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SENSORY AND RHEOLOGICAL PROPERTIES OF REDUCED-FAT ROCK BUNS AND MANGO PIE CONTAINING A PAPAYA (*Carica papaya*)-DERIVED FAT REPLACER

A THESIS SUBMITTED TO THE BOARD OF POSTGRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE MASTER OF SCIENCE (MSc) DEGREE IN FOOD SCIENCE AND TECHNOLOGY

BY
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DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this work is the result of my own original research and that no part of it has been published in part or in whole for another certificate in this university or elsewhere.

Candidate's name: YVONNE PERPETUA PAINTSIL Signature: ……

Date: …….

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this project work were supervised in accordance with guidelines on supervision of project work laid down by the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Supervisor's name: PROFESSOR J. H. OLDHAM Signature: ……

Date: …….

ABSTRACT

Two perishable fruits Papaya (*Carica papaya*) and mango (Keit variety) which are locally abundant in Ghana were selected for this study. Freeze dried papaya was used as a fat replacer in two pastry products, namely rock buns and mango pies (with dried mango and mango puree as filler). The effect of fat reduction on the sensory and rheological properties of the rock buns and mango pies were determined. The dried fruits were also assessed for their physicochemical properties. Five rock buns treatments (full (100%)-fat, 25%, 50% and 75% reduced-fat and fat-free (0%) treatments) were produced as well as two pie crust treatments(full (100%)-fat and 25% reduced-fat treatments). Trained sensory panellists determined that the 25 % reduced-fat rock buns treatment was more similar in sensory attributes to the full-fat control, whilst the 50 % reduced-fat treatment was found to be satisfactory in comparison to the other reduced-fat treatments. With the exception of mouth feel in which differences between the full-fat control and the fat-free treatment were not significant ($p > 0.05$), there were significant differences ($p \leq 0.05$) in sensory attributes between the control and the fat-free treatment for all other attributes. In the pie crust as well, sensory results showed that the reduced-fat treatment was not significantly different ($p > 0.05$) from the full-fat control for most attributes. Texture profile analysis of rock buns showed that hardness, springiness, cohesiveness, gumminess, chewiness and resilience increased with increasing fat reduction; however, values for fracturability and modulus of deformation decreased with increasing fat reduction. In the pie, texture analysis indicated that the reduced-fat treatment was not significantly different ($p > 0.05$) in hardness from the full-fat control; nevertheless, for fracturability, differences between them were found to be significant ($p \leq 0.05$). Colorimetric measurements revealed that the 25 % reduced-fat treatment was more similar in appearance (colour) to the control than the other reduced-fat treatments which were dull in appearance. Notwithstanding the colorimetric results, sensory results also proved that the 50 % reduced-fat treatment was also not significantly different ($p > 0.05$) in colour from its full-fat complement. Dried fruits and puree produced from mango were more shelf stable than the unprocessed fruit. Analytical results indicated that the fat replacer contains 2.51 g/100 g and 12 % pectin and total nutrition fibre respectively. This is an indication that the pawpaw-derived fat replacer could be a viable additive for fat replacement.

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1. INTRODUCTION

1.1. Background

Fats together with proteins and carbohydrates constitute an essential and major part of the diet of most people. Fats increase the energy density of the diet and facilitate the absorption of the fat soluble vitamins (A, D, E and K) (Rosenberg, 2006). Fat is the most concentrated source of dietary calorie at nine (9) calories per gram (International Food Information Council, 2005). Dietary fat is essential for growth and development, maintaining good health and in general for survival (Calorie Control Council, 2006).

In foods, fats impart a pleasant taste, texture, mouth feel, and aroma to foods (International Food Information Council, 2005). Fats also provide lubrication, volume/bulk or heat transfer, contribute to juiciness and tenderness of foods and also affect the overall palatability of diets (American Dietetic Association, 2006; Giese, 1996 and Stauffer, 1998). Fats can be found in various food items such as whole milk, coconut oil, palm oil, etc.

Despite the numerous benefits of fats in our diet, excessive intake of fats, however, is known to be associated with an increased risk of obesity, gall bladder diseases, serious co-morbidities including type 2 diabetes, coronary heart diseases and some types of cancers (Weber and Clavein, 2006).

Obesity is one of today's most visible yet neglected public health problems (Weber and Clavein, 2006). Obesity has been declared a global epidemic by the World Health Organisation (WHO, 2005). In Europe more than half of the adult population is overweight or obese. In the United States, a report suggests that approximately one-third of persons 20 years of age and above fall into this category. A study carried out in Accra, Ghana showed that overweight/obesity is common in Ghana and that obesity rises with increasing age till age 65. The study concluded

that the prevalence of hypertension in both sexes was twice as high in overweight/obese persons as in normal weight persons (Escalona *et al.*, 2004). Compared with the lean population, the risk of death doubles for individuals with Body Mass Index of 40 kg/m^2 (morbidly obese persons) or more and their life expectancy is reduced by between 5 and 20 years (Samore, 2006).

Chronic diseases associated with excessive fat intake including diabetes, heart diseases and obesity pose a staggering cost, particularly for developing countries and economies in transition (Johns and Eyzaguirre, 2006). These ailments are associated with substantial costs such as the direct cost of healthcare and the indirect cost of low productivity caused by illness and disability (May and Buckman, 2007).

Knowledge and concerns of the adverse health implications of high fat intake in consumers has culminated in a rising demand for low-fat foods. Consequently, the use of fat replacers as alternative food source is fast gaining attention among producers and consumers. These low-fat foods are the result of new and existing food technologies used to replace some or most of the fat without sacrificing the taste, texture and aroma consumers desire. For instance, whole milk has been replaced with skimmed milk in ice creams, leaner meats in frozen entrees, baking snack foods instead of frying and replacing the fat in some products with water or air (Calorie Control Council, 2006).

Pastries constitute a part of the daily snack or diet of most people; however, they are known to be high in fat and calories. There is therefore the urgent need to develop fat replacers which can substitute for fat in these pastries and produce reduced-fat pastry options which will be able to match the quality of their full fat complements. Fat replacers, variously categorised as fat substitutes, fat mimetics, fat extenders, fat barriers and fat analogs as reported by Roller and Jones (1996) are products which recreate some or all the attributes of fat while significantly

reducing fat and calorie contents as well as imparting special properties that improve health (American Dietetic Association, 2006). Fat replacers are derived from three main sources, namely:

1. Carbohydrate-based: cellulose, fibre (e.g. pectin), gums, starches, etc.
2. Protein-based: cream soups, baked goods, etc.
3. Fat-based: olestra, cocoa butter substitutes, etc (Calorie Control Council, 2006)

Some fat replacers have been derived from fruits including applesauce, plums and citrus. The water-retaining property of their inherent fibre which is mostly pectin makes them fat replacers of choice (Vaclavik and Christian, 2003). Studies have shown that when bread is baked with a small percentage of pectin, it increases its moistness and extends shelf life from the tactile stand point by five (5) to seven (7) more days (Hergenbart, 2001).

In baking and in other food applications, pectin from fruits forms a film around the tiny air bubbles in the batter, similar to what occurs when there is cream of solid shortenings with sugar (Phillips, 1999).

The fruit of pawpaw (*Carica papaya*) is one of the tastiest and healthiest foods in the world (Pamplona–Roger, 2003). Besides its highly nutritious composition, pawpaw has high pectin content (1.80 g per 100 g of raw edible portion) compared to plums which have pectin content of 1.50 g per 100 g raw edible portion. The high pectin content of pawpaw attests to its potential as a fat replacer; thus it can be used for fat replacement purposes in pastries like rock buns and pies.

Another tropical fruit widely enjoyed by both children and adults is the mango fruit (*Mangifera indica L.*). Each mango is a master work for its aroma, its delicate flavour and its dietary and therapeutic properties (Pamplona-Roger, 2003). It is a nutritious fruit, healthy, cheap and tasty

and an excellent source of vitamins A and C (South Pacific Commission, 1995). In spite of its nutritional qualities, the potential for incorporating mangoes into various food products such as pastries has not been extensively exploited. Such a venture will not only add value to the mango fruits, but will also help alleviate the seasonal vitamin A deficiency prevalent in the Northern part of Ghana (Benamba, 2005).

Fruits and vegetables represent an important part of the world's agricultural production and form an indispensable part of the human diet in Ghana. Their nutritional value which provides essential amounts of vitamins, minerals, dietary fibre, protein and calories are well documented (www.fao.org/docrep/woo78e07.htm). Fruits and vegetables also provide variety, taste and aesthetic appeal in the diet. However these fruits and vegetables are usually in short supply during the dry seasons and because the indigenous ones are grown abundantly in the rainy season, they are mostly wasted, due to lack of effective processing and preservation methods.

In Ghana, fruits and vegetables are abundantly produced during peak seasons but due to lack of proper storage and preservation facilities, the market becomes overstocked during such seasons and a large proportion gets rotten before reaching the final consumer. Of the fruits and vegetables produced in developing countries, about 30-50% never reach the final consumer due to spoilage during transportation, storage and processing (Alzamora *et al*., 2000a).

Due to high postharvest losses in fruits and vegetables, there is the need for efficient and effective processing and preservation of these perishable fruits and vegetables during bumper harvest to make these fruits and vegetable available throughout the market year in a value-added form (www.fao.org/docrep/woo78e07.htm).

1.2. Research Objective

- To study the effect of fat replacement with a papaya-derived fat replacer on the qualities of reduced-fat rock buns and mango pie.

1.2.1. Specific Research Objectives

1. To determine the pectin and total nutrition fibre contents of the pawpaw-derived fat replacer.
2. To determine the physicochemical properties of freeze dried papaya and solar dried mango fruits.
3. To develop value added products with dried papaya as fat replacer for rock buns and mango pies (with dried mango and mango puree as fillers).
4. To evaluate the physical, sensory, textural and colorimetric properties as well as the overall consumer acceptability of the reduced-fat rock buns and mango pies developed from the fat replacer.
5. To observe the effects of fat reduction on the shelf life of reduced-fat rock buns and mango pies.

2. REVIEW OF LITERATURE

2.1. Tropical Fruits and their Health Benefits

Tropical fruits constitute a major nutritional and economic resource for developing countries. Major tropical fruits, such as banana, papaya, pineapple, mango and avocado, are generally the most important in economic and marketing terms. World production of tropical fruits is estimated to have increased by almost three (3) million tonnes over the last biennium to reach about sixty five (65) million tonnes in 2002 of which developing countries account for ninety eight (98) percent. Mango is the dominant fruit produced worldwide accounting for about thirty five (35) percent of global tropical fruit production, followed by pineapple, papaya and avocado (FAO, 2003).

The important nutritional-health and economic values of both fruits and vegetables cannot be overemphasized. Fresh fruits are the best carriers of vitamins, essential minerals, phenolic antioxidants, glucosinolates and other bioactive substances/nutrients which help prevent micronutrient deficiencies. Most fruits are low in energy and fat and high in fibre. Additionally, consumption of fruit is increasingly recognized in the prevention of diseases. A recent FAO/ WHO report on diet and chronic disease shows convincing evidence that consumption of fruits can decrease risk of obesity, cardiovascular diseases, type 2 diabetes and cancer (WHO/FAO, 2003).

Chronic diseases (noncommunicable conditions) including cardiovascular diseases, diabetes, obesity and cancer account for 59 percent of the 57 million deaths annually and 46 percent of the global burden of diseases. Excessive fat intake is a risk factor for the development of these diseases (http://www.who.int/dietphysicalactivity/publications/facts/chronic/en/print.html; Joint FAO/WHO, 2005).

In USA, the Surgeon General's report on nutrition and health states: "High intake of dietary fat is associated with increased risk for obesity, hypertension, diabetes mellitus, gall bladder diseases and some types of cancer for instance: endometrial cancer and postmenopausal cancer in women, prostate cancer in men, and colorectal cancer in both men and women. Epidermiological, clinical and animal studies provide strong evidence for the relationship between saturated fat intake, high blood cholesterol, and increased risk for coronary heart diseases. Excessive saturated fat consumption is the major dietary contributor to the total blood cholesterol levels (Calorie Control Council, 2006). Garrow *et al*. (2002) also found out that obesity also causes osteoarthritis, reproductive disorders, sleep apnoea and physiological and social disorders.

2.2. Dietary Fats

Fat molecules are essentially made up of fatty acids and glycerol. A fatty acid consists of a long carbon skeleton of 16 or 18 carbon atoms, or longer in most natural fats and oils. The carbonyl group, is a carbon atom double-bonded to an oxygen atom and single-bonded to an oxygen attached to a hydrogen (OH-C=O). Fatty acids are hydrophobic in nature (Stretch, 2006). Fats are combinations of different fatty acids that exert characteristic physiological and metabolic effects on the body. Saturated fatty acids have single bonds between the carbon atoms. Most animal fat such as butter, milk, cheese and coconut oil are highly saturated. Unsaturated fatty acids have one or more double bonds between carbon atoms. Monounsaturated fatty acids (MUFAs) contain only one double bond and polyunsaturated fatty acids (PUFAs) have more than one double bond (Piper, 1999). In general saturated fatty acids are more stable and are solid at room temperature. Foods high in unsaturated fatty acids include: vegetable oils (e.g. soybean and sunflower) and fish such as salmon, tuna, and herring (Gurr, 2002).

2.2.1. Fat Metabolism and Storage

Fats are metabolized primarily in the small intestines because the enzymes of the stomach cannot break down fat molecules due to their hydrophobicity. In the small intestines, fat molecules stimulate the release of cholecystokinin (CCK), a small-intestine hormone, into the bloodstream. The CCK in the blood triggers the pancreas to release digestive enzymes that can break down lipids. The gallbladder is also stimulated to secrete bile into the small intestines. Bile acids coat the fat molecules, which results in the formation of small fat globules, which are called micelles. The coating prevents the small fat globules from fusing together to form larger fat molecules, and therefore the small fat globules are more easily absorbed. The pancreatic enzymes can also break down triglycerides into monoglycerides and fatty acids. Once this occurs, the broken-down fat molecules are able to diffuse into the intestinal cells, in which they are converted back to triglycerides, and finally into chylomicrons (Piper, 1999).

Chylomicrons, which are composed of fat and protein, are macromolecules that travel through the bloodstream into the lymphatic capillaries called lacteals. The lymphatic system is a special system of vessels that carries a clear fluid called lymph, in which lost fluid and proteins are returned to the blood. The lacteals absorb the fat molecules and transport them from the digestive tract to the circulatory system, dumping chylomicrons in the bloodstream. The adipose and liver tissues, which release enzymes called lipoprotein lipase, break down chylomicrons into monoglycerides and fatty acids. These molecules diffuse into the adipose and liver cells, where they are converted back to triglycerides and stored as the body's supply of energy (Gurr, 2002).

2.2.2. Fat Nutrition

Actual intake of fat can vary from 10 percent to 40 percent of the calories consumed daily, depending on personal or cultural regimens. Limiting one's daily fat intake to less than 30 percent of total calorie intake and increasing consumption of polyunsaturated fatty acids have

been shown to be beneficial in maintaining a healthful diet (Stretch, 2006). New food-labeling regulations scheduled to take effect in 2006 require manufacturers to list trans fat content on their products' nutrition facts panel (Calorie Control Council, 2005; Food and Drug Administration, 1994).

2.2.3. Fat Function

Fats and lipids play critical roles in the overall functioning of the body, such as in digestion and energy metabolism. Usually, 95 percent of the fat in food is digested and absorbed into adipose or fatty tissue (Piper, 1999). Fat aids in the absorption of fat-soluble vitamins and other phytochemicals. Fats are the body's energy provider and energy reserve, which helps the body maintain a constant temperature (Stretch, 2006). Fats and lipids are also involved in the production and regulation of steroid hormones, which are hydrophobic (or "water-fearing") molecules made from cholesterol in the smooth endoplasmic reticulum, a compartment within a cell in which lipids, hormones, and proteins are made. Steroid hormones are essential in regulating sexuality, reproduction, and development of the human sex organs, as well as in regulating the water balance in the body. Steroid hormones can also freely flow in and out of cells, and they modify the transcription process, which is the first step in protein synthesis, where segments of the cell's DNA, or the genetic code, is copied (Piper, 1999).

Fats and lipids also have important structural roles in maintaining nerve impulse transmission, memory storage, and tissue structure. Lipids are the major component of cell membranes. The three most common lipids in the membranes of eukaryotes or nucleus-containing cells are phospholipids, glycolipids, and cholesterol. A phospholipid has two parts: (1) the hydrophilic ("water-loving") head, which consists of choline, phosphate, and glycerol, and (2) the hydrophobic ("water-fearing") fatty acid tail, which consists of carbon and hydrogen (Piper, 1999).

2.2.4. Functional Role of Dietary Fat in Food

Fat in food has multiple functions during cooking processes. Its heat transfer properties enable rapid heating and attainment of very high temperatures. High temperatures achieved by frying and deep-fat frying create many browning (eg, Maillard Reaction) taste components that have positive sensory attributes. Fat absorbs many flavour compounds and rounds the flavour by reducing the sharpness of acid ingredients. In meats, fat carries the flavour and contributes to the juiciness and tenderness, key to the difference in taste of the various kinds of meat and poultry (Sandrou and Arvanitoyannis, 2000).

Functionally, fats affect the melting point, viscosity and body, crystallinity, and spreadability of many foods (Sandrou and Arvanitoyannis, 2000). Fat imparts a velvety mouth feel to products such as ice creams, desserts, and cream soups. Smoothness in ice creams and some candies is due to fat preventing the formation of large water or sugar crystals. Fat removal from cheeses results in a pasty curd or a rubbery texture. Low-fat puddings, salad dressings, soups, and dairy products are watery without the addition of fat extenders or mimics. Fats are responsible for the aroma and texture of many foods, thereby affecting the overall palatability of the diet. In baked products, fat inhibits the formation of tough gluten strands, softens the crumb, imparts tenderness, and delays staling (Penfield and Campbell, 1990a). Fats, if present in sufficient amounts coats the surface of flour particles thus inhibiting the development of gluten proteins (Menjivar and Faridi, 1994 and Maache-Rezzoug *et al*., 1998). Spies (1990) reported that if fat level is high, the lubricating function in the dough is so pronounced that little water is required to achieve the required consistency. Fats also affect the rheological properties of cookie dough (Jissy and Leelavathi, 2007). Crispiness in cookies is due to fat in combination with some of the other ingredients. In flaky products such as croissants and pastries, fat's ability to pool in layers and coat gluten strands is crucial. Thus, fat replacers must be chosen with care to replicate the

functions of fat (flavour, texture, lubrication, volume/bulk, or heat transfer) to produce an acceptable product. Although fat in food may increase acceptance, high-fat foods and diets are also high in calories (Drewnowski, 1998), which may be problematic for the majority of people struggling with energy balance.

2.2.5. Statistics on Fat Related Ailments

Knowledge of the adverse health implications of excessive fat intake has raised lots of concerns though dietary fats are needed for an overall healthy lifestyle. Chronic diseases associated with excessive fat intake, including diabetes, heart diseases and obesity pose a staggering cost, particularly for developing countries and economies in transition. A recent report by WHO (2005) calculates the lost national income associated with heart disease, stroke and diabetes over the next 10 years for key developing countries. The accumulated losses (US dollars x 10^9) that will be suffered are for Brazil 49.2, for China 557.7, for India 236.6 and for Russia 303.2, while for some smaller developing economies like Nigeria, Pakistan and Tanzania the losses will be 7.6, 30.7 and 2.5 respectively.

Yeboah, (2007) indicated in a Ghanaian newspaper, Daily Graphic that statistics on the prevalence of overweight and obesity in seven (7) African Countries showed that Ghana has the largest number of overweight and obese people, which is more than three (3) million out of the estimated population of 20.7 million. The costs in human lives and on economic growth and development are not acceptable. All resources particularly the accessible, sustainable and locally-adapted resources such as biodiversity for dietary diversity need to be mobilized to reverse this trend (Johns and Eyzaguirre, 2006). Fat replacers have come as a timely solution to help alleviate the problem.

2.3. Fat Replacers

A fat replacer is an ingredient that can be used to provide some or all of the functions of fat, yielding fewer calories than fat (Calorie Control Council, 2006). The fat in foods can be lowered by simple techniques such as dilution with water or substituting with ingredients such as fruit purees or with the use of compounds developed by food technologists (Schwenk and Guthrie, 1997). There are several categories of fat replacers:

- Fat substitutes are ingredients that resemble conventional fats and oils and can replace fat on a gram-for-gram basis. Due to their fat based nature, they are often stable at cooking and frying temperatures and provide all the functions of fat while yielding <9 kcal/g, which could be zero calories if none is absorbed.
- Fat analogs are compounds with many of the characteristics of fat but have an altered digestibility and altered nutritional value.
- Fat extenders optimize the functionality of fat, thus allowing a decrease in the usual amount of fat in the product.
- Fat mimetics are ingredients that mimic one or more of the sensory and physical functions of fat in the food. They are based on carbohydrate, protein, or fat components used alone or in combination and provide from 0 to 9 kcal/g. They provide lubricity, mouth feel, and other characteristics of fat by holding water. The additional water makes them unsuitable for fat functions such as frying; however, some can be used for baking and at retort temperatures. They may however be subject to excessive browning at high heat (Schwenk and Guthrie, 1997).
- Fat Barriers are ingredient systems that provide a barrier for products that use fat as a heat exchange medium such as to create a crispy, brown crust (Michaelides and Cooper, 2004).

The four broad categories of fat replacers include carbohydrate-based, protein-based, fat-based, and combination fat replacers.

2.3.1. Carbohydrate-Based Fat Mimetics

These fat replacers are based on carbohydrates, such as cellulose, dextrins, maltodextrins, polydextrose, gums, fibre, and modified starch. Carbohydrate-based fat replacers can provide up to 4 kcal/g, but, because they are often mixed with water, they typically provide only 1 to 2 kcal/g, and, some (such as cellulose) provide zero calories. They are used mainly as thickeners and stabilizers and are typically used in a variety of foods, including dairy-type products, frozen desserts, sauces, salad dressings, processed meats, baked goods, spreads, chewing gums, and sweets. However, they are not suitable for use in foods that will be fried. The most common ones are dextrins and modified starches, which absorb water and form gels that impart a texture and mouth feel similar to fat. Gums are used in baked goods and salad dressings, in which they act as stabilizers and thickeners and retain moisture in the reduced-fat product. Pectins can also be used as fat substitutes because of their gelling properties. Indigestible fibre such as cellulose is ground into microparticles that can form gels for use as fat substitutes. Polydextrose, a glucose polymer, resistant to digestive enzymes, provides about 1 kcal/g, is used to replace sugar or fat in foods, keeps the food moist, and acts as a bulking agent replacing fat and sugar volume. Yackel and Cox (1992) reported that carbohydrate-based fat replacers form a gel-like matrix in the presence of substantial levels of water, resulting in lubricant and flow properties similar to those of fats. When hydrated, polydextrose forms a gel that mimics some of the functional characteristics of fat. Maltodextrins, a nutritive polysaccharide derived from hydrolysis of cornstarch, can function as fat mimetics in flour-based dry mixes, baking systems, fillings, and icings (Swanson *et al.*, 2002). Maltodextrins can be substituted for 25% to 35% of fat in cookies, whereas indigestible fibre, such as cellulose, can replace 50% of fat in bakery

products without compromising sensory characteristics (Conforti *et al*., 2001). Suffice to say that there is a maximum at which a fat substitute can be used for fat and still produce an acceptable product (Conforti *et al*., 1996). Thus, the diverse properties of these plant-based carbohydrates and their derivatives are used when developing fat mimetics. These plant-derived carbohydrates offer many benefits to product developers and ultimately consumers: (1) they are often more effective at reducing activity in a reduced-fat formula, compared to protein-based substitutes, (2) they are hydrophilic, available to bind water, creating a carbohydrate-water network that can mimic the texture of fat, (3) they are completely digestible as part of the normal metabolic process, (4) they are economical and consistently available, and (5) they are generally recognized as safe (GRAS), so no Food and Drug Administration (FDA) approvals are needed. Maltodextrin use in baked goods such as cakes, muffins, and soft cookies is increasing; however, no one formulation will fit every application (Nonaka, 1997).

2.3.2. Protein-Based Fat Mimetics

Made from whey protein or milk and egg protein, these fat replacers provide 1 kcal/g to 4 kcal/g. Microparticulated protein products are tiny, spherical particles, which can provide a creamy mouth feel similar to fats. They often incorporate water and may be usable in amounts less than fat, for example, 1 g of protein-based fat mimetics can replace 3 g of fat in cream. Protein-based fat mimetics are not suitable for use in fried foods but can be used in dairy products, such as fat-free ice creams, frozen desserts, and milkshakes; reduced-fat versions of butter; sour cream; low-fat cheese; yogurt; low-fat baked goods; salad dressing; margarine; mayonnaise; coffee creamers; soups; and sauces (Cheung *et al*., 2002). Protein blends, another group of protein-based fat mimetics that combine animal or vegetable protein, gums, food starch, and water, are used in frozen desserts and baked goods. A combination of protein, starches, and hydrocolloids has been suggested to have synergistic effects for lowering fat and

retaining textural characteristics of the products (Ordonez *et al*., 2001 and Ruthig *et al*., 2001). Inulin, a nondigestible natural fructooligosaccharide, is considered to have functional properties that enable it to act as a fat mimetic without adversely affecting flavour, based on its ability to stabilize structure of the aqueous phase, creating an improved creaminess mouth feel. A combination of these fat replacers can have tremendous potential in the development of fat-modified foods with greater acceptability while lowering the total energy and fat intake (El-Nager *et al*., 2002 and Aryana and Hagne, 2001).

2.3.3. Fat-Based Substitutes

Fat-based substitutes include chemical alterations of fatty acids to provide fewer calories or no calories. Emulsifiers and fat-based substitutes provide up to 9 kcal/g. SALATRIM (short-and long-chain acyltriglyceride molecules) is an example. Other fat-based fat substitutes, such as olestra have properties similar to naturally occurring fat but provide zero calories and pass through the body unabsorbed. Olestra is a sucrose polyester consisting of a mixture of hexa, hepta, and octa esters of sucrose, esterified with long-chain fatty acids, derived from common edible oils. Olestra can be liquid or solid at room temperature based on the fat source in the sucrose polyester. It has organoleptic and thermal properties of fat but cannot be hydrolyzed by gastric or pancreatic lipase and is too large a molecule to be absorbed in the gastrointestinal tract and therefore cannot be metabolized for energy (Burns *et al*., 2000).

Other fat-based fat substitutes with triglycerides containing short-, medium-, and long-chain fatty acids randomly distributed on the glycerol backbone are only partially digested and absorbed and provide 5 kcal/g. Mono- and diglyceride fat-based substances have also been created. Emulsifiers are fat-based substances that are used with water to replace all or part of the shortening content in cake reduction mixes, cookies, icings, vegetables, and dairy products. They provide the same calories as fat but less is required in the product, resulting in a total fat

and energy. Some of these ingredients are heat stable and very versatile. Several studies have shown that their application in fried snack foods and yogurt may lead to decreased energy and macronutrient intakes in lean, overweight, and obese adult subjects up to 36 hours post consumption (Burns *et al*., 2002).

The challenge that food scientists face when reducing the fat in foods is to maintain the functional processing benefits of fat in reduced fat systems. The first step in substituting fat in foods is to understand the functionality of fat. More specifically, understanding the functionality of fat in the particular food system that will be modified. After identifying fat's role in this system, a fat-substitute or combination of fat substitutes that will mimic these functions can be chosen. Other factors that should be considered when choosing a fat substitute system are cost, availability, safety, and quality (Clark, 1994).

2.3.4. Energy Density, Satiety and Fat Replacers

Some research suggest that an increased intake of energy-dense foods, which are often high in fat, may lead to increased energy intake (Kral *et al*., 2004; Devitt and Mattes, 2004; Alfanas and Mattes, 2003). However, there are exceptions. Sweetened soft drinks have low-energy density but can promote positive-energy balance potentially because of their weak satiety signals (DiMigelio and Mattes, 2004). Nuts have high-energy density and are associated with lower BMI in adults, potentially because of the presence of other dietary components such as dietary fibre, which can increase satiety (Jiang *et al*., 2002). Nevertheless, manipulation of the energy density of the diet can lead to modest changes in body weight and can lower energy consumption by 20% to 25% (Kral *et al*., 2002; Bowen *et al*., 2003; De Castro, 2004).

The energy density of foods has been demonstrated to have a robust and substantial effect on both satiety and satiation. Satiety refers to the effects of a food or meal after eating has ended,

whereas satiation refers to the process involved in the termination of a meal. Individuals have a tendency to consume a constant weight or volume of food irrespective of the energy and fat content, thus suggesting that the energy density of food will be a critical determinant of energy intake. Lowering energy density of food can affect satiation independent of macronutrient content and palatability (Rolls, 2000; Gerstein *et al*., 2004).

High-energy density of high-fat foods tends to be associated with high palatability but not with satiation (Kral *et al*., 2002). In short-term studies, low-energy-dense foods were observed to promote satiety, decrease hunger, and reduce energy intake (Poppitt *et al*., 1998; Rolls *et al*., 2000; Holt *et al*., 2001; Archer *et al*., 2004). In addition, the use of low-energy-dense foods was found to promote moderate weight loss in long-term studies (Rolls, 2000). In one study, when matched for palatability and energy density, fat and carbohydrate content of a preload had similar effects on subsequent food intakes in lean adult females. Macronutrient composition of the preload was observed to have an effect on hunger and satiety, with protein contributing to this differential (Poppitt *et al*., 1998).

The volume of food consumed can affect satiety. The volume of a preload was shown to significantly affect energy intake at lunch by affecting the perception of the amount of food consumed (Rolls *et al*., 2000). Increasing the satiety values of foods while keeping energy density low can be a strategy for preventing over consumption and energy imbalances.

Foods that contain more water and less fat (i.e., low-energy-dense foods) tend to be more satiating but less palatable (Gerstein *et al*., 2004; Holt *et al*., 2001). However, because fat exerts only a weak effect on satiety, removing some of this fat by substitution will not drastically decrease the satiety power of the food. Hence, fat replacers can potentially help to prevent passive over consumption while allowing people to experience the sensory properties of fat

without the substantial weakening of appetite control (Blundell and Macdiarmid, 1997). Archer *et al.* (2004) noted that reduced-fat sausage containing inulin or lupin-kernel fiber as a fat replacer resulted in the lowering of total fat intake and total energy intake, with the lupin-kernel fibre patty being the most satiating as compared with the inulin and full-fat patty. This application demonstrates that reduced-fat foods developed using fat replacers can preserve the sensory properties of the foods they are used in and can also play a potentially important role in lowering the energy density of the foods. This can play an important role in lowering total dietary energy intake but only if the total energy content of the foods containing fat replacers is reduced. Fat replacers can help overcome the problem of palatability commonly associated with low-fat and reduced-fat products and may contribute to satiating effects of these foods. Factors that affect energy balance, specifically portion control and physical activity, are likely to have a greater impact on body weight than the sole use of fat-modified products.

2.3.5. How Fibre Affects Weight Regulation

Consumption of carbohydrates and dietary fibre protects against obesity (Slavin, 2005). Examining the relationship between dietary fibre intake and body weight, however is difficult due to the struggle to define dietary fibre and agree on recommended intake levels. In 2002, the Dietary Reference Intakes (DRIs) published definitions for fibre (DRI, 2002). Dietary fibre consists of nondigestible carbohydrates and lignin that are intrinsic and intact in plants. Functional fibre describes isolated nondigestible carbohydrates that have beneficial physiological effects in humans. Total fibre is the sum of dietary fibre and functional fibre. Nondigestible means not digested and absorbed in the small intestine. Fibres can be fermented in the large intestine or pass through the digestive tract unfermented. The adequate intake (AI) of fibre is based on the median fibre intake level observed to achieve the lowest risk of coronary heart disease (CHD): 14 g dietary/1000 kcal intake (Slavin *et al*., 2008). Saris (2003) reported

an inverse relationship between carbohydrate intake and body mass index (BMI) in 8 of 9 studies. The "fibre hypothesis" suggests that consumption of unrefined, high-fibre, carbohydrate-based foods protects against diseases including diabetes, cancer, heart disease and obesity. However, this diet is both high in dietary fibre and low in dietary fat, making it difficult to separate out the cause of these beneficial effects. A multidisciplinary study of more than 5000 individuals found that obesity was associated with increased energy intake and decreased consumption of fibre-rich foods like fruits and vegetables (Lissner *et al*., 1998). Maskarinec *et al*. (2006) reported that plant-based foods and dietary fibre were most protective against excess body weight in a large, ethnically diverse population. Heaton (1973) proposed that fibre acts as a physiological obstacle to energy intake through at least three mechanisms: 1) fibre displaces available calories and nutrients from the diet; 2) fibre increases chewing, which limits intake by promoting the secretion of saliva and gastric juice, resulting in an expansion of the stomach and increased satiety; and 3) fibre reduces the absorption efficiency of the small intestines. Intrinsic, hormonal and colonic effects of dietary fibre decrease food intake by promoting satiation and/or satiety. Examples of these controls include decreased gastric emptying and/or slowed energy and nutrient absorption. Gut hormone signaling also plays a significant role in satiety. Additionally, dietary fibre may also influence fat oxidation and storage. Moorhead *et al*. (2006) reported that both fibre content and food structure are important determinants of satiety. A study conducted using apples, applesauce and apple juice (with added fibre) as a pre-load before a meal revealed that although the three foods contained the same calories and fibre, subjects ate significantly less lunch when consuming the whole apple compared with the applesauce and the apple juice or no pre-load. This suggests that adding fibre to a beverage may not necessarily enhance satiety and that solid foods are more satiating than liquids (Flood and Rolls, 2007). Many studies support that increased dietary fibre intake promotes satiety and decreases hunger and thus helps provide a feeling of fullness. Short-term studies that assess energy intake after

subjects are fed fibre-containing meals suggest that large amounts of total fibre (total nutrition fibre) are most successful for reducing subsequent energy intake (Slavin and Green, 2007). It must be stressed, however, that dietary fibre sources are not equally effective in reducing food intake and promoting satiety (Slavin *et al*., 2008).

2.3.6. Rules Governing the Use of Fat Replacers

Under the FDA regulations, fat replacers fall into one of two categories: food additives or generally recognized as safe (GRAS) substances. Fat replacers made with a combination of existing ingredients such as starches, gums, fibres, or proteins that are widely used in the food supply require no special approval. GRAS substances can be used if they have been shown to be safe through long-term ingestion and use. Many GRAS substances are similar to substances already present in food. Examples of GRAS substances used as fat replacers are cellulose gel, dextrins, guar gum, and gum arabic. Microparticulated protein fat mimetics are also considered as GRAS substances. Some GRAS ingredients used in a new or unfamiliar way may need a petition that affirms them as GRAS, such as a new fibre extracted from a plant that is regularly ingested. New substances not present in the food supply must be approved as food additives. Even food additives, which are in the food supply, may require a special petition for use in a food category when no such approval exists or when the amount needed is greater than currently permitted (American Dietetic Association, 2006).

2.3.7. Utility of Fat Replacers

Fat replacers could positively impact overall diet quality if they are used as part of a total diet plan that promotes choosing fats wisely and balancing total energy intake. For example, the use of salad dressings that contain fat replacers can allow the intake of nutrients from the vegetables in a salad while adding few calories. In meat and other food items, fat replacers may not only reduce the calories and saturated fat, they may actually increase their antioxidant value when

foods such as prune, raisin, or cherry paste or wild rice replace some of the fat. Peterson and Sigman-Grant (1997) observed that fat-modified products assisted children to reach dietary recommendations for total energy and total fat intake. However, a concomitant reduction in antioxidants occurred (i.e., vitamin E), suggesting that careful attention should be paid to the overall quality of the diet of individuals utilizing these products.

Protein-based fat replacers from milk powder, whey, soy, or legumes may increase the protein quality of the diet and may have an impact on satiety and food consumption in the short term (Layman and Baum, 2004; Anderson and Moore, 2004). Fat replacers in spreads, margarines, and dessert products have the potential to reduce the calories, saturated fat, and trans-fatty acid intakes of frequent consumers of these food categories. Studies show that consumption of cakes and frozen ice-cream-like products made with oat fibre may decrease saturated fat intake by as much as 50% and increase the viscous fibre in the diet (Howarth *et al*., 2001). Fat replacers that are fibres such as inulin, lupin fibre, may increase diet quality in that they add to the intake of dietary fibre. This is important because the average American eats less than half the amount of recommended dietary fibre intake (Howarth *et al*., 2001). Furthermore, several short-term studies in adults indicate that fibre used as a fat replacer may be important for regulating food intake, preventing weight gain, and helping with weight maintenance (Archer *et al*., 2004; Reyna *et al*., 2003). In one study with diabetic male participants, diets encouraging foods containing fibre-based fat and sugar replacers, together with other lifestyle changes, caused greater increase in high-density lipoprotein cholesterol and larger decreases in hemoglobin A1c, weight, and BMI than was seen with the standard treatment plant (Reyna *et al*., 2003). However, if foods with fat replacers are neither lower in calories nor encourage the consumption of foods that are central to the 2005 Dietary Guidelines for Americans, they may do little to improve the diet and may actually have deleterious effects.

Fat replacers have facilitated the development of reduced-fat and fat-free foods that emulate the taste and texture of high-fat foods but with less calories, fat, or cholesterol. Although they do not replace the need for practicing moderation and good nutrition, they may afford palatable alternatives and facilitate compliance with low-calorie, low-fat, and/or low-cholesterol dietary recommendations.

2.3.8. Fruits Which Have Been Used as Fat Replacers

2.3.8.1. Fruit Purees and Powders

Fruits and fruit purees can be effective fat mimics. Purees of bananas, plums, pears and apples, can perform many of the functions of fat due to their pectin, fibre and sugar content. In particular, the complexes of fibre and pectin provide texture and body. Fruit sugars provide additional solids and water-binding. Added health benefits may include antioxidant activity. These replacers may partially or completely replace fat in cookies, muffins, cakes and other bakery mixes. Since these replacers are not modified to the extent others are, their addition must be carefully managed on a case-by-case basis (Michaelides and Cooper, 2004). Pawpaw fruit powdered by the freeze drying method could also be used as a fat replacer since it has a high fibre and pectin content. According to Pamplona-Roger (2003), the fruit of pawpaw contains 1.5 g/100 g pectin per raw edible portion of pawpaw fruit.

2.4. Pectin

2.4.1. Source

Pectin (E440) is a heterogeneous grouping of acidic structural polysaccharides, found in fruit and vegetables and mainly prepared from 'waste' citrus peel and apple pomace (http://www.isbu.ac.uk/water/hypec.html).

2.4.2. Structural unit

Pectin has a complex structure. Preparations consist of sub structural entities that depend on their source and extraction methodology. Commercial extraction causes extensive degradation of the neutral sugar-containing side chains. The majority of the structure consists of homopolymeric partially methylated poly-α-(1⟶4)-D-galacturonic acid residues ('smooth', see right) but there are substantial 'hairy' non-gelling areas (see below) of alternating α -(1⟶2)-L-rhamnosyl-α -(1⟶4)-D-galacturonosyl sections containing branch-points with mostly neutral side chains (1 - 20 residues) of mainly L-arabinose and D-galactose (rhamnogalacturonan I). Pectins may also contain rhamnogalacturonan II side chains containing other residues such as D-xylose, L-fucose, D-glucuronic acid, D-apiose, 3-deoxy-D-*manno*-2-octulosonic acid (Kdo) and 3-deoxy-D-*lyxo*-2-heptulosonic acid (Dha) attached to poly-α-(1⟶4)-D-galacturonic acid regions.

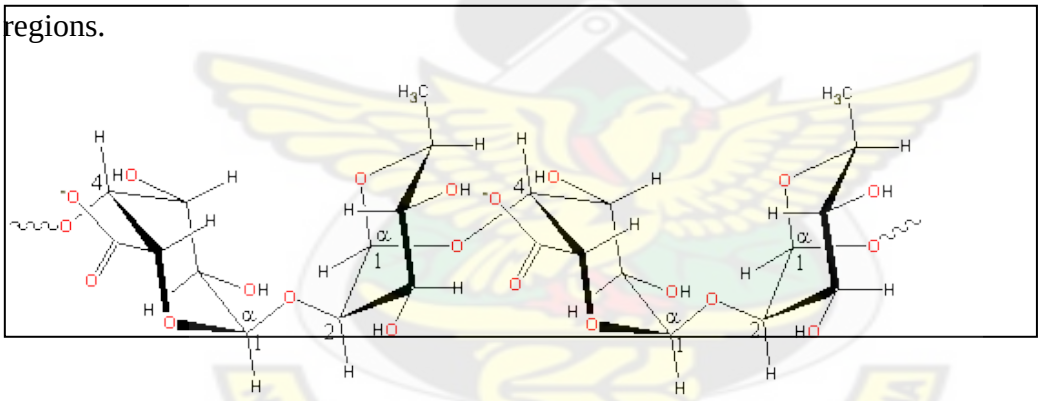

Figure 1: Structure of Pectin
Source: (http://www.isbu.ac.uk/water/hypec.html).

2.4.3. Molecular structure

Generally, pectins do not possess exact structures. D-galacturonic acid residues form most of the molecules, in blocks of 'smooth' and 'hairy' regions. The molecule does not adopt a straight conformation in solution, but is extended and curved ('worm-like') with a large amount of flexibility. The `hairy' regions of pectins are even more flexible and may have pendant arabinogalactans. The carboxylate groups tend to expand the structure of pectins as a result of

their charge, unless they interact through divalent cationic bridging (their pK_a of about 2.9 ensuring considerable negative charge under most circumstances). Methylation of these carboxylic acid groups forms their methyl esters, which take up a similar space but are much more hydrophobic and consequently have a different effect on the structuring of the surrounding water. The properties of pectins depend on the degree of esterification, which is normally about 70%. Low methoxyl-pectins (< 40% esterified) gel by calcium di-cation bridging between adjacent two-fold helical chains forming so-called 'egg-box' junction zone structures so long as a minimum of 14-20 residues can cooperate. Gel strength increases with increasing Ca^{2+} concentration but reduces with temperature and acidity increase (pH < 3). It may well be that the two carboxylate groups have to cooperate together in prizing the bound water away from the calcium ions to form the salt links that make up these junction zones. The gelling ability of the di-cations is similar to that found with the alginates (Mg^{2+} << Ca^{2+}, Sr^{2+} < Ba^{2+}) with Na^+ and K^+ not gelling. If the methoxyl esterified content is greater than about 50%, calcium ions show some interaction but do not gel. The similarity to the behavior of the alginates is that poly-α-(1⟶4)-D-galacturonic acid is almost the mirror image of poly-α-(1⟶4)-L-guluronic acid, the only difference being that the 3-hydroxyl group is axial in the latter. The controlled removal of methoxyl groups, converting high methoxyl pectins to low-methoxyl pectins, is possible using pectin methylesterases but the reverse process is not easily achieved. High methoxyl-pectins (> 43% esterified, usually ~67%) gel by the formation of hydrogen-bonding and hydrophobic interactions in the presence of acids (pH ~3.0, to reduce electrostatic repulsions) and sugars (*e.g.* about 62% sucrose by weight, to reduce polymer-water interactions). Low methoxy-pectins (~35% esterified), in the absence of added cations, gel by the formation of cooperative 'zipped' associations at low temperatures (~10°C) to form transparent gels. This hydrogen-bonded association is likely to be similar to that of alginate. The rheological properties of low methoxy-

pectins are highly dependent on the salt cation, salt concentration and pH (http://www.isbu.ac.uk/water/hypec.html).

2.4.4. Functionality

Pectins are mainly used as gelling agents, but can also act as thickener, water binder and stabilizer. Low methoxyl pectins (< 50% esterified) form thermoreversible gels in the presence of calcium ions and at low pH (3-4.5) whereas high methoxyl pectins rapidly form thermally irreversible gels in the presence of sufficient (*e.g.* 65% by weight) sugars such as sucrose and at low pH (< 3.5); the lower the methoxyl content, the slower the set. The degree of esterification can be (incompletely) reduced using commercial pectin methylesterase, leading to a higher viscosity and firmer gelling in the presence of Ca^{2+} ions. Highly (2-O- and/or 3-O-galacturonic acid backbone) acetylated pectin from sugar beet is reported to gel poorly but have considerable emulsification ability due to its more hydrophobic nature, but this may be due to associated protein impurities. As with other viscous polyanions such as carrageenan, pectin may be protective towards milk casein colloids, enhancing the properties (foam stability, solubility, gelation and emulsification) of whey proteins whilst utilizing them as a source of calcium (http://www.isbu.ac.uk/water/hypec.html).

2.4.5. Role of Pectin in Diet

Studies at the University of Florida and elsewhere indicate that citrus pectin and fibre have potential health benefits. Several studies have shown, for example, that pectin can decrease serum cholesterol levels without effecting serum triglyceride levels. Isolated viscous fibres such as pectin, rice bran or oat bran lower both total serum cholesterol and low density lipoprotein (LDL or bad) cholesterol levels. At the same time, research continues to show that diets high in a mix of dietary fibre also protect against coronary heart disease (CHD) (Trinidad *et al*., 2004).

Pectin also can reduce blood sugar spikes when consumed with a meal. Soluble fibre, may slow digestion and absorption of carbohydrates and hence lower the rise in blood glucose that follows a meal (postprandial) and insulin response. This can help people with diabetes improve control of their blood glucose levels. Still more research indicates pectin may reduce the risk of certain cancers. For example, researchers at the School of Medicine, University of Michigan, Ann Arbor, studied pH-altered modified citrus pectin and found that it prevented spontaneous prostate cancer metastasis by inhibiting cancer cells from adhering to other cells in the body (Trinidad *et al*., 2004).

Other researchers in Texas also have discovered a link between pectin and reduced prostate cancer risk. Scientists at the Texas A&M-Kingsville Citrus Center at Weslaco, the University of Texas-Pan American at Edinburgh and Texas A&M's Institute of Biotechnology (IBT) at the Texas Medical Center in Houston collaborated on the research, which was published in the June 2001 issue of the Journal of Agriculture and Food Chemistry. As with the Michigan research, this study showed that citrus pectin somehow inhibits the mechanism that triggers prostate malignancy. The Texas researchers are yet to identify the active component of the pectin. After this, they'll explore ways to increase pectin consumption by enhancing pectin's presence in citrus via modified growing and harvesting practices, or by extracting and modifying the active ingredient of pectin and making it available as an ingredient (Hergenbart, 2001). Pectin fibre provides bulk in the diet, without added calories, and thus it can have a satiating effect on appetite; helping in weight management (Trinidad *et al*., 2004).

2.5. Pawpaw (Papaya)

Pawpaw has the scientific name; *Carica papaya*. It comes from the family Caricaceae and it is known in most countries as papaw or papaya. It is native to the tropical lowlands of Central

America but it is now widely cultivated throughout the tropics and sub-tropics (Tweneboah, 2001).

2.5.1. Description

Pawpaw is a fast-growing, short-day, herbaceous and hollow-stemmed tree with unbranched stem and a crown of large leaves. The leaves emerge directly from the upper part of the stem in a spiral on nearly horizontal petioles 1 to 3 1/2 ft (30-105 cm) long, hollow, succulent, green or more or less dark purple. The life of a leaf is 4 to 6 months. Generally, the fruit is melon-like, oval to nearly round, somewhat pyriform, or elongated club-shaped, 6 to 20 inches (15-50 cm) long and 4 to 8 inches (10-20 cm) thick; weighing up to 20 lbs (9 kg). Semi-wild (naturalized) plants bear miniature fruits 1 to 6 inches (2.5-15 cm) long (Tweneboah, 2001).

In Ghana, it is mostly a backyard crop grown mostly for home consumption but in recent years is assuming some importance as a commercial crop, especially with the availabiity of cultivars with smaller sweet fruits. It is also found self-sown in food farms in the forest and derived savanna zones where it has almost assumed the status of a weed plant in some areas. Pawpaw is nevertheless a nutritious fruit of high quality and grows well under most conditions (Tweneboah, 2001).

2.5.2. Botany

Pawpaw is usually dioecious, with male and female flowers borne on separate plants though, hermaphrodite varieties (bisexual) of plants do occur (Tweneboah, 2001).

2.5.3. Varieties

In Ghana, dioecious cultivars such as 'Solo', 'Golden Surprise', 'Hawaii', and 'No. 5595', were introduced and commonly cultivated by farmers but they hybridized with local types and lost their identities after several generations. A number of types were collected at the Agricultural

Research Station at Kade from 1966 to 1970 and classified according to sex type, fruit form, weight, skin and flesh colour, flesh thickness, texture and flavour, number of seeds, and various plant factors. It was determined that preference should be given female plants with short, stout stems, early maturing, and bearing heavily all year medium-size fruits of bright colour, thick-flesh and with few seeds. At the moment most common varieties are round-fruited types with orange flesh but bisexual ovoid or long-fruited types are frequently seen, mostly in backyard gardens (Tweneboah, 2001).

2.5.4. Food Value and Uses

2.5.4.1. Food Uses

Ripe papayas are most commonly eaten fresh, merely peeled, seeded, cut in wedges and served with a half or quarter of lime or lemon. Sometimes a few seeds are left attached for those who enjoy their peppery flavor but not many should be eaten. The flesh is often cubed or shaped into balls and served in fruit salad or fruit cup. Firm-ripe papaya may be seasoned and baked for consumption as a vegetable. Ripe flesh is commonly made into sauce for shortcake or ice cream sundaes, or is added to ice cream just before freezing; or is cooked in pie, pickled, or preserved as marmalade or jam. Papaya and pineapple cubes, covered with sugar syrup, may be quick-frozen for later serving as dessert. Half-ripe fruits are sliced and crystallized as a sweetmeat (Morton, 1987).

Papaya juice and nectar may be prepared from peeled or unpeeled fruit and are sold fresh in bottles or canned. In Hawaii, papayas are reduced to puree with sucrose added to retard gelling and the puree is frozen for later use locally or in mainland USA in fruit juice blending or for making jam (Morton, 1987).

Unripe papaya is never eaten raw because of its latex content. Raw green papaya is frequently used in Thai and Vietnamese cooking. Even for use in salads, it must first be peeled, seeded, and boiled until tender, then chilled. Green papaya is frequently boiled and served as a vegetable. Cubed green papaya is cooked in mixed vegetable soup. Green papaya is commonly canned in sugar syrup in Puerto Rico for local consumption and for export. Green papayas for canning in Queensland must be checked for nitrate levels. High nitrate content causes detinning of ordinary cans, and all papayas with over 30 parts per million nitrate must be packed in cans lacquered on the inside. Australian growers are hopeful that the papaya can be bred for low nitrate uptake. A lye process for batch peeling of green papayas has proven feasible in Puerto Rico. The fruits may be immersed in boiling 10% lye solution for 6 minutes, in a 15% solution for 4 minutes, or a 20% solution for 3 minutes. They are then rapidly cooled by a cold water bath and then sprayed with water to remove all softened tissue. Best proportions are 1 lb (0.45 kg) of fruit for every gallon (3.8 liters) of solution (Morton, 1987).

Young leaves are cooked and eaten like spinach in the East Indies. Mature leaves are bitter and must be boiled with a change of water to eliminate much of the bitterness. Papaya leaves contain the bitter alkaloids, carpaine and pseudocarpaine, which act on the heart and respiration like digitalis, but are destroyed by heat. In addition, two previously undiscovered major piperideine alkaloids, dehydrocarpaine I and II, more potent than carpaine, were reported from the University of Hawaii in 1979. Sprays of male flowers are sold in Asian and Indonesian markets and in New Guinea for boiling with several changes of water to remove bitterness and then eaten as a vegetable. In Indonesia, the flowers are sometimes candied. Young stems are cooked and served in Africa. Older stems, after peeling, are grated, the bitter juice squeezed out, and the mash mixed with sugar and salt (Morton, 1987).

In India, papaya seeds are sometimes found as an adulterant of whole black pepper. Collaborating chemists in Italy and Somalia identified 18 amino acids in papaya seeds, principally, in descending order of abundance, glutamic acid, arginine, proline, and aspartic acid in the endosperm; and proline, tyrosine, lysine, aspartic acid, and glutamic acid in the sarcotesta. A yellow to brown, faintly scented oil was extracted from the sundried, powdered seeds of unripe papayas at the Central Food Technological Research Institute, Mysore, India. A white seed yielded 16.1% and black seeds 26.8% and it was suggested that the oil might have edible and industrial uses. The papaya is regarded as a fair source of iron and calcium; a good source of vitamins A, B complex and G and an excellent source of vitamin C (ascorbic acid).

Table 1- Food Value per 100 g of Edible Portion of Pawpaw

	Fruit	*Leaves**
Calories	23.1-25.8	
Moisture	85.9-92.6 g	83.3 %
Protein	.081-.34 g	5.6 %
Fat	.05-.96 g	0.4 %
Carbohydrates	6.17-6.75 g	8.3 %
Crude Fibre	0.5-1.3 g	1.0 %
Ash	.31-.66 g	1.4 %
Calcium	12.9-40.8 mg	0.406 %
Phosphorus	5.3- 22.0 mg	
Iron	0.25- 0.78 mg	0.00636 %
Carotene	.0045-.676 mg	28,900 I.U.
Thiamine	.021- 0.036 mg	
Riboflavin	.024- 058 mg	
Niacin	.227- 0.555 mg	
Ascorbic Acid	35.5- 71.3 mg	38.6 %
Tryptophan	4-5 mg	
Methionine	1 mg	
Lysine	15-16 mg	
Magnesium		0.035 %
Phosphoric Acid		0.225 %

Source: www.hort.purdue.edu/newcrop/morton/papaya_ars.html

Carotenoid content of papaya (13.8 mg/100 g dry pulp) is low compared to mango, carrot and tomato. The major carotenoid is cryptoxanthin (Morton, 1987).

Papain

The latex of the papaya plant and its green fruits contains two proteolytic enzymes, papain and chymopapain. The latter is most abundant but papain is twice as potent. In 1933, Ceylon (Sri Lanka) was the leading commercial source of papain but it has been surpassed by East Africa where large-scale production began in 1937. The latex is obtained by making incisions on the surface of the green fruits early in the morning and repeating every 4 or 5 days until the latex ceases to flow. The tool is made of bone, glass, sharp-edged bamboo or stainless steel (knife or razor blade). Ordinary steel stains the latex. Tappers hold a coconut shell, clay cup, or glass, porcelain or enamel pan beneath the fruit to catch the latex, or a container like an "inverted umbrella" is clamped around the stem. The latex coagulates quickly and for best results, is spread on fabric and oven-dried at a low temperature, then ground to powder and packed in tins. Sun-drying tends to discolor the product. One must tap 1,500 average-size fruits to gain 1 1/2 lbs (0.68 kg) of papain (Morton, 1987).

The lanced fruits may be allowed to ripen and can be eaten locally, or they can be employed for making dried papaya "leather" or powdered papaya, or may be utilized as a source of pectin. Because of its papain content, a piece of green papaya can be rubbed on a portion of tough meat to tenderize it. Sometimes a chunk of green papaya is cooked with meat for the same purpose. One of the best known uses of papain is in commercial products marketed as meat tenderizers, especially for home use. A modern development is the injection of papain into beef cattle a half-hour before slaughtering to tenderize more of the meat than would normally be tender. Papain-treated meat should never be eaten "rare" but should be cooked sufficiently to inactivate the enzyme. The tongue, liver and kidneys of injected animals must be consumed quickly after cooking or utilized immediately in food or feed products, as they are highly perishable (Morton, 1987).

Papain has many other practical applications. It is used to clarify beer, also to treat wool and silk before dyeing, to de-hair hides before tanning, and it serves as an adjunct in rubber manufacturing. It is applied on tuna liver before extraction of the oil which is thereby made richer in vitamins A and D. It is included in the production of toothpastes, cosmetics and detergents, as well as pharmaceutical preparations to aid digestion. Papain has been employed to treat ulcers, dissolve membranes in diphtheria, and reduce swelling, fever and adhesions after surgery. With considerable risk, it has been applied on meat impacted in the gullet. Chemopapain is sometimes injected in cases of slipped spinal discs or pinched nerves. Precautions should be taken because some individuals are allergic to papain in any form and even to meat tenderized with papain (Morton, 1987).

2.5.4.2. Use in Fat Replacement

Pawpaw fruit (*Asimina triloba)* has the potential function as a carbohydrate- based fat replacement in baked products (Duffrin *et al.* (2001); Wiese and Duffrin, 2003). The intense tropical, fruit-like flavour makes it a potential source of natural fruit flavour (McGrath and Karahadian, 1994). The fruit's high nutritional quality also makes it an excellent contribution to a balanced diet. Pawpaw also has high levels of potassium, calcium and iron making it an excellent food source. Wiese and Duffrin (2003) investigated the sensory properties of plain cake using pawpaw fruit puree as a partial replacement for the fat in the food formulation. The influence on the colour, texture and tenderness appeared to influence preference ratings for the category of overall acceptability. Participants preferred the no pawpaw pulp control and 25 % compared to 50 % and 75 % of the fat replacement with pawpaw puree. The 50 % and 75 % replacement of fat with pawpaw fruit puree in cake samples resulted in reduced preference for the colour, texture, tenderness and overall acceptability. In examining a muffin formulation, Duffrin *et al*. (2001) found some fat is required in a food formulation along with pawpaw fruit

puree for a desirable product. The custard-like nature of the pawpaw fruit, its nutrient composition and acceptance by tasters makes it a good choice as a partial fat-reducing agent in baked goods.

2.5.4.3. Health Benefits

Papayas are rich sources of antioxidant nutrients such as carotenes, vitamin C and flavonoids; the B vitamins, folate and pantothenic acid; and the minerals, potassium and magnesium; and fibre. Together, these nutrients promote the health of the cardiovascular system and also provide protection against colon cancer. In addition, the digestive enzyme, papain, in papaya is used like bromelain, a similar enzyme found in pineapple, to treat sports injuries, other causes of trauma and allergies (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

Protection against Heart Disease

Papayas may be very helpful for the prevention of atherosclerosis and diabetic heart disease. Papayas are an excellent source of vitamin C as well as a good source of vitamin E and vitamin A (through their concentration of pro-vitamin A carotenoid phytonutrients); three very powerful antioxidants. These nutrients help prevent the oxidation of cholesterol. Only when cholesterol becomes oxidized is it able to stick to and build up in blood vessel walls, forming dangerous plaques that can eventually cause heart attacks or strokes. One way in which dietary vitamin E and vitamin C may exert this effect is through their suggested association with a compound called paraoxonase, an enzyme that inhibits LDL cholesterol and HDL cholesterol oxidation. Papayas are also a good source of fibre, which has been shown to lower high cholesterol levels. The folic acid found in papayas is needed for the conversion of a substance called homocysteine into benign amino acids such as cysteine or methionine. If unconverted, homocysteine can directly damage blood vessel walls and, if levels get too high, is considered a significant risk factor for a heart attack or stroke (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

Promotes Digestive Health

The nutrients in papaya have also been shown to be helpful in the prevention of colon cancer. Papaya's fibre is able to bind to cancer-causing toxins in the colon and keep them away from the healthy colon cells. In addition, papaya's folate, vitamin C, beta-carotene, and vitamin E have each been associated with a reduced risk of colon cancer. These nutrients provide synergistic protection for colon cells from free radical damage to their DNA (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

Anti-Inflammatory Effects

The papain and chymopapain enzymes in papaya have been shown to help lower inflammation and to improve healing from burns. In addition, the antioxidant nutrients found in papaya, including vitamin C, vitamin E, and beta-carotene are also very good at reducing inflammation. This may explain why people with diseases that are worsened by inflammation, such as asthma, osteoarthritis and rheumatoid arthritis, find that the severity of their condition is reduced when they get more of these nutrients (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

Immune Support

Vitamin C and vitamin A, which is made in the body from the beta-carotene in papaya, are both needed for the proper function of a healthy immune system. Papaya may therefore be a healthy fruit choice for preventing such illnesses as recurrent ear infections, colds and flu (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

Protection against Macular Degeneration

Data reported in a study published in the *Archives of Ophthalmology* indicates that eating 3 or more servings of fruit per day may lower one's risk of age-related macular degeneration (ARMD), the primary cause of vision loss in older adults by 36% compared to persons who

consume less than 1.5 servings of fruit daily. In this study, which involved over 110,000 women and men, researchers evaluated the effect of study participants' consumption of fruits; vegetables; the antioxidant vitamins A, C, and E; and carotenoids on the development of early ARMD or neovascular ARMD, a more severe form of the illness associated with vision loss. While, surprisingly, intakes of vegetables, antioxidant vitamins and carotenoids were not strongly related to incidence of either form of ARMD, fruit intake was definitely protective against the severe form of this vision-destroying disease (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

Protection against Rheumatoid Arthritis

While one study suggests that high doses of supplemental vitamin C makes osteoarthritis, a type of degenerative arthritis that occurs with aging, worse in laboratory animals, another indicates that vitamin C-rich foods, such as papaya, provide humans with protection against the inflammatory polyarthritis, a form of rheumatoid arthritis involving two or more joints. The findings, presented in the *Annals of the Rheumatic Diseases* were drawn from a study of more than 20,000 subjects and focused on subjects who developed inflammatory polyarthritis and similar subjects who remained arthritis-free during the follow-up period. Subjects who consumed the lowest amounts of vitamin C-rich foods were more than three times more likely to develop arthritis than those who consumed the highest amounts (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

Promote Lung Health

If anyone is a smoker, or if one is frequently exposed to second hand smoke, then making vitamin A-rich foods, such as papaya, part of your healthy way of eating may save your life, suggests research conducted at Kansas State University. While studying the relationship between vitamin A, lung inflammation, and emphysema, Richard Baybutt, associate professor of

nutrition at Kansas State, made a surprising discovery: a common carcinogen in cigarette smoke, benzo(a)pyrene, induces vitamin A deficiency. Baybutt's earlier research had shown that laboratory animals fed vitamin A-deficient diet developed emphysema. His latest animal studies indicate that not only does the benzo(a)pyrene in cigarette smoke cause vitamin A deficiency, but that a diet rich in vitamin A can help counter this effect, thus greatly reducing emphysema. Baybutt believes vitamin A's protective effects may help explain why some smokers do not develop emphysema (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

Papaya and Green Tea Work Together to Prevent Prostate Cancer

Choosing to regularly eat lycopene-rich fruits, such as papaya, and drink green tea may greatly reduce a man's risk of developing prostate cancer. In this case-control study involving 130 prostate cancer patients and 274 hospital controls, men drinking the most green tea were found to have an 86% reduced risk of prostate cancer compared, to those drinking the least (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

A similar inverse association was found between the men's consumption of lycopene-rich fruits and vegetables such as tomatoes, apricots, pink grapefruit, watermelon, papaya, and guava. Men who most frequently enjoyed these foods were 82% less likely to have prostate cancer compared to those consuming the least lycopene-rich foods. Regular consumption of both green tea and foods rich in lycopene resulted in a synergistic protective effect, stronger than the protection afforded by either, the researchers also noted (www.whfoods.org/genpage.php?tname=foodspice&dbid=47).

2.5.4.4. Folk Uses

In tropical folk medicine, the fresh latex is smeared on boils, warts and freckles and given as a vermifuge. The latex from the fruit may be used in the treatment of hepatic jaundice, diphtheria,

kidney stones and urinary disorders. It is also a coagulant (Arbonnier, 2004). In India, it is applied on the uterus as an irritant to cause abortion. The unripe fruit is sometimes hazardously ingested to achieve abortion. Seeds, too, may bring on abortion. They are often taken as an emmenagogue and given as a vermifuge. The root is ground to a paste with salt, diluted with water and given as an enema to induce abortion. A root decoction is claimed to expel roundworms. Also in the treatment of dysentery, tooth decay, whitlow, convulsion, rheumatism and gonococcal infections, the roots may be used (Arbonnier, 2004).

The leaves are used in the treatment of headaches, rheumatism, hernia, orchitis, blennorrhea and haemorrhoids (Arbonnier, 2004). They may also be used in the treatment of toes with athlete's foot infection (Abudu, 2000). The fresh green leaves may be used to scrub metal pails and rid them of contamination and other infected organic substances (Abudu, 2000). They may also be used in the treatment of wounds, whitlow amoebiasis, gangrenous ulcers, difficult deliveries and high blood pressure (Arbonnier, 2004). They also serve as an antidote against poisoning and rabies and for the promotion of milk production. The leaves serve as an invaluable anti-malarial medication. They may also be used for retarding the development of arthritis, for cleaning the teeth, checking unpleasant breath and also as an antidote against diarrhea (Abudu, 2000). Crushed leaves wrapped around tough meat will tenderize it overnight. The leaf also functions as a vermifuge and as a primitive soap substitute in laundering and for the removal of stains. The leaves may also serve as poison for fishing (Arbonnier, 2004). Dried leaves have been smoked to relieve asthma or as a tobacco substitute. Packages of dried, pulverized leaves are sold by "health food" stores for making tea, despite the fact that the leaf decoction is administered as a purgative for horses in Ghana and in the Ivory Coast it is a treatment for genito-urinary ailments. The dried leaf infusion is taken for stomach troubles in Ghana and it is said to be a purgative and may cause abortion. The flowers are used to make medication for coughs (Abudu, 2000) and

also for the treatment of guinea worm, and yellow fever. The fruits are also used as useful medication for the treatment of digestive disorders, wounds, yaws, ergotism, wart and callus (Arbonnier, 2004).

Antibiotic Activity

Studies at the University of Nigeria have revealed that extracts of ripe and unripe papaya fruits and of the seeds are active against gram-positive bacteria. Strong doses are effective against gram-negative bacteria. The substance has protein-like properties. The fresh crushed seeds yield the aglycone of glucotropaeolin benzyl isothiocyanate (BITC) which is bacteriostatic, bactericidal and fungicidal. A single effective does is 4-5 g seeds (25-30 mg BITC). In a London hospital in 1977, a post-operative infection in a kidney-transplant patient was cured by strips of papaya which were laid on the wound and left for 48 hours, after all modern medications had failed.

2.5.5. Papaya Allergy

Mention has already been made of skin irritation in papaya harvesters because of the action of fresh papaya latex, and of the possible hazard of consuming undercooked meat tenderized with papain. It must be added that the pollen of papaya flowers has induced severe respiratory reactions in sensitive individuals. Thereafter, such people react to contact with any part of the plant and to eating ripe papaya or any food containing papaya, or meat tenderized with papain.

2.5.6. Chemistry of Papaya

Sugars

Much of the early work on the estimation of sugars in ripe papaya is now known to be incorrect due to the presence of an invertase enzyme. A more recent evaluation which heated the samples

in a microwave oven to deactivate the enzyme has given the distribution as follows: sucrose (48.3% early reports suggested NONE), glucose (29.8%) and fructose (21.9%). The total carbohydrate content has been found to be around 10 g per 100 g of edible portion.

Acids

The acid content of papayas is low and the pH is generally between 5.5-5.9 and comes from almost equal amounts of citric and malic acid.

Pigments

The difference between yellow and red-fleshed papayas was first described in 1964 and the total carotenoid content was reported to be 3.7 mg/100 g and 4.2 mg/100 g respectively.

Table 2- The major differences between red and yellow fleshed papayas.

Percent composition of carotenoid pigments		
pigment	**yellow**	**Red**
beta-carotene	4.8	4.8
zeta-carotene	24.8	5.9
cryptoxanthin and monoepoxide	15.6	4.4
cryptoxanthin	38.9	19.2
lycopene	0.0	63.5
unresolved	15.9	2.2

Source: www.chem.uwimona.edu.jm:1104/lectures/papaya.html

Volatiles

One hundred and six (106) volatile compounds were identified in 1977 using Gas Chromatographic and Mass Spectroscopic techniques. The compound thought to give the odour that most closely resembled that of papayas was linalool - 68%. Benzyl isothiocyanate - 13% contributes a pungent off-odour and is present as a major component (www.chem.uwimona.edu.jm:1104/lectures/papaya.html).

2.6. Importance of Shelf Stable Fruit Products

Fruits and vegetables are highly perishable products. Currently, up to 23% of the most perishable fruits and vegetables are lost during their journey through the agri-food chain due to spoilage, physiological decay, water loss, mechanical damage during harvesting, packaging and transporting or due to transportation. These losses have been estimated to be more than 40 to 50% in the tropics and subtropics (FAO, 1995 a, b). Losses also occur during shelf life and food preparation in home and food services. Moreover, in many developing countries, only a limited quantity of fruit and vegetable products are produced for local markets or for exportation due to lack of machinery and infrastructure. It is estimated that Ghana loses 30-40% of her fruits and vegetables annually due to lack of storage and preservation facilities. One feature of the distribution of these highly perishably food crops in Ghana throughout the year is that it is highly skewed. Soon after harvest, the local markets become flooded with the commodities over and above the demand for consumption (Gyabaah-Yeboah, 1985). Reduction of the high wastage of fruits and vegetables entails various measures to be adopted to minimize these losses during harvesting, handling, storage, packaging and processing of fresh fruits and vegetables in suitable products with improved storage characteristics (which can be used during the lean season).

Consumer demand has increased for processed products that keep more of their original characteristics. In industrial terms, this requires the development of operations that minimize the adverse effects of processing. At the moment, there is a high demand for high-quality fruit ingredients to be used in many food formulations such as pastry and confectionary products, ice cream, frozen desserts and sweets, fruit salads, cheese and yoghurt. For such uses, fruit pieces must maintain their natural flavour and colour, they must preferably be free of preservatives and their texture must be agreeable. Proper application of “combined processes” may fulfill these

specific requirements. These processes use a sequence of technological steps to achieve controlled changes of the original properties of the raw material (Maltini *et al*., 1993). In most cases, the aim is to obtain ingredients suitable for a wide range of food formulations, although end products can also be prepared. These high quality fruit products include dried fruits, fruit leathers, pastes, pulps and sauces (Torreggiani and Bertolo, 2001).

2.6.1. Dried Fruits

Product Description

These are dried pieces of fruits for confectionary or for use in baked goods or other food preparations. They have a soft rubbery texture and a sweet taste with the characteristic flavour and colour of the fruit which has been used. Dried fruits can be made from most fruits including mango, guava, banana, grapes, papaya (pawpaw), pineapple and passion fruit (Fellows, 1997).

2.7. Mango

Mango fruits are healthy, cheap and tasty (South Pacific Commission, 1995). They form a very important dietary supplement in both urban and rural areas when the fruits are in season. Mango fruits are one of the most important sources of vitamin A and also have fairly high content of vitamin C and minerals (Tweneboah, 2001). In spite of the nutritional qualities of mangoes, post harvest losses in mangoes remain high since they are mostly eaten fresh and no proper preservation steps are taken to process the fruits into shelf stable products. Mangoes can be processed into high quality fruit products e.g. dried fruits for use in areas where there is a high incidence of vitamin A deficiency due to its high vitamin A content. Processing mangoes into dried fruits will also help improve its keeping qualities so that they can be available all year round.

2.7.1. Origin of Mangoes

Mango originated on the Indian sub-continent and was in cultivation before 2000 BC. However, it spread to world wide cultivation in relatively recent times, when the Portuguese opened the sea route to the Far East. Although the fruit appears to have reached East Africa by the 9th century through Arab incursions, recorded history indicates that the mango was first taken to South Africa from Goa near Bombay by the Portuguese in the 17th century and had spread throughout West Africa by the middle of the 19th century (Tweneboah, 2001).

2.7.2. Botany

Mango is the most important member of the cashew family (*Anacardiaceae*) with the cashew (*Anacardium occidentale*) as the only relative grown in West Africa. The mango is a large evergreen tree up to 15 to 20 m when grown from seed, but most vegetatively propagated clones are relatively small, compact trees, about 10 m tall. The tree grows in flashes often in different parts of the same tree, with the young leaves thin, flaccid and purple-coloured, turning to stiff, dark-green as they mature. The inflorescence is a terminal panicle bearing up to 5000 reddish, pink or white flowers. Two types of flowers occur in one inflorescence: hermaphrodite flowers which may comprise between 1 to 35 % of the total flowers produced, depending on the variety, and male flowers making up the rest of the inflorescence. Only about 30 % of the hermaphrodite flowers are ever fertilized; most of the fertilized flowers are also eventually shed so that only 0.1 to 0.3 % of the total hermaphrodite flowers on a tree grow into mature fruits. Yields fluctuate annually, abnormally high yields often preceding very low yields the following year. Low yields often attributed to low food reserves in the plants may also be due to flower shedding even when food reserves are adequate. Flower shedding is most abundant in wet, humid weather which occurs at the time the flowers open. Improved husbandry practices, especially application of inorganic fertilizers and manure, help build up food reserves and increase the proportion of fertilized flowers that are able to develop and mature into fruits. The

fruit is a drupe with variable shape and dimensions, but usually ovoid-oblong, round or flattened, green, yellow, or orange when ripe with some varieties being tinged with purple or red. Polyembryonic varieties have seeds which produce trees with the same characteristics as the parent. Monoembryonic tissues do not breed true from seeds and are propagated vegetatively. All the local varieties in Ghana are also from monoembryonic sources (Tweneboah, 2001).

2.7.3. Varieties

There are several varieties, strains and races of the mango, many of which have been imported into the West African sub-region by various sources. These may be grouped into the following distinct races:

- Indian group

The bark of the tree is relatively rough; fruits are often rounded, plump or flat; fruit colour dark-green turning to dark red, commonly yellow with crimson blush; fibre is usually present in the fruit; fruit tastes resinous or aromatic (rich in turpentine or kerosene flavour); acid sweet; seed is usually monoembryonic. The local varieties in West Africa are derived from this source.

- Indo-chinese Group

The bark of the tree is usually relatively smooth, fruits are always pointed in shape; usually longer than broad and flattened; fruit colour turning to golden yellow or greenish yellow; fruit has a tinge of pink if present at all; fruit fibre is usually absent; fruit taste bland, not rich, usually sub-acid; seed is usually polyembryonic.

A number of locally adapted varieties were imported from India, Ceylon and the West Indies. Improved varieties imported in recent times include *Pitter, Julie, Devine* and *Blackman* from Trinidad and *Jaffra* and *Rupee* from Ceylon. These clonal cultivars have been established at Asuansi and Ejura agricultural stations in Ghana and are best perpetrated by vegetative propagation. In Ghana the USAID also established a bud-wood garden at Somanya some years

ago with imported varieties such as *Palmer* and *Aphonse* from India and *Yellow Bombay* from West Indies. Varieties being promoted by the government of Ghana include: Haden, Irwin, Julie, Keitt, Kent, and Tommy Atkins (Tweneboah, 2001).

2.7.4. Uses and Food Value

Mango fruits form a very important dietary supplement in both urban and rural areas when they are in season. Mango fruits are one of the most important sources of vitamin A. They also have fairly high contents of vitamin C (ascorbic acid) and minerals (Tweneboah, 2001). The ripe mango fruits are eaten raw as dessert and are used in the manufacture of juice, squash, jams, jellies and preserves. The juice is usually canned. Unripe fruits are used in pickles, chutneys and culinary preparations. The leaves may be fed to livestock (Yayock *et al*., 1988).

2.8. Principles of Preservation and Processing

Although some treatments e.g., blanching, pasteurization and freezing, have primarily a stabilizing effect, other steps, namely, partial dehydration and osmodehyration, allow the properties of the material to be modified. Modification may include physical properties such as water content, water activity, and consistency, and chemical and sensory properties as well; the latter two are also associated with a change in composition. A partial dehydration step is useful to set the ingredients in the required moisture range, whereas a finer adjustment of water activity, consistency, sensory properties, and other functional properties is better achieved by an osmotic step i.e. temporary dipping in concentrated syrup (Torreggiani and Bertolo, 2001).

Food preservation techniques are applied to control the quality deterioration of foods. Deterioration may be initiated by microorganisms and/or by a variety of physicochemical reactions that take place after harvesting. The priority of preservation is to minimize the potential for the occurrence and growth of food spoilage and food poisoning microorganisms.

Food preservation techniques are aimed at exposing microorganisms to a hostile environment to prevent or delay their growth, shorten their survival or cause their deaths. Examples of such factors are acidity (i.e. lowered pH), limitation of water available for growth (i.e. reduction in water activity), presence of preservatives, high temperatures, and low temperatures, limitation of nutrients, ultraviolet radiation, and ionizing radiation. Microorganisms have evolved different mechanisms, called "homeostatic mechanisms", to resist the effects of these environmental stresses. These homeostatic mechanisms act to ensure that key physiological activities and parameters in the microorganisms remain relatively unchanged, even when the environment around the cell is different and greatly perturbed (Leitsner and Gould, 2002). To be effective, the preservation factors must overcome the microbial homeostatic resistance. This will involve a combination of preservation techniques which act in concert to achieve the aim of preservation through the hurdle technology. The different preparation steps to which fresh fruits are subjected in the production process for High Moisture Fruit Products (HMFP) and Intermediate Moisture Fruits products have a clear impact on the flora of fresh fruits, since some procedures remove or inactivate many of the microorganisms present, while others might have the opposite effect.

2.8.1. Washing, Sorting, Grading, Cutting, Slicing

Thus, while washing may remove many of the surface organisms, some operations like peeling, cutting and slicing may cause damage to the cells, exposing nutritious internal tissue fluids to external environments and providing new portals of entry of microorganisms and other contaminants (Tapia de Daza *et al*., 1995).

2.8.2. Blanching

Blanching which is the exposure of fruit pieces to high temperatures for a few minutes is a critical control operation in the processing of shelf-stable fruits. In traditional preservation

methods, the main function of this heat treatment is to destroy the enzymes (e.g. peroxidase and polyphenoloxidase) that could deteriorate vegetables and fruits by degrading flavour and colour and also cause vitamin loss during subsequent processing and storage (Arthey and Ashurst, 1996). Blanching in addition, acts to reduce the initial microbial load by inactivating heat sensitive micro-organisms (Wiley, 1997). The temperatures used are lethal for yeasts, most moulds, and aerobic micro- organisms. Alzamora *et al*. (1995) found that blanching reduces the microbial load from 60 % to 90 %. In addition the heat treatment has a sensitizing effect on the survivors; which would be less resistant to the stresses imposed by water activity and pH reduction and by the presence of sorbate and sulphite or other antimicrobials. Blanching can be performed in boiling or hot water or in saturated water vapour. The latter method is preferred since it allows retention of sensory and nutrients (mainly water soluble vitamins) (Vidales *et al*., 1998; Alzamora *et al*., 2000b).

2.8.3. Use of Humectants/Osmotic Dehydration

Osmotic preconcentration (dehydration) is the partial removal of water by direct contact of a product with a hypertonic medium, which is high concentration of sugar or salt solution for fruits and vegetables respectively. During osmotic processing, two major countercurrent flows take place simultaneously. Under the water and osmotic solute activity, gradients cross the product- medium interface and water flows from the solution into the product. A third transfer process, leaching of product solutes (sugars, acids, minerals and vitamins) into the solution, although recognized as affecting the organoleptic and nutritional characteristics of the product (Dixon and Jen, 1977), it is considered quantitatively negligible.

Increasing the concentration of dissolved compounds or solutes (humectants) decreases the water activity (a_w). The choice of humectants depend on factors such as: it's a_w lowering capacity, cost, solubility and the organoleptic characteristics of the final product (Argaiz *et al*.,

1995). Salt and sucrose solutions have been traditionally employed as humectants in the formulation of intermediate moisture foods. More recently new intermediate moisture foods use other solutes like glycerol, glucose and fructose corn syrups, sorbitol, dextrose, lactose, etc. (Jayaraman, 1995). For fruits the possibility of choice is mostly reduced to sugars as glucose, fructose and sucrose and polyols, as glycerol. A fruit juice concentrate can also be used as osmotic solution resulting in a softer product totally of fruit origin (Alzamora *et al*., 1995; Argaiz *et al*., 1995; Welti-Chanes *et al*., 2000).

The kind and concentration of humectant greatly affects the water and solute exchanges during osmosis and also the characteristic final product. Low molar mass saccharides (glucose, fructose sorbitol, etc) favour the sugar uptake due to the easy penetration of the molecules; thus, solid enrichment instead of dehydration is the main effect of the process. On the contrary, high molar mass solutes favour water loss instead of solid gain, resulting in a product with low solute content.

The barrier of water activity may change along product storage when sucrose is utilized as humectant. Sucrose hydrolysis occurs releasing the monosaccharide units: glucose and fructose (Montes de Oca *et al*., 1991). Sucrose decreases the a_w (and so increases the effect of the hurdle on microbial growth) of the preserved fruit because of the greater capacity of glucose and fructose to reduce a_w. Chirife *et al*. (1980) also observed that glucose and fructose have the same a_w lowering capacity.

2.8.4. Drying

The main purpose of drying is to preserve food by removing the water that is needed for microbial growth and enzyme activity. It also reduces the weight and bulk of foods for cheaper transport and storage. Dried foods sometimes have poorer nutritional and eating qualities than

the corresponding fresh foods. Due to this, the correct design and operation of dryers is needed to minimize the changes to food (Fellows, 1997). Sun drying is the oldest food preservation method in Ghana (Gyabaah-Yeboah, 1985). It is traditionally carried out in places where in the average year the climate allows food to be dried and stored without the risk of them becoming moist and spoiled. In this method, produce for drying are spread on roof tops, on concrete constructions, along side walks and in courtyards. This method of preservation has advantages such as:

- A lot of produce can be dried at a time
- Since the items are treated under natural conditions they may not be very different in appearance and flavour from the fresh items.

Despite its advantages, it suffers from inadequacies such as infestation by insects and even humans, contamination by dirt, and by rodent and bird droppings and rewetting (Bassey and Schmidt, 1986). In addition, if the products are not spread evenly or trimmed as uniformly as possible, drying may not be even. Browning of some fruits and vegetables may also occur when exposed to air (Gyabaah-Yeboah, 1985). Drying is slow and sometimes incomplete under unfavourable climatological conditions. Constant supervision of the dryer is necessary as the produce must be gathered and moved under cover in the event of rain and predators must be chased away (Minka,1986).

In Ghana, a major on-going project aimed at finding an alternative to traditional sun-drying has found solar drying as the alternative. The project is being carried out by Food Research Institute of the Centre for Scientific and Industrial Research of Ghana (Gyabaah-Yeboah, 1985).

2.8.4.1. Solar Drying

The solar dryer is based on the principle of absorption of heat from solar radiation by a black surface. The temperature inside a solar dryer can be maintained at 60° to 70°C, which minimizes

the damage to vitamins and other nutrients. Recent results obtained in the laboratory by using high-pressure liquid chromatography (HPLC) to separate the carotenoids show that carotene retention after solar drying is around 40 to 80 percent depending on the product, which is much higher than retention following traditional methods of drying (www.fao.org/DOCREP/W0078e00.htm).

Solar drying is known to have several advantages over direct sun drying:

- Food is enclosed in the dryer and therefore protected from dust, insects, birds and animals.
- The higher temperature, movement of air and lower humidity all increase the rate of drying compared with sun drying.
- The higher temperatures deter insects and the faster drying rate reduces the risk of spoilage by microorganisms.
- The higher drying rate also gives a higher throughput of food and hence a smaller drying area is needed.
- The dryers are waterproof and so the food does not need to be moved when it rains.
- Dryers can be constructed from locally available materials, and these are relatively low in cost (Fellows, 1997).

2.8.4.2. Freeze Drying

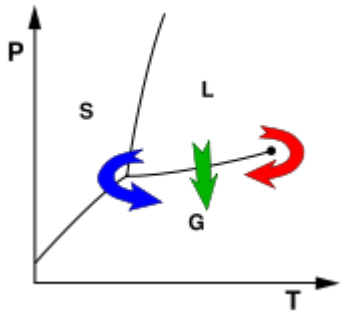

Figure 2: Phases in Freeze Drying

In a typical phase diagram, the boundary between gas and liquid runs from the triple point to the critical point. Freeze drying (blue arrow) brings the system around the triple point, avoiding the direct liquid-gas transition seen in ordinary drying (green arrow). Freeze drying (also known as lyophilization) is a dehydration process typically used to preserve a perishable material or make the material more convenient for transport. Freeze drying works by freezing the material and then reducing the surrounding pressure and adding enough heat to allow the frozen water in the material to sublime directly from the solid phase to gas.

The Freeze drying process

There are three stages in the complete freeze drying process: Pre-freezing, Primary Drying, and Secondary Drying.

Pre-Freezing

The freezing process consists of freezing the material. In a lab, this is often done by placing the material in a freeze drying flask and rotating the flask in a bath, called a shell freezer, which is cooled by mechanical refrigeration, dry ice and methanol, or liquid nitrogen. On a larger scale, freezing is usually done using a freeze drying machine. In this step, it is important to freeze the material at a temperature below the eutectic point of the material. Since the eutectic point occurs at the lowest temperature where the solid and liquid phase of the material can coexist, freezing the material at a temperature below this point ensures that sublimation rather than melting will occur in the following steps. Larger crystals are easier to freeze dry. To produce larger crystals the product should be frozen slowly or can be cycled up and down in temperature. This cycling process is called annealing.

Amorphous (glassy) materials do not have a eutectic point, but do have a critical temperature, below which the product must be maintained to prevent melt-back or collapse during primary and secondary drying.

Primary Drying

During the primary drying phase the pressure is lowered and enough heat is supplied to the material for the water to sublimate. The amount of heat necessary can be calculated using the sublimating molecules' latent heat of sublimation. In this initial drying phase about 98 % of the water in the material is sublimated. This phase may be slow, because if too much heat is added the material's structure could be altered.

In this phase, pressure is controlled through the application of partial vacuum. The vacuum speeds sublimation making it useful as a deliberate drying process. Furthermore, a cold condenser chamber and/or condenser plates provide a surface(s) for the water vapour to re-solidify on. This condenser plays no role in keeping the material frozen; rather, it prevents water vapor from reaching the vacuum pump, which could degrade the pump's performance. Condenser temperatures are typically below -50 °C.

Secondary Drying

The secondary drying phase aims to sublimate the water molecules that are adsorbed during the freezing process, since the mobile water molecules were sublimated in the primary drying phase. This part of the freeze drying process is governed by the material's adsorption isotherms. In this phase, the temperature is raised even higher than in the primary drying phase to break any physico-chemical interactions that have formed between the water molecules and the frozen material. Usually the pressure is also lowered in this stage to encourage sublimation. However,

there are products that benefit from increased pressure as well. After the freeze drying process is complete, the vacuum is usually broken with an inert gas, such as nitrogen, before the material is sealed.

Properties of Freeze dried Products

a. If a freeze dried substance is sealed to prevent the reabsorption of moisture, the substance may be stored at room temperature without refrigeration, and be protected against spoilage for many years. Preservation is possible because the greatly reduced water content inhibits the action of microorganisms and enzymes that would normally spoil or degrade the substance.
b. Freeze drying also causes less damage to the substance than other dehydration methods using higher temperatures. Freeze drying does not usually cause shrinkage or toughening of the material being dried. In addition, flavours and smells generally remain unchanged making the process popular for preserving food. Unfortunately, water is not the only chemical capable of sublimation and the loss of other volatile compounds such as acetic acid (vinegar) and alcohols can yield undesirable results.
c. Freeze dried products can be rehydrated (reconstituted) much more quickly and easily because it leaves microscopic pores. The pores are created by the ice crystals that sublimate, leaving gaps or pores in its place. This is especially important when it comes to pharmaceutical uses. Lyophilization can also be used to increase the shelf life of some pharmaceuticals for many years.
d. Freeze drying allows the preparation of a stable product that is easy to use and aesthetic in appearance.

e. The cost of the specialized equipment required for freeze drying can be substantial thus; the process may appear to be an expensive undertaking. However, savings realized by stabilizing an otherwise unstable product at ambient temperatures, thus eliminating the need for refrigeration, more than compensate for the investment in freeze drying equipment (Baker *et al*., 1994).

Uses of Freeze drying

Freeze drying is used in many different industries, sometimes for different reasons.

Pharmaceutical and Bio-Tech

Pharmaceutical companies often use freeze drying to increase the shelf life of products, such as vaccines and other injectables. By removing the water from the material and sealing the material in a vial, the material can be easily stored, shipped and later reconstituted to its original form for injection.

Food Industry

Figure 3: A package of Freeze dried ice cream, sold as a novelty item

The process has been popularized in the forms of freeze dried ice cream; an example of astronaut food. It is also popular and convenient for hikers because the reduced weight allows

them to carry more food and reconstitute it with available water. Instant coffee is sometimes freeze dried, despite high costs of freeze dryers. The coffee is often dried by vaporization in a hot air flow, or by projection on hot metallic plates. Currently, the freeze drying process is used more commonly in the pharmaceutical industry.

Technological Industry

In chemical synthesis, products are often lyophilized to make them more stable, or easier to dissolve in water for subsequent use. In bioseparations, freeze drying can also be used as a late-stage purification procedure, because it can effectively remove solvents. Furthermore, it is capable of concentrating molecules with low molecular weights that are too small to be filtered out by a filtration membrane. Freeze drying is a relatively expensive process. The equipment is about three times as expensive as the equipment used for other separation processes, and the high energy demands lead to high energy costs. Furthermore, freeze drying also has a long process time, because the addition of too much heat to the material can cause melting or structural deformations. Therefore, freeze drying is often reserved for materials that are heat-sensitive, such as proteins, enzymes, microorganisms, and blood plasma. The low operating temperature of the process leads to minimal damage of these heat-sensitive products.

Other Uses

Recently, some taxidermists have begun using freeze drying to preserve animals. Organizations, such as the Document Conservation Laboratory at the United States National Archives and Records Administration (NARA), have done studies on freeze drying as a recovery method of water-damaged books and documents. While recovery is possible, restoration quality depends on the material of the documents. If a document is made of a variety of materials, which have different absorption properties, expansion will occur at a non-uniform rate which could lead to

physical deformations. Water can also cause mold to grow and prompt image media to become soluble causing bleeding. In these cases, freeze drying may not be an effective restoration method. In high altitude environments, the low temperatures and pressures can sometimes produce natural mummies by a process of freeze drying.

Freeze drying Equipment

There are essentially three categories of freeze dryers: rotary evaporators, manifold freeze dryers, and tray freeze dryers.

- Rotary freeze dryers are usually used with liquid products, such as pharmaceutical solutions and tissue extracts.
- Manifold freeze dryers are usually used when drying a large amount of small containers and the product will be used in a short period of time. A manifold dryer will dry the product to less than 5 % moisture content. Without heat only primary drying (removal of the unbound water) can be achieved. A heater needs to be added for secondary drying, which will remove the bound water and will produce lower moisture content.
- Tray freeze dryers are more sophisticated and are used to dry a variety of materials. A tray freeze dryer is used to produce the driest product for long term storage. A tray freeze dryer allows the product to be frozen in place and performs both primary (unbound water removal) and secondary (bound water removal) freeze drying, thus producing the driest possible end-product. Tray freeze dryers can dry product in bulk or in vials. When drying in vials, the freeze dryer is supplied with a stoppering mechanism that allows a stopper to be pressed into place sealing the vial before it is exposed to the atmosphere. This is used for long term storage, such as vaccines (Labconco Corporation, 1998).

2.9. Product Development

A new product may be defined in various ways such as:

a) An already existing product that has been replaced and given a new name and image.

b) An improve version of an old product that may have new packaging and/or brand name.

c) A completely new product that serves an unmet need of the consumer.

Steps involved in developing a product include: 1) idea stage, 2) development stage, 3) taste-panelling stage 4) consumer sampling stage 5) shelf life studies stage 6) packaging stage 7) production stage 8) market testing stage, and 9) commercialization (Baker *et al*., 1994).

2.9.1. Idea Stage

This is the first and most important stage in developing a product. It involves coming out with product(s) the consumer will purchase and continue to purchase. Communication is the key word in the generation of new product ideas. The ideas mostly arise from two main sources: 1) communications with the consumer, and 2) communications within a company (Baker *et al*., 1994).

2.9.2. Development Stage

This stage must coincide with the taste-panelling or sensory evaluation stage. As changes are made during the development stage, the product must be checked by experienced tasters. Satisfying the taste panel accomplishes one hurdle, but proper shelf life must also be achieved (Baker *et al*., 1994).

2.9.3. Taste-Panelling Stage

Ideally, in developing new products, there should be two taste panels. One is a semi-trained or experienced panel for checking the acceptability of the product in various stages of development. This panel must have enough experience to distinguish good from undesirable

flavour, proper texture, degree of tenderness, and degree of juiciness. The second panel is a small group of consumers who can help the developers produce products that will be popular with the consuming public (Baker *et al*., 1994).

2.9.4. Consumer Sampling Stage

Valuable information can be obtained at a relatively low cost by checking with a small population to know their opinion of the product. Such sampling gives an indication of the product's potential success (Baker *et al*., 1994).

2.9.5. Shelf Life Stage

To determine shelf life, it is important to run total plate counts of microbes that cause spoilage. One must also know if the problem is with bacteria, yeasts or moulds because this will vary with different food products. It is also essential to understand the potential of pathogens in the food product. Pathogens of concern in most food products are: *Salmonella*, *Staphylococcus aureus*, *Clostridium perfringens,* and *Clostridium botulinum*. The relationship between rancidity and the shelf life of a product must also be considered (Baker *et al*., 1994).

2.9.6. Packaging Stage

Good packaging is extremely important in product development. Consumers now demand attractive and convenient packages for food products and are willing to pay the price. In addition to attractiveness and convenience, many other attributes of packaging are of importance. These include: protecting the food, not imparting flavour, resistance to tearing, ease of application, lightness of weight, not reacting chemically with the food, and being economical (Baker *et al*., 1994).

2.9.7. Production Stage

Some of the factors to consider when establishing a production line include: cost of equipment, cost of energy to operate, yield, safety, saving labour, sanitation, ease of cleaning and adherence to government regulations. The ideal is to produce the best product possible at the lowest possible cost (Baker *et al*., 1994).

2.9.8. Market-Testing Stage

It is normally done by the larger food companies because they want to reduce risk of having an expensive failure with the national introduction. Market testing is done to obtain more accurate information on the product's sale potential. It is important to select a site in which the population is made of many different ethnic groups with a broad spectrum of income (Baker *et al*., 1994).

2.9.9. Commercialization Stage

This is the final stage in determining the success or the failure of a product. Many excellent food products fail because the product did not receive proper introduction into the marketplace. A company may decide to use the institutional market or to go retail or both. Within the institutional market there are many choices including restaurants of all sizes, hotels, hospitals, airline caterers and the fast-food trade. Retail outlets include privately owned stores in addition to small, medium and large chains. The many ways to advertise include: radio, television, newspapers, flyers and mailing samples to homes. In addition, many food companies offer incentives when they introduce a new retail product. These incentives might include introductory low price, coupons, money back if not satisfied and various gimmicks (Baker *et al*., 1994).

2.10. Optimal Pastry Characteristics

A high-quality pastry has a high-specific volume and is symmetrical (Penfield and Campbell, 1990b). The crumb of a high-quality pastry is moist, elastic, has a fine grain, cells of uniform size, and thin cell walls. Crusts should be thin and tender (Bennion, 1995c).

2.11. Functions of Pastry Ingredients

The main ingredients used in pastry formulations are flour, sugar, fat, eggs, liquid, and leavening agents. Flavouring ingredients such as salt, vanilla, spices, colouring agents, etc. are also used in small amounts. Each ingredient has its own function in pastries, and if slightly changed will alter final pastry quality. Therefore, a proper balance of ingredients needs to be obtained to produce consistent high-quality pastries (Penfield and Campbell, 1990b).

2.11.1. Flour

Pastry flour, chlorinated soft wheat flour, is used in pastries. Chlorinated cake flour improves the performance in high-ratio cakes. Chlorine breaks inter- and intramolecular hydrogen bonds and some peptide bonds in flour proteins, resulting in increased dispersibility. The percent of protein in flour determines gluten strength in baked products. Gluten proteins found in wheat flours give structure to baked goods. Soft wheat flours contain less than 10 % protein, while hard wheat flours have more than 10 % protein. Pastry flour usually has about 7.5 % protein, whereas all-purpose flour has about 10.5 % protein. Soft wheat flours are preferred in soft baked goods, such as cakes because soft baked goods require a small amount of gluten formation. All-purpose flour, however, can be substituted in cakes using one cup minus two tablespoons of all-purpose flour to replace one cup of cake flour. Since little gluten is developed in cakes, the gelatinization of starch is more important to a cake's structure. Flour contributes structure to pastries. If too little flour is used, the pastry structure is weak and may fall, and the texture is coarse. If too much flour is used, a compact, dry pastry is produced (Bennion, 1995c).

2.11.2. Sugar

Sugar adds sweetness to pastries. But more importantly, it affects texture, volume, moisture retention and colour. Pastry tenderness is increased because sugar delays the gelatinization of the starch and interferes with gluten development. Sugar increases pastry volume by decreasing the cohesive forces (resistance to the movement of cake batter during baking) and allowing the batter to move more freely (Bennion, 1995c). Sugar also increases moisture retention and keeping quality of pastries by absorbing water. Finally, sugar adds colour through Maillard browning. Alternative sweeteners such as high-fructose corn syrup can replace sugar in pastries. High-fructose corn syrups can reduce caloric content in pastries, and increase moisture retention and colour because they are sweeter, more hygroscopic and are reducing sugars. Excessive amounts of sugar produce a coarse, thick-celled, gummy pastry with a rough, sugary, and overly brown crust (Bennion, 1995c).

2.11.3. Fat

Fats contribute tenderness, air retention, flavour and a smooth, moist mouth feel in pastries. Like sugar, fat interferes with gluten development, weakening the pastry structure. It interferes with gluten development by inhibiting contact between water and flour proteins . Fineness and uniformity of grain is enhanced with fats of good creaming quality, compared to soft or liquid fats, unless methods of mixing are altered (Bennion, 1995c). Plastic fats aid in incorporating and retaining air in the form of small bubbles distributed throughout the batter. These bubbles serve as gas cell nuclei into which carbon dioxide and steam diffuse during baking (Penfield and Campbell, 1990b). Thus, the smaller the air cells, the larger the volume and finer the grain in the final pastry. The larger and fewer the air cells, the lower the volume and coarser the grain. Fats extend the shelf life of bakery products by coating starch granules, inhibiting the re- association

of starch molecules during retrogradation. The amount of fat in a product determines the tenderness and other properties of pastries (Kulp *et al*., 1991).

2.11.4. Eggs

Eggs contribute structure, emulsification, volume, texture, colour, flavour, and nutritive value. The easily coagulable proteins of egg contribute structure to pastries. Eggs that are gradually added to a creamed fat-sugar mixture aid in forming a stable emulsion, and retaining air, which will increase pastry volume. When the optimum amount of egg is added to a pastry mixture, fine cells and thin cell walls are produced. In contrast, the addition of too many eggs produces a tough, rubbery crumb (Bennion, 1995c).

2.11.5. Liquid

The liquid ingredient in pastries serves as a solvent for sugar, salt, and leavening agent. It disperses the fat and flour particles and hydrates the flour proteins and gelatinizes starch. Liquid also provides steam, which helps leaven the pastry (Bennion, 1995c). If milk is used in the pastry formulation, the carbonyl-amine reactants contribute to crust browning. Too little liquid may result in a cracked crust because of excessive batter viscosity. Too much liquid may result in a heavy pastry with low volume (Penfield and Campbell, 1990b).

The moisture content of a food is one indication of the stability and quality of foods (Pomeranz and Meloan, 1994). Moistness is a favourable sensory attribute in baked products because it is synonymous with a soft and tender product. However, too much moisture promotes microbial growth (Nonaka, 1997).

2.11.6. Leavening Agents

The three main leavening gases are air, steam, and carbon dioxide. Air is incorporated into cakes by beating eggs, creaming fat and sugar, or beating batters (Bennion, 1995c). Liquid ingredients in pastries provide steam, leavening the flour mixture. Carbon dioxide is produced by chemical

leavening agents such as baking soda and baking powder. Sodium bicarbonate (baking soda) releases carbon dioxide, in the presence of an acid when it is heated. Baking powder contains mixtures of dry acid or acid salts and baking soda. Double acting powder (SAS-phosphate baking powder) releases carbon dioxide at two different times during the baking process. First, carbon dioxide is released when the dry ingredients are moistened. The calcium phosphate acid reacts with baking soda at room temperature. Then, carbon dioxide is released again when heat is applied. This occurs because sodium aluminium sulphate (SAS) requires heat and moisture to complete its reaction with baking soda. If too much leavening is added the cell walls expand beyond their limit and result in a coarse, irregular crumb. The addition of too little leavening insufficiently expands the cell walls, resulting in a compact, low volume product (Bennion, 1995b).

2.12. Sensory Characteristics

2.12.1. Appearance

The appearance of food is very important because the consumer's purchasing decisions are largely based on the expected appearance of certain foods (Meilgaard *et al.*, 1991). Consequently, if the appearance of a food is not appealing or does not match the consumer's idea of what the food should look like, it may be rejected without being tasted (Bennion, 1995a). Appearance characteristics include: colour, size and shape, surface texture and clarity. Often, the sensory attribute deemed most critical in foods is colour. In bakery products, uniform golden brown crusts are desired (McWilliams, 1993a). Browning in rock buns occurs in the crust and crumb. Browning is most apparent in the crust of rock buns and pies. Browning, a result of Maillard reaction and some caramellization, occurs most rapidly when monosaccharides are contained in a pastry (McWilliams, 1993b).

2.12.2. Colour

Colour and discoloration of many foods are important quality attributes in marketing. Though they do not reflect nutrition or flavour, they are important as they relate to consumer preference based on appearance. Colour measurement is a critical objective parameter that can be used as quality index measurements of raw and processed foods in quality control documentation, for determination of food quality and for analyses of quality changes as a result of food processing and storage. The colour of the food material changes during processing, drying or dehydration due to the evaporation of water and certain enzymatic and non-enzymatic reactions. Enzymatic reactions include the formation of brown colour pigments called melanins due to oxidation of phenols present in fruits and vegetables when exposed to air, in the case of potatoes or pears. Non-enzymatic reactions are those caused due to Maillard reaction during heating and storage e.g., brown discoloration occurs in turkey during freezing. These colour changes (into brown) are desirable in case of meat and bakery products but are undesirable for fruits and vegetables. Therefore colour measurement is important for consumer acceptability (Giese, 2000).

Colour is the stimulus that results from the detection of light after it has interacted with an object. The light may be reflected, transmitted, absorbed, or refracted by an illuminated object. If all the radiated energy is reflected back then the object is opaque and appears white and similarly if all the energy is absorbed then it appears black. Therefore colour arises from the presence of light in greater intensities at some wavelength than others and is mainly determined by the reflected light (Lewicki and Duszczyk, 1998).

The colour appearance can change depending on amount of light, the light source, the observer's angle of view, size, and background differences. The visual colour results can be affected by all these factors and therefore instrumentation to measure colour provides a subjective and consistent method of colour quality (Giese, 2000).

2.12.2.1. CIE XYZ

CIE (Commission Internationale de l' Eclairage) in 1931 introduced CIE system for describing any colour, visible or invisible to human eye in three components X, Y and Z called tristimulus values. It offered the knowledge of spectral response of the human eyes, based on the statistic data collected by human observers i.e., based on human eye's perception. This system uses the concept that any colour in the system can be obtained by combining three primary colours: red, blue and green but found that it is not always possible. So, the CIE has redefined the model by introducing CIE L*, a*, b* notation (Perez-Magarino and Gonzalez-Sanjose, 2003).

2.12.2.2. CIE L*, a*, b*

Colour representation by the L*, a*, b* notation was recommended by the CIE (Commission Internationale de l' Eclairage) in 1976. The calculation of L*, a*, b* for each colour is based on CIE XYZ values. They are commonly used in food industry (Perez-Magarino *et al*., 2003).

L* is the degree of lightness of the colour. This refers to the relation between reflected and absorbed light. L* values equals to zero for black and 100 for white, a* (red-green) is the degree of redness (0 to 60) or greenness (0 to -60) and b *(yellow-blue) is the degree of yellowness (0 to 60) or blueness (0 to -60) (Perez-Magarino *et al*., 2003).

2.12.2.3. Hue

Hue is the aspect of the colour described in words such as green, blue, yellow, or red. This perception of colour results from differences in absorption of radiant energy at various wavelengths. For example if shorter wavelengths of 400-500 nm are reflected to a greater extent than other wavelengths then the colour is described as blue. A darkness factor b*/a* was used to quantify possible discoloration. The hue angle, H*, was obtained as: $H^* = \tan^{-1} (b^*/a^*)$.

An angle of 90 represented a yellow hue (when b* is yellowness measured). It is expressed in degrees: 0 (red), 90 (yellow), 180 (green) and 270 (blue). Objects with higher hue angles are greener while lower angles are more orange-red. Hue and chroma are the qualities or attributes of any colour. Colour can be measured using a colorimeter or a spectrophotometer. In case of colorimeters "tristimulus filter is designed to reproduce the psycho-physical sensation of the human eye's view of colour" (Giese, 2000). For this purpose glass filters with standard observer angle are used. The light reflected from an object is measured using a photo cell and meter in terms of X, Y, and Z values. Colorimeters can be used for quick quality check during processing. Spectrophotometers measure a ratio of light reflected or transmitted from a food product to that from a known reference standard. These are more accurate and expensive than the colorimeters (Perez-Magarino *et al*., 2003).

2.12.3. Taste

Taste is the most important factor consumers consider when shopping for food. Since fats act as flavour carriers, the perception of taste is enhanced. Taste sensations are produced when salty, sweet, sour or bitter substances dissolved in solution are detected by the taste buds (Bruhn *et al*., 1992).

2.13. Texture

Texture is one of the most important parameters connected to product quality. It is defined as the sensory manifestation of the structure of a food and the manner in which that structure reacts to the applied force. Texture analysis involves measuring the properties related to how a food feels in our mouth. Characterization of food texture falls into sensory and instrumental method of analysis. A sensory analysis includes use of the senses of smell, taste, sound and touch. Sometimes it is preferable to use instrumental methods for assessing food texture rather than sensory analysis as they can be carried out under more strictly defined and controlled conditions.

Moreover the sensory analysis is costly and time consuming. Instrumental methods can save time, reduce costs, and provide more consistent, objective results (Meullenet *et al*., 1997).

2.13.1. Instrumental Techniques

Instrumental techniques of studying the textural behaviour of foodstuffs can be classified into three groups:

- Fundamental tests- a simple force versus time curve resulting from compression of food products

- Empirical tests- a flow meter to measure viscosity of a product

- Imitative tests - texture profile analysis

Instrumental texture measurements that relate to human perception are both imitative and empirical in nature. Imitative tests (imitate biting and chewing) involve instrument simulation of conditions under which sensory properties of the sample are assessed by humans. Thus, the imitative tests should have the most consistent correlation with sensory evaluation (Szczesniak, 1963). These tests generate several instrumental parameters e.g., hardness, springiness, chewiness etc., unlike empirical, which generates only one. In the case of empirical tests special instrument is designed to measure a particular parameter e.g., to measure springiness for gels (Yongsawatdigul, 1995).

The breakthrough in food texture evaluation came with the development of the General Food Texturometer designed to simulate the mastication action of the human mouth. The General Texturometer generated a force as a function of time curve, which is known as texture profile. Instrumental Texture Profile Analysis first developed for the General Food Texturometer in 1963 is an example of an imitative test (Yongsawatdigul, 1995).

2.14. Texture Profile Analysis

Texture Profile Analysis (TPA) is an imitative test designed to subject food to severe crushing and breaking similar to that which occurs during chewing. The method is based on a system of classification and definition of different textural characteristics (or attributes). suggested that textural characteristics be classified into three main groups:

- Geometrical attributes;
- Attributes related to moisture and fat content;
- Mechanical attributes (Szczesniak, 1963).

2.14.1. Geometrical Characteristics

These characteristics fall into two categories: those related to particle size and shape such as gritty, grainy, or coarse, and those related to shape and orientation such as fibrous, cellular, or crystalline (Szczesniak, 1963).

2.14.2. Characteristics Related to Moisture and Fat

Moisture content and fat content are the primary parameters and oiliness and greasiness are the secondary parameters that determine texture. These parameters usually show the degree of moistness or dryness, oiliness or greasiness of a product (Szczesniak, 1963).

2.14.3. Mechanical Characteristics

The mechanical characteristics are most important in determining the manner in which the food behaves during mastication in the mouth. These characteristics are a result of the reaction of food to applied stress. The mechanical characteristics are divided into five primary parameters and three secondary properties. The first four primary parameters in the table below are related to forces of attraction between particles of food that oppose disintegration, and the adhesiveness is that related to surface properties. The secondary properties are composed of two or more of the primary parameters (Szczesniak, 1963).

Table 3- Mechanical Texture Parameters

Primary Parameter	Secondary characteristics	Defined Terms	Examples
Hardness		Soft, firm, hard	Hard candy
Cohesiveness	Brittleness	Crumbly, crunchy, brittle	Raisins
	Chewiness	Tender, chewy	Caramel
	Gumminess	Short, mealy, pastry, gummy	Hot dog
Viscosity		Thin, viscous	
Springiness		Plastic, elastic	Marshmallows
Adhesiveness		Sticky, tacky, gooey	Peanut butter

2.14.4. Definitions of Mechanical Characteristics

2.14.4.1. Primary Properties

Hardness: Hardness is the force required to compress a substance between the molar teeth or between the tongue and the palate. Measured as force necessary to attain a given deformation e.g., hard candy (Szczesniak, 1963).

Cohesiveness: The degree to which a substance is compressed between the teeth before it breaks. Measured as the extent to which a material can be deformed before it ruptures e.g., Raisins.

Viscosity: Rate of flow per unit force e.g. liquids.

Springiness: Degree to which a product returns to its original shape once it has been compressed. Measured as the rate at which a deformed material goes back to its undeformed condition after the deforming force is removed e.g., marshmallows, gel.

Adhesiveness: Work necessary to overcome the attractive forces between the surface of the food and the surface of the other materials with which the food comes in contact e.g. peanut butter (Szczesniak, 1963).

2.14.4.2. Secondary Properties

Fracturability: Force with which a material fractures: a product of high degree of hardness and low degree of cohesiveness e.g., cracker.

Chewiness: Length of time required to chew a sample to a consistency suitable for swallowing. A product of hardness, cohesiveness, and springiness e.g., caramel

Gumminess: Energy required to disintegrate a semi-solid food to a state ready for swallowing: a product of a low degree of hardness and a high degree of cohesiveness e.g. hot dog (Szczesniak, 1963)

Textural properties are usually related to mechanical tests that examine the viscoelastic behaviour of the material. Agricultural products that exhibit characteristics of both solid and liquid are referred to as viscoelastic (Szczesniak, 1963). Mechanical properties such as hardness, springiness, fracturability are those having to do with the behaviour of the material under applied forces.

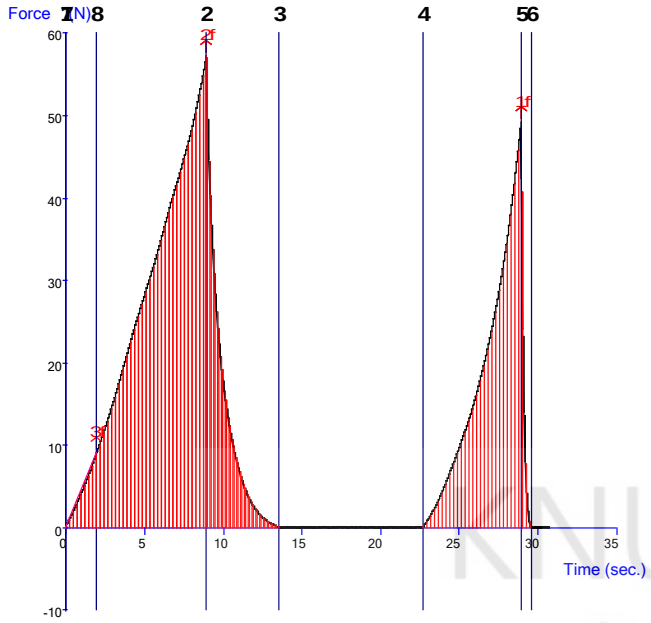

Figure 4: A Typical Force versus Time Texture Profile Analysis Curve

A compression test is one of the most common techniques for the estimation of textural properties. The viscoelastic behaviour can be determined by compression tests. The simplest approach is to measure the maximum applied force or stress at the fracture of the material. These tests are performed by applying a constant deformation rate while recording force and deformation. The compression test is continued until the specimen fractures. The quantification of the complex terms such as hardness and chewiness has been made possible by a methodology called Texture Profile Analysis (Szczesniak, 1963).

3. MATERIALS AND METHODS

3.1. Source

Pawpaw (*Carica papaya*) (Solo variety with red pulp) and mango (*Mangifera indica*) fruits (Kent variety) used in this study were obtained from Horticulture Department, KNUST, Kumasi in the Ashanti Region and the Mission farms at Somanya in the Eastern Region respectively.

3.2. Experimental Design and Statistical Analysis

The fixed treatments design was used to study the effect of fat replacement on the sensory and rheological properties of rock buns and fruit pies. Data obtained was analysed using the one-way Analysis of Variance (ANOVA), Kruskal-Wallis tests and Multiple Range Tests (i.e. Fisher's least significant difference test) employing the Microsoft Excel and the Statgraphics Softwares.

3.3. Preparation of Dried Fruits

Principle

Preservation relies on the removal of moisture by soaking in sugar syrup and by drying. An acid dip was used to reduce the number of contaminating microorganisms.

Procedure

Mango fruits were harvested at the correct stage of maturity (at the stage when the fruits were just firm enough but not over ripe) and left to ripen. Clean running water was then used to wash the ripe fruits to remove stones, leaves, or soils. The fruits were then sorted by hand for colour and maturity. Afterwards, the fruits were peeled by hand using a stainless steel knife. Cutting, slicing and coring of the fruits were done and the size of the fruits were reduced to strips of 1.5 cm thickness. This was also done by hand using a stainless steel knife. To reduce browning during drying, the sliced fruits were dipped in lemon juice for 10 minutes. The sliced pieces were then boiled in 60 per cent sugar solution for 10 minutes and then soaked in the sugar solution for 10 hours. The fruits were then dried in a solar drier for four (4) days. Drying temperature and relative humidity were maintained daily at an average of 50 ºC and 30 respectively by regulating the vents of the solar drier. Temperature and relative humidity values were taken with the aid of a thermo-hygrometer. Dried fruits were then cooled under ambient conditions, packaged with polypropylene and stored in a cool (27.5 ºC), dry place away from sunlight. The flow diagram is shown in Figure 5.

Mango fruit
↓
Wash
↓
Sort/ Grade
↓
Peel
↓
Cut/ Slice/ Core
↓
Dip in Lemon Juice
↓
Soak Sliced Fruit Pieces in Sugar Solution

↓

Dry Mango Fruits in Solar Drier

↓

Package

↓

Store

Figure 5: Flow diagram for the preparation of dried mango fruits

3.4. Preparation of Mango Puree

Procedure

Mango fruits were harvested at the correct stage of maturity (at the stage when the fruits were just firm enough but not over ripe) and left to ripen. Clean running water was then used to wash the ripe fruits to remove stones, leaves, or soils. The fruits were then sorted by hand for colour and maturity. Afterwards, the fruits were peeled by hand using a stainless steel knife. Cutting, slicing and coring of the fruits were done and the size of the fruits were reduced to smaller strips. This was also done by hand using a stainless steel knife. The papaya strips were then pulped in an electronic blender for five (5) minutes into a fine, thick and smooth sauce called puree. The puree was then placed in a white cheese cloth and hanged for about an hour to allow the water to drain out. The puree was filled into a plastic container with a cover and refrigerated at 20 ºC. The flow diagram is shown in Figure 6.

Mango fruit

↓

Wash

↓

Sort/ Grade

↓

Peel

↓

Trim/ Deseed/ Slice

↓

Pulp Mangoes (using a blender)

↓

Concentration of Puree by the Gravity Concentration Method → Water

↓

Puree

↓

Package

↓

Store

Figure 6: Flow diagram for the preparation of mango puree

3.5. Preparation of Fat Replacer

Principle

Preservation is achieved by drying. Low moisture content prevents the growth of micro-organisms. When the product is carefully dried and packed in containers that offer protection from moisture, light, insects and rodents and stored in a cool, dry room, these products have a shelf life of many months.

Procedure

Pawpaw fruits with red pulp were harvested at the stage when they were green and had only a few streaks of yellow. Clean running water was then used to wash the ripe fruits to remove stones leaves, or soils. The fruits were then sorted by hand for colour and maturity. Afterwards, the fruits were peeled by hand using a stainless steel knife. Cutting, slicing and coring of the fruits were done and the size of the fruits were reduced to smaller strips to facilitate blending. This was also done by using a stainless steel knife. The mango strips were then pulped in an electronic blender for five (5) minutes into a fine, thick and smooth sauce. The pulp was then dried in a freeze drier into a smooth powder called the fat replacer. The fat replacer was then packaged with high density polyethylene and stored in a cool, dry place away from sunlight. The flow diagram is shown in Figure 7.

Fresh Pawpaw Fruit

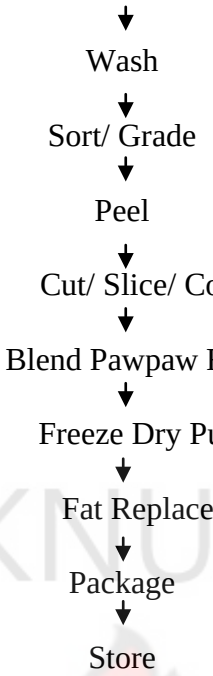

Figure 7: Flow diagram for the preparation of fat replacer

3.6. Preparation of Fruit Pie

A preheated oven was prepared and maintained at a temperature of 200 ºC. The baking tray was then greased. Flour and salt were then sieved (to obtain finer particles and to exclude adulterating materials) together into a bowl and the fat (shortening) was rubbed in and mixed with the other dry ingredients including baking powder, sugar and nut meg. Enough water (26.5 ml and 39.2 ml of water for FPO and FPT respectively) was measured and added from a measuring cylinder and mixed to a high viscous (stiff) paste. The paste was kneaded lightly until smooth. The kneaded paste was placed on a floured board, rolled out and divided into smaller sections. Dried mango fruits and puree were placed half way on the rolled out sections leaving 1 cm at the edges of the rolled out dough. After, the other half of the section was placed on the other and the edge sealed by pressing the edges (about 1 cm away from the edge) of the section with a fork. In the subsequent pies, their fat contents were reduced and replaced with some of the fat replacer as presented in Table 4.

Table 4- Formulated Composition for the Substitution of Fat Replacer in Fruit Pie Crust

Fruit Pie Code	Percentage Composition			
	Flour	Shortening	Fat Replacer	Sugar
FPO	56%	28%	0%	16%
FPT	56%	21%	7%	16%

3.7. Preparation of Rock Buns

A preheated oven was prepared and maintained at a temperature of 200 ºC. Flour, baking powder and salt were sieved (to obtain finer particles and to exclude adulterating materials) into a mixing bowl and the shortening was rubbed into the flour until the mixture looked like fine bread crumbs. Sugar was then stirred into the rubbed-in mixture and water mixed flavour was added from a measuring cylinder until a stiff, crumbly texture was formed. The amount of water added were 30 ml, 50 ml, 70 ml, 140 ml and 150 ml for RBO, RBT, RBF, RBS and RBH respectively. The mixture was then placed in rough heaps in grease-proof paper cake tins and arranged on a prepared baking sheet. The heaps were then baked in the pre-heated oven for 20 minutes and then cooled. Subsequently, rock buns prepared had some of their shortening substituted with fat replacer as shown in table 5.

Table 5- Formulated Composition for the Substitution of Fat Replacer in Rock Buns

Rock Buns Code	Percentage Composition			
	Flour	Shortening	Fat Replacer	Sugar
RBO	56%	28%	0%	16%
RBT	56%	21%	7%	16%
RBF	56%	14%	14%	16%
RBS	56%	7%	21%	16%
RBH	56%	0%	28%	16%

3.8. Quality Control Analytical Measurements and Proximate Analysis

Determination of proximate composition (moisture, mineral ash, crude protein, crude fibre and carbohydrates) and other physicochemical properties (pH, total soluble solids, specific gravity, titrable acidity, etc.) provide information on the basic chemical composition, nutritional, functional, physical and microbial properties of foods. All quality control analytical measurements on the samples were done in duplicates and blank determinations done where necessary. Sample calculations are shown in appendix 1.

3.8.1. Moisture Content Determination

Principle

A known weight of food sample was dried to constant weight in an oven and the loss of weight was equated to the moisture content of the food. The total solids content was however determined by subtracting the percentage moisture value from hundred (James, 1995).

Procedure

Two grams of sample was weighed and transferred to a previously washed, dried and weighed crucible. The crucible containing the sample was placed in a Gallenkamp oven (model XOV 880, Gallenkamp Co. Ltd., England) thermostatically controlled at 105 ºC for five hours. Soon after the stipulated duration of drying, the crucible was removed and placed in a dessicator to cool after which it was weighed. It was re-placed in the oven for further drying, cooled and reweighed. The entire process was repeated until a constant weight was obtained. Loss in weight was reported as moisture (Kirk and Sawyer, 1991; AOAC, 1990). Calculations are shown in Appendix 1. It was reported in percentage.

3.8.2. Total Ash Determination

Principle

The total mineral content of a food may be estimated as the ash content, which is the inorganic residue remaining after the organic matter has been burnt away (James, 1995).

Procedure

Two grams of dried fruit sample was weighed and transferred to previously washed, ignited, cooled and weighed porcelain crucible and placed in a Gallenkamp muffle furnace (model AS 260D, Gallenkamp Co. Ltd., England) (preheated to 600 ºC) for 2 hours until a white or light gray ash resulted. The porcelain crucible was removed after 2 hours and placed in a dessicator, permitting it to cool after which it was weighed and the ash content calculated, (Kirk and Sawyer, 1991; James, 1995). Calculations are shown in Appendix 1 and was reported as percentage ash.

3.8.3. Protein/ Total Nitrogen Determination

Principle

The Kjeldahl method determines the total nitrogen present as –NH- in the food, i.e. true protein N, amino N and amide N. This is then converted into protein by multiplying this percentage of nitrogen by an appropriate conversion factor 100/x, where x is the percentage of nitrogen in the food protein.

Procedure

Two grams (2.00 g) of sample was digested with 25 ml conc. H_2SO_4 in a Kjeldahl digestion flask in the presence of a catalyst (selenium) and antibumping agent until the mixture was clear. The clear digested sample was transferred to a 100 ml volumetric flask and made to the mark after cooling at room temperature. Distillation / condensation apparatus was set up. The distillation apparatus was flushed with distilled water. Twenty five millilitres of 2 % boric acid

was poured into a 250 ml conical flask with two drops of mixed indicator (4 ml of 0.l % methyl red solution + 20 ml of 0.1 % in 95 % alcohol bromocresol green solution) added to it and placed under the condenser with the tip of the condenser completely immersed in the boric acid solution. Ten milliliters of the digested sample solution and 20 ml of 40 % NaOH were transferred into the decomposition tube and well closed. Ammonia liberated during the distillation process was collected by the boric acid solution (for 5 minutes) turning it bluish green. The distillate was titrated with 0.1N HCl solution until the solution became colourless and then pink. The titre values obtained were used to calculate the nitrogen and hence the protein content (Kirk and Sawyer, 1991). Calculations are shown in Appendix 1 and are reported as percentage protein.

3.8.4. Crude Fat Determination (Soxhlet and Soxtec Method)

Principle

In the Soxhlet system of fat estimation, lipids are extracted out of the food by continuous extraction with petroleum ether. The Soxtec system is based on the use of a commercial instrument allowing a safer, more efficient extraction (James, 1995).

Procedure

Dried sample obtained from moisture determination was transferred into a 22 x 80 mm paper. A 250 ml round bottom flask was accurately weighed and then 150 ml of petroleum ether, BP 60-80 ^{o}C was poured into it (flask). The thimble was fixed on the flask and the quickfit condenser connected to the soxhlet extracter and refluxed for 16 hours on low heat application by the heating mantle. Flask was removed and evaporated on a steam bath. The flask containing the extracted fat was subjected to drying in a Gallenkamp oven at 103 ^{o}C for 30 minutes, after

which it was cooled to room temperature in a dessicator and then accurately weighed for the computation of fat in the sample (AOAC, 2000) method 920.39. Calculations are shown in Appendix 1. It was reported in percentage.

3.8.5. Crude Fibre Determination

The food sample was treated with boiling dilute sulphuric acid, the residue was washed and then the sample was treated with boiling dilute sodium hydroxide. It was then washed and the residue was treated with alcohol and finally ether. The final residue, the crude fibre remaining after ignition (removal of organic matter/fibre) was then taken to represent the insoluble dietary fibre (James, 1995). Sample from crude fat determination was transferred to a 750 ml Erlenmeyer flask and 0.5 g of asbestos was added. Two hundred millilitres (200 ml) of 1.25 % boiling H_2SO_4 was added and the flask immediately set on a hot plate and connected to a condenser. At the end of 30 minutes of digestion, the flask was removed and its contents filtered immediately through a cheese cloth in a funnel and then washed with boiling water until washings were no longer acidic. The entire procedure was repeated but this time with 200 ml of 1.25 % boiling NaOH. After, the residue was transferred to a previously washed, dried and weighed Gooch crucible (using funnel with water from a wash bottle) and then washed with 15 ml of alcohol. The crucible together with its contents was subjected to drying for one hour at 100 ºC in an oven, cooled in a dessicator and then reweighed. The sample was then subjected to ignition in an electric furnace for 30 minutes, cooled and reweighed. The crude fibre content of the sample was then calculated and reported as percentage (Kirk and Sawyer, 1991). Calculations are shown in Appendix 1.

3.9. Pectin Determination

3.9.1. Sample Preparation

Twenty grams (20 g) of papaya fruit pulp was weighed and homogenized at low speed for 2 min. Five grams (5 g) of homogenized tissue was placed in a centrifuge tube and 30 ml ethanol (100 %) was added and centrifuged at 10 000 rpm for 10 min. The alcoholic supernatant was discarded. The precipitate was extracted with 30 ml ethanol (100 %). The supernatant was centrifuged and discarded. The residue was dried for 24 hrs in a conventional oven at 35 ºC, weighed and ground in mortar. This precipitate from the alcohol solution was alcohol-insoluble-solids (AIS)

3.9.2. Total Pectin

Five grams (5 g) of dried AIS was weighed into a beaker containing a magnetic stirring bar. Two millilitres (2 ml) of concentrated sulphuric acid (stock: 98 %) was added and a beaker was placed on a stir plate and stirred gently as 0.5 ml distilled water is added dropwise. Stirring of the 0.5 ml distilled water addition continued until the AIS is completely dissolved. The dissolved sample was filtered through glass wool into a 25 ml volumetric flask. The beaker was rinsed several times with distilled water into the flask and diluted to volume. The solution was filtered again through glass wool before use.

3.9.3. Determination of Pectin Content

One millilitre (1 ml) of extract was pipetted into a test tube and 6 ml sulphuric acid/tetraborate solution (0.0125 M sodium tetraborate in conc. sulphuric acid) was added with tube in an ice water bath and mixed carefully using vortex mixer at moderate speed with intermittent stopping to assure complete mixing. Duplicate samples for pectin measurement were prepared with a corresponding blank. Tubes were heated in a boiling water bath for 5 min and immediately placed in ice water to cool. 0.1 ml aliquot of 0.15 % m-hydroxydiphenyl was added to develop

colour. To the blank tube, 0.1 ml of 0.5 % sodium hydroxide was added. All samples and blanks were vortexed and allowed to stand for 15 min at room temperature. Following chromogen formation, the absorbances of samples were measured at 520 nm. Galacturonic acid was used as standard. A solution of 1 ml distilled water, 6 ml sulphuric acid/ tetraborate and 0.1 ml 0.5 % sodium hydroxide was used as reagent blank to zero the instrument (AOAC, 1990). Results were reported in g/100 mg pectin.

3.10. Total Dietary Fibre

Principle

One gram of the freeze dried pawpaw sample was weighed, cooked with heat-stable α-amylase at 100 ºC (to gelatinize, hydrolyse and depolymerise starch); incubated at 60 ºC with protease (to solubilise and depolymerise proteins) and amyloglucosidase (to hydrolyse starch fragments to glucose). Each sample was treated with four volumes of ethanol to precipitate soluble fibre and remove depolymerised protein and glucose (from starch). The residue was filtered; washed with 78 % ethanol, 95 % ethanol and acetone, dried and weighed. One duplicate was analysed for protein and the other incinerated at 525 ºC for ash determination. The total dietary fibre (TDF) was calculated as the weight of the filtered and dried residue less the weight of the protein and ash (AOAC, 1990).

Procedure

One gram of fat replacer was weighed into a 600 ml beaker in duplicate. Then 40 ml of MES-TRIS blend buffer solution (pH 8.2) was added to the sample and stirred until the sample was completely dispersed in solution. Fifty millilitres (50 µl) of heat stable α-amylase solution was added while being stirred at low speed. The beakers were covered with aluminium foil and placed in a shaking water bath at a temperature between 95-100 ºC and incubated for 35 min with continuous agitation. The samples were cooled to 60 ºC. Adhered samples on beakers were

scraped with a plastic spatula and the spatula and walls of the beakers rinsed with 10 ml distilled water. Hundred millilitres (100 µl) of protease solution was added to each sample, covered with aluminium foil and incubated in a water bath at 60±1 ºC for 30 min with continuous agitation. Samples were removed and 5 ml of 0.561 N HCl solution was added. The pH of the sample was adjusted to between 4.1 and 4.8 with either 5% NaOH solution. Amyloglucosidase (200 µl) was added to the sample in the beakers with stirring. The beakers were covered with aluminium foil, placed in a water bath and heated for 30 min at 60 ºC.

To each sample, 225 ml of 95% ethanol preheated to 60 ºC was added and the samples were covered with large sheets of aluminium foil. The samples were left at room temperature for 60 min to precipitate. The precipitated enzyme digested were filtered through already prepared and weighed fritted crucibles (fritted crucibles were ashed overnight at 525 ºC and impurities removed by suction using a vacuum. They were soaked in 2% cleaning solution for 1 hour, and rinsed with water and deionised water. For a final rinse, 15 ml acetone was used and air-dried. One gram (1.0 g) of celite acid washed was added to the crucibles and dried at 130 ºC overnight. Crucibles containing celite were cooled for 1 hour and weighed. The celite was wetted with 15 ml ethanol and suction was applied to draw celite unto the crucible as an even mat). With the use of a wash bottle, all remaining samples in the beakers were quantitatively transferred into the crucibles and the residues were washed successively with 15 ml 78% ethanol, 95% ethanol and acetone (twice). The crucibles containing residues were dried overnight in an oven at 103 ºC, cooled for one hour and weighed. One duplicate was analysed for protein and the other was incubated at 525 ºC to determine the ash content. Total dietary fibre was calculated and reported as percentage total dietary fibre as in Appendix 1.

3.11. Sensory Analysis

Panel: Trained staff of the Food Research Institute of the Centre for Scientific and Industrial Research, Accra, Ghana volunteered to partake in the sensory evaluation. Twenty (20) trained panellist were used in the descriptive analysis of the rock buns of which ten (10) men and ten (10) women participated. For the mango pie sample, sixteen (16) trained panellists including nine (9) women and seven (7) men participated in its evaluation. The ages of the panellists ranged from 24-45 years. The selection criteria were based on good health, availability, interest and no aversion (liking) for the products. Panellists (judges) were compensated for participation.

Term generation/Training: Panellists were trained during two 2- hour sessions with a panel leader. During each two hour session, panellists were reminded on the principles of sensory evaluation and descriptive analysis, three identical samples were served and descriptive terms generated through group discussions. Further discussions were held to achieve consensus on a preliminary set of terms and definitions. In the succeeding session, the three samples comprising a reference and two other samples were presented to the panellists along with terms. A preliminary questionnaire was used by the panellists to practice rating the intensity of attributes, using samples and reference materials. The reference samples for the rock buns and mango pie were rock buns without fat replacer and mango pie crust having no fat replacer respectively. These were used as anchor for use of the questionnaire. For each level of fat replacement mango pies containing dried fruits produced by Ebenut Foods and from dried fruit produced in this study were made. Since most panellists preferred mango pies made from dried fruits produced in this study, only mango pies made from these dried fruits were used in the actual sensory study. Panellists discussed and agreed on the numerical position of the reference sample on the rating scale for all attributes. Ten (10) and (8) attributes were used to describe the mango pie and the rock buns respectively.

Protocol: All judges used a numerical intensity scale (0= not to 100= very intense) to rate each attribute across the 5 and 2 samples respectively. Each sample was given a three (3) digit code and presented in white polystyrene plates. The order of presentation was randomised to reduce position effects. Samples were presented monadically to the panellists, and the order of presentation was randomised among judges and sessions. Rinse water presented in transparent cups and unsalted crackers presented in white polystyrene plates were presented to the panellists for cleansing of the palate between samples. All evaluations were conducted in isolated sensory booths illuminated with white incandescent lighting. Panellists were provided with questionnaires on which they marked vertical lines on the 100 point scale to show the intensity of their rating for each sample attribute. All statistical analyses were performed with the MS Excel and Statgraphics softwares. Individual ANOVAs were conducted on each attribute rated by panellists to determine the difference among treatments. Fisher's least significant difference (LSD) at $p \leq 0.05$ was used to compare sample means.

3.12. Colour Measurements

Surface colour of raw and baked rock buns and mango pie crust samples and internal colour of baked rock buns and mango pie crusts were measured using the CIE colour scale. The CIE colour scale measured the degree of lightness L* (black [0] to light [100]), a* (red [60] to green [- 60]), b* (yellow [60] to blue [-60]) using a chroma meter CR- 310 (Minolta Co. Ltd., Osaka, Japan). From the CIE a* and b* values, the chroma $(a^{*2} + b^{*2})^{1/2}$ and the hue angle $(\tan^{-1} b^*/a^*)$ were calculated. The chroma meter was standardised using a white (Y= 93.7, x= 0.3138 and y= 0.3194) standard plate. The surface colour of raw and baked rock buns and pie crusts were measured immediately after production. The internal colour of the baked samples was also measured immediately after cutting them horizontally. Three samples (3 rock buns and 3 pie crusts) were used per experimental unit.

3.13. Instrumental Texture Profile Analysis

For instrumental texture profile analysis (TPA), rock buns samples were moulded in small round aluminium cans. Each can was tared using an electronic balance before the pastry was placed in it. It was ensured that each weighed 15 g so that there will be uniformity in the size and shape of the samples. The top of each sample was then smoothened to ensure uniform rise in dough during baking. The baked samples were warmed to room temperature (27.5 ºC) prior to the test. TPA tests were performed using a TA. XT2 Texture Analyser (Stable Microsystems, Godalming, UK). Optimised test conditions were; probe, TA- 75mm; test speed, 1.0 mm/ sec; pre- test and post- test speed, 5.0 mm/s; compression, 50%; time pause, 2 sec; load cell, 25 kg. Data collection and calculations were done using the Microsoft Texture Expert and Microsoft Excel softwares. The parameters of the TPA were determined as described by Bourne (1978). Data reported were averages of 3 measurements for three replicates of each rock buns sample. For instrumental texture analysis (TA) on the pie crusts, the dough was rolled out to the same thickness and biscuit cutters were used to cut the dough into uniform size and shape, each having a thickness of 8 mm. Baked samples were cooled to room temperature (27.5 ºC) prior to the test. The TA. XT2 Texture analyser (Stable Microsystems, Godalming, UK) was used for the texture analysis. Optimised test conditions were; probe, TA- 2 mm; test speed, 1.0 mm/sec; pre-test and post-test speed, 5.0 mm/s; compression, 75 %; time pause, 2 sec; load cell, 25 kg. Data collection and calculations were done using the Microsoft Texture Expert and Microsoft Excel softwares. The parameters of the Texture Analysis were determined as described by Bourne (1978). Data reported are averages of 3 measurements for three replicates of each of each pie crust sample.

4. RESULTS AND DISCUSSIONS

4.1. Moisture and Fat contents of Rock Buns and Fruit Pie Crusts

The fat and moisture contents of the five formulated rock buns treatments are shown in Table 6. Results of analysis of variance is summarised in Appendix 2.

Table 6- Mean percent moisture and fat values of the five rock buns and pie crust treatments[1]

Parameter	**Treatments[2]**						
	RBO	RBT	RBF	RBS	RBH	FPO	FPT
Moisture Content	13.88^{e} (0.04)	23.68^{d} (0.04)	27.59^{c} (0.01)	31.12^{b} (0.04)	36.88^{a} (0.22)	2.77^{z} (0.05)	14.6^{y} (0.01)

(g/100 g)							
Fat Content (g/100 g)	23.71[a] (0.28)	15.78[b] (0.19)	10.81[c] (0.05)	5.76[d] (0.06)	0.76[e] (0.00)	30.81[y] (0.21)	20.37[z] (0.20)

[1]Numbers in rows followed by different letters are significantly different ($p \leq 0.05$).
Numbers in parentheses represent the standard deviation of the mean.
[2]RBO- full-fat control rock buns, RBT, RBF, RBS, RBH- reduced fat rock buns containing 25, 50, 75, 100% (w/w) added freeze dried blended pawpaw pulp respectively. FPO- full-fat control fruit pie crust, FPT- fruit pie with 25% (w/w) added freeze dried blended pawpaw pulp respectively.

4.1.1. Fat Content

Significant differences ($p \leq 0.05$) in fat content were observed between the five rock buns treatments and that of the two fruit pie crusts as a result of the varying proportions of fat that were used in the formulation of the various treatments. Treatment RBO recorded the highest fat content of 23.71 g/100 g, with RBH recording the lowest fat content of 0.76 g/100 g. With the reduced-fat treatments, decrease in their fat contents during dough formation resulted in corresponding decreases in the fat contents of the baked samples (Table 6). In the fruit pie crusts, FPO had the highest fat content with FPT recording the least fat content.

4.1.2. Moisture Content

Results showed significant differences ($p \leq 0.05$) in the moisture contents of the rock buns treatments. The mean moisture contents of the five rock buns treatments ranged between 36.88 g /100 g and 13.88 g/100 g with RBH and RBO having the highest and the lowest values respectively (Table 6). There was an increase in moisture content with increasing fat reduction. These results are consistent with the work of Conforti *et al*. (1996) on the effect of three different carbohydrate-based fat substitutes in baking powder biscuits. In their work, they reported that increased use of fat substitute produced a moister biscuit. The higher moisture content with increased use of fat substitute could be attributed to the fact that during the dough formation, dough with less fat required more water to achieve the desired consistency. Spies

(1990) reports that if fat level is high the lubrication functions in the dough is so pronounced that little water is required to achieve a desired consistency.

4.2. Effect of Fat Reduction on the Sensory Qualities of Rock Buns

The changes in sensory attributes of rock buns with fat reduction are shown in Table 7. Appendix 3 sums up results of analysis of variance and Kruskal-Wallis tests carried out to ascertain the effect of fat reduction on the sensory qualities of the five rock buns treatments.

Table 7- Mean values and standard deviations of sensory attributes[1]

Rock buns[2]	App[3]	Col	Aro	Tas	Mtf	Crb	Chw	Overall
RBO	83.65^{a} (9.92)	83.05^{a} (9.82)	85.95^{a} (8.54)	83.20^{a} (9.53)	53.45^{bc} (7.51)	86.10^{a} (9.81)	24.30^{a} (5.17)	86.15^{a} (10.25)
RBT	85.65^{a} (9.65)	83.90^{a} (6.56)	80.90^{a} (8.35)	83.85^{a} (8.82)	57.70^{b} (5.75)	66.25^{b} (9.42)	26.55^{a} (8.91)	86.30^{a} (9.62)
RBF	72.75^{b} (8.67)	80.35^{a} (8.99)	69.50^{b} (8.64)	75.40^{b} (9.90)	63.05^{a} (7.29)	47.25^{c} (9.52)	36.35^{b} (7.41)	71.20^{b} (9.30)
RBS	54.10^{c} (9.20)	50.40^{b} (9.32)	49.20^{c} (8.75)	60.95^{c} (9.52)	54.95^{bc} (8.26)	25.20^{d} (6.02)	43.20^{c} (4.43)	53.80^{c} (8.35)
RBH	43.55^{d} (7.49)	53.90^{b} (7.03)	38.65^{d} (7.01)	52.80^{d} (9.30)	51.35^{c} (7.90)	12.30^{e} (3.36)	54.50^{d} (6.22)	37.25^{d} (7.99)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$). Numbers in parentheses represent the standard deviation of the mean.

[2]RBO- full-fat control rock buns, RBT, RBF, RBS, RBH- reduced fat rock buns containing 25, 50, 75, 100% (w/w) added fat replacer respectively.
[3]App- appearance, col- colour, aro- aroma, tas- taste, mtf- mouth feel, crb- crumbliness, chw- chewiness, overall- overall acceptability.

4.2.1. Appearance

There was a general decrease in panellists' ratings for appearance with increasing fat reduction. Panellists' response for the rock buns treatments were in the order: RBT > RBO > RBF > RBS> RBH as shown in Figures 8 and 9. In general, significant differences ($p \leq 0.05$) existed between most of the samples (Table 7 and Appendix 3). There were no significant differences ($p > 0.05$) between treatments RBO and RBT. They were however found to be significantly different ($p \leq 0.05$) from RBF, RBS and RBH which were also significantly different ($p \leq 0.05$) from each other. The results show that RBT was most attractive and RBH was the least attractive. The uniform, golden brown crust of RBT made it more attractive to the panellists. A report by McWilliams (1993a) indicated that in pastries a uniform, golden brown crust is desirable. RBH on the contrary was dark and appeared shrunken. Sudha *et al*. (2006) reported the same observation in soft dough biscuits.

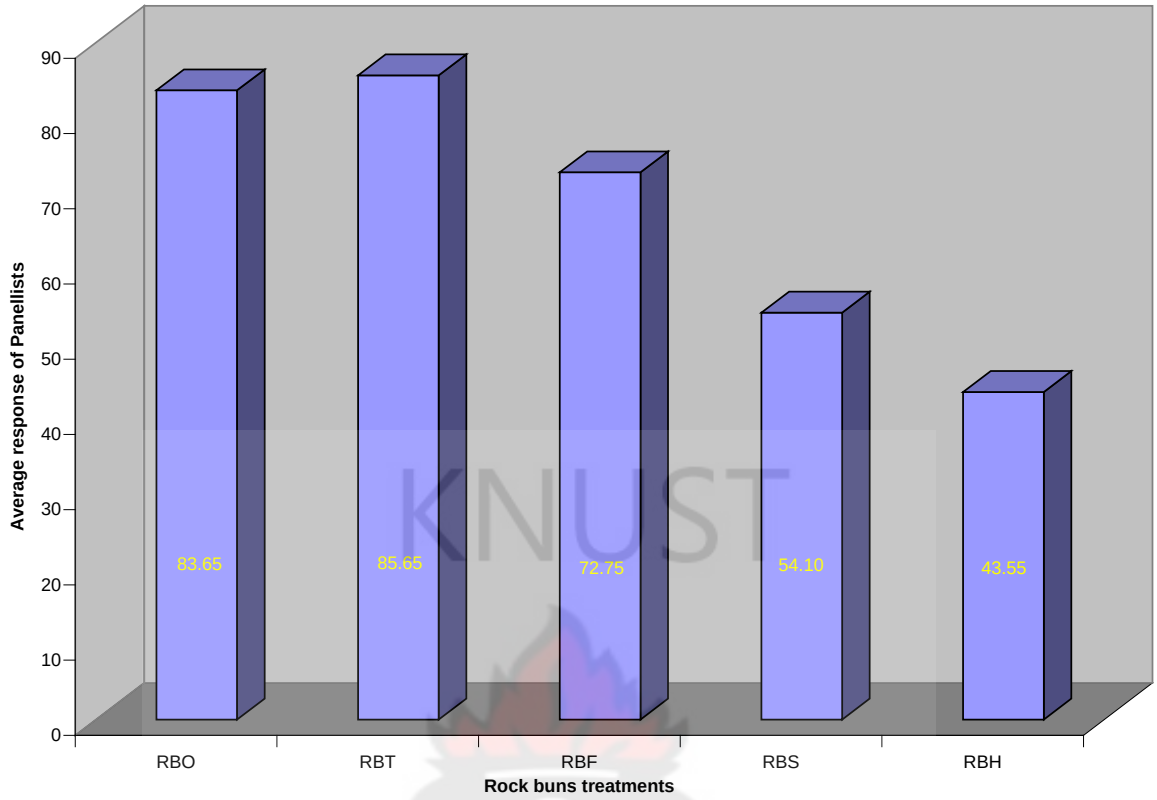

Figure 8: Average response of panellists to the appearance of rock buns treatments

Figure 9: Photographs showing the appearances of treatments RBT, RBO, RBF, RBS and RBH after baking

4.2.2. Colour

Results on the five rock buns treatments showed significant differences ($p \leq 0.05$) in colour among the treatments (Table 7 and Appendix 3). There were no significant differences ($p > 0.05$) in colour between RBO, RBT and RBF on one hand and RBS and RBH on the other hand. RBO, RBT and RBF were significantly different ($p \leq 0.05$) from RBS and RBH. Consumer preference for the colour of the treatments was in the order: RBT > RBO > RBF > RBH > RBS as shown in Figure 10. The higher consumer preference for the rock buns with higher fat content could be due to the fat imparting a pleasant uniform, golden brown colour to the pastry. McWilliams (1993a) has confirmed that in bakery products, uniform, golden brown crusts are desired. Browning could be as a result of Maillard reaction and some caramellization (McWilliams, 1993b). The lower consumer preference for RBS and RBH could be due to excessive Maillard reaction through a reaction between the simple sugars of the fat replacer and the flour proteins in the presence of heat. Schwenk and Guthrie (1997) have confirmed that fat mimetics may be subject to excessive browning under high heat. This could also have accounted for the lower consumer preference for RBS and RBH since they contained high amounts of the fat replacer.

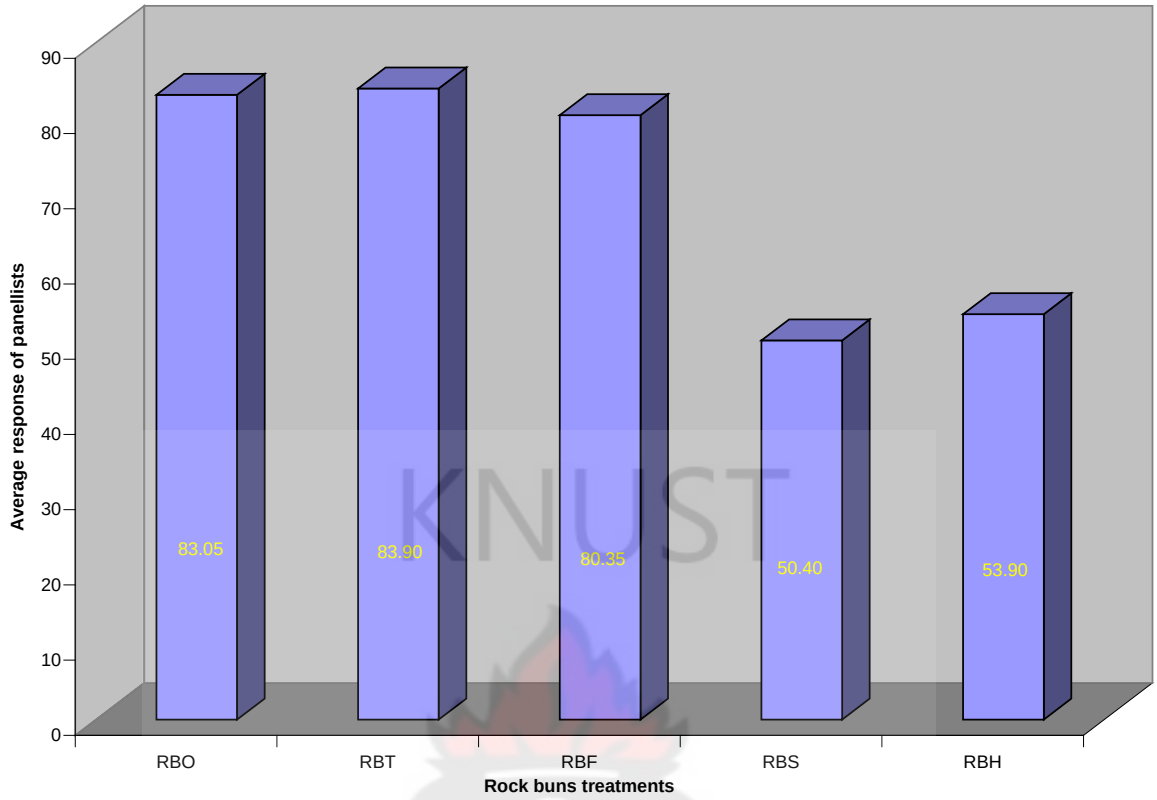

Figure 10: Average response of panellists to the colour of rock buns treatments

4.2.3. Taste

Significant differences ($p \leq 0.05$) were found in the tastes of the five rock buns treatments (Table 7 and Appendix 3). RBO and RBT were not significantly different ($p > 0.05$) in taste, however, they were both significantly different ($p \leq 0.05$) from RBF, RBS and RBH. RBT had a higher score than RBO. Some panellists commented that they preferred RBT to RBO because the fat replacer made from pawpaw imparted a fruity taste to treatment RBT which they liked very much. Also, the higher fat content of RBT compared to RBF, RBS and RBH might have masked the acidity imparted by the fruit to the rock buns treatments, because some panellists said treatments RBF, RBS and RBH were a bit acidic. This is concurrent with observations made by Sandrou and Arvanitoyannis (2000) that fat absorbs many flavour compounds and rounds the flavour by reducing the sharpness of acid ingredients. Panellists' response to taste followed the trend: RBT > RBO > RBF > RBS > RBH (Figure 11).

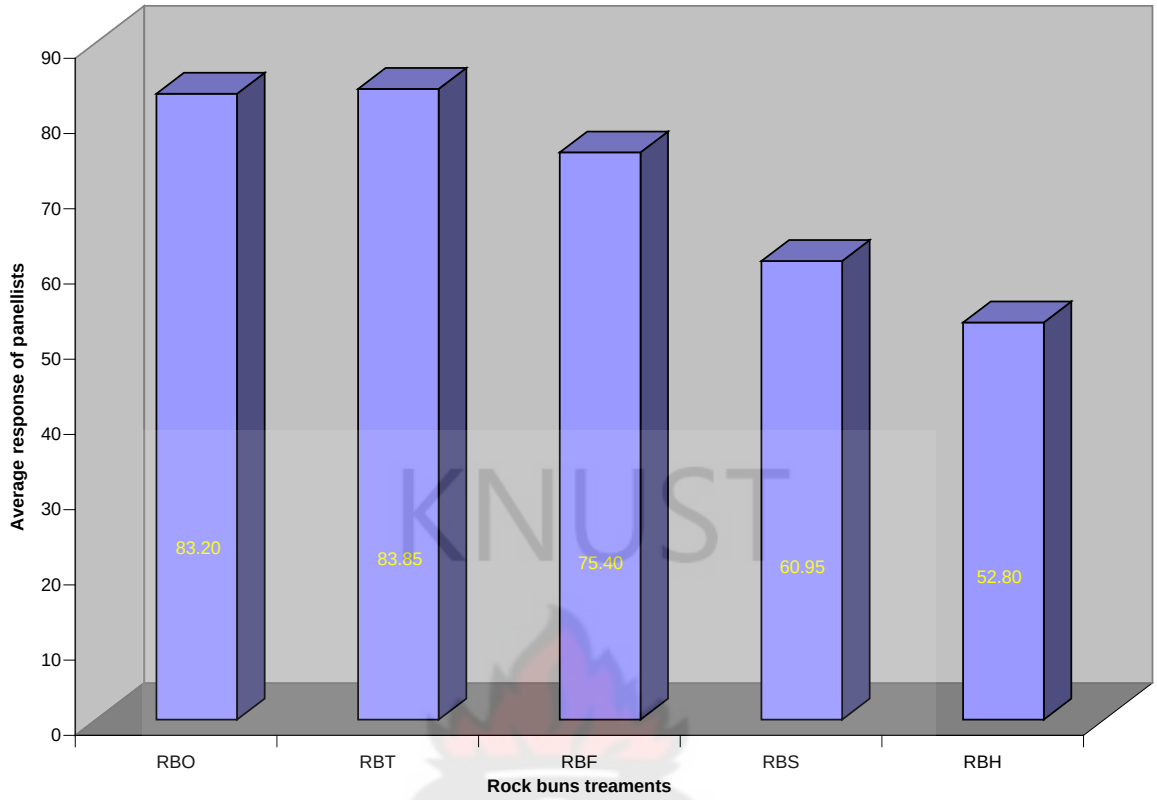

Figure 11: Average response of panellists to the taste of rock buns treatments

4.2.4. Aroma

With regards to aroma, significant differences ($p \leq 0.05$) were found between all or at least two of the treatments (Table 7 and Appendix 3). This occurred because the treatments contained varying proportions of fat and fat replacer. No significant differences ($p > 0.05$) were found between treatments RBO and RBT, nonetheless, they were significantly different ($p \leq 0.05$) from RBF, RBS and RBH. The latter treatments were also significantly different ($p \leq 0.05$) in aroma from each other. Panellists' preference for aroma was in the order: RBO > RBT > RBF > RBS > RBH (Figure 12).

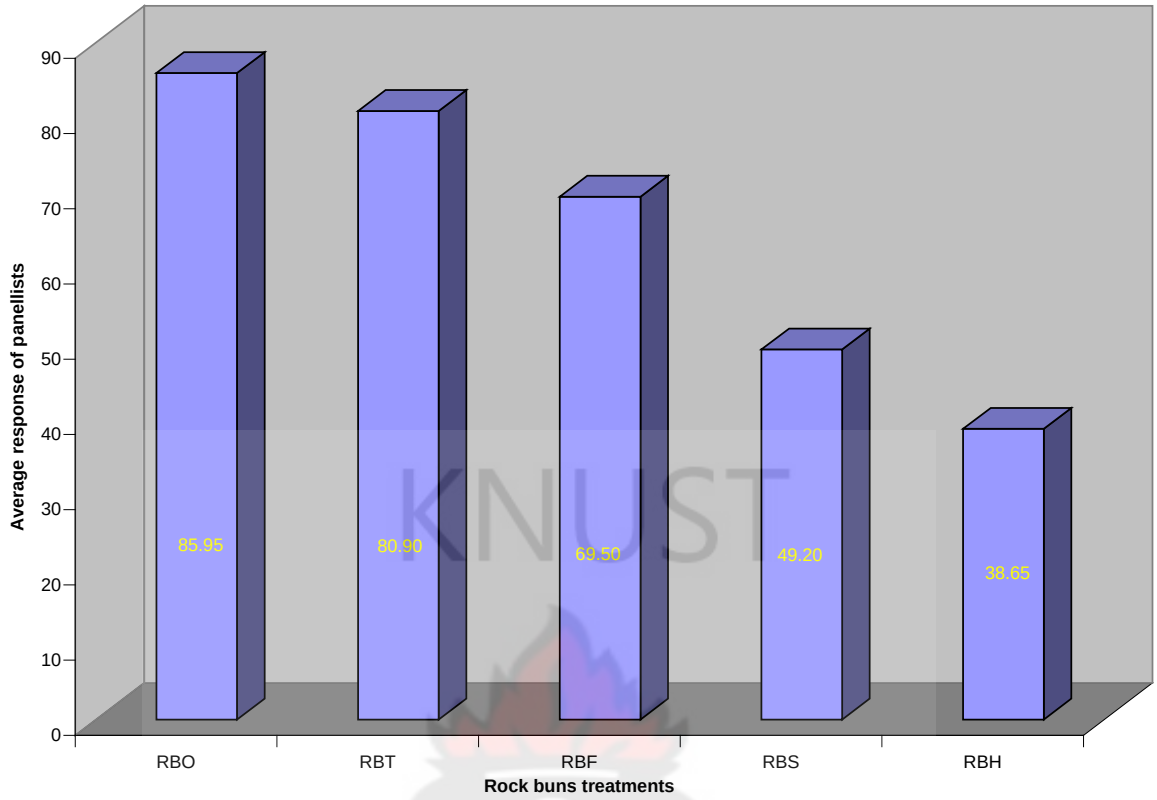

Figure 12: Average response of panellists to the aroma of rock buns treatments

4.2.5. Mouth Feel

Panellists' responses indicated that, RBF had the highest value for mouth feel followed by RBT, RBS, RBO and RBH respectively (Figure 13). Significant differences ($p \leq 0.05$) in mouth feel were observed among the rock buns treatments (Table 7 and Appendix 3). Treatment RBF was significantly different ($p \leq 0.05$) from all the other treatments. There were no significant differences ($p > 0.05$) in mouth feel between RBO, RBT and RBS. In addition, RBO, RBS and RBH were also not significantly different. The complexes of fibre and pectin in fat replacers provide texture and body (Michaelides and Cooper, 2004). This could have accounted for the higher mouth feel values for the reduced-fat rock buns treatments. Schwenk and Guthrie (1997) reported that fat mimetics provide mouth feel, lubricity and other functions of fat by holding water. This is evidenced by the higher water holding capacity of the reduced-fat rock buns treatments with increasing fat reduction. Giese (1996) and Stauffer (1998) have reported that fat

interact with other ingredients to develop and mould texture, mouth feel and overall sensation of lubricity of the product. The results confirm the reason why all reduced fat treatments had higher mouth feel values. It also accounts for the reason why the fat-free rock buns treatment (RBH) had a lower value for mouth feel since there was no fat to combine with other ingredients to provide mouth feel. Panellists perceived RBH as being gummy. Yackel and Cox (1992) reported that carbohydrate-based fat replacers form a gel-like matrix in the presence of substantial levels of water, resulting in lubricant and flow properties similar to fats. This phenomenon was more pronounced in RBH than in the other treatments thus accounting for its gummy nature.

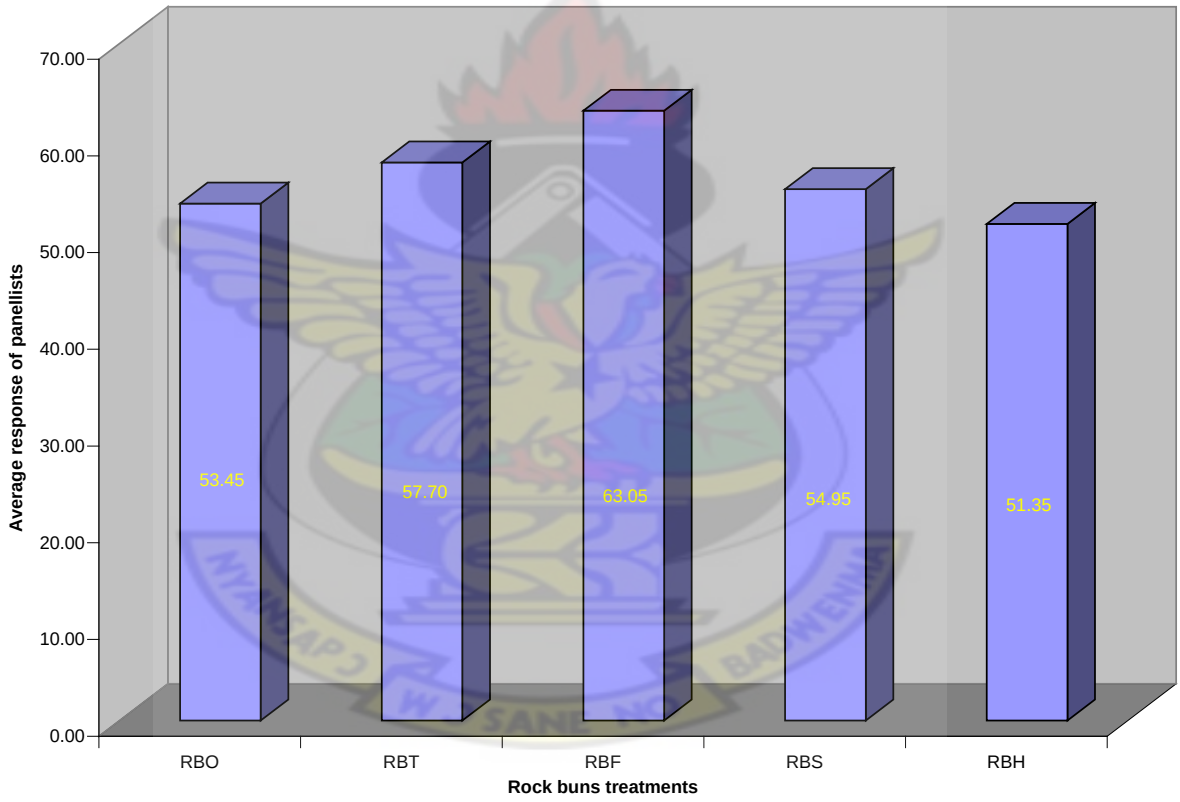

Figure 13: Average response of panellists to the mouth feel of rock buns treatments

4.2.6. Crumbliness

The pattern for crumbliness showed that varying proportions of fat replacer and fat have significant effects ($p \leq 0.05$) on the crumbliness of various rock buns treatments (Table 7 and Appendix 3). Panellists' preference was in the order: RBO > RBT > RBF > RBS > RBH (Figure

14). RBO treatment gave the crumbliest rock buns. RBH was the least crumbly of all the rock buns treatments. The reduction in crumbliness of the treatments with decreasing fat content implies that fats aid in tenderizing pastries (Penfield and Campbell, 1990a).

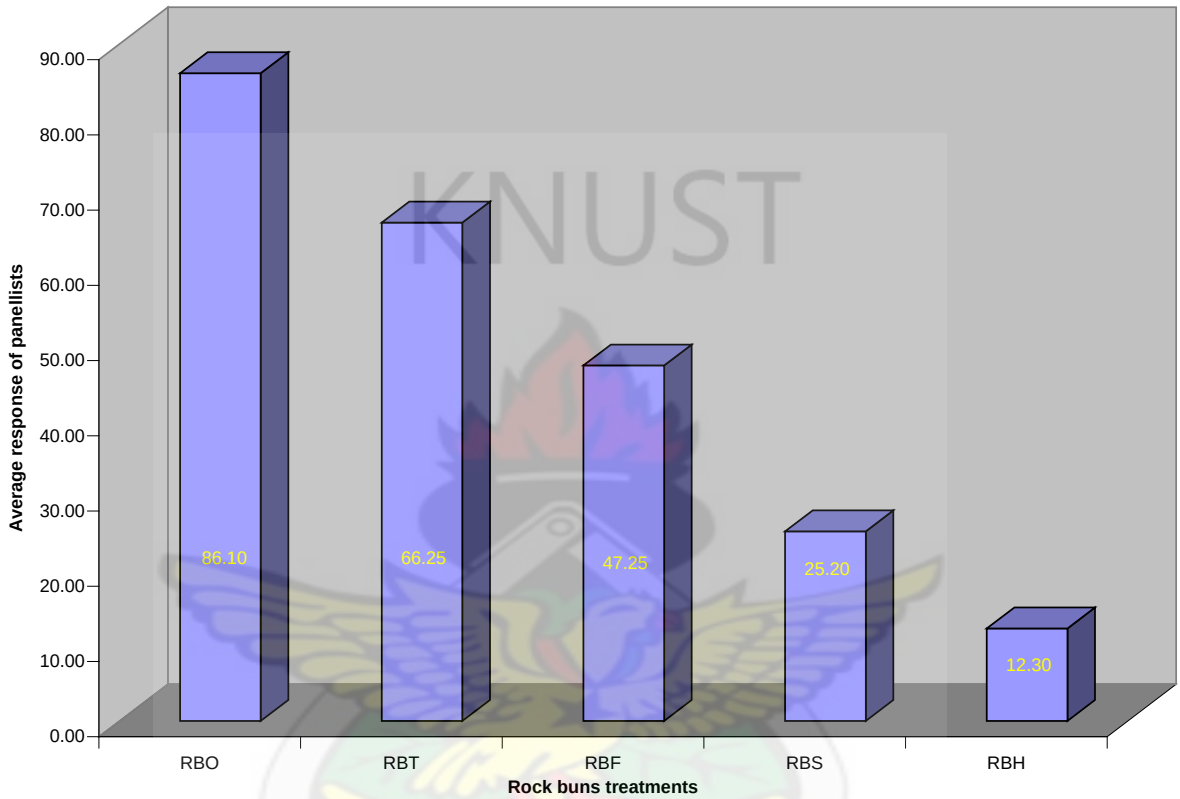

Figure 14: Average response of panellists to the crumbliness of rock buns treatments

4.2.7. Chewiness

The panellists' score for the chewiness of rock buns treatments in increasing order of occurrence was as follows: RBO < RBT < RBF < RBS < RBH (Figure 15). Significant differences ($p \leq 0.05$) in chewiness were found to exist between the five rock buns treatments, in spite of this, no significant differences ($p > 0.05$) were found among RBO and RBT (Table 7 and Appendix 3). Reduction in fat at the 25 % level did not significantly affect chewiness, thus RBT was similar to RBO. RBH was the chewiest (i.e. the most difficult to chew) whiles RBO was the least chewy

(easiest to chew). This also implies that fat is required for the production of tender pastries (i.e. rock buns) (Bennion, 1995c).

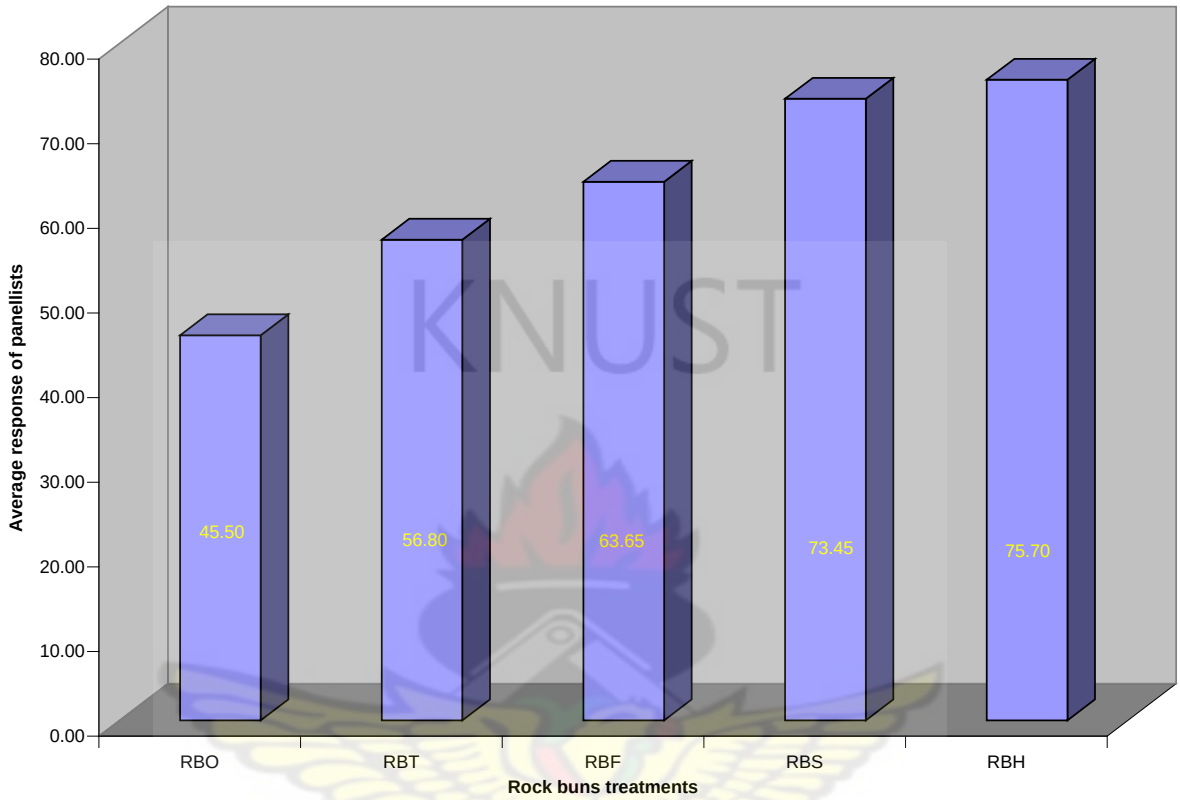

Figure 15: Average response of panellists to the chewiness of rock buns treatments

4.2.8. Overall Acceptability

The overall acceptance score indicated that RBT with a score of 86.30 was the most preferred. Preference for the treatments was in the order: RBT > RBO > RBF > RBS > RBH (Figure 16). No significant differences ($p > 0.05$) in overall acceptability were found to exist between RBO and RBT. They were however significantly different ($p \leq 0.05$) from RBF, RBS ad RBH (Table 7 and Appendix 3). This indicates that a twenty five percent reduction in fat used to make the rock buns treatments had no significant effect on the sensory properties or quality of rock buns.

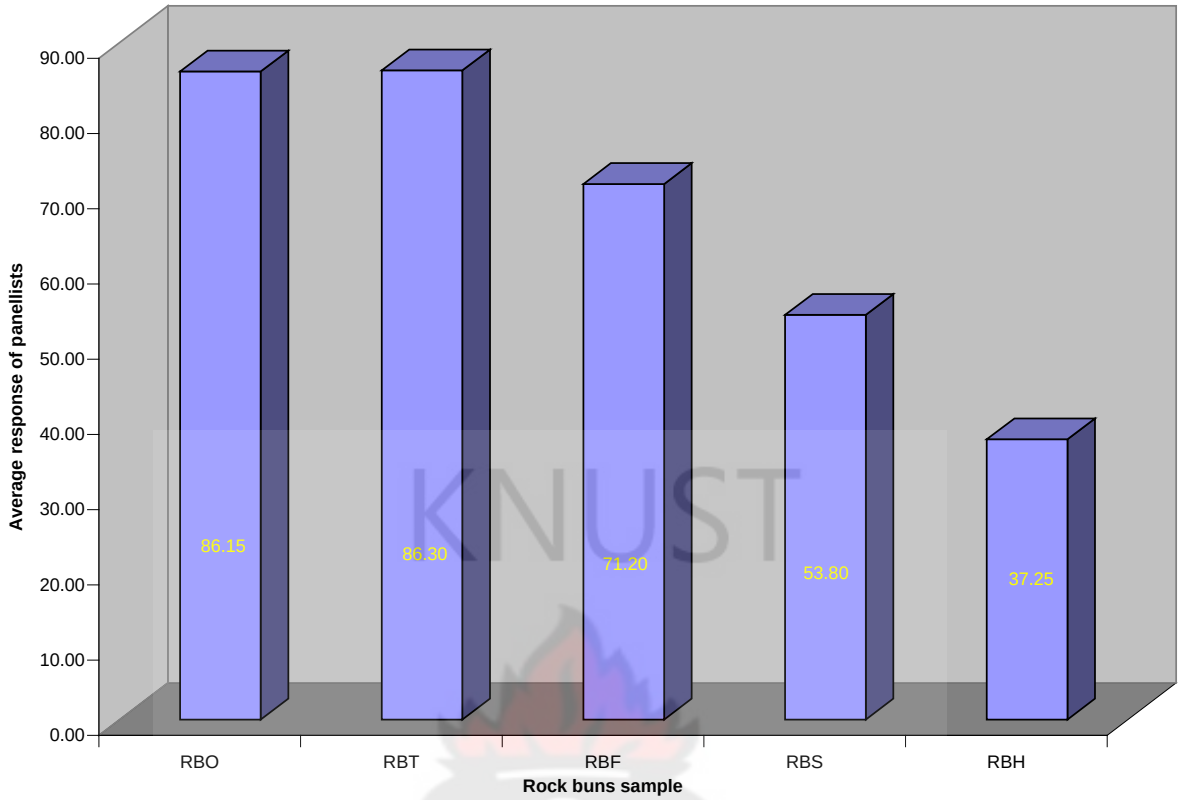

Figure 16: Average response of panellists to the overall acceptability of rock buns treatments

Further decreases in fat content did affect the sensory quality of the rock buns treatments significantly. This indicates that the amount of fats in rock buns has a direct effect on the sensory attributes of the rock buns and consequently its acceptability.

4.3. Effects of Fat Reduction on the Texture of Rock Buns

Table 8- Mean TPA values for rock buns[1]

Rock buns[2]	Har[3]	Fra	Adh	Spr	Coh	Gum	Chw	Res	Mod
RBO	37.82^{b}	15.88^{a}	-0.02	0.57^{e}	0.25^{e}	8.85^{d}	5.08^{d}	0.10^{e}	7.83^{a}
	(5.90)	(0.69)	(0.00)	(0.00)	(0.00)	1.49	(0.82)	(0.00)	(0.39)
RBT	44.26^{b}	8.33^{b}	-0.02	0.62^{d}	0.37^{d}	16.60^{c}	10.33^{c}	0.17^{d}	4.13^{b}
	(6.78)	(0.62)	(0.01)	(0.04)	(0.01)	(2.83)	(2.29)	(0.01)	(0.31)
RBF	73.20^{a}	8.28^{b}	-0.03	0.68^{c}	0.43^{c}	31.69^{b}	21.41^{b}	0.24^{c}	4.10^{b}
	(13.85)	(2.29)	(0.01)	(0.03)	(0.02)	(7.04)	(4.74)	(0.02)	(1.16)
RBS	68.91^{a}	8.35^{b}	-0.02	0.78^{b}	0.46^{b}	31.96^{b}	24.79^{b}	0.30^{b}	4.14^{b}
	(3.66)	(1.13)	(0.01)	(0.01)	(0.01)	(1.67)	(1.51)	(0.02)	(0.56)
RBH	82.45^{a}	5.13^{c}	-0.01	0.90^{a}	0.53^{a}	43.65^{a}	39.08^{a}	0.47^{a}	2.58^{c}
	(5.42)	(0.29)	(0.00)	(0.01)	(0.00)	(3.23)	(2.97)	(0.00)	(0.16)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$).
Numbers in parentheses represent the standard deviation of the mean.
[2]RBO- full-fat control rock buns, RBT, RBF, RBS, RBH- reduced fat rock buns containing 25, 50, 75, 100% (w/w) added fat replacer respectively.
[3]Har- hardness, Fra- fracturability, Adh- adhesiveness, Spr- springiness, Coh- cohesiveness, Gum- gumminess, Chw- chewiness, Res- resilience, Mod- modulus of deformation.

4.3.1. Hardness

Measurement of rock buns hardness using the texture analyser showed that the hardness of the baked rock buns increased with increasing fat reduction (Table 8 and Appendix 4). Menjivar and Faridi (1994) reported that, fat, if present in sufficient amounts, coats the surface of flour particles inhibiting the development of gluten proteins. This infers that the free fat disrupts the gluten network resulting in softer dough. There were no significant differences ($p > 0.05$) in hardness between RBO and RBT which had the lowest hardness values of 37.82 and 44.26 respectively. The hardness of RBT was thus comparable to that of RBO. RBF, RBS, and RBH had the highest values for hardness. O' Brien *et al*. (2003) explained that water uptake by flour in the absence of sufficient fat results in dough hardness. This therefore resulted in a corresponding hardness in the baked product. The results were consistent with comments made by panellists that rock buns treatments with less fat were harder i.e. there was a positive

correlation between the results from the sensory and the texture profile analysis tests. Coincidentally, rock buns containing less fat required more water for the formulation of the dough.

4.3.2. Fracturability

The results showed a decrease in fracturability with increasing fat reduction. Significant differences ($p \leq 0.05$) were observed between the five rock buns treatments (Table 8 and Appendix 4). The highest fracturability value was recorded in RBO with RBH recording the least value. The two treatments were significantly different ($p \leq 0.05$). This implies that RBO had the softest crust or was the easiest to break and RBH had the hardest crust or was the most difficult to break. No significant differences ($p > 0.05$) were found among RBT, RBF and RBS. These three treatments were however significantly different ($p \leq 0.05$) from RBO and RBH.

4.3.3. Adhesiveness

Results showed that adhesiveness decreased with decreasing fat reduction from RBO through to RBF and then increased with decreasing fat reduction from RBS to RBH. This trend could be due to increase in gumminess with increasing fat reduction making RBS and RBH more adhesive.

4.3.4. Springiness

The results showed an increase in springiness with increasing fat reduction (Table 8 and Appendix 4). Differences in springiness between the rock buns treatments were significant ($p \leq 0.05$). RBO was the most plastic treatment whilst RBH was the most elastic of all the treatments. This observation could be due to the formation of a gluten network which produces elasticity in the dough and its subsequent baked product in the absence of sufficient fat in the dough.

4.3.5. Cohesiveness

Differences in cohesiveness between the rock buns treatments were significant ($p \leq 0.05$). Results showed an increase in cohesiveness with increasing fat reduction (Table 8 and Appendix 4). Cohesiveness of the rock buns treatments was in the order: RBO < RBT < RBF < RBS < RBH. The increase in cohesive properties of the rock buns treatments observed could be attributed to the absence of normal fat level in the formulation. When fat is mixed with flour before hydration it prevents the formation of tough gluten network and produces less elastic (or less cohesive) dough and subsequently a less elastic product (Maache-Rezzoug *et al*., 1998). The absence of fat in the RBH formulation accounts for its higher cohesive property.

4.3.6. Gumminess

With a decrease in fat content of the rock buns treatments, gumminess increased especially in the crumb. Differences in gumminess between the rock buns treatments were significant ($p \leq 0.05$), however, no significant differences ($p > 0.05$) were found between RBF and RBS (Table 8 and Appendix 4). The trend could be as a result of the presence of sucrose and reducing sugars with increasing addition of fat replacer in the formulated products. Bennion (1995c) reported that excessive amount of sugar produces a coarse, thick-celled gummy cake with a rough, sugary and overly brown crust. This phenomenon could account for the trend observed. This trend was consistent with observations made by sensory panellists that gumminess increased with increasing fat replacer addition.

4.3.7. Chewiness

Significant differences ($p \leq 0.05$) in chewiness were found among the five treatments (Table 8 and Appendix 4). RBO treatment was rated the most tender rock buns. It was significantly chewier ($p \leq 0.05$) than all the other treatments. Comparatively, RBH treatment produced the toughest rock buns. No significant differences ($p > 0.05$) were found between RBF and RBS

though they were significantly different ($p \leq 0.05$) from all other treatments. The trend observed was: RBO < RBT < RBF < RBS < RBH. The trend observed was consistent with results for sensory scores for chewiness, in the sensory, though, panellists found no significant differences ($p > 0.05$) between RBO and RBT.

4.3.8. Resilience

The results for resilience were in the order: RBO < RBT < RBF < RBS < RBH (Table 8 and Appendix 4). Differences between the treatments were significantly different ($p \leq 0.05$). This could be attributed to the decreasing fat contents of the treatments.

4.3.9. Modulus of Deformation

Significant differences ($p \leq 0.05$) were observed between the five rock buns treatments (Table 8 and Appendix 4). No significant differences ($p > 0.05$) were found among RBT, RBF and RBS. These three treatments were however significantly different ($p \leq 0.05$) from RBO and RBH. There was a general decrease in the modulus of deformation values as fat replacer content increased. This implies that firmness of the rock buns treatments increased with decreasing fat content. RBO was thus the softest of the five rock buns treatments and RBH was the firmest. The presence of fat accounted for the softness or tenderness in RBO relative to the other treatments. The general decrease in modulus of deformation values (i.e. increase in firmness) could be attributed to the gradual decrease in fat as fat contributes tenderness to pastries. Penfield and Campbell (1990a) reported that one of the most important functions of fat is to tenderise baked goods. RBH produced the firmest rock buns because no fat was available to interfere with gluten development, consequently developing a cohesive, solid gluten structure (Penfield and Campbell, 1990a).

4.4. Effects of Fat Reduction on the CIE L*, a*, b* Colour Parameters of Rock Buns

Table 9- Treatment effects on CIE L*, a*, b* colour parameters of rock buns dough before baking[1]

Treatment[2]	L (lightness)[3]	A (redness)	B (yellowness)	Chroma	Hue angle
RBO	74.74[a] (0.22)	-2.57[d] (0.07)	27.01[a] (0.36)	26.89[a] (0.35)	84.57[b] (0.08)
RBT	71.64[b] (1.19)	-0.81[c] (0.65)	25.37[b] (0.89)	25.36[b] (0.87)	88.19[a] (1.40)
RBF	71.46[b] (0.20)	0.60[b] (0.19)	24.67[b] (0.96)	24.67[b] (0.95)	88.60[a] (0.48)
RBS	71.05[b] (0.58)	0.78[b] (0.52)	24.59[b] (0.81)	24.60[b] (0.80)	88.18[a] (1.26)
RBH	68.58[c] (0.55)	2.36[a] (0.19)	20.59[c] (0.43)	20.73[c] (0.40)	83.44[b] (0.64)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$). Numbers in parentheses represent the standard deviation of the mean.
[2]RBO- full-fat control rock buns, RBT, RBF, RBS, RBH- reduced fat rock buns containing 25, 50, 75, 100% (w/w) added fat replacer respectively.
[3]L*- lightness, a*- redness, b*- yellowness, Chroma- chroma, h*- hue angle.

Results (shown in Table 9 and Appendix 5) showed a gradual decrease in lightness values, L*, for the unbaked rock buns dough with increasing fat reduction. The trend of the results was in the order: RBO > RBT > RBF > RBS > RBH. The trend implies that the samples got darker with increasing addition of fat replacer. This could be due to the impartation of the colour of the fat replacer to the dough. The intensity of the colour impartation increased with increasing fat substitute addition leading to the relatively higher darkness in colour of rock buns treatments containing more fat replacer. Results showed significant differences ($p \leq 0.05$) between the rock buns treatments. Results indicated that there were no significant differences ($p > 0.05$) between the rock buns treatments: RBT, RBF and RBS. They were however significantly different from RBO and RBH which were also significantly different ($p \leq 0.05$) from each other.

Redness values, a*, of rock buns treatments' dough increased with increasing addition of fat substitute (shown in Table 9 and Appendix 5). The variety of papaya with red pulp was used in the preparation of the fat replacer. RBH was significantly redder ($p \leq 0.05$) than the other treatments, however, no significant differences ($p \leq 0.05$) in redness were found between RBF and RBS. The dough for RBO was the least red since it contained no fat replacer. The higher a* value for RBH could be due to the impartation of the red colour of the fat replacer which was highest in RBH because it had the highest fat replacer content. The increase in a* values could be due to the higher content of carotenoid pigment with increasing addition of fat replacer (Ameny and Wilson, 1997).

Yellowness, b*, in the dough of the rock buns treatments decreased with increasing fat replacer addition (shown in Table 9 and Appendix 5). Yellowness values, b*, for the rock buns treatments exhibited the following trend: RBO > RBT > RBF > RBS > RBH. RBO had significantly yellow ($p \leq 0.05$) dough compared with all other treatments. This is due to its higher fat content. RBH on the other hand had the least yellow dough because it had the highest fat replacer content. No significant differences ($p > 0.05$) were found between RBT, RBF and RBS. This implies that fats contributed yellowness to the treatments.

Significant differences ($p \leq 0.05$) in hue angle, h*, were observed between the dough of the five rock buns treatments as shown in Table 9 and Appendix 5. RBH which recorded the lowest h* value (83.44) in its dough was not significantly different ($p > 0.05$) from RBO which recorded h* value of 84.57. The hue angle of the dough of RBO like that of RBH was significantly different ($p \leq 0.05$) from that of RBT, RBF, and RBS between which no significant differences ($p > 0.05$) were observed. Higher h* values in RBT, RBF and RBS shows that their colours were closer to yellow compared to that of RBO and RBH which were closer to orange-red. The orange-red colour of RBH could be due to the impartation of the colour of the carotenoid

pigments present in the fat replacer. The low h* value of RBO could be as a result of it's a* and b* values since the h* value was calculated from these values.

Significant differences ($p \leq 0.05$) in chroma were observed between the dough of the five rock buns treatments (Table 9 and Appendix 5). There was a gradual decrease in chroma with decreasing fat content. RBO had the highest chroma value and RBH recorded the lowest chroma value. The chroma values of RBO and RBH were significantly different ($p \leq 0.05$) whiles the chroma values of their dough were significantly different ($p \leq 0.05$) from that of the dough of RBT, RBF and RBS. The latter treatments were not significantly ($P > 0.05$) different from each other. RBO thus had the brightest appearance whiles RBH was dull.

Table 10- Treatment effects on CIE L*, a*, b* colour parameters of baked rock buns crumb[1]

Treatment[2]	L (lightness)[3]	A (redness)	B (yellowness)	Chroma	Hue angle
RBO	67.38^{a}	-2.07^{d}	18.02^{b}	17.90^{b}	83.42^{b}
	(1.39)	(0.13)	(0.91)	(0.92)	(0.69)
RBT	64.00^{b}	0.73^{c}	19.36^{ab}	19.38^{ab}	87.79^{a}
	(1.12)	(0.51)	(1.69)	(1.68)	(1.59)
RBF	62.35^{bc}	2.33^{b}	20.69^{a}	20.82^{a}	83.54^{b}
	(3.25)	(0.40)	(1.35)	(1.33)	(1.32)
RBS	61.38^{bc}	2.47^{b}	18.36^{b}	18.52^{b}	82.35^{b}
	(0.93)	(0.10)	(0.33)	(0.33)	(0.30)
RBH	59.16^{c}	3.88^{a}	15.24^{c}	15.72^{c}	75.72^{c}
	(0.89)	(0.09)	(0.19)	(0.19)	(0.35)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$). Numbers in parentheses represent the standard deviation of the mean.

[2]RBO- full-fat control rock buns, RBT, RBF, RBS, RBH- reduced fat rock buns containing 25, 50, 75, 100% (w/w) added fat replacer respectively.

[3]L*- lightness, a*- redness, b*- yellowness, Chroma- chroma, h*- hue angle.

The lightness values, L*, for the crumb of the rock buns samples followed the same trend as that for the unbaked dough. However, in addition to the similarity found between RBT, RBF and RBS as in the case of the unbaked dough; RBF, RBS and RBH were also found to be similar.

RBO was significantly different ($p \leq 0.05$) in lightness from the rest of the treatments (Table 10 and Appendix 5). The result shows that the colour (lightness) of the dough has a direct relation with the lightness of the crumb of the baked product.

Redness, a*, in the crumb of the rock buns followed exactly the same pattern as found in the dough (Table 10 and Appendix 5). Redness increased with increasing addition of fat replacer. RBH was significantly redder ($p \leq 0.05$) than the other treatments and RBO was the least red. No significant differences ($P > 0.05$) were observed between RBF and RBS. This trend could be due to the higher content of carotenoid pigment with increasing addition of fat replacer (Ameny and Wilson, 1997).

The crumb of RBF which recorded the highest yellowness, b*, value was not significantly different ($p > 0.05$) in b* values from RBT, however, its crumb was significantly more yellow than RBO, RBS and RBH. In addition, the crumbs of RBO, RBT and RBS were not significantly different ($p \leq 0.05$) in yellowness. RBH was significantly ($p \leq 0.05$) less yellow than all the other treatments (Table 10 and Appendix 5). The decrease in b* values from RBF through to RBH show that colour shifted slightly from yellow towards blue probably due to isomerisation of carotenoids (Ameny and Wilson, 1997).

The highest hue angle value, h*, was recorded in RBT crust with the lowest occurring in RBH. These two treatments were significantly different ($p \leq 0.05$) from each other and from the other treatments. RBO, RBF and RBS were on the contrary not significantly ($p > 0.05$) different from each other (Table 10 and Appendix 5). The lower h* value in RBH crumb indicated that the colour of its crumb was closer to orange-red on the colour wheel. The red-orange colour is largely due to the impartation of orange-red colour from the fat replacer to the crumb. The colours of the rest of the treatments were closer to yellow.

Significant differences in chroma were found between the five treatments. RBF recorded the highest chroma value for its crumb and RBH had the lowest value for crumb chroma. The crumb chroma of RBF was significantly different ($p \leq 0.05$) from that of RBO, RBS and RBH. It was however not significantly different ($p > 0.05$) from that of RBT. There were also no significant differences ($p > 0.05$) in chroma between the crumbs of RBO, RBT and RBS (Table 10 and Appendix 5). Results show that RBF had a saturated or a more vivid appearance whilst RBH had a dull colour.

Table 11- Treatment effects on CIE L*, a*, b* colour parameters of baked rock buns crust[1]

Treatment[2]	L (lightness)[3]	A (redness)	B (yellowness)	Chroma	Hue angle
RBO	67.51[a]	0.18[d]	20.61[a]	20.61[a]	88.74[a]
	(1.40)	(0.58)	(1.18)	(1.17)	(0.70)
RBT	64.80[a]	2.26[c]	19.55[a]	19.69[a]	88.35[a]
	(1.32)	(0.76)	(1.11)	(1.04)	(2.53)
RBF	56.00[c]	4.91[a]	9.09[b]	10.37[b]	60.85[b]
	(1.52)	(0.16)	(2.08)	(1.76)	(6.66)
RBS	58.55[bc]	3.86[b]	11.58[b]	12.21[b]	71.55[b]
	(1.16)	(0.06)	(0.50)	(0.49)	(0.49)
RBH	59.37[b]	3.94[b]	8.57[b]	9.53[b]	62.75[b]
	(3.05)	(0.11)	(3.48)	(3.02)	(1.97)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$). Numbers in parentheses represent the standard deviation of the mean.
[2]RBO- full-fat control rock buns, RBT, RBF, RBS, RBH- reduced fat rock buns containing 25, 50, 75, 100% (w/w) added fat replacer respectively.
[3]L*- lightness, a*- redness, b*- yellowness, Chroma- chroma, h*- hue angle.

With respect to L* values, the crust of RBO was not significantly darker ($p > 0.05$) than RBT. However, RBT like RBO was significantly lighter ($p \leq 0.05$) than RBF, RBS and RBH. Although RBF was significantly darker ($p \leq 0.05$) than RBH, its crust was not significantly darker ($p > 0.05$) than RBS. The lightness of the crusts of RBS and RBH were also not significantly different ($p > 0.05$) (Table 11 and Appendix 5).

In the crust of the rock buns, significant differences ($p \leq 0.05$) in redness, a*, were found among the five treatments. RBO was the least red. RBF had a significantly redder crust than all other treatments. No significant differences ($p > 0.05$) in redness were found between RBS and RBH whose crusts were significantly less red compared to RBF. The crusts of RBF, RBS and RBH were nevertheless redder than RBO and RBT (Table 11 and Appendix 5).

Yellowness, b*, values decreased with increasing addition of fat replacer. Significant differences ($p \leq 0.05$) in yellowness were observed between the five rock buns treatments. Yellowness values of the crust were in the order: RBO > RBT > RBS > RBF > RBH. Yellowness in the crusts of RBO and RBT were not significantly different ($p > 0.05$). Further the crusts of RBF, RBS and RBH were not significantly different in yellowness from each other (Table 11 and Appendix 5). This trend implies that the colour shifted from yellow towards blue due to decreasing fat content. Isomeric shifts in carotenoids might have contributed to the decrease in b* values as well (Ameny and Wilson, 1997).

Considering the crusts, RBO recorded the highest h* value and its crust was not significantly different ($p \leq 0.05$) from the crust of RBT. Similarly, the h* values of RBF, RBS and RBH were not significantly different ($p > 0.05$) though they were significantly different ($p \leq 0.05$) from that of RBO and RBT. The crust of RBO recorded the lowest h* value (Table 11 and Appendix 5). The lower h* values recorded in RBF, RBS and RBH indicates that they had an orange-red colour largely due to the increasing addition of fat replacer. The higher h* values in the crusts of RBO and RBT show that they were more yellow due to their higher fat content.

Crust chroma decreased with decreasing fat content. The chroma values of the crusts of RBO and RBT were not significantly different ($p > 0.05$). Similarly, chroma values of the crusts of RBF, RBS and RBH were also not significantly different ($p > 0.05$). RBO like RBT was

significantly different ($p \leq 0.05$) from RBF, RBS and RBH (Table 11 and Appendix 5). The higher chroma values in RBO and RBT shows that they had a brighter or more vivid appearance. RBF, RBS and RBH on the other hand had a dull colour.

4.5. Effects of Fat Reduction on the Physical Properties of Rock Buns

After baking, measurements taken using vernier calipers showed that RBO had a thickness or height of 24 mm compared to the reduced-fat treatments which had a height of 18 mm each and RBH which had a height of 17 mm. Physical examination of each rock buns treatment revealed that a decrease in the fat content of the rock buns treatments resulted in a corresponding shrinkage in the size of the rock buns. The lower the fat content, the more shrunken the rock bun looked. Hergenbart (1996) reported that fat crystals promote dough and batter aeration not only to enhance volume, but to create a more even cell structure.

4.6. Effects of Fat Reduction on the Sensory Properties of Fruit Pie Crusts

The changes in sensory attributes of fruit pie crusts with fat reduction are shown in Table 12. Appendix 6 sums up results of analysis of variance and Kruskal-Wallis tests carried out to ascertain the effect of fat reduction on the sensory qualities of the two fruit pie (crust) treatments.

Table 12- Mean value and standard deviations of sensory attributes for fruit pie[1]

Pie crust[2]	App[3]	Col	Aro	Tas	Mtf	Crb	Chw	Aci	Gum	Overall
FPO	83.25^{a} (9.48)	76.88^{a} (9.22)	68.75^{a} (9.01)	83.80^{a} (9.98)	68.31^{a} (9.21)	76.31^{a} (9.28)	25.63^{a} (9.71)	67.25^{a} (10.87)	47.75^{b} (8.78)	78.88^{a} (8.19)
FPT	71.63^{b} (8.03)	69.56^{b} (8.78)	73.33^{a} (6.66)	81.19^{a} (9.89)	74.81^{a} (9.39)	70.63^{a} (9.76)	32.19^{b} (7.64)	68.00^{a} (10.65)	57.50^{a} (7.63)	78.31^{a} (4.33)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$). Numbers in parentheses represent the standard deviation of the mean.

[2]FPO- full-fat control fruit pie, FPT- reduced-fat fruit pie containing 25 % (w/w) added fat replacer.

[3]App- appearance, col- colour, aro- aroma, tas- taste, mtf- mouth feel, crb- crumbliness, chw- chewiness, aci- acidity, gum- gumminess, overall- overall acceptability.

4.6.1. Appearance

Significant differences ($p \leq 0.05$) in appearance of mango pies were found between the control (FPO) and the reduced-fat treatment (FPT) (Table 12 and Appendix 6).

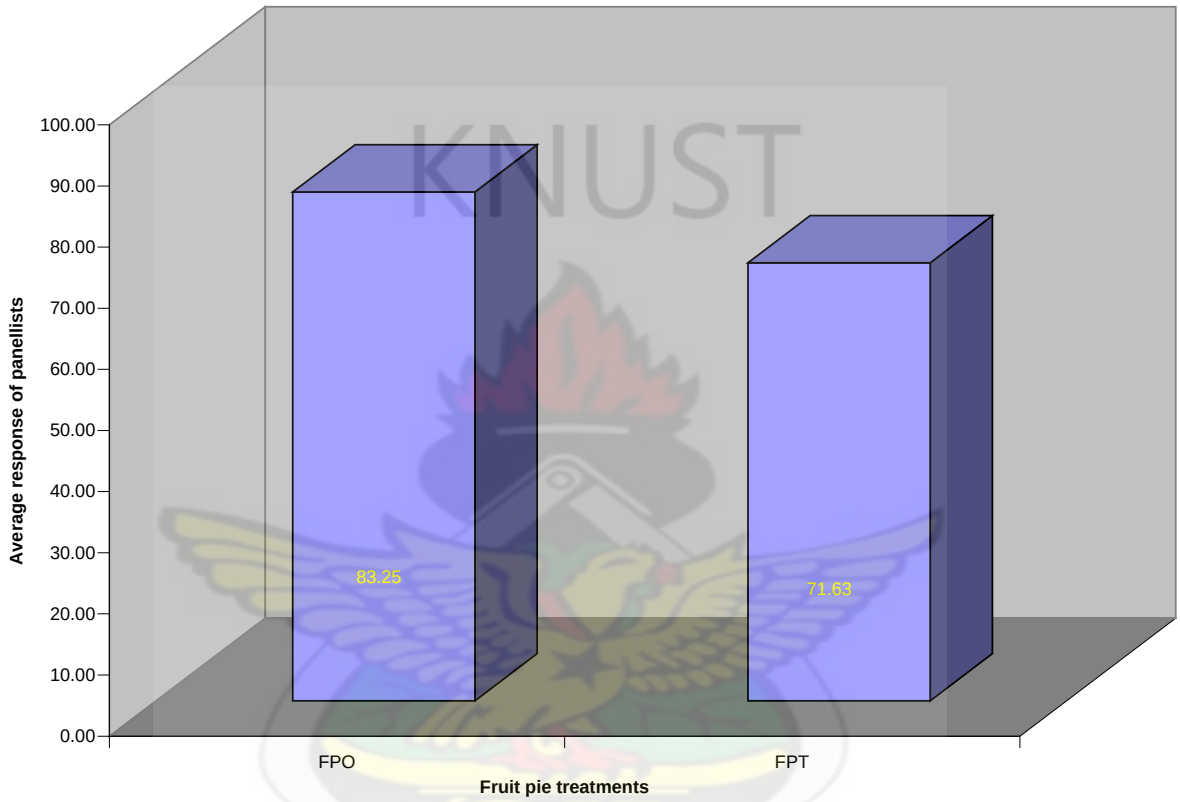

Figure 17: Average response of panellists to the appearance of fruit pie

Sensory score for appearance decreased with increased fat reduction (Figure 17). Sudha *et al*. (2006) reported the same observation in biscuit dough.

4.6.2. Colour

There was a significant difference ($p \leq 0.05$) in colour for the fruit pie crusts with the colour of FPO being most preferred (Table 12; Figure 18 and Appendix 6). FPO was the most preferred because its higher fat content gave it a golden brown colour.

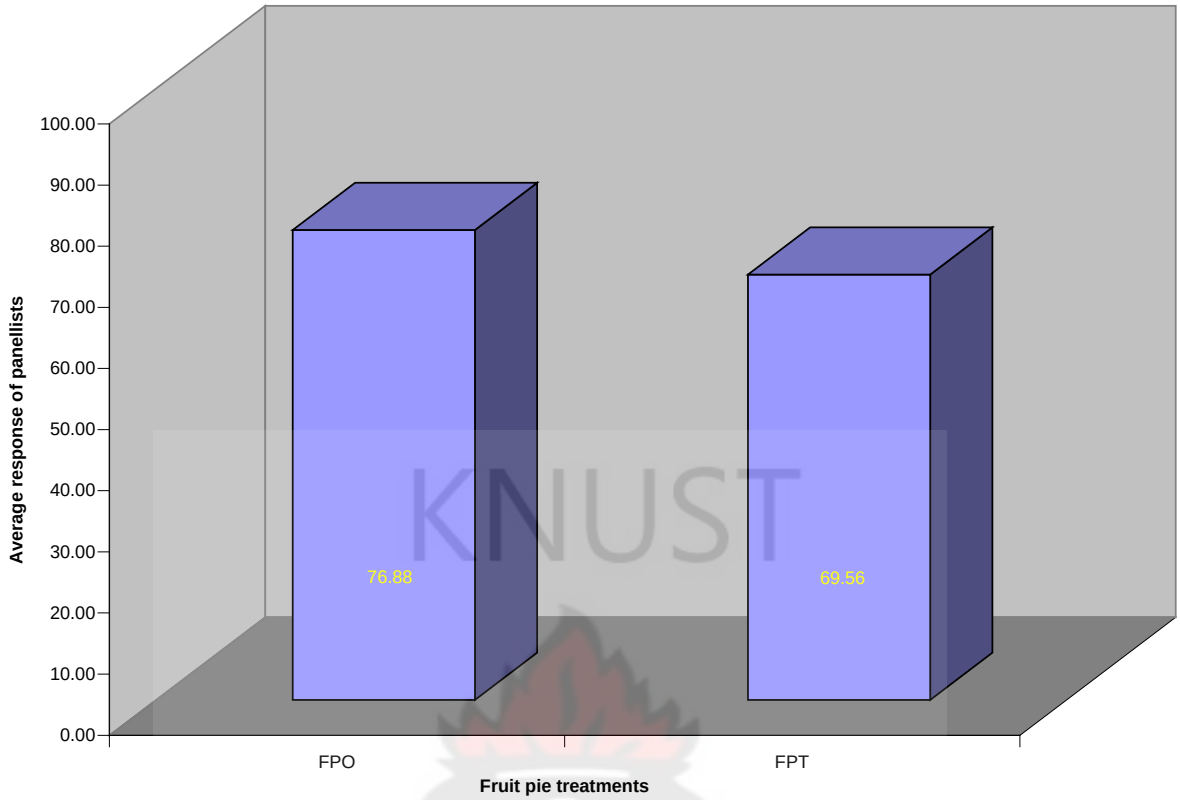

Figure 18: Average response of panellists to the colour of fruit pie treatments

4.6.3. Taste

Panellists preferred the taste of FPO more compared to FPT (Figure 19). Nonetheless, there were no significant differences ($p > 0.05$) between FPO and FPT (Table 12 and Appendix 6). Some panellists found FPT to be a bit acidic; this could be the reason why FPO was more preferable compared to FPT.

Figure 19: Average response of panellists to the taste of fruit pie treatments

4.6.4. Acidity

Panellists commented that as the fat content of the fruit pie crust reduced, the fruit pie crust increased in acidity (Figure 20). This was due to the presence of the fruit-based fat replacer used. FPT was found to be more acidic than FPO although no significant differences ($p > 0.05$) were found to exist between them (Table 12 and Appendix 6).

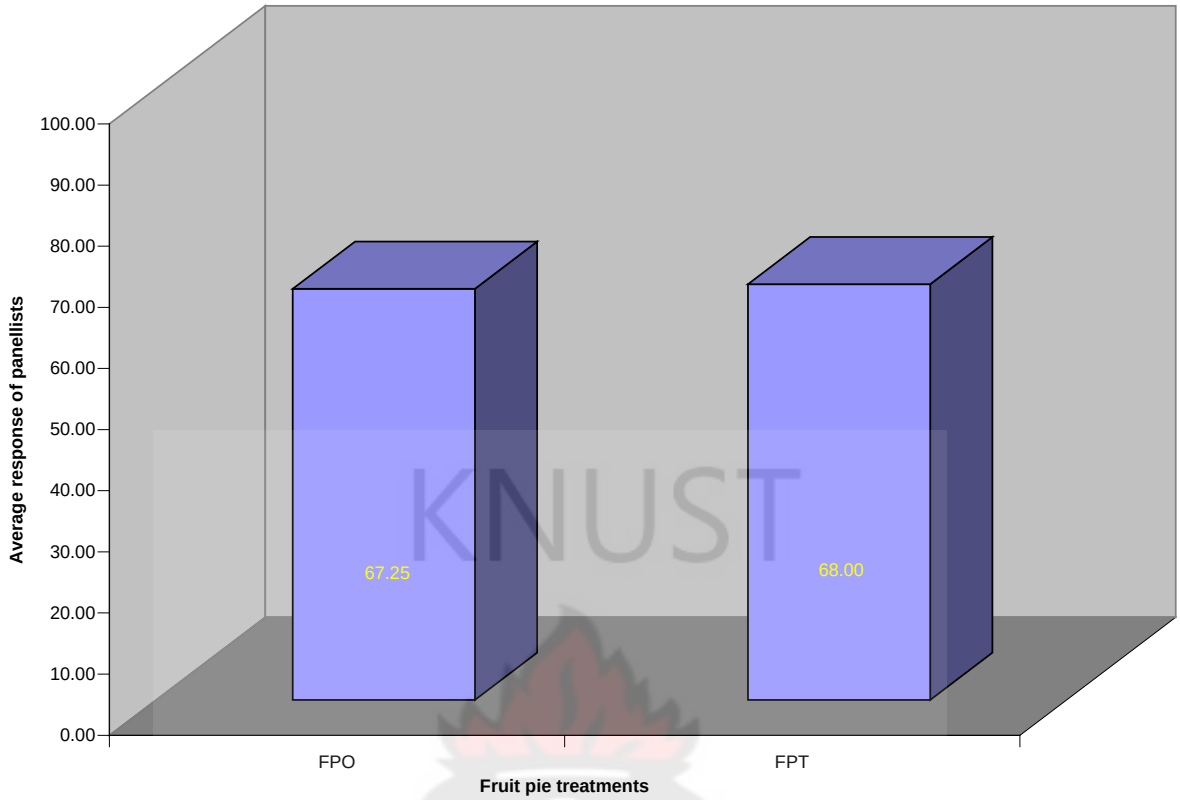

Figure 20: Average response of panellists to the acidity of fruit pie treatments

4.6.5. Aroma

There were no significant differences ($p > 0.05$) in aroma between the two fruit pie treatments (Table 12 and Appendix 6). The aroma of FPT was more typical of rock buns than that of FPO. Panellists preferred FPT to FPO because FPT had a fruity flavour imparted by the papaya-derived fat replacer (Figure 21).

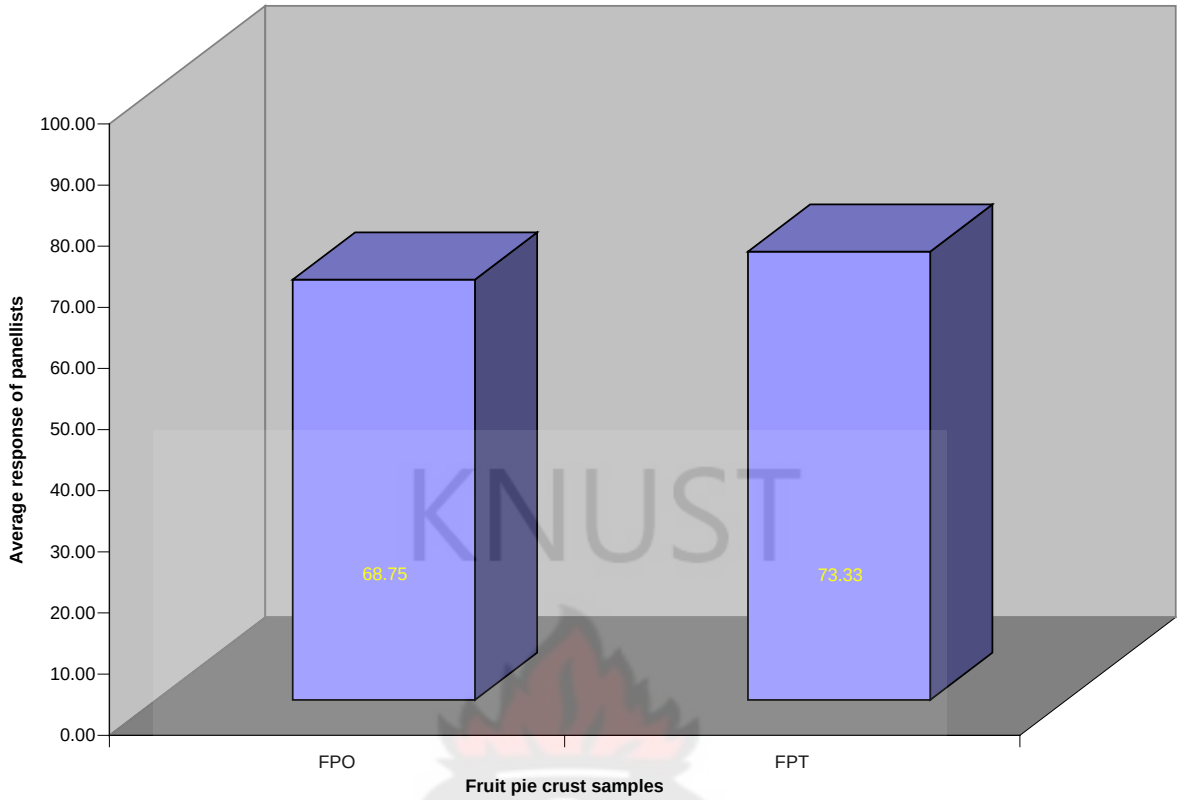

Figure 21: Average response of panellists to the aroma of fruit pie

4.6.6. Mouth Feel

There were no significant differences ($p > 0.05$) in mouth feel between the two fruit pie treatments (Table 12 and Appendix 6). Mouth feel values increased with increasing fat reduction (Figure 22). FPT had a smoother mouth feel than FPO.

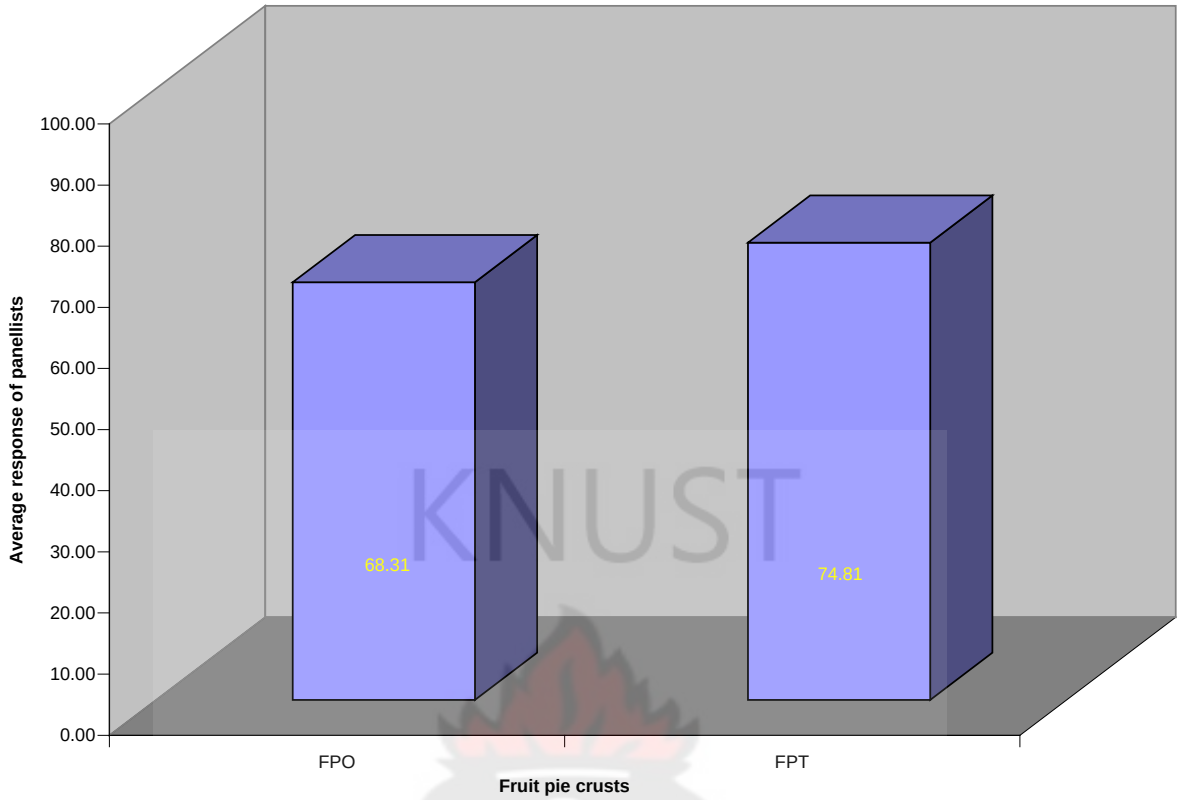

Figure 22: Average response of panellists to the mouth feel of fruit pie treatments

4.6.7. Crumbliness

For the fruit pie crusts, however, there were no significant differences ($p > 0.05$) between FPO and FPT (Table 12 and Appendix 6). This implies that the 25 % reduction in fat did not affect the crumbliness of the pie crust. Crumbliness however, decreased with decreasing fat content (Figure 23).

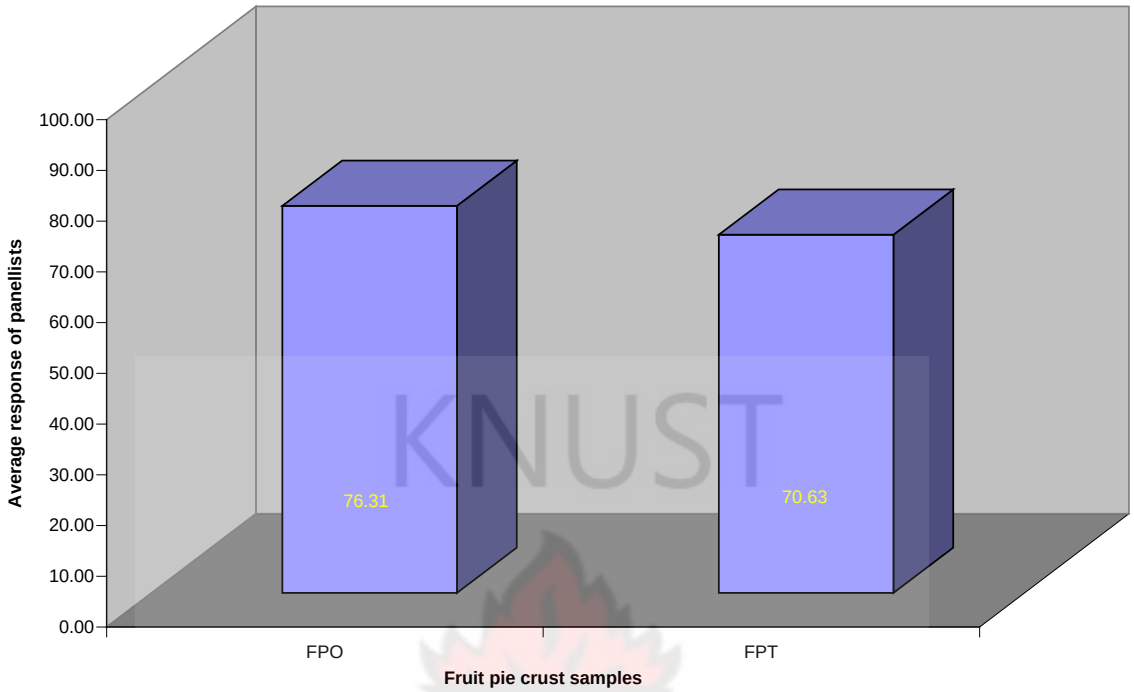

Figure 23: Average response of panellists to the crumbliness of fruit pie treatments

4.6.8. Chewiness

Significant differences ($p \leq 0.05$) in chewiness were found to exist between FPO and FPT (Table 12 and Appendix 6). FPO was easier to chew in comparison to FPT (Figure 24).

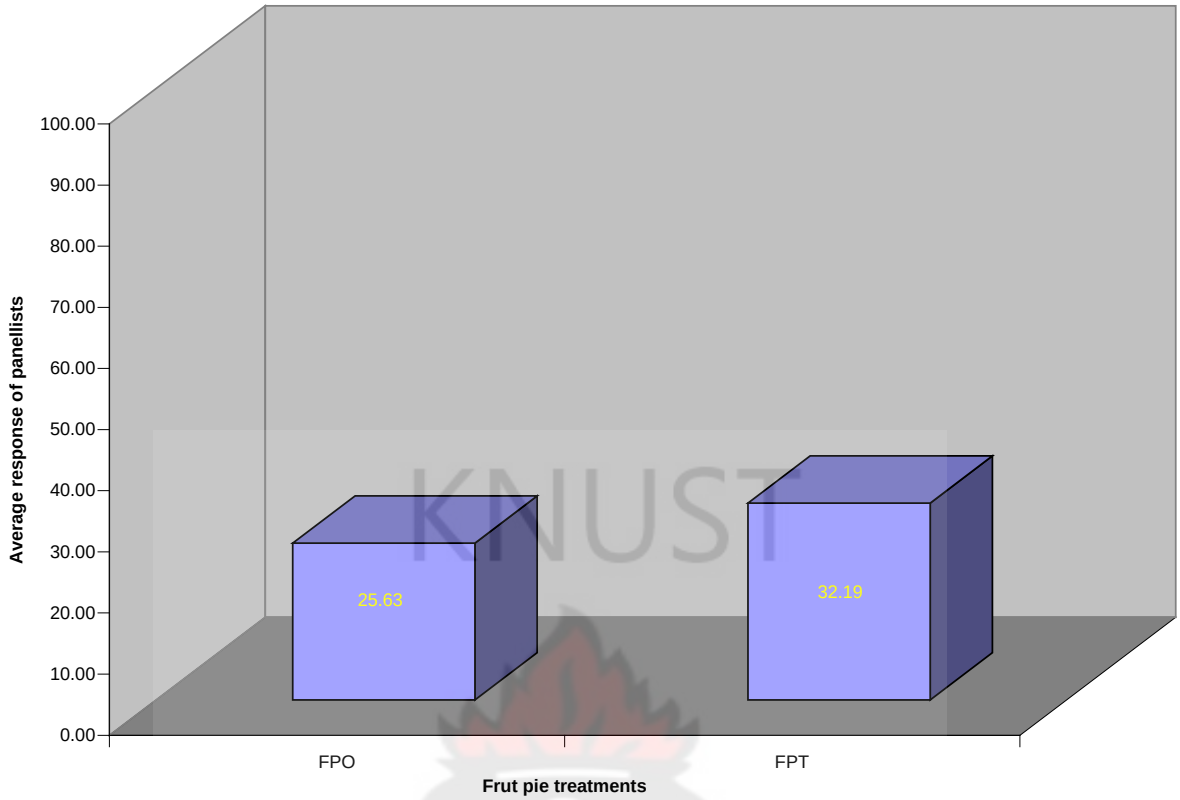

Figure 24: Average response of panellists to the chewiness of fruit pie treatments

4.6.9. Gumminess

FPT had a higher score for gumminess compared to FPO (Figure 25). Differences between them were found to be significant ($p \leq 0.05$) (Table 12 and Appendix 6).

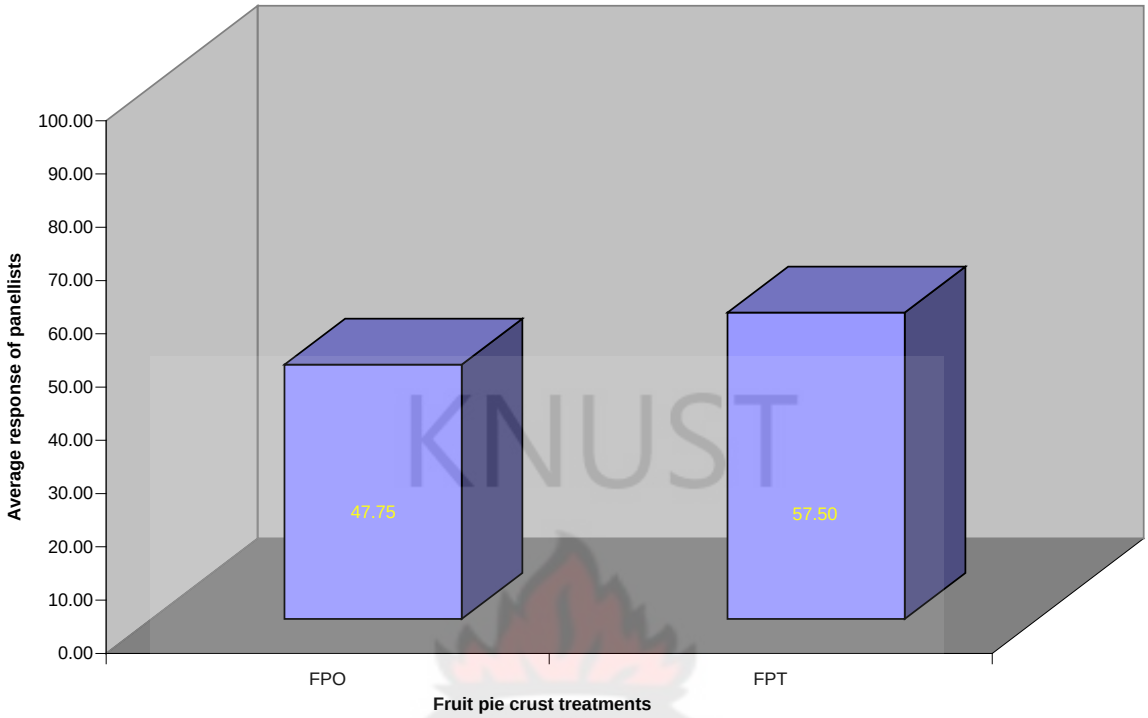

Figure 25: Average response of panellists to the gumminess of fruit pie treatments

4.6.10. Overall Acceptability

There were no significant differences ($p > 0.05$) in overall acceptability between the two treatments (Table 12 and Appendix 6). FPO had a higher value of 78.88 for overall acceptability whilst FPT had a value of 78.31 (Figure 26). FPO was the most preferred treatment.

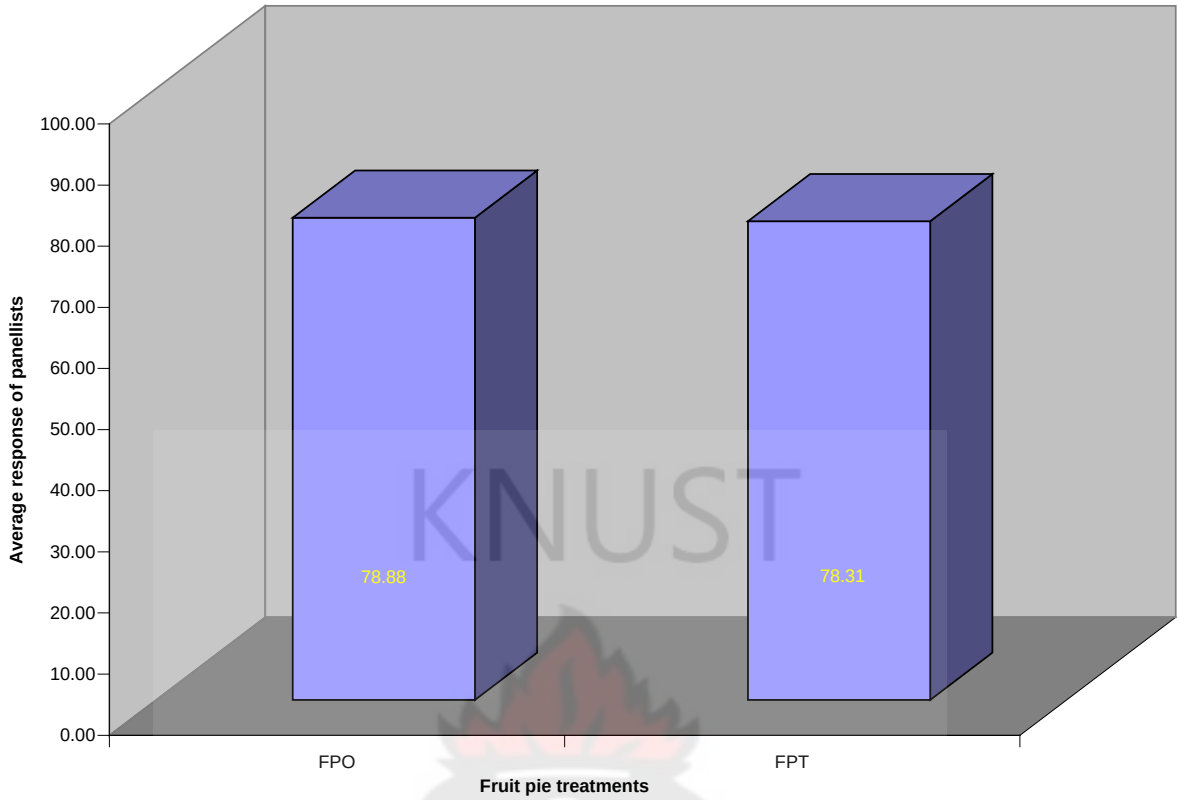

Figure 26: Average response of panellists to the overall acceptability of fruit pie treatments

4.7. Effects of Fat Reduction on the Texture of Fruit Pie Crusts

Table 13- Mean Texture Analysis values for fruit pie crust[1]

Pie crust[2]	Har[3]	Fra
FPO	84.68[a] (9.63)	98.48[a] (7.98)
FPT	77.21[a] (11.04)	78.23[b] (5.10)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$). Numbers in parentheses represent the standard deviation of the mean.

[2]FPO- full-fat control fruit pie, FPT- reduced-fat fruit pie containing 25 % (w/w) added fat replacer.

[3]Har- hardness, Fra- fracturability.

4.7.1. Hardness

The reduced-fat fruit pie crust (FPT) was less hard compared with the full fat control (FPO). No significant differences ($p > 0.05$) were found between FPO and FPT which had hardness values of 84.68 and 77.21 respectively (Table 13 and Appendix 7).

4.7.2. Fracturability

Fracturability decreased with increasing fat reduction. Differences in fracturability between the two treatments were significant ($p \leq 0.05$) (Table 13 and Appendix 7). This implies that the crumbliness of the fruit pie crust decreased with increasing fat reduction. This was in consistence with sensory scores for crumbliness. Fracturability decreased because of the reduced fat content of FPT.

4.7.3. Effects of Fat Reduction on CIE L*, a*, b* Colour Parameters of Fruit Pie

There were significant differences ($p \leq 0.05$) in lightness, L*, between FPO and FPT (Table 14 and Appendix 8). FPT was found to be darker than FPO since it had a lower L* value.

Table 14- Treatment effects on CIE L*, a*, b* colour parameters of fruit pie dough[1]

Treatment[2]	L* (lightness)[3]	a* (redness)	b* (yellowness)	Chroma	h* (Hue angle)
FPO	76.30[a]	-4.48[b]	20.11[a]	19.61[b]	77.45[b]
	(1.33)	(0.33)	(1.26)	(1.23)	(0.37)
FPT	67.41[b]	-0.03[a]	22.45[a]	22.45[a]	89.80[a]
	(1.25)	(0.11)	(1.13)	(1.13)	(1.30)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$). Numbers in parentheses represent the standard deviation of the mean.
[2]FPO- full-fat control fruit pie, FPT- reduced-fat fruit pie containing 25 % (w/w) added fat replacer.
[3]L*- lightness, a*- redness, b*- yellowness, Chroma- chroma, h*- hue angle.

Redness values, a*, showed significant differences ($p \leq 0.05$) between FPO and FPT. FPT was relatively redder than FPT because it had a higher a* value of -0.03 (Table 14 and Appendix 8).

FPT was relatively redder because it contains fat replacer which derives its red colour from carotenoid pigments (Ameny and Wilson, 1997).

There were no significant differences ($p \leq 0.05$) in yellowness between the two treatments, however, FPT and FPO had b* values of 22.45 and 20.11 respectively (Table 14 and Appendix 8).

In terms of the h* value, significant differences ($p \leq 0.05$) were found between the dough of FPO and FPT. The following was the trend: FPO < FPT (Table 14 and Appendix 8). This implies that the colour of FPT was more yellow than that of FPO which was more orange-red in colour.

Chroma increased with decreasing fat content. Differences in chroma between the dough of FPO and FPT were significantly different ($p \leq 0.05$) (Table 14 and Appendix 8). FPT had a higher chroma value than FPO. The inference from the result is that FPT had a relatively dull colour in comparison to FPO which had a more intense colour.

Table 15- Treatment effects on CIE L*, a*, b* colour parameters of fruit pie crumb[1]

Treatment[2]	L* (lightness)[3]	a* (redness)	b* (yellowness)	Chroma	h* (Hue angle)
FPO	68.93[a]	-1.07[a]	19.08[a]	19.04[a]	85.36[a]
	(1.00)	(0.71)	(1.91)	(1.94)	(0.44)
FPT	67.65[a]	-0.56[a]	17.72[a]	17.71[a]	88.13[a]
	(0.53)	(0.46)	(1.90)	(1.91)	(1.49)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$). Numbers in parentheses represent the standard deviation of the mean.
[2]FPO- full-fat control rock buns, FPT- reduced fat rock buns containing 25 % (w/w) added fat replacer.
[3]L*- lightness, a*- redness, b*- yellowness, Chroma- chroma, h*- hue angle.

For each CIE L*, a*, b* colour parameter, differences between FPO and FPT were not significant ($p > 0.05$) (Table 15 and Appendix 8). Considering the L* values, FPT was

comparatively darker than FPO. The redness, a*, values also showed that FPT was relatively redder than FPO. FPO and FPT had redness values of -1.07 and -0.56 respectively. The redder colour of FPT is due to its fat replacer content. Yellowness, b*, values decreased with increased fat replacer addition. This implies that FPO was more yellow than FPT. This could be because FPO did not contain the fat replacer.

Results also showed an increase in h* values with increasing fat reduction. FPO and FPT had h* values of 86.66 and 88.13 respectively. FPT was relatively more yellow than FPO. The lower h* value of FPO could be as a result of a* and b* values used in the calculation of its h* value. Chroma values also decreased with increasing fat reduction. FPT was therefore relatively dull in colour compared to FPO which was relatively brighter in colour.

Table 16- Treatment effects on CIE L*, a*, b* colour parameters of fruit pie crust[1]

Treatment[2]	L* (lightness)[3]	a* (redness)	b* (yellowness)	Chroma	h* (Hue angle)
FPO	66.78[a]	-0.08[b]	19.06[a]	19.06[a]	88.79[a]
	(0.76)	(0.41)	(0.30)	(0.29)	(0.46)
FPT	66.53[a]	1.51[a]	20.37[a]	20.43[a]	85.72[a]
	(0.93)	(0.49)	(1.25)	(1.24)	(1.42)

[1]Numbers in columns followed by different letters are significantly different ($p \leq 0.05$). Numbers in parentheses represent the standard deviation of the mean.
[2]FPO- full-fat control fruit pie, FPT- reduced-fat fruit pie containing 25 % (w/w) added fat replacer.
[3]L*- lightness, a*- redness, b*- yellowness, Chroma- chroma, h*- hue angle.

In the crust, with the exception of redness, a*, values for which FPO and FPT were significantly different ($p \leq 0.05$), for all other CIE L*, a*, b* colour parameters, FPO and FPT were not significantly ($p > 0.05$) different. L* values indicated that FPT was darker than FPO since it had a lower L* value than FPO. FPT in addition was redder than FPO because of its higher a* value. The fat replacer content of FPT accounts for its redder colour. FPO and FPT had yellowness values of 19.06 and 20.37 respectively. FPT was therefore more yellow than FPO.

Values for hue angle, h*, decreased with decreasing fat content. This indicates that FPO was more yellow than FPT. FPO had a lower chroma value than FPT indicating that the crust of FPT was brighter than the crust of FPO which was comparatively dull. The results are shown in Table 15 and Appendix 8).

4.8. Effects of Fat Reduction on the Physical Properties of Fruit Pie Crusts

FPO and FPT both had a thickness of 8 mm. The volumes of the two pie crust treatments were not markedly different.

4.9. Effects of Fat Reduction on the Shelf Life of Rock Buns and Fruit Pie Crusts

Physical observations made on the rock buns showed that, RBH, RBS, RBF stayed on the shelf without microbial attack for 3, 5, and 7 days respectively. RBT and RBO could stay longer than a week on the shelf. The shorter shelf lives of RBH, RBS and RBF could be attributed to their higher moisture contents (water activities) compared with the lower moisture contents (water activities) of RBO and RBT. Photograph of treatment RBH four days after baking is shown in Figure 27.

Figure 27: Photograph of treatment RBH four (4) days after baking

The pie crusts required less water during formulation of their dough as a result, the fruit pie crusts had longer shelf life than the rock buns crusts.

4.10. Shelf Life of Dried Mango Fruits

Dried fruits produced had a moisture content of 7.5 % and stayed on the shelf for at least nine (9) months without any physical sign of microbial attack (Figure 28).

Figure 28: Photograph of solar dried mango fruits nine (9) months after packaging

4.11. Nutritional Composition of the Pawpaw-derived Fat Replacer

Table 17- Nutrient content of Pawpaw-derived Fat Replacer

Nutrient	Amount/ Unit(s)
Pectin	2.51 g/100 g
Total nutrition fibre	12.0 %
Humidity (Moisture)	19.2 %
Fat	0.6 %
Protein	3.3 %
Ashes	2.8 %
Calcium	184.7 mg/100 g
Magnesium	119.4 mg/100 g
Potassium	1.50 g/100 g
Sodium	15.2 mg/100 g
Raw fibre	5.9 %

4.11.1. Pectin

The pawpaw-derived fat replacer contains 2.51 g/100 g pectin. This implies that pawpaw has substantial amounts of pectin and therefore can be used as a fat replacer. This assertion is based on comparison with plums which contain 1.5g pectin/100g raw edible portion and are being used in fat replacement.

4.11.2. Total Nutrition Fibre

The fat replacer contains 12 % total nutrition fibre. Maskarinec *et al*. (2006) reported that plant-based foods and dietary fibre were most protective against excess body weight. Short-term studies that assess energy intake after subjects were fed fibre-containing meals also suggest that large amounts of total fibre are most successful for reducing subsequent energy intake (Slavin and Green, 2007). The presence of the pawpaw-derived fat replacer in the rock buns and fruit (mango) pie crust could potentially help in checking excess body weight. This is because its fibre could act as a physiological obstacle to energy intake by displacing calories and nutrients from the diet (Heaton, 1973) and therefore promote moderate weight loss. Also, incorporating the fat replacer into pastries could help in reducing the public health problems (diseases) associated with eating high-fat foods. The "fibre hypothesis" suggests that consumption of unrefined, high-fibre, carbohydrate-based foods protects against diseases including diabetes, cancer, heart disease and obesity (Slavin *et al*., 2008).

Apart from the pectin and total nutrition fibre contents of the pawpaw-derived fat replacer, it is highly nutritious. It contains essential amounts of ash, calcium, magnesium, potassium, sodium, raw fibre, protein and is low in fat. Its nutritional composition makes it a viable and nutritious additive for fat replacement.

5. CONCLUSIONS AND RECOMMENDATIONS

Proximate analyses on the baked rock buns and mango pies showed that treatments with lower fat contents required more water to achieve the desired consistency during formulation of the pastries.

Products produced from the fat mimetic at the 25 % substitution level were comparable or even better than their full fat complements since most of the sensory attributes for the 25 % substitution level were rated higher than that for the control. The 50 % reduced-fat rock buns were rated as being fairly satisfactory. The fat-free rock buns treatment was significantly different ($p \leq 0.05$) from all other treatments in terms of quality. Thus, some fat is needed in the formulation of rock buns to produce an acceptable product.

The fat mimetic made from pawpaw could be used as an excellent replacement for fat up to the 50 % substitution level. The research revealed that, the fat replacer is limited in the extent to which it can substitute for fat and still produce an acceptable product.

Rock buns and mango pie crusts with lower fat contents had shorter shelf lives. In general commercial biscuits had longer shelf life than rock buns.

Mango pies produced were very well accepted by the panellists. Panellists showed a keen interest in having mango pies on the (Ghanaian) market to serve as a line extender adding to the variety of pastries already on the market.

Dried fruits produced from the mangoes had a longer shelf life than the unprocessed fruit and thus will serve as a value-added product which will make mangoes available year round. The dried fruits will also be a nutritious everyday snack available to consumers.

The pawpaw-derived fat replacer contained 2.51 g/100 g and 12 % pectin and total nutrition fibre respectively. The nature and nutrient composition of pawpaw gives it a high potential for use as a fat replacer.

It is recommended for future research that:

1. A systems or holistic approach be adopted to improve the sensory as well as the rheological properties of reduced-fat pastries produced from the fat replacer.
2. Research be undertaken to improve the maximum limit at which the fat replacer can be used to replace fat and still produce an acceptable product.
3. Research be undertaken to extend the shelf life of pastries produced from the fat replacer.
4. Proper packages are found for preserving the dried fruits and the puree.

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APPENDIX

APPENDIX 1 – FORMULAE USED FOR CALCULATIONS

a). % Moisture = $\frac{W_2 - W_3}{W_2 - W_1} \times 100$

Where: W_1 = Weight of crucible, W_2= Weight of crucible + Sample,
W_3 = Weight of crucible + Dry sample

b). % Ash = $\frac{W_3 - W_1}{W_2 - W_1} \times 100$

Where: W_1 = Weight of porcelain crucible, W_2= Weight of porcelain crucible + Food Sample,
W_3 = Weight of porcelain crucible + Ash

c). % Total nitrogen (% N) = $\frac{X \text{ moles}}{1000 \text{ cm}^3} \times \frac{(V_s - V_b) \text{ cm}^3}{\text{mg}} \times \frac{14 \text{ g}}{\text{moles}} \times 100$

% Protein = % N × 6.25

Where: mg = Mass of sample
X = Normality of acid, HCl
V_s = Titration value of sample
V_b = titration value of blank
6.25 = Protein conversion factor

d). % Fat = $\frac{W_2 - W_1}{W_3} \times 100$

Where: W1 = Weight of empty flask
W2 = Weight of flask + fat
W3 = Weight of food sample taken

e). % Fibre = $\frac{\text{Weight of fibre obtained}}{\text{Dry weight of sample}} \times 100$

f). Total dietary fibre = weight of residue – weight (protein + ash)

Determination of blank:
B = blank, mg = weight of residue – P_B - A_B
Where: weight of residue = average residue weights (mg) for duplicate blank determinations; P_B and A_B = weights (mg) of protein and ash, respectively, determined in first and second blank residues.

Calculate Total Dietary Fibre (TDF) as follows:
TDF % = [(weight of residue – P- A – B)/weight of sample] × 100
Where: Weight of residue = average of weights (mg) for duplicate sample determinations; P and A = weights (mg) of protein and ash, respectively, in first and second sample residues; and weight of sample = average of two (2) sample weights (mg) taken.

APPENDIX 2 – ANOVA FOR PERCENT MOISTURE AND FAT CONTENTS OF ROCK BUNS AND MANGO PIE (CRUST) TREATMENTS

APPENDIX 2A: ANOVA table for percent moisture and fat contents of rock buns treatments

Parameter	Source of Variation	Sum of Squares	Df	Mean Square	F- Ratio	P- Value
Moisture						
	Treatments	594.818	4	148.705	14339.88	0
	Within groups	0.05185	5	0.01037		
	Total (Corr.)	594.87	9			
Fat						
	Treatments	632.085	4	158.021	6470.98	0
	Within groups	0.1221	5	0.02442		
	Total (Corr.)	632.208	9			

APPENDIX 2B: ANOVA table for percent moisture and fat contents of mango pie crust treatments

Parameter	Source of Variation	Sum of Squares	Df	Mean Square	F- Ratio	P- Value
Moisture						
	Treatments	140.186	1	140.186	112148.5	0
	Within groups	0.0025	2	0.00125		
	Total (Corr.)	140.188	3			
Fat						
	Treatments	108.994	1	108.994	2588.92	0.0004
	Within groups	0.0842	2	0.0421		
	Total (Corr.)	109.078	3			

APPENDIX 3A: QUESTIONNAIRE FOR SENSORY EVALUATION OF ROCK BUNS TREATMENTS

ACCEPTABILITY TEST

Name ---------- Date ----------

Product: ----------

Sample code ----------

Please before you are samples of Rock Buns. Using the scale below please examine them in terms of appearance, colour, aroma, taste, mouth feel, crumbliness, chewiness, and
overall acceptability by drawing a vertical line at a point which perfectly fits your description.

Appearance

not attractive — very attractive

Colour

not uniform — very uniform

Aroma

not typical of Rock Buns — typical of Rock Buns

Taste

not tasty — very tasty

Mouth feel

Rough — smooth

Texture

Crumbliness

not crumbly — very crumbly

Chewiness

not chewy — very chewy

Overall acceptability

not acceptable — very acceptable

Comment(s): ----------

- Of the five samples which do you like best?

Would you buy this product? Yes No

APPENDIX 3B: ANOVA TABLE FOR SENSORY EVALUATION OF ROCK BUNS TREATMENTS

Attribute	Source of Variation	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Appearance						
	Treatments	27400	4	6850.01	84.06	0
	Within groups	7741.6	95	81.4905		
	Total (Corr.)	35141.6	99			
Colour						
	Treatments	22269.9	4	5567.46	78.08	0
	Within groups	6773.9	95	71.3042		
	Total (Corr.)	29043.8	99			
Aroma						
	Treatments	33115.9	4	8278.99	120.68	0
	Within groups	6517.5	95	68.6053		
	Total (Corr.)	39633.4	99			
Taste						
	Treatments	15305.5	4	3826.38	43.14	0
	Within groups	8426.7	95	88.7021		
	Total (Corr.)	23732.2	99			
Mouth feel						
	Treatments	1635.4	4	408.85	7.48	0
	Within groups	5191.6	95	54.6484		
	Total (Corr.)	6827	99			
Crumbliness						
	Treatments	71557.7	4	17889.4	276.76	0
	Within groups	6140.7	95	64.6389		
	Total (Corr.)	77698.4	99			
Chewiness						
	Treatments	12312.1	4	3078.02	70.19	0
	Within groups	4165.9	95	43.8516		
	Total (Corr.)	16478	99			
Overall Acceptance						
	Treatments	36322.7	4	9080.68	108.69	0
	Within groups	7936.9	95	83.5463		
	Total (Corr.)	44259.6	99			

APPENDIX 3C: TABLE FOR KRUSKAL-WALLIS TESTS ON ROCK BUNS TREATMENTS

Attribute	Sample	Sample Size	Average Rank
Appearance			
	1	20	74.65
	2	20	78.3
	3	20	56.325
	4	20	29.075
	5	20	14.15
	Test statistic = 75.377		P-Value = 0.0
Colour			
	1	20	72.175
	2	20	72.525
	3	20	65.9
	4	20	18.675
	5	20	23.225
	Test statistic = 70.1253		P-Value = 0.0
Aroma			
	1	20	82.225
	2	20	73.35
	3	20	54.9
	4	20	28.175
	5	20	13.85
	Test statistic = 80.5915		P-Value = 0.0
Taste			
	1	20	72.925
	2	20	74.6
	3	20	57.525
	4	20	29.85
	5	20	17.6
	Test statistic = 62.8455		P-Value = 0.0
Mouth feel			
	1	20	42.225
	2	20	56.175
	3	20	73.825
	4	20	46.775
	5	20	33.5
	Test statistic = 22.5632		P-Value = 0.000154785
Crumblines s			
	1	20	88.7
	2	20	70.75
	3	20	51.6
	4	20	30.675
	5	20	10.775
	Test statistic = 91.3161		P-Value = 0.0

APPENDIX 3C: TABLE FOR KRUSKAL-WALLIS TESTS ON ROCK BUNS TREATMENTS CONTINUED

Attribute	Sample	Sample Size	Average Rank
Chewiness			
	1	20	21.15
	2	20	26.875
	3	20	49.6
	4	20	65.7
	5	20	89.175
	Test statistic = 74.8547		P-Value = 0.0
Overall Acceptability			
	1	20	77.825
	2	20	77.225
	3	20	54.625
	4	20	30.975
	5	20	11.85
	Test statistic = 79.7136		P-Value = 0.0

APPENDIX 4: ANOVA TABLE FOR TEXTURE PROFILE ANALYSIS OF ROCK BUNS TREATMENTS

Attribute	Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Hardness						
	Treatments	4465.91	4	1116.48	17.7	0.0002
	Within groups	630.89	10	63.089		
	Total (Corr.)	5096.8	14			
Fracturability						
	Treatments	190.43	4	47.6074	31.96	0
	Within groups	14.8949	10	1.48949		
	Total (Corr.)	205.325	14			
Springiness						
	Treatments	0.204485	4	0.0511213	100.66	0
	Within groups	0.00507867	10	0.000507867		
	Total (Corr.)	0.209564	14			
Cohesiveness						
	Treatments	0.133852	4	0.0334629	193.65	0
	Within groups	0.001728	10	0.0001728		
	Total (Corr.)	0.13558	14			
Gumminess						
	Treatments	2280.99	4	570.247	39.03	0
	Within groups	146.091	10	14.6091		
	Total (Corr.)	2427.08	14			
Chewiness						
	Treatments	2115	4	528.75	66.89	0
	Within groups	79.0501	10	7.90501		
	Total (Corr.)	2194.05	14			
Resilience						
	Treatments	0.243578	4	0.0608944	387.86	0
	Within groups	0.00157	10	0.000157		
	Total (Corr.)	0.245148	14			
Modulus of deformation						
	Treatments	45.4922	4	11.373	29.66	0
	Within groups	3.835	10	0.3835		
	Total (Corr.)	49.3272	14			

APPENDIX 5A: ANOVA TABLE FOR TREATMENT EFFECTS ON CIE L*, a*, b* COLOUR PARAMETERS OF ROCK BUNS DOUGH

Attributes	Source of Variation	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Lightness						
	Treatments	57.8577	4	14.4644	33.9	0
	Within groups	4.26667	10	0.426667		
	Total (Corr.)	62.1244	14			
Redness						
	Treatments	41.358	4	10.3395	66.68	0
	Within groups	1.55067	10	0.155067		
	Total (Corr.)	42.9087	14			
Yellowness						
	Treatments	67.1138	4	16.7784	31.36	0
	Within groups	5.3506	10	0.53506		
	Total (Corr.)	72.4644	14			
Hue angle						
	Treatments	69.4422	4	17.3606	20.76	0.0001
	Within groups	8.36347	10	0.836347		
	Total (Corr.)	77.8057	14			
Chroma						
	Treatments	62.1367	4	15.5342	29.83	0
	Within groups	5.20787	10	0.520787		
	Total (Corr.)	67.3446	14			

APPENDIX 5B: ANOVA TABLE FOR TREATMENT EFFECTS ON CIE L*, a*, b* COLOUR PARAMETERS OF ROCK BUNS CRUMB

Attributes	Source of Variation	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Lightness						
	Treatments	113.56	4	28.39	9.19	0.0022
	Within groups	30.9003	10	3.09003		
	Total (Corr.)	144.46	14			
Redness						
	Treatments	61.8832	4	15.4708	171.36	0
	Within groups	0.9028	10	0.09028		
	Total (Corr.)	62.786	14			
Yellowness						
	Treatments	48.888	4	12.222	10.82	0.0012
	Within groups	11.2983	10	1.12983		
	Total (Corr.)	60.1863	14			
Hue angle						
	Treatments	227.622	4	56.9055	57.29	0
	Within groups	9.93333	10	0.993333		
	Total (Corr.)	237.555	14			
Chroma						
	Treatments	42.7146	4	10.6787	9.6	0.0019
	Within groups	11.1272	10	1.11272		
	Total (Corr.)	53.8418	14			

APPENDIX 5C: ANOVA TABLE FOR TREATMENT EFFECTS ON CIE L*, a*, b* COLOUR PARAMETERS OF ROCK BUNS CRUST

Attributes	Source of Variation	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Lightness						
	Treatments	270.853	4	67.7131	20.36	0.0001
	Within groups	33.2595	10	3.32595		
	Total (Corr.)	304.112	14			
Redness						
	Treatments	61.8832	4	15.4708	171.36	0
	Within groups	0.9028	10	0.09028		
	Total (Corr.)	62.786	14			
Yellowness						
	Treatments	48.888	4	12.222	10.82	0.0012
	Within groups	11.2983	10	1.12983		
	Total (Corr.)	60.1863	14			
Hue angle						
	Treatments	1825.86	4	456.464	11.73	0.0009
	Within groups	389.283	10	38.9283		
	Total (Corr.)	2215.14	14			
Chroma						
	Treatments	333.856	4	83.464	28.01	0
	Within groups	29.794	10	2.9794		
	Total (Corr.)	363.65	14			

APPENDIX 6A: QUESTIONNAIRE FOR SENSORY EVALUATION OF MANGO PIE TREATMENTS

ACCEPTABILITY TEST

Name _____ Date _____

Product: _____

Sample code _____

Please before you are samples of Mango Pie. Using the scale below please examine them in terms of appearance, colour, aroma, taste, mouth feel, acidity, crumbliness, chewiness, gumminess, and overall acceptability by drawing a vertical line at a point which perfectly fits your description.

Appearance

not attractive — very attractive

Colour

not uniform — very uniform

Aroma

not typical of Mango — typical of Mango

Taste

not tasty — very tasty

Mouth feel

not smooth — smooth

Acidity

not acidic — acidic

Texture

Crumbliness

not crumbly — very crumbly

Chewiness

not chewy — very chewy

Gumminess

not gummy — very gummy

Overall acceptability

not acceptable — very acceptable

Comment(s): _____

- Of the five samples which do you like best?
- Would you buy this product? Yes No

APPENDIX 6B: ANOVA TABLE FOR SENSORY EVALUATION OF MANGO PIE TREATMENTS

Attribute	Source of Variation	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Appearance						
	Treatments	1081.12	1	1081.12	14	0.0008
	Within groups	2316.75	30	77.225		
	Total (Corr.)	3397.87	31			
Colour						
	Treatments	427.781	1	427.781	5.28	0.0288
	Within groups	2431.69	30	81.0563		
	Total (Corr.)	2859.47	31			
Aroma						
	Treatments	162.634	1	162.634	2.57	0.1201
	Within groups	1838.33	29	63.3908		
	Total (Corr.)	2000.97	30			
Taste						
	Treatments	52.8399	1	52.8399	0.54	0.4703
	Within groups	2862.84	29	98.7185		
	Total (Corr.)	2915.68	30			
Mouth feel						
	Treatments	338	1	338	3.91	0.0573
	Within groups	2593.88	30	86.4625		
	Total (Corr.)	2931.88	31			
Crumbliness						
	Treatments	258.781	1	258.781	2.85	0.1016
	Within groups	2721.19	30	90.7062		
	Total (Corr.)	2979.97	31			
Chewiness						
	Treatments	344.531	1	344.531	4.52	0.0419
	Within groups	2288.19	30	76.2729		
	Total (Corr.)	2632.72	31			
Acidity						
	Treatments	4.5	1	4.5	0.04	0.8451
	Within groups	3475	30	115.833		
	Total (Corr.)	3479.5	31			
Gumminess						
	Treatments	760.5	1	760.5	11.23	0.0022
	Within groups	2031	30	67.7		
	Total (Corr.)	2791.5	31			
Overall Acceptability						
	Treatments	2.53125	1	2.53125	0.06	0.8097
	Within groups	1287.19	30	42.9062		

Total (Corr.)	1289.72	31	

APPENDIX 6C: TABLE FOR KRUSKAL- WALLIS TESTS ON MANGO PIE TREATMENTS

Attribute	Sample	Sample Size	Average Rank
Appearance			
	1	16	21.8438
	2	16	11.1563
	Test statistic = 10.4202		P-Value = 0.00124587
Colour			
	1	16	19.9375
	2	16	13.0625
	Test statistic = 4.31427		P-Value = 0.0377906
Aroma			
	1	16	14.875
	2	16	18.125
	Test statistic = 0.963229		P-Value = 0.326373
Taste			
	1	15	17.3333
	2	16	14.75
	Test statistic = 0.628039		P-Value = 0.428074
Mouth feel			
	1	16	13.4375
	2	16	19.5625
	Test statistic = 3.41615		P-Value = 0.0645579
Crumblines s			
	1	16	19.5938
	2	16	13.4063
	Test statistic = 3.50682		P-Value = 0.061113
Chewiness			
	1	16	12.8125
	2	16	20.1875
	Test statistic = 4.96097		P-Value = 0.0259227
Acidity			
	1	16	16.0313
	2	16	16.9688
	Test statistic = 0.0800914		P-Value = 0.777174
Gumminess			
	1	16	11.375
	2	16	21.625
	Test statistic = 9.58628		P-Value = 0.00195958
Overall Acceptability			
	1	16	16.9375
	2	16	16.0625

Test statistic = 0.0700775 P-Value = 0.791224

APPENDIX 7: ANOVA TABLE FOR TEXTURE ANALYSIS OF MANGO PIE CRUST TREATMENTS

Attribute	Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Hardness						
	Treatments	83.7013	1	83.7013	0.78	0.427
	Within groups	429.123	4	107.281		
	Total (Corr.)	512.824	5			
Fracturability						
	Treatments	615.094	1	615.094	13.72	0.0207
	Within groups	179.266	4	44.8165		
	Total (Corr.)	794.36	5			

APPENDIX 8A: ANOVA TABLE FOR TREATMENT EFFECTS ON CIE L*, a*, b* COLOUR PARAMETERS OF MANGO PIE DOUGH TREATMENTS

Attributes	Source of Variation	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Lightness						
	Treatments	118.548	1	118.548	71.33	0.0011
	Within groups	6.64793	4	1.66198		
	Total (Corr.)	125.196	5			
Redness						
	Treatments	29.6593	1	29.6593	500.44	0
	Within groups	0.237067	4	0.0592667		
	Total (Corr.)	29.8963	5			
Yellowness						
	Treatments	8.16667	1	8.16667	5.72	0.075
	Within groups	5.71133	4	1.42783		
	Total (Corr.)	13.878	5			
Hue angle						
	Treatments	228.907	1	228.907	2939.73	0
	Within groups	0.311467	4	0.0778667		
	Total (Corr.)	229.219	5			
Chroma						
	Treatments	12.07	1	12.07	8.73	0.0418
	Within groups	5.53147	4	1.38287		
	Total (Corr.)	17.6015	5			

APPENDIX 8B: ANOVA TABLE FOR TREATMENT EFFECTS ON CIE L*, a*, b* COLOUR PARAMETERS OF MANGO PIE CRUMB TREATMENTS

Attributes	Source of Variation	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Lightness						
	Treatments	2.4576	1	2.4576	4.02	0.1155
	Within groups	2.4458	4	0.61145		
	Total (Corr.)	4.9034	5			
Redness						
	Treatments	0.380017	1	0.380017	1.07	0.3587
	Within groups	1.41613	4	0.354033		
	Total (Corr.)	1.79615	5			
Yellowness						
	Treatments	2.76082	1	2.76082	0.76	0.4326
	Within groups	14.5347	4	3.63367		
	Total (Corr.)	17.2955	5			
Hue angle						
	Treatments	3.21202	1	3.21202	0.87	0.4044
	Within groups	14.8103	4	3.70258		
	Total (Corr.)	18.0223	5			
Chroma						
	Treatments	2.64007	1	2.64007	0.71	0.4455
	Within groups	14.7787	4	3.69467		
	Total (Corr.)	17.4187	5			

APPENDIX 8C: ANOVA TABLE FOR TREATMENT EFFECTS ON CIE L*, a*, b* COLOUR PARAMETERS OF MANGO PIE CRUST TREATMENTS

Attributes	Source of Variation	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Lightness						
	Treatments	0.0962667	1	0.0962667	0.13	0.733
	Within groups	2.87627	4	0.719067		
	Total (Corr.)	2.97253	5			
Redness						
	Treatments	3.79215	1	3.79215	18.79	0.0123
	Within groups	0.807333	4	0.201833		
	Total (Corr.)	4.59948	5			
Yellowness						
	Treatments	2.54802	1	2.54802	3.07	0.1546
	Within groups	3.31953	4	0.829883		
	Total (Corr.)	5.86755	5			
Hue angle						
	Treatments	11.2486	1	11.2486	7.92	0.0671
	Within groups	4.26332	3	1.42111		
	Total (Corr.)	15.5119	4			
Chroma						
	Treatments	2.80167	1	2.80167	3.45	0.1366
	Within groups	3.24367	4	0.810917		
	Total (Corr.)	6.04533	5			