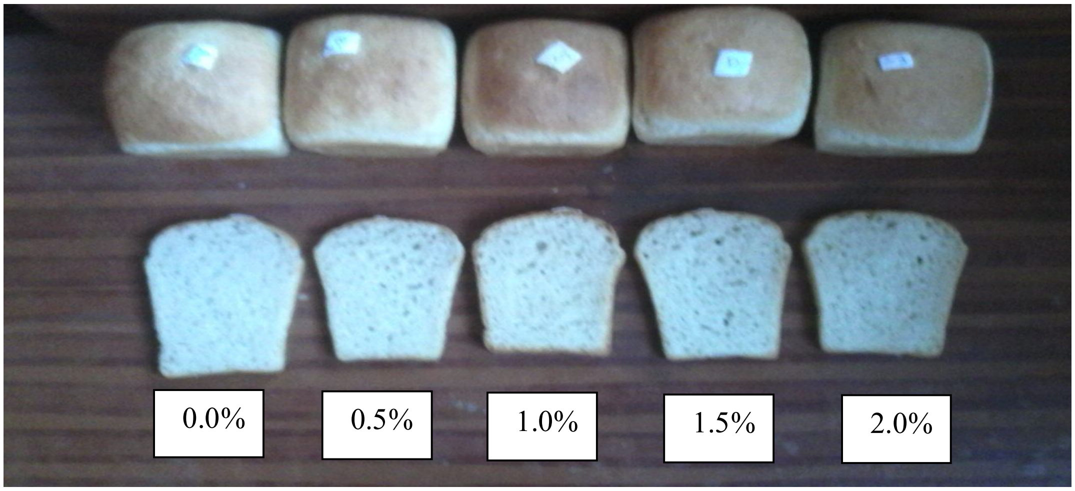

Plate 1: A_1 bread

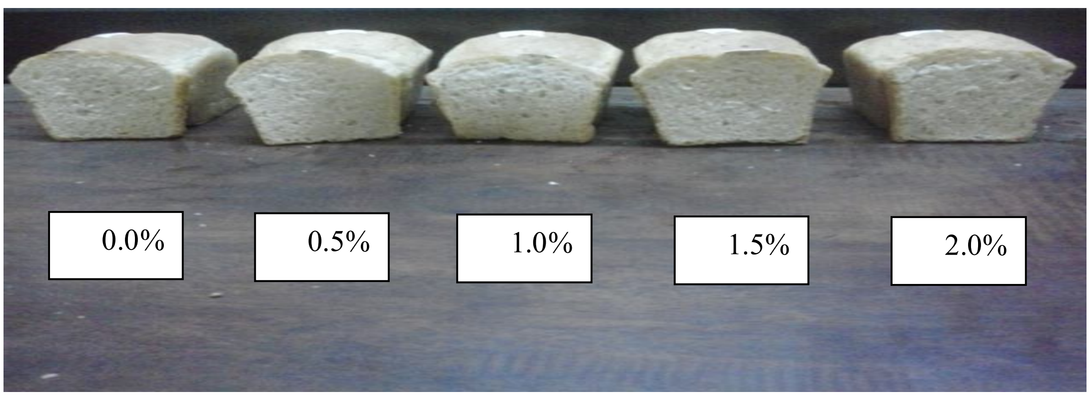

Plate 2: A_2 bread

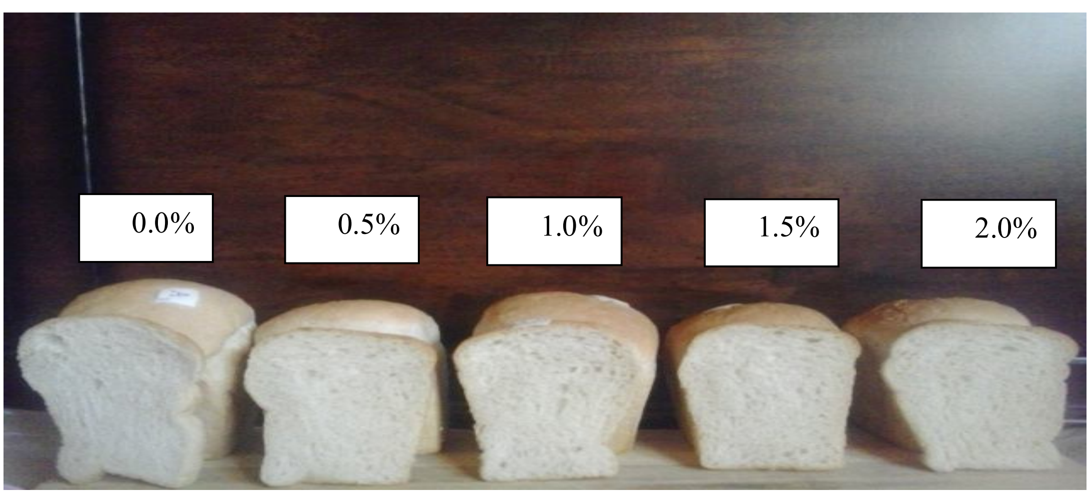

Plate 3: B bread

Table 18: *Specific volume of A bread samples*

Gum treatment	A_1 bread	A_2 bread
0.0	2.54	3.24
0.5	2.44	2.74
1.0	2.4	2.65
1.5	2.36	2.59
2.0	2.31	2.49
Mean	2.3775	2.6175
SD	0.087	0.292
Pearson Correlation	-0.979	-0.891
P-Value	0.004	0.043

SD = Standard deviation

Table 19: *Decreasing of specific volume of A bread samples (%)*

Gum treatment	A_1 bread	A_2 bread
0.5	-4.10	-18.25
1	-5.51	-18.21
1.5	-7.09	-20.06
2	-9.06	-23.15
Mean	-6.44	-19.92

Note: Gum arabic had been decreased Specific volume by 6.44 % and 19.92 % for A_1 bread and A_2 bread, respectively.

Table 20: *Specific volume of B bread*

No	Gum treatment	B bread
1	0.0	4.35
2	0.5	3.75
3	1.0	3.72
4	1.5	3.43
5	2.0	3
Mean	3.475	
SD	0.494	
Pearson Correlation	-0.967	
P-Value	0.007	

SD = Standard deviation

Table 21: *Decreasing of specific volume of B bread (%)*

No	Gum treatment	B bread
1	0.5	-16.00
2	1.0	-14.48
3	1.5	-21.15
4	2.0	-31.03
Mean	-20.67 %	

Note: gum arabic had been decreased Specific volume by 20.67 % (Average) every 0.5 % (w/w flour) of gum arabic on B bread.

Table 22: *Summary of decreasing of specific volume (%) on bread samples*

Gum treatments (%)	A_1	A_2	B
0.5	3.94	15.43	13.79
1.0	5.51	18.21	14.48
1.5	7.09	20.06	21.15
2.0	9.06	23.15	31.03
Mean	6.40	19.21	20.11

In table (22) specific volume of all bread types treated by gum arabic decreased with increasing amount of gum arabic. However, the decreasing was different from one type to another. Therefore, gum arabic treatment did not improve specific volume of all bread types, this result was opposite result that found by Kohajdova *et al.* (2009) the addition of gum arabic concludes in increased loaf volume and bread characteristics. The improvement of bread external appearance and its internal characteristics such as texture, cell wall structure, color and softness were also described.

4.6 Effect of gum arabic on bread colors (a/b) of crumb and crust of A_1 and A_2 breads:

Table 23 shows the gum addition did not had significant effected on color (a/b) of crumb and crust of breads. (P-values are greater than the α-level) so, failed to reject the null hypothesis in crumb and crust color.

4.7 Effect of gum arabic addition on sensory evaluation:

The gum addition has significant effects on sensory evaluation p-value is less than the α-level, failed to reject the null hypothesis in favor of the alternative hypothesis (Look Appendices).

Gum arabic had different effect on sensory attributes at fresh and at stored bread.

In A_1 bread, taste, texture and general acceptability were preferred in gum arabic addition 0.5%. Whereas, color and flavor were preferred in 1.5% and 1.0% respectively. Nevertheless, after 8 hours taste, texture and general acceptability were preferred in 0.5 % and color and flavor were preferred in 2% addition (Table 24). Generally, 0.5% gum Arabic addition was preferred by panelists in overall sensory evaluation, however after 8 hours from evaluation, 1.0 % of gum Arabic addition panelists preferred it, figure 6 presented that clearly.

Addition of gum arabic on A_2 bread was given findings differ from those findings in A_1 bread, as 1.0 % gum Arabic is better in color acceptance. flavor, texture and general acceptability preferred in 0.5% addition and taste was better in 1.0% addition.

After 8 hours, taste, texture and general acceptability were preferred in 0.5% addition; color and flavor were preferred in 1.5% and 1.0% addition respectively (Table 25).

Generally, 0.5% was overall preferred in fresh bread but after 8 hours 0.5% was overall preferred too, this finding was opposite result of A_1 bread (Figure 7).

Table 23: *Effect of gum arabic on color (a/b) in A bread samples*

Bread type	A_1 bread		A_2 bread	
Treatment	Crumb	Crust	Crumb	Crust
0.0	-0.0391	0.5841	-0.0398	0.5334
0.5	-0.0403	0.5863	-0.0378	0.3576
1.0	-0.0239	0.6903	-0.0303	0.4986
1.5	-0.0191	0.5834	-0.0245	0.541
2.0	-0.0386	0.5316	-0.0358	0.4094
Pearson correlation	0.353	-0.294	-0.087	-0.126
P- value	0.56	0.631	0.89	0.84

(α-Level = 0.05)

Table 24: *Grouping sensory attributes of* A_1 *bread using Fisher method*

Fresh Bread				After 8 hours		
Gum treatment (%)	N	Mean	Grouping	Gum treatment	Mean	Grouping
2.0	5	3.72	A	0.0	5.0	A
1.5	5	3.42	A	0.5	3.1	B
1.0	5	3.29	A	1.5	2.5	BC
0.0	5	2.40	B	2.0	2.3	C
0.5	5	2.21	B	1.0	2.1	C

* Means that do not share a letter are significantly different.

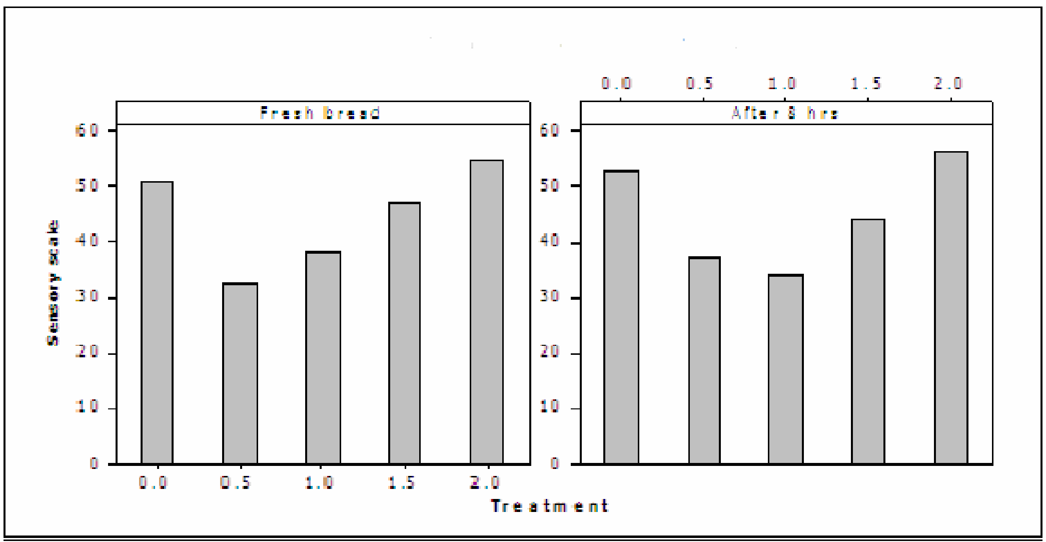

Figure 6: Comparison of overall acceptability of A_1 fresh bread (Left) and after 8 hours of storage bread (Right). (Note: Preference is for the shortest bar).

Table 25: *Grouping sensory attributes of A_2 bread using Fisher method.*

Fresh bread				After 8 hours		
Gum treatment%	N	Mean	Grouping	Gum treatment%	Mean	Grouping
0.0	5	3.26	A	2.0	4.76	A
2.0	5	3.22	A	1.5	3.10	B
1.5	5	2.76	A	0.0	2.70	BC
0.5	5	2.69	A	1.0	2.40	BC
1.0	5	2.65	A	0.5	1.80	C

Note: Means that do not share a letter are significantly different

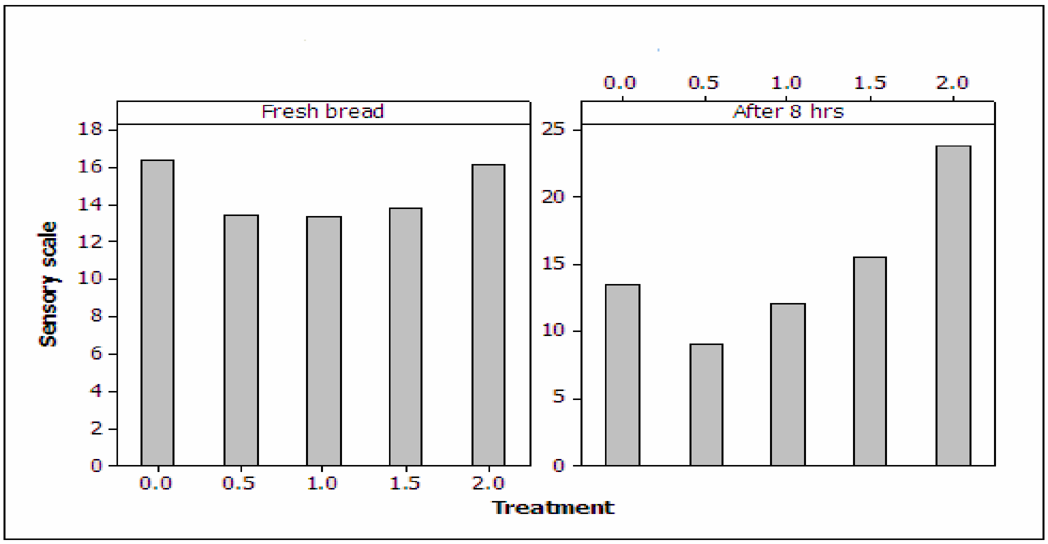

Figure 7: Comparison of overall acceptability of A_2 fresh bread (Left) and after 8 hours of storage bread (Right). (Note: Preference is for the shortest bar).

Effect of gum arabic addition on B bread to compare sensory attributes with other samples. All sensory attributes were preferred in 0.5% gum arabic addition except taste was preferred in 2.0% addition in fresh bread, but after 8 hours texture and general acceptability were preferred in 1.0% addition, and color and texture were preferred in 2.0% and 0.5% addition respectively (table 26).

Generally 1.0% was preferred in fresh bread and 0.5% in same bread after 8 hours (Figure 8).

In overall preferring for all types of bread 0.5% gum arabic was preferred in fresh bread, whereas; 1.0% gum arabic was preferred in the same bread after 8 hours in room temperature (Table 27).

Sensory evaluation results of fortified bread with gums, it was found that no significant ($P \leq 0.05$) differences between the all organoleptic properties of control sample and samples with gum arabic and locust bean gum at different ratios except with regard to appearance and color which were significant($P \leq 0.05$) lower in pan bread with locust bean gum and the same result were observed in samples with mixture gum. Hardness of bread sample increased significantly with time during storage. The increase in firmness was found to associate with the decrease in moisture content. When moisture content decreases, it accelerate the starch-starch interaction, .. gum addition could be useful in retarding staling in terms of hardness values (Hemeda and Mohamed, 2010).

In this study gum arabic was improved organoleptic characteristics and extended shelf life of bread by maintain bread quality for few hours. But the main negative effect- according to this study- was observed in specific volume of bread in spit of varieties of fermentation time and baking time, to enhance this evidence B dough was fermented and baked in constant time period. The addition of gums did not show a detrimental effect on arabic bread and addition of gums to arabic flat bread improved quality and extended shelf life (Hemeda and Mohamed, 2010). Therefore, gum arabic can be added as 1.0% for bread to protect quality of bread from deterioration.

Gum arabic did not had significant effect on fermentation time, baking time, color measurement, but, had negative effect on specific volume of bread, and had different effect on organoleptic characteristics according to type of flour. Generally, gum arabic did not improve the bread quality according to the results.

Table 26: *Grouping sensory attributes of B bread using Fisher method*

Fresh Bread				After 8 hours		
Gum treatment %	N	Mean	Grouping	Gum treatment%	Mean	Grouping
0.0	5	4.50	A	2.0	4.76	A
2.0	5	3.96	A	1.5	3.10	AB
1.5	5	3.21	B	0.0	2.70	AB
1.0	5	1.74	C	0.5	2.40	B
0.5	5	1.57	C	1.0	1.80	B

* Means that do not share a letter are significantly different

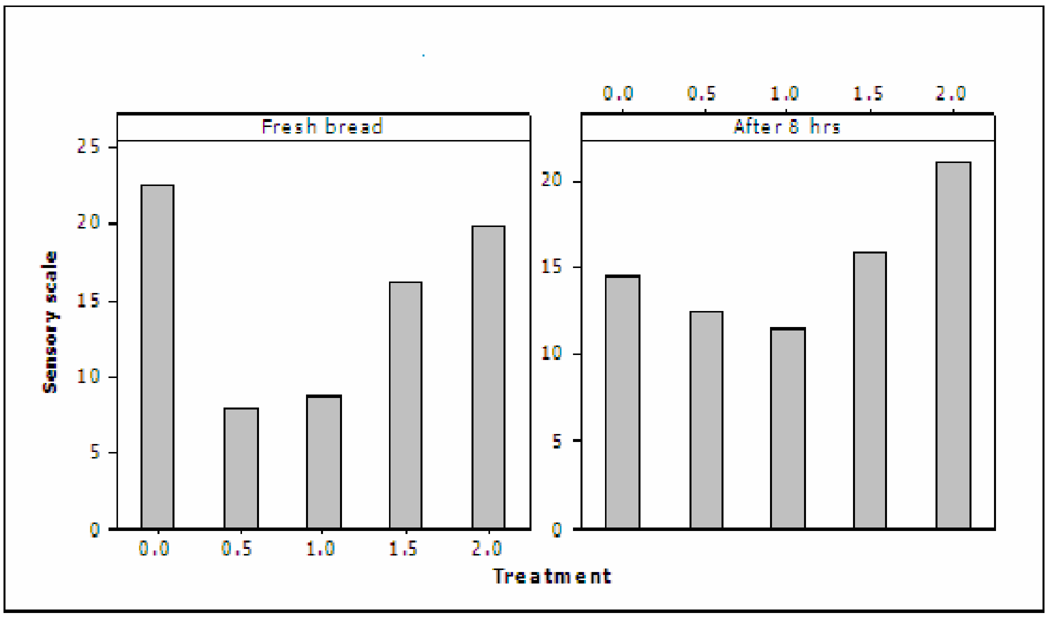

Figure 8: Comparison of overall acceptability of fresh and after 8 hours storage of B bread. (Note: Preference is for the shortest bar).

Table 27: *General comparison between fresh bread and bread after 8 hours*

Sample	Treatment	Color	Flavor	Taste	Texture	G. Accept.
Fresh bread	0.00	3.53	3.67	3.36	3.20	3.20
	0.50	2.22	2.40	2.58	1.80	1.80
	1.00	2.69	2.31	2.40	2.71	2.71
	1.50	2.82	3.16	3.38	3.16	3.16
	2.00	3.82	3.47	3.29	3.80	3.80
After 8 hrs	0.00	4.67	3.60	2.50	3.43	3.43
	0.50	3.33	2.30	2.53	2.07	2.07
	1.00	3.00	2.27	2.43	1.80	1.80
	1.50	1.67	2.83	3.37	3.37	3.37
	2.00	2.00	3.93	4.17	4.33	4.33

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions:

1) Gum arabic had significant effect on bread quality according to its percent.
2) Addition of gum arabic as general was preferred in organoleptic attributes at percent 0.5% and 1.0% for fresh bread and after 8 hours in A_1 bread and B bread.
3) Addition of 0.5% gum arabic was preferred in both, fresh bread and after 8 hours of A_2 bread.
4) Specific volume of bread was generally decrease by addition of gum arabic.
5) Fermentation time, baking time, and color measurement did not show significant effect by addition of gum arabic in confidence level (0.05).
6) Gum arabic maintains bread quality (Expended shelf life of bread for few hours).

5.2 Recommendations:

1) To use gum arabic in bread making process especially bakers who produce very large quantities and they need time for selling.
2) To use gum arabic less than or equal to 1.0%, to reduce the negative effect on specific volume.
3) To investigate what exact percent of gum arabic should be added to reduce the negative effect and maintain bread quality as long as possible by modifying some parameters.
4) It is recommended for the consumers to consume bread with gum arabic especially patients with chronic renal failure and those who have diarrhea diseases.
5) Further studies are needed on the effect of gum arabic on bread volume.

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Appendices:

Appendix 1: *Crosstabulation of color*

	Fresh bread						Bread after 8 hours					
Bread samples	Poor	Acceptable	Good	Very good	Excellent	Total	Poor	Acceptable	Good	Very good	Excellent	Total
A_1 -A	0	0	6	9	0	15	0	0	0	5	5	10
A_1 -B	0	4	0	2	9	15	0	0	5	0	5	10
A_1 -C	4	0	9	0	2	15	0	0	5	5	0	10
A_1 -D	0	11	0	4	0	15	0	10	0	0	0	10
A_1 -E	11	0	0	0	4	15	10	0	0	0	0	10
A_2 -A	0	0	5	0	10	15	0	0	5	5	0	10
A_2 -B	0	5	3	7	0	15	0	0	0	0	10	10
A_2 -C	5	5	2	3	0	15	0	0	5	5	0	10
A_2 -D	0	5	5	0	5	15	0	10	0	0	0	10
A_2 -E	10	0	0	5	0	15	10	0	0	0	0	10
B -A	0	6	0	0	9	15	10	0	0	0	0	10
B -B	15	0	0	0	0	15	0	10	0	0	0	10
B -C	0	0	0	15	0	15	0	0	10	0	0	10
B -D	0	4	11	0	0	15	0	0	0	10	0	10
B -E	0	5	4	0	6	15	0	0	0	0	10	10
Total	45	45	45	45	45	225	30	30	30	30	30	150

Appendix 2: *Crosstabulation of flavor*

	Freah bread						Bread after 8 hours					
Bread samples	Poor	Acceptable	Good	Very good	Excellent	Total	Poor	Acceptable	Good	Very good	Excellent	Total
A_1 -A	0	9	0	2	4	15	10	0	0	0	0	10
A_1 -B	0	4	2	9	0	15	0	5	5	0	0	10
A_1 -C	4	2	9	0	0	15	0	5	5	0	0	10
A_1 -D	2	4	0	0	9	15	0	0	0	10	0	10
A_1 -E	9	0	0	4	2	15	0	0	0	0	10	10
A_2 -A	5	0	5	0	5	15	0	10	0	0	0	10
A_2 -B	0	5	0	10	0	15	0	0	5	5	0	10
A_2 -C	0	0	10	0	5	15	0	0	5	5	0	10
A_2 -D	5	5	0	3	2	15	0	0	0	0	10	10
A_2 -E	5	5	0	2	3	15	5	0	5	0	0	10
B -A	10	5	0	0	0	15	10	0	0	0	0	10
B -B	0	0	0	5	10	15	0	10	0	0	0	10
B -C	0	0	6	4	5	15	0	0	10	0	0	10
B -D	0	0	9	6	0	15	0	0	0	10	0	10
B -E	5	10	0	0	0	15	0	0	0	0	10	10
Total	45	49	41	45	45	225	25	30	35	30	30	150

Appendix 3: *Crosstabulation of taste*

	Fresh bread						Bread after 8 hours					
Bread samples	**Poor**	**Acceptable**	**Good**	**Very good**	**Excellent**	**Total**	**Poor**	**Acceptab le**	**Good**	**Very good**	**Excellent**	**Total**
A_1 -A	4	0	0	9	2	15	10	0	0	0	0	10
A_1 -B	0	4	9	2	0	15	0	0	5	5	0	10
A_1 -C	0	0	6	0	9	15	0	5	0	0	5	10
A_1 -D	0	11	0	4	0	15	0	5	0	5	0	10
A_1 -E	11	0	0	0	4	15	0	0	5	0	5	10
A_2 -A	5	5	0	5	0	15	0	5	0	5	0	10
A_2 -B	5	2	0	0	8	15	0	0	10	0	0	10
A_2 -C	0	0	12	3	0	15	0	0	0	5	5	10
A_2 -D	0	5	3	7	0	15	0	5	0	0	5	10
A_2 -E	5	3	0	0	7	15	9	0	1	0	0	10
B -A	10	5	0	0	0	15	0	6	0	0	4	10
B -B	0	0	0	5	10	15	0	0	0	4	6	10
B -C	0	0	10	0	5	15	0	4	0	6	0	10
B -D	0	6	5	4	0	15	0	0	10	0	0	10
B -E	5	4	0	6	0	15	10	0	0	0	0	10
Total	45	45	45	45	45	225	29	30	31	30	30	150

Appendix 4: *Crosstabulation of texture*

	Freah bread						Bread after 8 hours					
Bread samples	**Poor**	**Acceptable**	**Good**	**Very good**	**Excellent**	**Total**	**Poor**	**Acceptable**	**Good**	**Very good**	**Excellent**	**Total**
A_1 -A	0	0	4	9	2	15	10	0	0	0	0	10
A_1 -B	0	0	0	6	9	15	0	5	5	0	0	10
A_1 -C	4	2	9	0	0	15	0	0	0	5	5	10
A_1 -D	2	13	0	0	0	15	0	5	0	0	5	10
A_1 -E	9	0	2	0	4	15	0	0	5	5	0	10
A_2 -A	3	10	2	0	0	15	0	0	0	5	5	10
A_2 -B	10	0	0	2	3	15	0	0	0	5	5	10
A_2 -C	0	0	10	3	2	15	0	0	10	0	0	10
A_2 -D	0	2	3	10	0	15	0	10	0	0	0	10
A_2 -E	2	3	0	0	10	15	10	0	0	0	0	10
B -A	4	5	6	0	0	15	0	0	0	0	10	10
B -B	0	4	0	11	0	15	0	0	6	4	0	10
B -C	0	0	0	0	15	15	0	4	0	6	0	10
B -D	6	0	5	4	0	15	0	6	4	0	0	10
B -E	5	6	4	0	0	15	10	0	0	0	0	10
Total	45	45	45	45	45	225	30	30	30	30	30	150

Appendix 5: *Crosstabulation of general acceptability*

	Fresh bread						Bread after 8 hours					
Bread samples	**Poor**	**Acceptable**	**Good**	**Very good**	**Excellent**	**Total**	**Poor**	**Acceptable**	**Good**	**Very good**	**Excellent**	**Total**
A_1 -A	0	0	4	9	2	15	10	0	0	0	0	10
A_1 -B	0	4	0	2	9	15	0	0	10	0	0	10
A_1 -C	4	2	9	0	0	15	0	0	0	5	5	10
A_1 -D	2	9	0	4	0	15	0	5	0	0	5	10
A_1 -E	9	0	2	0	4	15	0	5	0	5	0	10
A_2 -A	3	5	0	0	7	15	0	0	5	5	0	10
A_2 -B	0	0	5	7	3	15	0	0	0	0	10	10
A_2 -C	0	2	8	5	0	15	0	0	5	5	0	10
A_2 -D	0	5	2	3	5	15	0	10	0	0	0	10
A_2 -E	7	3	0	5	0	15	10	0	0	0	0	10
B -A	10	5	0	0	0	15	0	4	0	6	0	10
B -B	0	0	0	5	10	15	0	0	6	0	4	10
B -C	0	0	0	10	5	15	0	0	0	4	6	10
B -D	0	6	9	0	0	15	0	6	4	0	0	10
B -E	5	4	6	0	0	15	10	0	0	0	0	10
Total	40	45	45	50	45	225	30	30	30	30	30	150

Appendix 6: Questionnaire of panel test of bread samples

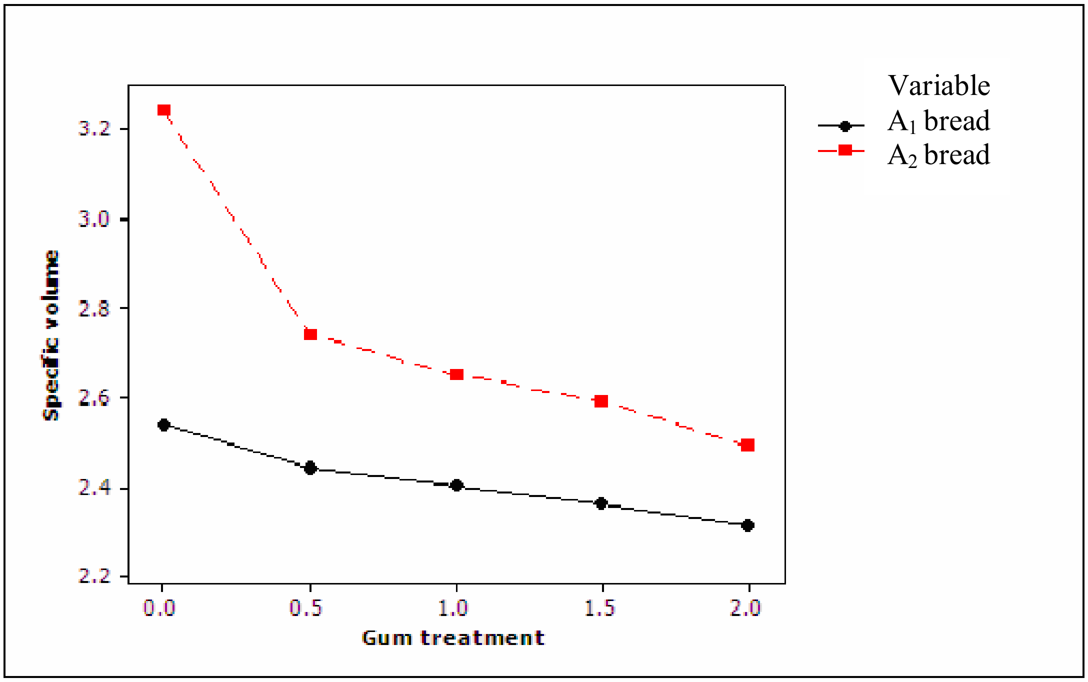
Please examine the following samples of bread samples in front of you and give values to attributes on the form sheet, taking (1) as excellent, (2) very good, (3) good (4) acceptable and (5) as poor in quality.

Samples	Color	Flavor	Taste	Texture	G. Acceptability
A					
B					
C					
D					
E					

A, B, C, D and E as Control sample or 0.0, 0.5, 1.0, 1.5, and 2.0 % gum arabic (w/w flour) respectively.

Appendix 7: *Color reading of crumb and crust of A bread samples*

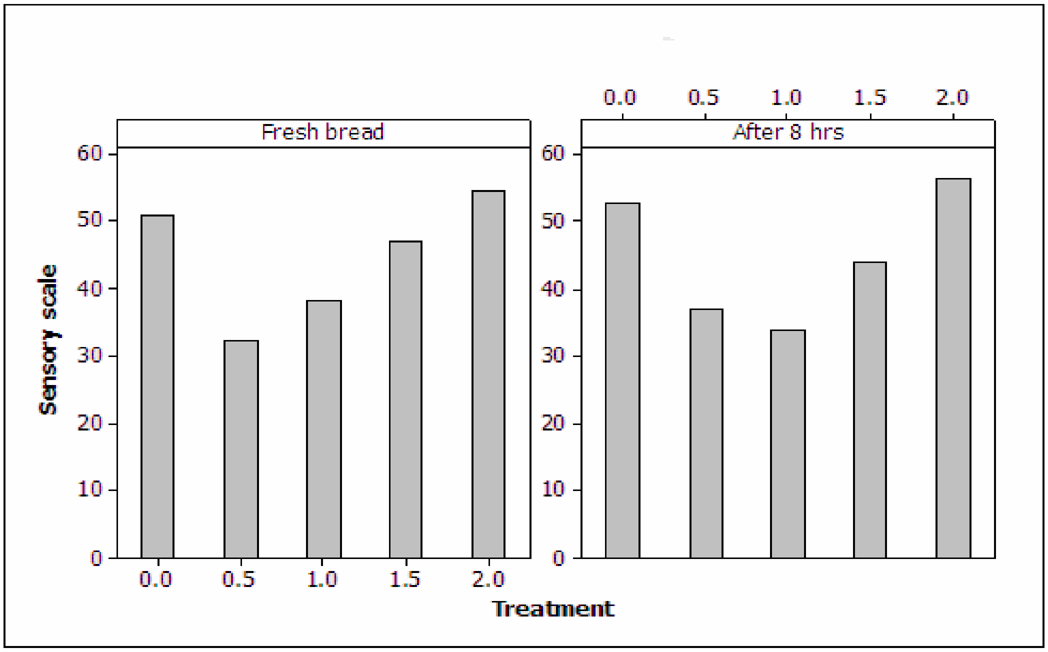
	A_1 bread					A_2 bread				
Para.	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
L	70.7	70.78	70.7	69.41	70.1	69.13	68.16	70.3	70.03	67.95
A	-0.67	-0.73	-0.45	-0.35	-0.69	-0.67	-0.63	-0.56	-0.86	-0.64
B	17.14	18.1	18.81	18.34	17.89	16.83	16.68	18.49	17.31	17.9
	-	-	-	-	-	-	-	-	-	-
a/b	0.0391	0.0403	0.0239	0.0191	0.0386	0.0398	0.0378	0.0303	0.0497	0.0358
L	49.35	49.37	42.4	54.42	50.81	58.58	60.27	53.08	49.77	57.21
A	12.88	13.04	13.17	13.67	12.02	11.03	8.39	10.82	11.29	9.36
B	22.05	22.24	19.08	23.43	22.61	20.68	23.46	21.7	20.87	22.86
a/b	0.584	0.586	0.690	0.583	0.532	0.533	0.358	0.499	0.541	0.409



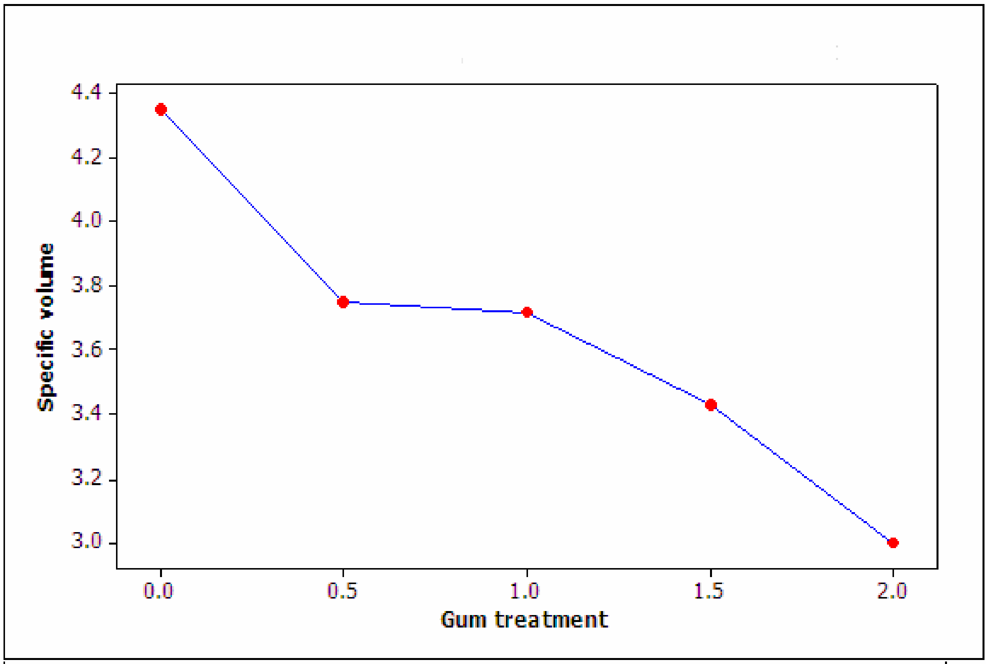
Appendix 8: Effect of gum arabic on specific volume of different bread types

Appendix 9: ANOVA table (Analysis Of Variance)

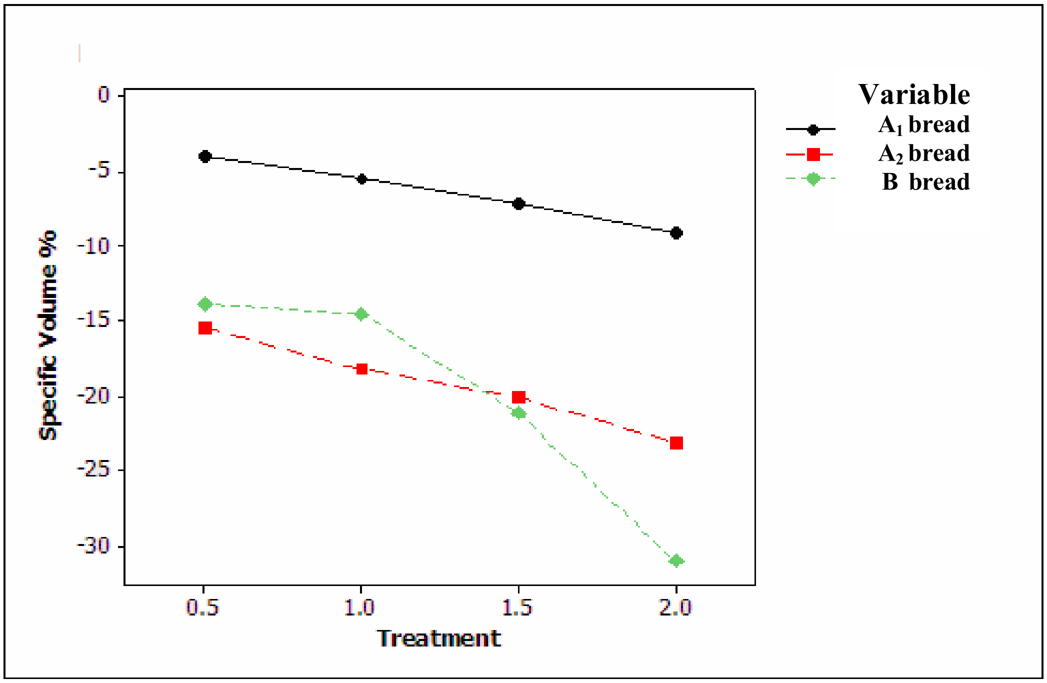
		Fresh bread					Bread after 8 hours				
		Sum of Squares	df	Mean Square	F	Sig.	Sum of Squares	df	Mean Square	F	Sig.
Color	Between Groups	182.000	14	13.000	10.187	.000	280.000	14	20.000	135.000	.000
	Within Groups	268.000	210	1.276			20.000	135	.148		
	Total	450.000	224				300.000	149			
Flavor	Between Groups	162.996	14	11.643	8.404	.000	259.333	14	18.524	125.036	.000
	Within Groups	290.933	210	1.385			20.000	135	.148		
	Total	453.929	224				279.333	149			
Taste	Between Groups	143.067	14	10.219	6.992	.000	178.773	14	12.770	14.709	.000
	Within Groups	306.933	210	1.462			117.200	135	.868		
	Total	450.000	224				295.973	149			
Texture	Between Groups	223.600	14	15.971	14.814	.000	250.600	14	17.900	48.917	.000
	Within Groups	226.400	210	1.078			49.400	135	.366		
	Total	450.000	224				300.000	149			
G.Accept .	Between Groups	197.867	14	14.133	12.569	.000	236.000	14	16.857	35.558	.000
	Within Groups	236.133	210	1.124			64.000	135	.474		
	Total	434.000	224				300.000	149			



Appendix 10: General comparison between fresh bread and Bread after 8 hours



Appendix 11: Relation between gum arabic addition and specific volume of B bread



Appendix 12: Relation of gum arabic treatment and specific voume in all bread samples