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EFFECT OF SOURSOP (*Annona muricata*)-DERIVED FAT REPLACER ON THE SENSORY AND TEXTURAL PROPERTIES OF ROCK CAKES

A THESIS SUBMITTED TO THE DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY; IN PARTIAL FUFILMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY

BY

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DECLARATION/CERTIFICATION

I hereby declare that I have fully undertaken this study report herein under the supervision of Professor James. H. Oldham and Mr. John Barimah and that except portions where references have been duly cited, this dissertation is the outcome of my own research and that no part of it has been published in part or in whole for another certificate in this university or elsewhere.

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ABSTRACT

In order to develop low calorie foods, fat in foods is being replaced with fat mimetics for health benefits. This research aimed to develop fat-reduced rock cakes by using a carbohydrate-based fat replacer prepared from freeze dried Soursop (*Annona muricata*). Analytical results indicated that the soursop-derived fat replacer had water holding capacity of 425.30% and a pectin content of 2.0 g/100 g, attesting to the high potentiality of soursop as a fat replacer in baked goods. Effects of fat reduction on the sensory and textural properties of the rock cakes were determined. Four rock cakes treatments (0%, 20%, 40% and 60% soursop-fat replaced treatments) were developed. Untrained sensory panelists determined that all fat reduced rock cakes (20%, 40% and 60%) were comparable in sensory attributes to the full-fat rock cake (0%- control). With the exception of astringency, no significant differences in sensory attributes existed between the full-fat rock cake and the fat reduced rock cakes. Statistical analysis of colorimetric measurements revealed that significant differences ($p \leq 0.05$) existed between the full-fat rock cake and the fat reduced rock cakes. Results from texture profile analysis indicated that hardness, fracturability, springiness, cohesiveness, gumminess, chewiness, resilience and modulus of deformation of the rock cakes increased with increasing fat reduction. Significant differences ($p \leq 0.05$) in textural properties existed between the full-fat rock cake and the fat reduced rock cakes. Rock cakes produced from soursop-fat replacer at a 40% substitution level were comparable to the full fat rock cake in terms of sensory attributes and also better than their full fat complements with respect to texture quality.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Fat is the body's most concentrated energy source providing 9 kcal/g compared to 4 kcal/g for proteins and carbohydrates (International Food Information Council, 2005). Our bodies need fat for growth and development as well as for the supply of essential fatty acids and fat-soluble vitamins such as vitamins A, D, E and K. As a food component, fat contributes key sensory and physiological benefits such as flavour, mouth feel, taste, aroma, appearance, texture, tenderness, lubricity and palatability in foods (Rosenberg, 2006). Therefore, without fat our food would be dry, flavourless, and gummy.

Even though fat is an important functional ingredient in many foods, dietary guidelines suggest reducing dietary fat consumption to 30% or less of total daily energy intake. These recommendations have been given to reduce the risk of heart disease, obesity, certain types of cancers, and gall bladder diseases, which have all been related with high fat intake from various clinical, epidemiological and metabolic researches (Glueck *et al.,* 1994). As consumers are becoming aware of the need to reduce fat in their diet, there has been an increase in the demand for healthy, flavourful and low-fat foods (Akoh, 1998). To meet this demand, the food industry has reduced the fat in various food products with the aid of fat replacers to replace some or all of the fat without sacrificing its functional properties in the food.

Though pastries have a high fat and calorie level, they are known to constitute a part of the daily diet of most people. According to Hollingsworth (1996), a 10% fat reduction in the proportion of pastries can result in a corresponding reduction of 238 kcal/day of total fat intake. It is therefore necessary to develop fat replacers which can substitute for fat in these pastries.

Fat replacers, usually categorised as fat substitutes or fat mimetics are ingredients designed to provide some or all of the functional properties of fat while providing fewer calories than the fat being replaced (Akoh and Swanson, 1994). Each fat replacer has its own functions, advantages, and disadvantages, which food processors must understand in order to select the most effective fat substitutes for specific food applications. They are obtained from three main sources, namely:

- Carbohydrate-Based Fat Replacers: cellulose, fibre (e.g pectin), gums, starches etc.
- Protein-Based Fat Replacers: milk, egg, whey, soy etc.
- Fat-Based Fat Replacers: olestra, caprenin, salatrim etc (Calorie Control Council, 2006).

In fruits, the water retaining property of their inherent fibre which is mostly pectin makes them fat replacers (Vaclavik and Christian, 2003).

Soursop (*Annona muricata*) is one of the most tastiest, nutritious and healthiest fruits in the world with a very detectable flavour. Apart from its nutritive composition, soursop has a high content of fibre compared to other fruits (Janick *et al.,* 2008). The high fibre (pectin) content of soursop attests to its potential as a fat replacer, thus it can be used for fat replacement purposes in pastries like rock cakes. Apart from its fibre content, soursops also have appreciable amounts of vitamins, minerals, protein and calories which are all well documented (Morton, 1987).

1.2 Problem statement

Research by Escalona *et al.* (2004) revealed that about 40% of people living in southern Ghana are suffering from obesity and may have problems with hypertension which is largely due to high amounts of fat in foods that they consume. Because of the awareness of consumers of high fat foods to be related to obesity and serious health ailments, food companies are now challenged in ensuring that the foods that they produce are low in fat but still palatable and attractive to the consumer (Miller and Groziak, 1996).

1.3 Justification

Good nutrition and health is a universal right that everyone must have. It is important for nation building and the development of any society. An assessment of the potential use of soursop as a fat replacer will therefore be an avenue for exploring ways of reducing fat in some types of fatty foods, thereby leading to reduction in cases of obesity and hypertension. The cultivation and use of soursop in different food products could also provide employment for socioeconomically vulnerable groups such as women and the youth. Their involvement will be an avenue for improving incomes and ultimately, their standard of living. In Ghana soursop is not widely cultivated but if new uses of the fruits can be found there will be an increase in its demand and also make the fruit receive attention from researchers.

1.4 Research Objective

To study the effect of soursop- derived fat replacer on the sensory and textural properties of reduced-fat rock cakes.

1.4.1 Specific Research Objectives

- To determine the proximate, water-holding capacity, pectin and some mineral contents of the soursop derived fat replacer.
- To determine the fat and moisture contents of the reduced fat rock cakes.
- To evaluate the sensory and colorimetric properties of the reduced-fat rock cakes.
- To evaluate the textural properties of the reduced-fat rock cakes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Health Benefits of Tropical Fruits

Botanically, a fruit is the developed ovary of a flower, after fertilization has taken place. Whatever the definition of a fruit may be, the nutritional, health and economic values of fruits cannot be over emphasized. Tropical fruits such as mango, papaya, banana, avocado and coconut are the most important in economic and marketing terms with mango being the most dominant produce worldwide (FAO, 2003).

Fresh fruits are the best carriers of essential minerals, vitamins, phenolic antioxidants, bioactive nutrients, dietary fibre and glucosinolates which together help to prevent micronutrient deficiencies and cardiovascular diseases. The World Health Organization (WHO) reported that high cholesterol contribute to 56% of cases of coronary heart disease worldwide and causes about 4.4 million deaths each year due to the low consumption of fruits (WHO, 2005). It has therefore been recommended by WHO that intake of at least 400 g/day of fruits and vegetables may protect against chronic diseases.

2.2 Dietary Fats

Collectively, fats and oils belong to a broad group of chemical compounds called lipids. Lipids are classified as triglycerides, phospholipids, and sterols. Most natural fatty acids contain an even number of carbons ranging from 4 to 24. The longer the fatty acid chain, the higher the melting point, and the more likely to be solid at mixing temperatures compared to shorter fatty acid chains (McWilliams, 1993). Saturated fatty acids have single bonds between the carbon atoms (Bennion, 1995). Animal fats such as cheese, butter and milk are saturated. Unsaturated fatty acids contain one or more double bonds between their carbon atoms. Monounsaturated fatty acids contain only one double bond and polyunsaturated fatty acids have more than one double bond between their carbon atoms. Foods such as salmon, tuna, soybean oil and sunflower oil are high in unsaturated fatty acids (Piper, 1999).

2.2.1 Fat Nutrition

The energy value of fats is 9 kcal/g, serving as an important source of calories for the body. According to Gifford (2002), the breaking of bonds within fat molecules releases the energy that the body uses. Some foods that are commonly known to contain large amounts of fat include butter, fried foods, hamburgers, e.t.c. However foods such as cookies, cakes, cheese, and ice cream have hidden sources of fat that may not be obvious to the person eating them (Gifford, 2002). Reducing fat intake in our diets daily to less than 30% of total calorie intake and increasing consumption of polyunsaturated fatty acids is very important in ensuring a healthful diet (Stubbs *et al.*, 1995).

2.2.2 Functions of Dietary Fat in Food Systems

Fat is found in many different foods, and can be obtained from either animal or plant source. Lipids that are solid at room temperature are referred to as fats, while those that are liquid at room temperature are called oils (Bennion, 1995). Fats that remain solid at room temperature appear to be a solid mass, when they are in fact crystals of fat (McWilliams, 1993). The crystalline nature determines the effectiveness of these solid fats in food preparation. According to McWilliams (1993), there are four types of fat crystals: alpha (α), beta prime (β^1), intermediate, and beta (β). Alpha crystals are extremely fine and unstable, quickly recrystallizing into the next crystalline form. Beta prime (β^1) crystals are very fine and stable when used for baking purposes. Using solid fats with β^1 crystals promotes a fine texture in the finished baked product (McWilliams, 1993).

Fat contributes many functional properties in foods. Penfield and Campbell (1990), reported that, one of the most important functions of fat is to tenderize baked products. Moreover, fat affects the texture of foods: they produce a fine cell structure in cakes, affect the smoothness of crystalline candies and frozen desserts, contribute flakiness in pastries, etc. A report by McWilliams (1993) indicated fat to interfere with development of tough gluten network by inhibiting contact between water and flour proteins. Fat also improves the volume of baked products by incorporating and retaining air during the mixing of the batter. It also provides colour, flavour, transfer heat and act as emulsifiers in food products (Bennion, 1995).

2.2.3 Statistics on Fat Related Diseases

Chronic diseases associated with high consumption of fat are diabetes, heart diseases, obesity, gall bladder diseases, cancer and hypertension. Yeboah (2007) indicated in a Ghanaian newspaper, Daily Graphic, that statistics on the prevalence of overweight and obesity in seven African Countries disclosed Ghana to have the largest number of overweight and obese people, constituting more than three million out of the estimated population of 20.7 million. A report by Wolf and Colditz (1998) indicated that overweight and obesity have reached epidemic proportions in the United States.

According to Wolf and Colditz (1998), more than 61% of Americans aged 20 years and above are overweight and one-fourth of American adults are obese, an estimated 97 million. They also reported that, since 1980 the number of overweight children has doubled, and the number of overweight adolescents has tripled worldwide which all poses an incredible negative impact on the economy of affected countries. Another report by Finkelstein (2009) revealed that the medical care costs of obesity in the United States are very staggering and that in 2008 these costs totalled about $147 billion. This trend is very alarming and has therefore been reported by Johns and Eyzaguirre (2006) for sustainable, accessible and locally-adapted resources to be assembled to revoke this trend.

2.3 Fat Replacers

Fat replacers are ingredients designed to replace all or part of the functions of fat in a product, with minimum impact on the organoleptic quality of the food product and also yielding fewer calories than the fat it is replacing (Akoh and Swanson, 1994). Fats have a variety of beneficial properties and functions in foods which make it difficult to find satisfactory substitutes. According to the Calorie Control Council (2006), the ideal fat replacer should be innocuous and have all the functional and organoleptic properties of fats except their calorie value, which should be significantly lower. Some properties to be considered in choosing a fat replacer are thermal stability, viscosity, tactile sensation, colour, aroma and taste (Jandacek, 1990).

According to researchers, there are several categories of fat replacers of which the most common ones are:

- Fat mimetics - These are ingredients belonging to other macronutrient categories such as carbohydrates or proteins, which replace the lubricity, bulk, body and mouthfeel of fats in food products by holding water. Examples of carbohydrate and protein fat mimetics are starch, cellulose, gums, dextrins, whey, zein, microparticulated egg and milk. Because they are carbohydrates or proteins, they are digestible but less energy dense than fats providing from 0 to 4 kcal/g. Fat mimetics are generally used in hydrated products like desserts and spreads (Clegg, 1996).
- Fat substitutes - These are ingredients that closely approximate the functional and sensorial properties of fats yielding less than 9 kcal/g though they are lipid-based.

According to Akoh (1998), they are usually modified triglycerides so that they are able to resist digestive enzymes, although some can partially be digested. They are also stable at cooking and frying temperatures due to their fat based nature (Jones, 1996).

- Fat barriers – These are ingredients 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).

There are three major types of fat replacers namely protein-based, carbohydrate-based and fat-based replacers (Owusu-Apenten, 2005).

2.3.1 Protein-Based Fat Mimetics

Several fat replacers are derived from a variety of protein sources such as microparticulated protein, egg, milk, whey, soy, gelatine and wheat gluten. According to Giese (1996), these protein- based fat mimetics are able to form coagulated particles that mimic the mouth feel and texture of fat. Like carbohydrate-based fat mimetics, protein-based fat mimetics provides four kilocalories per gram (4 kcal/g), thereby reducing the calorie content of food by five kilocalories per gram (5 kcal/g) of fat replaced (Cheung *et al.*, 2002). Cheung *et al.* (2002) reported that, microparticulated protein-based fat mimetics are suitable for frying, pasteurization, and ultra-high temperature processing but not suitable for high temperature frying. It is used in dairy products and the production of cheese, ice-cream, butter and sour cream.

Although protein-based fat mimetics are generally not sufficiently heat stable to withstand frying, they are suitable for use as ingredients in foods that may undergo cooking, retorting and baking (Brandt, 2000). According to Brandt, (2000), Simplesss® which is a protein based fat mimetic made from whey protein or milk and egg, is not suitable for frying but stable in baked goods, salad dressing, dairy products, margarine, butter, mayonnaise–type products, soups and sauces. Owusu-Apenten (2005), reported on a protein-based fat mimetic known as Dairy Lo®. Dairy Lo® is a protein-based fat mimetic manufactured through thermal denaturation of proteins from sweet whey producing 4 kcal/g in applied foods. Dairy Lo® helped to improve texture, flavour stability and mouth feel of low-fat foods (Owusu-Apenten, 2005).

2.3.2 Fat- Based Fat Mimetics

Fat-based fat replacers are made of fat molecules that are modified so that they cannot be absorbed or can only be partially absorbed in the intestine. Fat-based replacers mimic some or all the properties of the fat they replace and provide few calories or no calories at all because the chemical structure of the fat has been altered (Owusu-Apenten, 2005). Olestra, a calorie-free fat replacer made from vegetable oils and sugars is made up of six to eight fatty acids bound to a sucrose molecule (Akoh 1995). Research conducted on olestra by Akoh (1995) reported that unlike normal fats which have three fatty acids, the presence of extra fatty acids in olestra makes the olestra molecule too large to be absorbed, so it simply passes through the intestine and is eliminated as waste. In this way, it adds no calories to food and cannot be metabolized for energy. Also, according to Jandacek *et al.* (1990), olestra can be used as a 100% fat replacement in the preparation of savoury snacks such as potato chips, crisps, extruded snacks and crackers.

Other fat-based fat replacers such as caprenin and salatrim are partially digested and absorbed by the body supplying approximately 5 kcal/g as compared to 9 kcal/g for normal fats.

Owusu-Apenten (2005) reported that, caprenin is especially suited for confectionary products whereas salatrim is suited for confectionary, cookies, cakes, brownies and pie crusts.

Another group of fat-based mimetics referred to as emulsifiers, are combined with water to replace all or part of the fat in cookies, vegetables and dairy products (Akoh, 1998). Emulsifiers contain the same number of calories per gram as fat, but fewer grams are needed to achieve the same taste, texture, and mouth feel as fat when applied in food products (Swanson, 1998). Flack (1996) stated that emulsifiers possess many of the functionalities of fats and oils as exemplified in the fatty consistency, lubricity, texture and cohesiveness of fat.

According to Giese (1996), because emulsifiers have the same caloric value as fats, their role as fat replacers is in stretching the functionality of low fat levels and in replacing the functionality of fat when used in combination with other ingredients. Research conducted by many scientists have proven that some of these fat-based mimetics are highly versatile, heat stable and their addition to snack foods and yoghurt may result in a decreased energy and macronutrient absorption in lean, obese and overweight adults subjects up to 36 hours post consumption (Burns *et al.*, 2000).

The ultimate problem that the food industry is facing in reducing the amount of fat in their products is how they will be able to maintain the functional properties of fat in reduced fat systems during processing. The major requirement in achieving this goal is to have a better understanding of the functionality of fat in a particular food system before choosing a fat substitute that can mimic these functions and provide you with a better quality product. Clark (1994) stated that factors such as cost, availability, safety and quality are very important in the selection of fat replacers and should therefore be considered during food processing and food product development.

2.3.3 Carbohydrate-Based Fat Mimetics

Carbohydrates have been used in foods for several years to partially or totally replace fat and are generally recognised as safe (Akoh, 1998). Carbohydrate-based fat mimetics are derived from carbohydrates such as gums, modified food starches, fibre, dextrin, pectin, cellulose and maltodextrin (Glicksman, 1991). These carbohydrate ingredients provide some of the functions of fat in foods by binding water, adding volume, thickening and stabilizing foods. They are typically used in foods such as baked goods, frozen desserts, yogurts, cheeses, sour cream, low-fat puddings, processed meats, salad dressings, sauces and spreads due to their ability to serve as thickeners, stabilizers or gelling agents (Swanson *et al.,* 2002).

According to Giese (1996), dextrins and modified starches are the most commonly used carbohydrate-based fat mimetics because of their ability to absorb water and form gels impacting texture, mouth feel and opacity similar to fats. Harkema (1996) also reported on maltodexrins derived from potato starches in enhancing creaminess, providing body and giving a fatty mouth coating to food products such as cream soups and sauces, bakery fillings and frozen desserts. Modified starches of varying sources and types are used in fat replacing systems to provide sensory properties such as texture and mouth feel in food products (Akoh, 1995). Owusu-Apenten (2005) reported on commercially modified starches such as Oatrim and Z-trim used in food industries to provide texture, moistness, mouth feel, and smoothness in baked goods, burgers, hot dogs, cheese, salad dressings, ice creams and yoghurts. A report by Roller and Jones (1996) proved carbohydrate-based fat replacers obtained from starches to perform well in high moisture foods, such as margarine spreads, salad dressings, sauces, baked goods, frostings, filling and sausages.

Giese (1996) also reported that gels formed by pectin can be used to replace fat in various food products such as baked goods and burgers. According to Nielsen (1996), a special form of fat replacer obtained from pectin provides a range of properties such as heat stability, shear, neutral taste and fat-like dissipation and can be used in food applications such as spreads, mayonnaise, salad dressings, baked products, ice creams, processed meats and processed cheese. Like fats, methylcellulose gums helps to retain air in foodstuffs to improve structure, stabilize air or carbon dioxide bubbles to reduce volume loss and enhance moisture retention in fried foods, baked goods, liquid foods, frozen dairy products and low-fat whipped toppings (Akoh, 1994). Despite these numerous applications of carbohydrate-based fat mimetics, they are limited in their unsuitability for frying (Akoh, and Swanson, 1994).

2.3.3.1 Carbohydrate-Based Fat Mimetics in Baked Products

Combinations of carbohydrate-based fat replacers are often used in baked products because they can mimic the functions of fat in these products. Desired characteristics of a high-quality baked product include a golden brown colour, high volume, fine even crumb, pleasing flavour, and a soft, velvety, moist and tender texture and mouth feel (Bennion, 1995). Glueck *et al.* (1994) reported that different types of carbohydrate-based fat replacers have been used to mimic these characteristics in baked goods.

According to Glueck *et al.* (1994), xanthan gum is added as an ingredient in baked goods, as bulking agents and as a stabilizer in cake batters. Sodium carboxymethylcellulose (CMC) is also used in baked goods to increase volume, improve cell structure, and stabilize batters

(Nonaka, 1997). Maltodextrin provides a pleasing sensory profile of moisture, lubricity, texture, and taste in baked goods. High-fructose corn syrup also provides sweetness, colour, humectancy, and tenderness in baked products (Akoh, 1995).

2.3.4 Importance of Fat Replacers

A 2000 national survey revealed that the top three reasons for using reduced-fat products were to stay in better overall health, to eat or drink healthier foods and beverages, and to reduce intake of fat and calories (ADA, 2002). The food industry has been urged by many health advocates to create low-fat products, resulting in an increase in different kinds and amounts of palatable low fat foods, ranging from desserts and snack foods to cheeses and yogurts (Glueck *et al.*, 1994). Research done by Howarth *et al.* (2001) proved that, the 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. Consumption of fat replaced foods such as spreadable table fats, desserts, snacks, baked goods, cheese and yogurt, contribute significantly to lower intakes of total fat and saturated fat compared to the consumption of only high-fat food products (Bray *et al.*, 2002; Cheung *et al.*, 2002).

According to Weststrate *et al.* (1998), some fat replacers exhibit physiologically beneficial effects. This literature is supported by the findings of Ruthig *et al.* (2001); Elsner *et al.* (1998) and Satia-Bouta *et al.* (2003). They reported that a fat replacer obtained from powdered soluble oat fibre containing β-glucans in short-term clinical trials, lower body weight, blood lipids and systolic blood pressure among adults. They also observed that, the fat replacer exhibited the ability to improve glucose tolerance, act as an antioxidant and improve acceptability of low-fat products. This report is confirmed by Reyna *et al.* (2003)

who concluded that fibre used as a fat replacer may be very important in regulating food intake, maintaining weight and in avoiding weight gain in adults.

Therefore, a population strategy for combating overweight, obesity and chronic disease may feature the transition from the consumption of full-fat products to lower calorie, reduced-fat products (WHO, 1998). On a population level, replacing 1 to 2 g fat/day by using fat replacers and fat-modified foods can potentially prevent weight gain and associated chronic diseases and assist in promoting healthful eating behaviours (WHO, 1998; Eldridge *et al.*, 2002). Fat replacers can play a useful role in maintaining the palatability of reduced-fat foods without sacrificing the hedonic qualities of the food, provided that the resulting food is lower in fat and the consumer does not perceive "reduced-fat" or "fat-free" as a license to over consumption (ADA, 2002).

2.3.5 Safety of Fat Replacers

Consumers' safety concerns over ingredients added to compensate for fat removal highlight the need for educating the general population about fat replacers and their proper use (Archer *et al.*, 2004). Based on the GRAS status of the majority of these substances, FDA of United States of America provides assurances that the current fat replacers are safe to use in foods (FDA, 1994). Fat replacers could potentially be consumed in large quantities, given their widespread use in reduced-fat products.

According to ADA (2002), few, if any, health concerns have been raised regarding the adverse impact of carbohydrate-based or protein-based fat substitutes. Fat-based substitutes derived from modifying length or numbers of fatty acids also seem to have no known safety issues. FDA (1994) reported that polydextrose and olestra are products with known concerns about excessive use. Polydextrose can have a laxative effect when consumed above specified levels indicated on food labels. Olestra may cause leaky, fatty stools and loss of fat soluble vitamins. However, these side effects associated with over consumption of olestra and polydextrose are not long term and have no adverse health effects (FDA, 1994).

In general, the majority of fat replacers pose no health concerns after consumption. According to ADA (2002), there is limited evidence at the present time on the long-term adverse consequences associated with the consumption of foods substituted with fat replacers. However, further research is required to study the safe use of fat replacers by children and adults and to evaluate fully their long-term health effects.

2.4 Pectin

2.4.1 Source

Pectin is a heterogeneous group of acidic structural polysaccharides found in fruit and vegetables such as citrus, apples, guavas, quince, plums, gooseberries, cherries, grapes and strawberries. It forms about 2% to 35% of plant cell walls. The main raw-materials for pectin production are dried citrus peel or apple pomace (Ridley *et al.,* 2001).

2.4.2 Chemistry of Pectin

Pectin is defined as a complex polysaccharide consisting mainly of esterified D-galacturonic acid residues with α-(1→4) chain. The acid groups along the chain are esterified with methoxyl groups. The ratio of esterified to non-esterified galacturonic acid determines the behavior of pectin in food applications (Thibault and Ralet, 2001).

Commercially, pectins are categorised according to their methoxyl content and whether they form gels quickly or slowly. Marudova *et al.* (2004) reported that pectins are classified into two groups namely; high methoxyl pectins (> 50% esterified) and low methoxyl pectins (< 50 % esterified). According to Marudova *et al.* (2004), three pectic polysaccharides have been isolated from plant cell walls. These are:

- Homogalacturonans
- Substituted galacturonans
- Rhamnogalacturonans

Homogalacturonans are linear chains of α-(1→4)-D-galacturonic acid. Substituted galacturonans are characterized by the presence of saccharide appendant residues (such as D-xylose or D-apiose in the respective cases of xylogalacturonan and apiogalacturonan) branching from a backbone of D-galacturonic acid residues. Rhamnogalacturonan pectins contain a backbone of repeating disaccharide. From many of the rhamnose residues, side chains of various neutral sugars such as D-galactose, L-arabinose and D-xylose branch off (Voragen *et al.,* 1995).

Amidated pectin is a modified form of pectin, which has some of the galacturonic acid converted with ammonia to carboxylic acid amide. Gels from amidated pectin are thermo-reversible. That is, they can be heated to form liquid and after cooling solidify again (Thibault and Ralet, 2001).

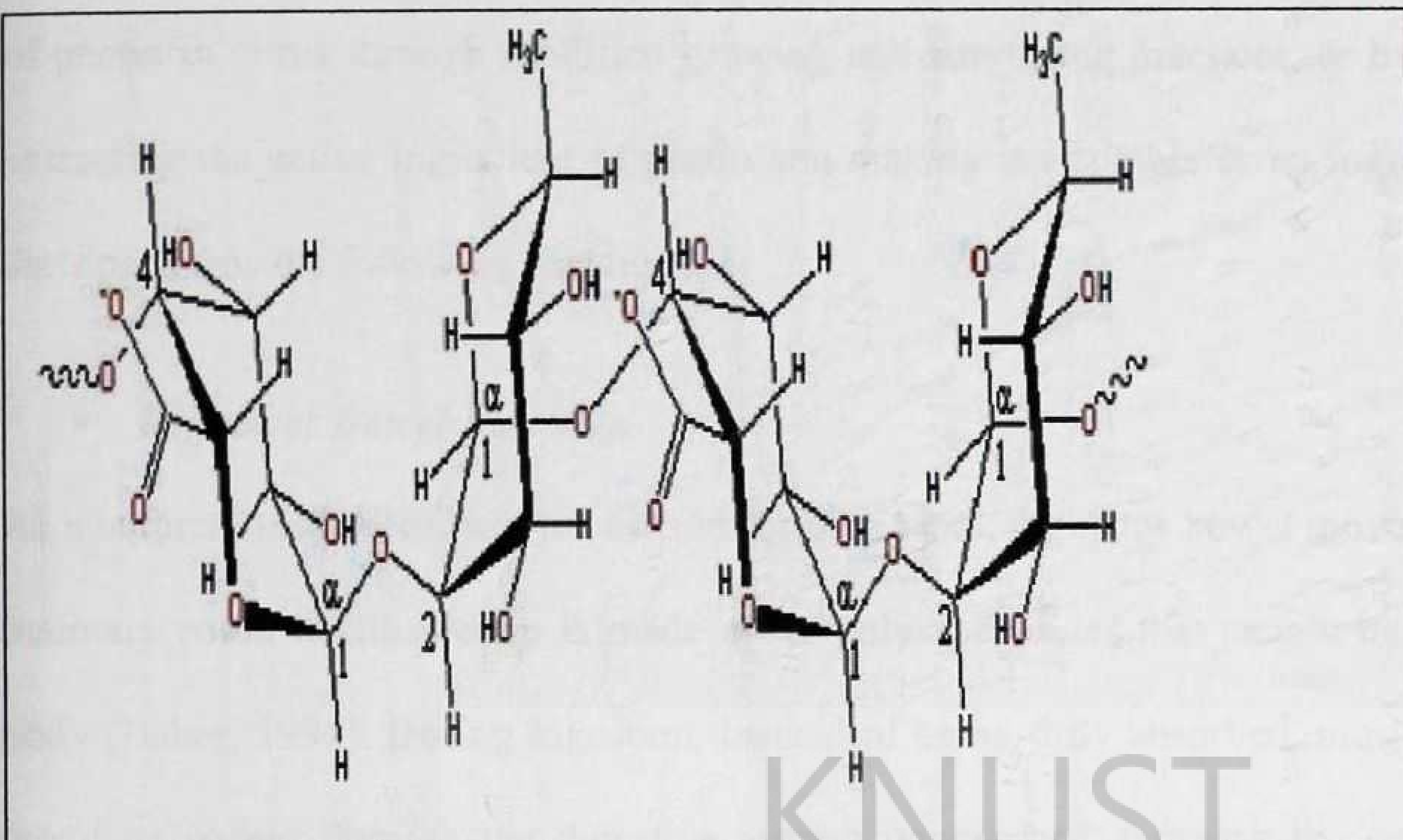

Figure 1: Structure of Pectin **Source: Ridley *et al.,* 2001.**

2.4.3 Dietary Uses of Pectin

According to Ridley *et al.* (2001), the main use of pectin is as a gelling agent, thickening agent and as a stabilizer in foods. As a soluble fibre that becomes thickened and gelatinous in water, pectin is used as an additive to solidify or texturize jams, jellies, yoghurt and also as fat substitutes in baked foods. The classical application is giving the jelly-like consistency to jams or marmalades, which would otherwise be sweet juices (Voragen *et al.,* 1995). In some countries, pectin is also available as a solution or an extract, or as a blended powder, for home jam making (Baker, 1980).

Typical levels of pectin used as food additives are between 0.5 – 1.0% which is about the same amount of pectin present in fresh fruits (Thibault and Ralet, 2001). Researchers in Texas have discovered a link between pectin consumption and reduced risk of prostate cancer. The study discovered that pectin from citrus in a way helps to prevent the mechanism that triggers prostate malignancy (Hergenbart, 2001). According to Hergenbart (2001), researchers can help explore ways to increase pectin consumption by promoting the presence of pectin in citrus through modified growing and harvesting practices, or by modifying and extracting the active ingredient of pectin and making it available as an ingredient. Pectin in diets performs the following functions:

- ***Regulates Bowel Function***

As a natural laxative, dietary pectin adds bulk to stool, regulates bowel movements and helps maintain colon health. Pectin is made up of polysaccharides that cannot be digested by the body (Baker, 1994). During digestion, instead of being fully absorbed, most of the pectin in our diets passes through the digestive system unabsorbed, carrying the waste products of digestion. Voragen *et al.* (1995) also stated that pectin helps to increase viscosity and volume of stool to prevent constipation and diarrhoea.

- ***Reduces Low-Density Lipoprotein ("Bad" Cholesterol)***

According to Hergenbart (2001), pectin's soluble fibre may help lower the amount of low-density lipoprotein (LDL) in the bloodstream which will help improve the cardiovascular health of the consumer. LDL, known as "bad" cholesterol, leads to the formation of fatty lesions on the arteries. These fatty lesions contribute to cardiovascular diseases and increase the risk of heart attack and stroke. The viscosity of soluble fibre helps to lower the body's production of LDL and hence protects the consumer against these ailments (Krauss and Howard, 2000).

- ***Stabilizes Blood Glucose***

It was reported by Baker (1980) that, the sugars in foods high in pectin are absorbed more slowly, hence reducing fluctuations in blood glucose level. Although apples, oranges, pears and other fruits contain sugar, the soluble fibre in these fruits prevents the body from digesting them quickly. Baker (1994) reported that the sugars in pectin rich foods are released slowly to provide sustained energy. When your blood glucose is stable, you are less likely to crave foods high in refined sugars and carbohydrates (Baker, 1994).

- ***Promotes Weight Loss***

Some research suggest that the effort that you put into chewing fruits or vegetables high in pectin gives your body more time to realize that you're full (Mattes, 2004). Kral *et al.* (2004) stated that consumption of low-calorie fruits, vegetables and dried beans can prevent overeating, which helps consumers to keep their weight under control. Voragen *et al.* (1995) also reported that snacks such as pears and grapes offer slow-release energy that can keep consumers active through the day, hence curbing their hunger between meals and cutting down on their cravings for sugary treats.

2.5 Soursop

Soursop is scientifically known as *Annona muricata*. Of the 60 or more species of the genus *Annona*, family Annonaceae, the soursop, *A. muricata*, is the most tropical, the largest-fruited and the only one lending itself well to preserving and processing (Paull, 1998). Though this magnificent fruit is native to Central America and the West Indies, it is now widely cultivated commercially throughout the tropics and sub-tropics (Janick *et al.*, 2008).

2.5.1 Soursop Description

The soursop tree is low-branching and bushy but slender because of its upturned limbs, and reaches a height of 25 or 30 ft (7.5-9 m). Young branchlets are rusty-hairy. The malodorous leaves, normally evergreen, are alternate, smooth, glossy, dark green on the upper surface, lighter beneath; oblong, elliptic or narrow obovate, pointed at both ends, 5 to 8 inches (6.25-20 cm) long and 1 to 10 inches (2.5-6.25 cm) wide (Paull, 1998). The flowers, which are borne singly, may emerge anywhere on the trunk, branches or twigs. The flowers are short stalked, 2 to 2.5 inches (45 cm) long, plump and triangular-conical (Salazar, 1965).

The fruit is more or less oval or heart-shaped, sometimes irregular, lopsided or curved, due to improper carper development or insect injury (Thompson, 2003). The fruit size ranges from 4 to 12 inches (10-30 cm) long and up to 6 inches (15 cm) in width and the weight may be up to 10 to 15 lbs (4.5-6.8 kg), (Paull, 1998). The skin of the fruit is dark-green at the immature stage, becoming slightly yellowish-green before the mature fruit is soft. When matured, the inner surface of the fruit is cream-colored and granular and separates easily from the mass of snow-white, fibrous, juicy segments (Morton, 1966). In terms of aroma, the pulp is somewhat pineapple-like but its musky, sub-acid to acid flavour is unique (Thompson, 2003). In each fertile segment there is a single oval, smooth, hard, black seed, 1/2 to 3/4 in (1.25-2 cm) long; and a large fruit may contain from a few dozen to 200 or more seeds. A typical soursop contains anywhere from 30-200 black-brown seeds (Morton, 1987).

2.5.2 Food Uses of Soursop

Ripe soursops of acid flavour and fibrous consistency are cut into sections and the flesh eaten with a spoon. The seeded pulp may be torn or cut into bits and added to fruit cups or salads, or chilled and served as dessert with sugar and a little milk or cream (FAO, 2001). The most common use of soursop throughout the tropics is the making of refreshing soursop drinks (Lutchmedial *et al.,* 2005). For this purpose, the seeded pulp may be pressed in a colander or sieve or squeezed in cheese cloth to extract the rich, creamy juice, which is then beaten with milk or water and sweetened with the addition of pink or green food colouring agents to make the drinks more attractive. Franco-Betancourt and Alvarez (1980) developed a method for canning soursop drinks by blending with sugar cane juice or papaya juice. These drinks were prepared by mixing 20% soursop juice and 80% sugarcane juice, heating to 100°C, canning, and heat processing at 100°C for 15 min.

A study conducted by Morton (1987) revealed that, in Puerto Rico and Netherlands Antilles, the pulp of soursop is used for making jellies, syrups and nectar for local use and export. The pulp can also be processed into excellent ice cream flavourings, candies, sorbets and beverages throughout much of Central and South America and is found in many supermarkets (Gratao *et al.,* 2007).

Soursop juice, thickened with a little gelatin, makes an agreeable dessert. Pinto *et al.* (2005) reported that, the canned pulp of soursop can be pureed or blended in the home and easily transformed into a delicious desert, although the fresh pulp is more desirable. In the Bahamas, frozen soursop ice cream is simply made by mashing the pulp in water, letting it stand, then straining to remove fibrous material and seeds. The liquid is then blended with sweetened condensed milk, poured into trays and stirred several times while freezing (FAO, 2001). In Indonesia, dodol sirsak, a sweetmeat, is made by boiling soursop pulp in water and adding sugar until the mixture hardens. Also in the Dominican Republic, soursop custard is enjoyed and a confection is made by cooking soursop pulp in sugar syrup with cinnamon and lemon peel (Gratao *et al.,* 2007).

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

Nutrient (unit)	Amount
Calories (kcal/g)	53.1.3-61.3
Moisture (g)	82.8
Protein (g)	1.00
Fat (g)	0
Carbohydrate (g)	14.63
Fibre (g)	0.79
Ash (g)	0.82
Calcium (mg)	10.3
Phosphorus (mg)	27.7
Iron (mg)	0.64
Vitamin A (mg)	0
Thiamine (mg)	0.11
Riboflavin (mg)	0.05
Niacin (mg)	1.28
Ascorbic acid (mg)	29.6
Tryptophan (mg)	11
Methionine (mg)	7

Source: Janick *et al.,* (2008).

2.5.3 Health Benefits of Soursop

Soursop does not only offer a sweet flavour for which it is well known for but is also rich sources of vitamin C, iron, folate, vitamin B_1, vitamin B_2, calcium, phosphorus, potassium and fibre (Janick *et al.,* 2008). These nutrients come together and promote a good immune and cardiovascular health system. Consumption of soursop provides the following health benefits:

- ***Prevents Urinary Tract Infection (UTI)***

Soursop is an excellent source of vitamin C, a nutrient which increases the acidity level of the urine. Increase in acidity level of urine will result in a decrease in the number of harmful bacteria that may be present in the urinary tract, hence protecting the tract from any form of infection (Lans, 2006).

- ***Regulate Digestion***

Besides nutritional components, soursop is also very rich in dietary fibre. Consumption of a whole fruit can satisfy 13 percent of daily needs of food fibre. Fibre is important in maintaining the health of the digestive tract and for proper bowel function. The fibre content can help prevent constipation by its role of facilitating digestion (Taylor, 2002).

- ***Prevents Bone Diseases***

Soursop contains half the potassium in bananas. Lack of potassium, together with magnesium, calcium and sodium (also known as electrolytes) in the body can cause muscle weakness and cramping. Minerals that are quite dominant in soursop are phosphorus and calcium. Both minerals are essential for the formation of bone mass, which is useful to form strong bones and prevent osteoporosis (Janick *et al.,* 2008).

- ***Boosts Good Cholesterol Levels***

Soursop is a good source of niacin, a vitamin which has been proven to exhibit significant benefits on levels of high-density-lipoprotein (HDL), the good cholesterol (Taylor, 2002).

- ***Prevents Pregnancy Complications***

The fruit contains appreciable levels of folate. Studies have also proven that soursop intake during pregnancy prevents folate deficiency in pregnant women. A lack of this vitamin during pregnancy may contribute to birth defects and pregnancy loss (Janick *et al.,* 2008).

- ***Helps Prevent Anaemia***

Soursops provide iron which prevents the common blood disorder anaemia. Anaemia is a condition in which the blood lacks enough healthy red blood cells. RBC is responsible for the distribution of oxygen to the body tissues, giving the body energy (Lans, 2006).

- ***Weight Regulation***

Soursop can help in weight regulation since it has a fat content of 0 g/100 g and high in dietary fibre. Fibre helps sate appetite and create a "full" feeling when consumed and is therefore recognized as a tool in controlling weight since the consumer will consume less energy and still feel "full" (Taylor, 2002).

2.5.4 Medicinal Benefits of Soursop

Soursop is not only a delicious and healthy fruit but it is used in the treatment of illnesses ranging from stomach ailments to worms (Taylor, 2002). Some of the medicinal benefits of soursops are;

- The seeds, which have emetic properties, can be used in the treatment of vomiting.
- The leaf decoction is effective for head lice and bedbugs.
- The crushed fresh leaves can be applied on skin eruptions to promote healing.
- The juice of the fruit can be taken orally as a remedy for urethritis, haematuria and liver ailments.
- The juice when taken during fasting is believed to relieve liver ailments and leprosy.
- To speed the healing of wounds, the flesh of the soursop is applied as a poultice unchanged for 3 days.
- A decoction of the young shoots or leaves is regarded as a remedy for gall bladder trouble, as well as coughs, catarrh, diarrhoea, dysentery, fever and indigestion.
- Mashed leaves are used as a poultice to alleviate eczema and other skin problems and rheumatism.
- The root bark is used as an antidote for poisoning.
- Soursop flowers are believed to alleviate catarrh.

- Decoction of leaves are used to compress inflammation and swollen feet (Asprey and Thornton, 1955; Taylor, 2002; Lans, 2006).

2.5.5 Soursop Allergy

Because soursop can be emetic, a large dose of its juice may make some people throw up (Morton, 1987). Soursop exhibits a depressant effect on the cardiovascular system and should therefore be avoided by people with heart conditions or people taking medications for blood pressure or cardiac problems. Eating too much may additionally accord to the development of Parkinson's ache due to its very high concentration of annonacin (Taylor, 2002).

2.6 Drying

Since most disease-causing organisms and microbes require a moist environment in which to survive and multiply, drying is a natural technique for food preservation. Drying preserves foods by removing enough moisture from food to prevent decay and spoilage (Fellows, 1997). The act of leaving foods out in the sun and wind to dry out is one of the earliest forms of food preservation (Singh and Heldman, 2001). Successful drying depends on factors such as enough heat to draw out moisture, dry air to absorb the released moisture and adequate air circulation to carry off the moisture. When drying foods, the key motive is to remove moisture as quickly as possible at a temperature that does not seriously affect the flavour, texture and colour of the food (Kaptan and Seylam, 1996). The oldest method of drying is sun drying. Despite its advantages, sun drying has limitations such as not being possible during rain and at night, any delay in drying leads to excess respiration which can cause browning and fungal growth, temperature control is also very difficult and there could be contamination by dirt, rodents and insects (Fellows, 1997). An improvement of sun drying is freeze drying. Freeze-drying is a dehydration process typically used to preserve and make a material more convenient for transport. Freeze-drying works by freezing the material and then reducing the surrounding pressure to allow the frozen water in the material to sublime directly from the solid phase to the gas phase.

2.7 Pastry Ingredients and their Functions

Ingredients such as flour, eggs, fats, sweeteners, liquids, leavening agents and flavouring agents are commonly used in pastry formulations. In pastry formulations, it should be noted that each ingredient has its own function. Hence, in order to obtain high quality baked goods, there should be a proper balance of ingredients (Paintsil, 2008).

2.7.1 Flour

Flour provides the structure in baked goods (Penfield and Campbell, 1990). Wheat flour contains two proteins namely, gliadin and glutenin, that interact with each other when mixed with water, forming gluten. Gluten in the dough will stretch to surround the leavening gases (carbon dioxide, air, or steam) that form and expand during rising (Bennion, 1995). Different types of wheat flours contain varying amounts of gluten-forming proteins. Flour made from hard wheat will form a strong gluten framework when mixed with water because it contains a high amount of proteins. It is this strong gluten framework that provides the structure desired in yeast bread. On the other hand, flour made from soft wheat cannot form gluten to the same degree as hard wheat flours because it contains less protein. Therefore, soft flours are good for cakes and pastries, where a tender product is desired (Penfield and Campbell, 1990).

2.7.2 Eggs

Eggs are important ingredients in baked goods because of the many functions they serve. They contribute to the structure of the baked product, incorporate air when beaten, add colour and flavour, provide protein, fat and liquid, and emulsify fat with liquid ingredients (McWilliams, 1993). Water from egg whites helps to activate gluten and provide some structure for baked goods. Reducing or omitting egg yolks in pastry formulations can lessen the fat and cholesterol content of the food but this may result in a less tender product as fat is a tenderizing ingredient (Bennion, 1995).

2.7.3 Fats

Fats such as butter, margarine, shortening, lard and oil contributes tenderness, flavour, moistness and a smooth mouth feel to baked goods (McWilliams, 1993). Because fats tenderize baked goods by interfering with gluten development, reducing the amount of fat in a recipe will result in a tougher baked product because gluten will develop more freely and this can be found in baked goods such as muffins (Penfield and Campbell, 1990).

2.7.4 Sweeteners

Sweeteners such as table sugar or sucrose, fructose and honey are commonly used in pastry formulation. Though it primarily provides sweetness, when used in small amounts, sugar also helps yeast to begin producing carbon dioxide for raising yeast dough whereas in large amounts sugar actually slows yeast fermentation (McWilliams, 1993). Sugar tenderizes dough and butter products and helps baked products to brown more readily through the Maillard reaction. Baked products that contain honey will be very moist because the fructose it contains absorbs moisture from the air. Excess honey may cause a baked product to become too brown. Fructose attracts more water than sugar, therefore, fructose sweetened baked products tend to be moist (Bennion, 1995).

2.7.5 Liquids

Liquids such as milk or juice are normally used in pastry formulations. Liquids are necessary ingredients in baked products for the hydration of protein, starch and leavening agents. Liquids contribute moistness, texture development, volume and improved mouth feel of baked products (Bennion, 1995). In addition to the contributions listed above, milk also contributes water, valuable nutrients, flavour and browning to baked goods (Penfield and Campbell, 1990).

2.7.6 Leavening Agents

Leavening involves the production of a gas that expands as the fat or dough is heated (Bennion, 1995). Evidence of leavening in baked products is provided by the tiny holes in a baked product. Leavening is desirable because it makes baked products light and fluffy (McWilliams, 1993). There are chemical leavening agents such as baking soda and baking powder and natural leavening agents such as yeast, air and steam. The volume of quick breads, cookies, cakes, and some candies depends largely on the amount of baking soda added to the butter or dough. Reducing the amount of baking soda without replacing it with another leavening agent will reduce the volume and lightness of the finished product (Bennion, 1995).

2.7.7 Salt

Salt enhances the flavours and sweetness of other ingredients in a baked product. In yeast dough, salt reduces yeast fermentation (Bennion, 1995). Reducing the amount of salt in yeast dough will cause the dough to rise too quickly, which will negatively affect the flavour and shape of the bread (Penfield and Campbell, 1990).

2.7.8 Flavouring Agents

In general, flavouring agents add flavour to baked goods (McWilliams, 1993).

2.8 Sensory Characteristics of Foods

Although there are many possible circumstances under which non-sensory factors such as price and nutritional image can have dominant effects, the sensory characteristics of foods are central to their continued purchase (Brannan *et al.,* 2001). During the sequences of actions that constitute food consumption, we perceive a whole range of different characteristics relating to the appearance, flavour and texture of the food. The perception of sensory characteristics of foods results from the stimulation of all our senses to some extent by the physicochemical properties of the foods. Sensory characteristics of a food item are typically perceived in the following order such as appearance, aroma, taste, texture and flavour (Kilcast, 2004).

2.8.1 Taste

Taste is one of the most critical factors that consumers consider in their selection of foods. Generally, there are five primary taste sensations including sweet, sour, bitter, salty and umami (Toldra, 2006). Taste is recognised on the surface of the tongue by specialized sensory receptors called taste buds which are found in small elevations, called papillae. Taste sensations are produced when bitter, salty, sweet or acid substances in a solution come into contact with taste receptors on the taste bud. A message is then sent to the brain from the taste cells to interpret and identify the specific taste (Fellows, 1999).

2.8.2 Appearance

The first purchasing decisions that are made by consumers are largely based on the appearance of a food (Brannan *et al.,* 2001). The appearance of a food is made up of many characteristics such as colour, shape, size and surface texture. In relation to appearance, the most important sensory attribute is colour (Fennema *et al.,* 2008). If the colour of a food is not attractive or does not match the consumers' idea of what the colour should be, it may be rejected no matter its nutritive quality or without even being tasted. In baked goods, the desired colour is a uniform golden brown crust (Meilgaard *et al.,* 1999).

2.8.3 Astringency

Astringency is a sensory attribute described as a drying-out, roughening, and puckery sensation felt in the mouth (Brannan *et al.,* 2001). Foods that are often astringent include red wine, green and black teas, soy-based foods, and certain fruits, especially when they're not yet ripe. In these foods, astringency is caused by the polyphenolic compounds they contain (Colona *et al.,* 2004). In sensory evaluation, astringency tends to be a difficult sensory attribute to assess because it takes over 15 seconds to fully develop, and it builds in intensity and becomes increasingly difficult to clear from the mouth over repeated exposures (Lyman and Green, 1990). A few approaches can be employed to overcome these issues: one suggested approach is to delay subsequent tasting of astringent samples until the oral environment has returned to a baseline state. A second option is to use a palate cleanser between samples. Several cleansers have been identified for their ability to alleviate astringency including various gums, oils and crackers (Brannan *et al.,* 2001).

2.8.4 Colour

Colour refers to the human perception of coloured materials which result from the detection of light after it has interacted with an object (Fennema *et al.,* 2008). Colour and appearance are major, if not the most important, quality attributes of foods. It is because of our ability to essentially perceive these that they are the first to be evaluated by the consumer when purchasing foods. One can provide consumers with the most nutritious, safest, and economical foods, but if they are not attractive, purchase will not occur (Giese, 1996). Consumers also relate specific colours of foods to quality. For instance, while redness of raw meat is associated with freshness, a green apple may be judged immature and more acidic though some are ripe when green (Fellows, 1999). During processing, drying or dehydration, the colour of foods undergoes changes due to evaporation, enzymatic and non-enzymatic reactions (Fennema *et al.,* 2008). Non-enzymatic reactions occur as a result of Maillard reactions during heating and storage whereas enzymatic reactions involve the formation of melanins due to oxidation of phenols present in fruits and vegetables in the presence of air (Giese, 2000).

2.8.5 Texture

The physical properties of foods including texture involve the sense of touch, also called the tactile sense. Texture is the term used to describe the characteristics or structure of a finished food product (Fennema *et al.,* 2008). Textural analysis of a food involves a measure of properties relating to how a food feels in the mouth. When food is contacted in the mouth, stimulation of the receptor muscles will lead to detection of sensations of smoothness, stickiness, graininess, brittleness, fibrous qualities or lumpy characteristics of a product. Only by observation, experience and perseverance will a person be able to know what the correct texture of a particular product should be (Elizabeth, 1977). Some commonly found textures in foods are firm and close, short and crumbly, spongy, flaky, coarse and hard textures. Textural analysis of a food can be done by sensory or instrumental method of analysis (Toldra, 2006). Sensory analysis of texture involves use of the senses of smell, taste, sound and touch. In some cases, instrumental mode of assessing food texture is preferred over sensory analysis since they can be done under well defined controlled conditions (Szczesniak, 1987). Also, whereas sensory analysis is time wasting, instrumental methods helps to reduce cost, save time and at the same time provides useful objective results. Both sensory evaluation techniques and instrumental measurements are used in food texture research to assess texture parameters (Bourne, 1978). According to Szczesniak (1987), correlations are generally used to assess the relationship between the instrumental measurement and sensory perception on order to predict consumer responses or to evaluate quality control parameters. Szczesniak *et al.* (1963), defined texture profile analysis as an imitative test used to subject food to severe crushing and breaking forces similar to what occurs during chewing.

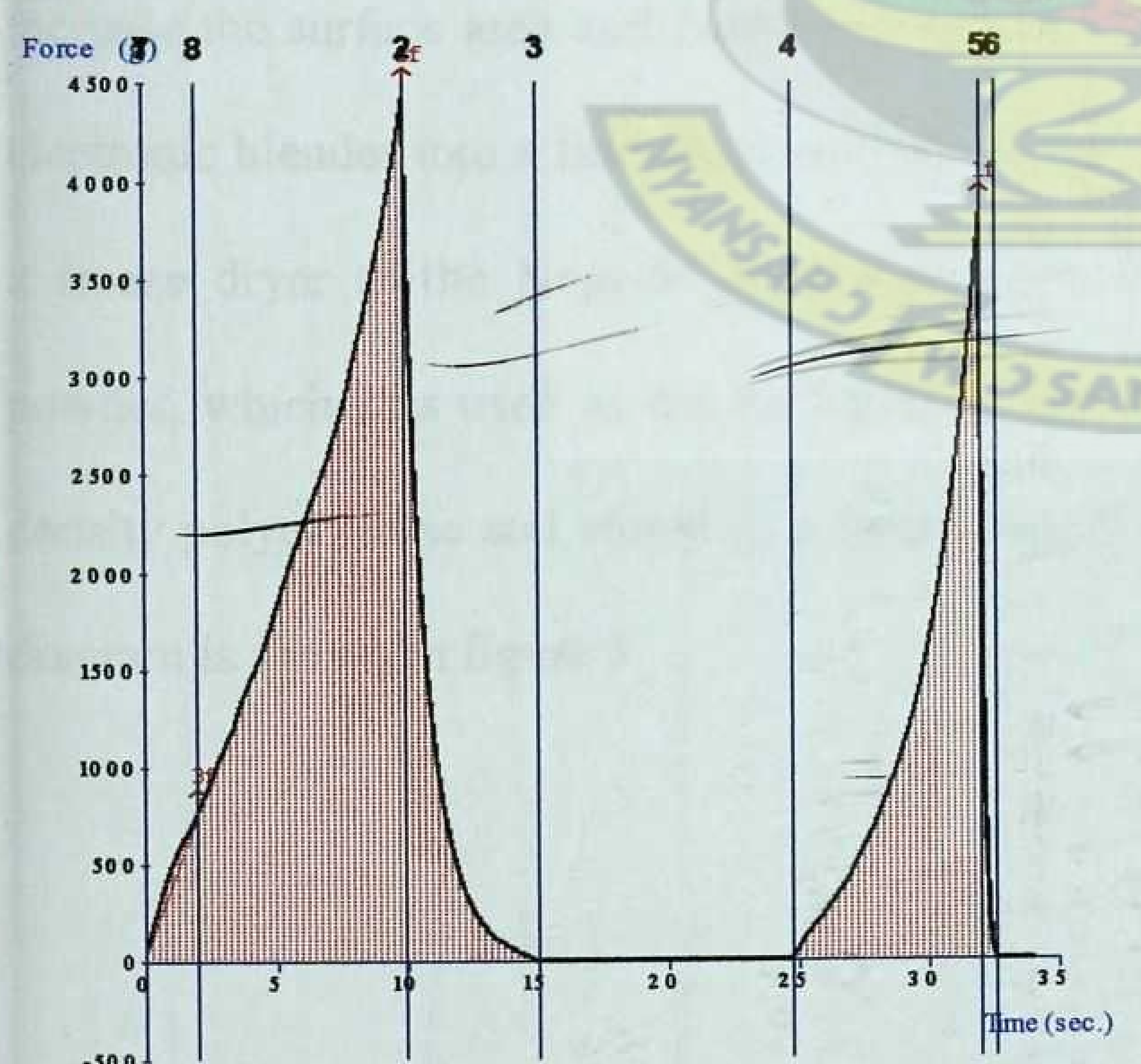

Figure 2: A Typical Force versus Time Texture Profile Analysis Curve

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Source of Materials

Soursop fruits used in this study were obtained from Horticulture Department, KNUST, Kumasi in the Ashanti Region of Ghana. Reagents used for analysis were obtained from the Food Science and Technology Department, KNUST.

3.2 Preparation of fat replacer

Procedure

Unripe soursop fruits were harvested at the matured stage when their fibre content was high. Clean water was then used to wash and clean the fruits to remove soils, stones and residues of dead insects. The fruits were then sorted and graded by hand for maturity. After sorting, the fruits were peeled by hand using a stainless steel knife. Cutting, slicing, coring and removal of seeds from the fruits were done and the size of the fruits was reduced to smaller strips to increase the surface area and facilitate blending. The soursop strips were then pulped in an electronic blender into a fine, thick and smooth sauce. The pulp was then frozen and dried in a freeze dryer at the Noguchi Memorial Institute of Medicinal Research, into a smooth powder, which was used as the fat replacer. The fat replacer was then packaged with high density polyethylene and stored in a freezer to preserve it from moisture pick up. The flow diagram is shown in figure 3.

Unripe soursop fruit

↓

Wash/clean

↓

Sort and grade

↓

Peel

↓

Cut/ Slice/ Core/ Remove seeds

↓

Blend Soursop Fruits

↓

Freeze Dry Pulp

↓

Fat Replacer

↓

Package

↓

Store

Figure 3: Flow diagram of fat replacer preparation

3.3 Preparation of Rock Cakes

A fairly hot oven was prepared and the baking tray was then greased. Flour, baking powder and salt were sieved into a mixing bowl and the shortening was rubbed onto the flour until the mixture looked like fine bread crumbs. Sugar was then stirred into the rubbed-in mixture and a mixture of water and milk was added from a measuring cylinder until stiff dough with crumbly texture was formed. The dough samples were 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 cakes prepared had some of their shortening substituted with fat replacer as in Table 2.

Table 2: Formulated Composition for Substitution of Fat Replacer in Rock Cakes

Rock Cakes Code	Flour (g)	Shortening (g)	Fat Replacer (g)	Sugar (g)	Replacement (%)
RCO	500	200	0	100	0
RCA	500	160	40	100	20
RCJ	500	120	80	100	40
RCS	500	80	120	100	60

3.4 Proximate Analysis of Fat Replacer and Rock Cakes

3.4.1 Moisture Content Determination

Procedure

Two grams of dried fat replacer and rock cakes in triplicates were weighed and transferred into 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°C 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. The entire process was repeated until a constant weight was obtained. Loss in weight was reported as moisture (AOAC, 2000).

3.4.2 Total Ash Determination

Procedure

Two grams of dried fat replacer was weighed and transferred to a previously washed, ignited, cooled and weighed porcelain crucible and placed in a Gallenkamp muffle furnace (preheated to about 600°C) for 2 hours until a white or light gray ash was obtained. 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 as the difference in weight (AOAC, 2000).

3.4.3 Protein Determination

Procedure

Two grams of dried fat replacer was digested with 25 ml of concentrated H_2SO_4 in a Kjeldahl digestion flask in the presence of a catalyst (selenium) and anti-bumping agents 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. Twenty five milliliters of 2% boric acid was poured into a 250 ml conical flask with two drops of mixed indicator (4 ml of 0.1% methylene red solution + 20 ml of 0.1% bromocresol green in 95% alcohol) added to it and placed under a condenser in a position such that the tip of the condenser was completely immersed in the boric acid solution. Ten millilitres of the digested sample solution and about 20 ml of 40% NaOH were transferred into the decomposition tube and well closed. The ammonia that was liberated during the distillation process was collected by the boric acid solution (for 5 minutes) turning it bluish green. The distillate was then titrated with 0.1M HCl to its end point which was indicated by the appearance of a faint pink color. The titre values obtained were recorded and used to calculate the % nitrogen content. The % protein was then calculated by multiplying the % nitrogen content with the appropriate conversion factor (6.25).

3.4.4 Crude Fat Determination (Soxhlet Extraction Method)

Procedure

Dried samples obtained from moisture determination were transferred into a cellulose extraction thimble. A 250 ml round bottom extraction flask was accurately weighed and a few glass beads were added. A 150 ml of petroleum ether was filled into the weighed flask. The thimble was fixed on the flask and the condenser was connected to the soxhlet extracter and refluxed for sixteen hours. The flask was then removed and evaporated on a steam bath. The flask containing the extracted fat was subjected to drying in a Gallenkamp oven at 103°C for 30 minutes, after which it was cooled to room temperature in a dessicator. The flask was then weighed again and the amount and percentage of fat recovered was calculated in the original sample (AOAC, 2000).

3.4.5 Crude Fibre Determination

Procedure

Sample residue from crude fat determination was transferred into a 750 ml Erlenmeyer flask and 0.5 g of asbestos was added. Afterwards, 200 ml of 1.25% boiling sulphuric acid (H_2SO_4) was added and the flask was immediately connected to a condenser over a hot plate and refluxed for 30 minutes after the first drop of condensate. At the end of the 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 filtrates were no longer acidic. The entire procedure was repeated but this time with 200 ml of 1.25% boiling sodium hydroxide ($NaOH$). The contents were then filtered through a cheese cloth and then washed with boiling water until the filtrate was no longer basic. Afterwards, the residue was transferred to a previously washed, dried and weighed crucible and then washed with 15 ml of alcohol. The crucible together with its contents was subjected to drying for four hours at 105°C, cooled in a dessicator and then reweighed. The crucible with dried sample was then subjected to ignition in a muffle furnace at 600°C and combusted for 2 hours. The sample was then allowed to cool and reweighed. The percentage crude fibre was then calculated by the difference in weight (AOAC, 2000).

3.5 Determination of Functional Properties of the Soursop-Derived Fat Replacer

3.5.1 Water - Holding Capacity (WHC) Determination

Procedure

The water holding capacity of the fat replacer was determined in triplicates according to the method of McConnell and Eastwood (1974). Five grams (5 g) of the freeze dried sample was soaked in 50 ml of water for 24 hours to ensure adequate water binding. It was then centrifuged at 2400 rpm for 1 hour to remove the interstitial water. After centrifugation, the free water was decanted from the wet fat replacer and drained for 10 minutes to ensure total removal of free water. The water holding capacity of the sample was then calculated from differences in weight of the centrifuge tubes before and after centrifugation.

3.5.2 Pectin Determination

In determining pectin, 5 g of the fat replacer was dispersed in 40 ml distilled water in a beaker and boiled for one hour. The content of the beaker was then transferred into a 50 ml volumetric flask and topped with distilled water. The contents of the flask were thoroughly mixed and filtered into a 50 ml volumetric flask, after which 10 ml of the filtrate was transferred into an 80 ml beaker, where 30 ml distilled water and 1 ml sodium hydroxide were added with constant stirring. The filtrate was then allowed to stand for 24 hrs. Five millilitres (5 ml) of 1 N acetic acid was then added to the filtrate with continuous stirring and allowed to stand for 5 min. After this, 2.5 ml of 1 N calcium chloride was added to the filtrate and allowed to stand for one hour after which the filtrate was boiled for 3 min. After boiling, the solution was filtered using a Whatman No. 44 filter paper. The residue was then washed with hot (40°C) distilled water until the residue was free from chloride. The residue was then transferred into a previously weighed watch glass. The watch glass, along with the residue, was placed in a water bath and dried in the oven at 100°C until a constant weight was obtained. The pectin content of the fat replacer was then calculated from the differences in weight of the watch glass before and after drying (Horwitz, 2000).

3.6 Sensory Analysis

Panel: Sensory analysis was carried out at Food Research Institute of the Centre for Scientific and Industrial Research, Accra, Ghana. Staff of the Food Research Institute volunteered to participate in the sensory evaluation. Fifteen panellists made up of five women and ten men were used in analysis of the rock cakes. The selection criteria were based on good health, suitable personality traits, availability, interest, no sensory impairment and no liking for the products as described by Iwe (2002). The panellists were remunerated for their participation.

Protocol: A nine (9) point hedonic scale (1= dislike extremely, 9= like extremely) was used by all judges to rate each attributes across the four samples. Each sample was given a three (3) digit code and presented in polystyrene disposable plates. Samples were presented monadically to the panellists, and the order of presentation was randomised among judges and sessions to reduce position effects. Unsalted crackers presented in white polystyrene plates and rinse water presented in transparent cups was presented to panellists for cleansing of the palate between the tasting of samples. Evaluations were carried out in isolated sensory booths illuminated with white incandescent lightning to reduce bias among judges. Panellists were also provided with questionnaires on which they marked on the 9 point scale to show the intensity of their rating for each attribute of a sample. Eight (8) attributes were used to describe the rock cakes. ANOVA was conducted on each attribute that was rated by panellists to determine the difference among treatments and sample means were compared with Bonferroni's Multiple Comparison Test at $p \leq 0.05$.

3.7 Colour Measurements

Surface colours of the raw and baked rock cakes were measured using the CIE colour scale. The CIE colour scale measures 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- 30 (Minolta Co. Ltd., Osaka, Japan). The chroma meter was standardised using a white (Y= 93.7, x= 0.3138 and y= 0.3194) standard plate. The surface colours of raw and baked rock cakes were measured immediately after baking. For each experimental unit, four samples, that is, 4 rock cakes were used.

3.8 Instrumental Texture Profile Analysis

Rock cake samples were moulded in small round aluminium cans for instrumental texture profile analysis (TPA). Before the rock cakes were placed in the cans, each can was greased with margarine to avoid the sticking of rock cakes in the cans. In order to maintain uniformity in the size and shape of the pastry, it was ensured that each can weighed 40 g. The surface of each sample was smoothened for uniform rise in dough during baking. Before the tests were done, the baked samples were cooled to room temperature. TPA test was performed using a TA-XT2i Texture Analyser (Stable Microsystems, Godalming, UK). Optimised test conditions were; probe, TA- 75 mm; 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. Calculations and data collection were done using the Microsoft Texture Expert and Microsoft Excel software. 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 cake sample.

3.9 Statistical Analyses

The experiment on rock cakes was a single factor design with the rock cakes made with four (4) fat replacement treatments (0%, 20%, 40% and 60%) with three (3) replicates. Data obtained was analysed using the one- way Analysis of Variance (ANOVA), and Bonferroni's Multiple Comparison Test to locate differences among means employing the Graph Pad package (version 5.0).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Nutritional composition of the Soursop-derived Fat Replacer

The nutritional composition, pectin and water holding capacity of the soursop-derived fat replacer are presented in Table 3.

Table 3- Nutritional Composition, Pectin and Water Holding Capacity of the Soursop-Derived Fat Replacer

Parameters (Unit)	Composition
Moisture (%)	25.38 ± 0.04
Fat (%)	0.00 ± 0.00
Protein (%)	1.73 ± 0.04
Ash (%)	0.68 ± 0.01
Crude fibre (%)	0.15 ± 0.04
Carbohydrate (%)	72.40 ± 0.23
Phosphorus (mg/100 g)	0.40 ± 0.00
Potassium (mg/100 g)	3.53 ± 0.00
Calcium (mg/100 g)	0.76 ± 0.02
Magnesium (mg/100 g)	4.44 ± 0.02
Pectin (g/100 g)	2.00 ± 0.00
Water holding capacity (%)	425.30 ± 0.03

The soursop-derived fat replacer contained a pectin content of 2.00 g/100 g, confirming report by Janick *et al*. (2008) implying that soursop can be used for fat replacement purposes. According to Giese (1996), carbohydrates such as pectin can be used for fat replacement purposes in baked goods. Paintsil (2008) reported on a pawpaw-derived fat replacer containing 2.51 g/100 g of pectin.

The soursop-derived fat replacer had a water holding capacity of 425.30%. The high water holding capacity indicates its potential ability of absorbing water and adding volume, thickening and stabilizing foods similar to fats by forming gels. Giese (1996) reported that carbohydrate-based fat mimetic components such as pectin, dextrins and modified starches are able to absorb water and form gels impacting texture, mouth feel and opacity similar to fats. Dhingra and Jood (2001) also reported on soy flour with a water holding capacity of 112.8% used in bread formulations.

The moisture content of the fat replacer was 25.38% indicating its susceptibility to bacterial and mould attack if not stored under proper conditions. Isabelle and André (2006) reported that powdered foods with moisture content more than 14.5% are susceptible to bacterial and mould growth. Though fat is one of the most important nutritional quality properties in foods, the soursop-derived fat replacer recorded a 0% fat. Paintsil (2008) reported on a pawpaw-derived fat replacer containing 0.6% of fat. The absence of fat observed in the soursop-derived fat replacer confirms its potentiality of reducing health complications associated with consumption of fatty foods such as pastries.

Protein, ash, crude fibre and carbohydrate contents of the soursop-derived fat replacer were 1.73%, 0.68%, 0.15% and 72.40% respectively. Chysirichote *et al.* (2010) reported on a maltodextrin gel fat replacer containing 0.02%, 0.08%, 0% and 54.38% of protein, ash, crude fibre and carbohydrate contents respectively. The soursop-derived fat replacer also contained high amounts of phosphorus, potassium, calcium, and magnesium at levels of 0.40%, 3.53%, 0.6% and 4.44% respectively compared to a pawpaw-derived fat replacer containing phosphorus, potassium, calcium and magnesium at levels of 0.40%, 1.50%, 1.84% and 1.19% respectively (Paintsil, 2008). The presence of these essential nutrients in the soursop-derived fat replacer confirms that it can help improve the nutritional value of pastries apart from its high potentiality as a fat replacer in rock cakes.

4.2 Fat and Moisture Contents of Rock Cakes

The amounts of fat and moisture in a reduced fat food affects the sensory and textural properties of the food. In this study, fat and moisture contents of the fat reduced rock cakes are shown in Figures 4 and 5.

4.2.1 Fat Content

Significant differences ($p \leq 0.05$) in fat were observed between rock cakes. The fat content of rock cakes were in the order of RCO > RCA > RCJ > RCS as shown in Figure 4. The decrease in fat content of rock cakes with increasing addition of soursop-fat replacer implies that different amounts of fat were used to formulate the various rock cakes. RCO recorded the highest fat content of 17.30 g/100 g, and RCS recorded the lowest fat content of 4.81 g/100 g. The decreasing fat content in the fat reduced rock cakes was due to a decrease in their fat content with increasing fat replacement during dough preparation, corresponding to a decrease in the fat contents of the consequent baked products.

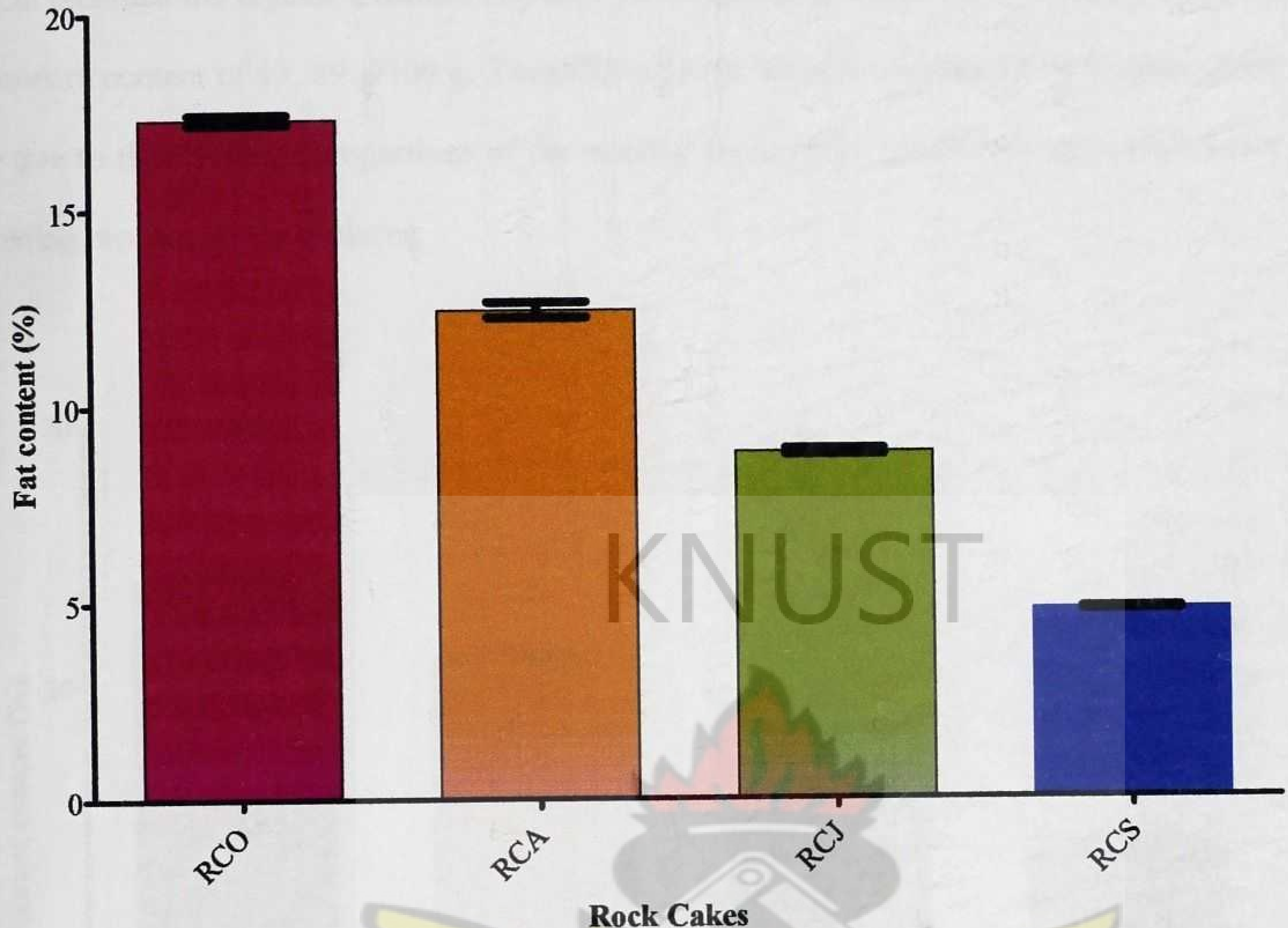

Figure 4: Effect of soursop-derived fat replacer on fat content of rock cakes

4.2.2 Moisture Content

From Figure 5, there was a decrease in moisture content with increasing fat replacement. The lower moisture content of rock cakes with increasing soursop fat replacer observed in rock cakes could be due to the fact that during dough preparation, dough with less fat and high soursop fat replacer (RCA, RCJ and RCS) required more water to achieve the desired consistency. Spies (1990) reported that the presence of low fat level in dough leads to a decreased pronouncement of its lubrication functions in the dough such that more water will be required to achieve the desired consistency. However, Conforti *et al.* (1996) reported on a carbohydrate-based fat substitute which produced a moister biscuit with its increasing replacement in the biscuit formulation. Though significant differences ($p \leq 0.05$) existed between rock cakes, RCJ and RCS were not significantly different ($p \geq 0.05$) from each other.

RCO recorded the highest moisture content of 24.98 g/100 g with RCS recording the lowest moisture content of 13. 89 g/100 g. The differences in moisture content of rock cakes could be due to their varying proportions of the soursop fat replacer coupled with the high water holding capacity of the replacer.

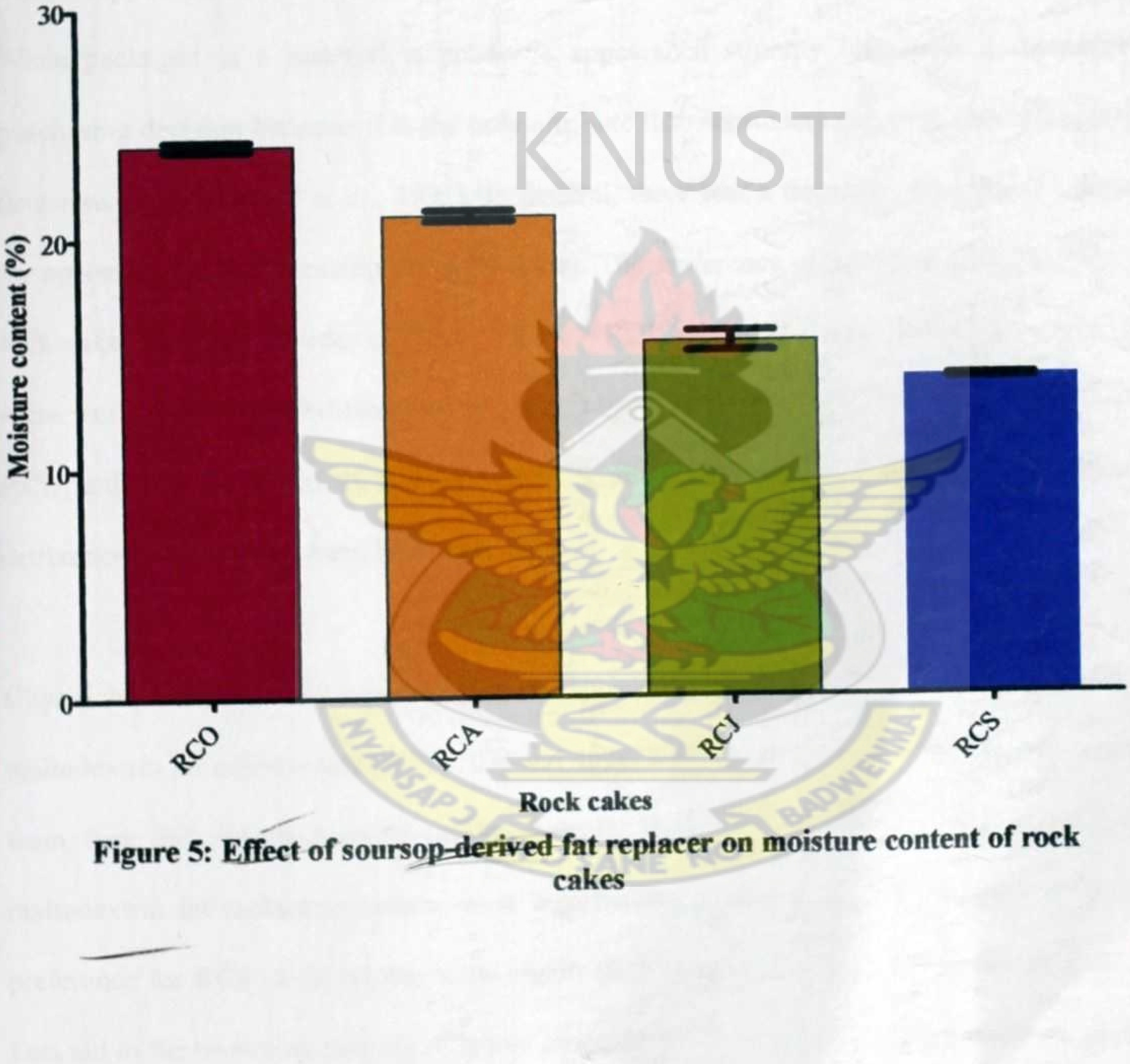

Figure 5: Effect of soursop-derived fat replacer on moisture content of rock cakes

4.3 Effect of Fat Reduction on the Sensory Qualities of Rock Cakes

According to Bennion (1995), food choices by consumers are influenced by sensory attributes such as aroma, appearance, taste, texture and mouth feel. In the study, responses of panellists to the sensory attributes of fat reduced rock cakes are shown in figures 6 to 14.

4.3.1 Appearance

When packaged in a material, a product's appearance strongly influences a consumer's purchasing decision because, it is the only attribute that consumers can base their purchasing decisions on (Meilgaard *et al*., 1991). In general, there was a decrease in panellists' ratings for appearance with increasing fat replacement. The preference of panellist' to appearance of rock cakes were in the order of RCO > RCA > RCJ > RCS as shown in Figure 6. However there were no significant differences ($p \geq 0.05$) between the following pairs: RCO and RCA, RCO and RCJ, RCA and RCJ, RCA and RCS, and RCJ and RCS. There was a significant difference ($p \leq 0.05$) between RCO and RCS.

Chysirichote *et al*. (2010) reported that, the appearance of products with different levels of maltodextrin fat replacement (15%, 30% and 45%) were not significantly different ($p \geq 0.05$) from their full fat counterpart (100%-control). However at a replacement of 60% the maltodextrin fat replaced products were significantly different from the control. The least preference for RCS could be due to its higher (60%) replacer content and lower fat content. Fats aid in the browning process of baked products by imparting the desired uniform, golden brown appearance in baked goods (Bennion, 1995). RCO was the most attractive because it had the highest fat content (100%) with no replacement which imparted the uniform, golden brown appearance always desired in rock cakes. RCS was the least attractive because it also appeared to have more surface cracking. The surface cracking observed in RCS could be due to crystallization of sugar on its surface since much of the water was bound to the fat replacer instead of sugar during mixing. Much of the water was bound to the fat replacer because of its high water holding capacity (425.30%) as shown in Table 4. Crystallization on the surface of RCS due to the expansion of gases during baking led to the formation of cracks. Freund (2003) stated that crystallization of sugar on surfaces of products leads to cracking as a result of expansion of leavening gases. Armbrister and Sester (1994) reported on chocolate chip cookies with less surface cracking at high levels (70%) of protein- based fat replacement.

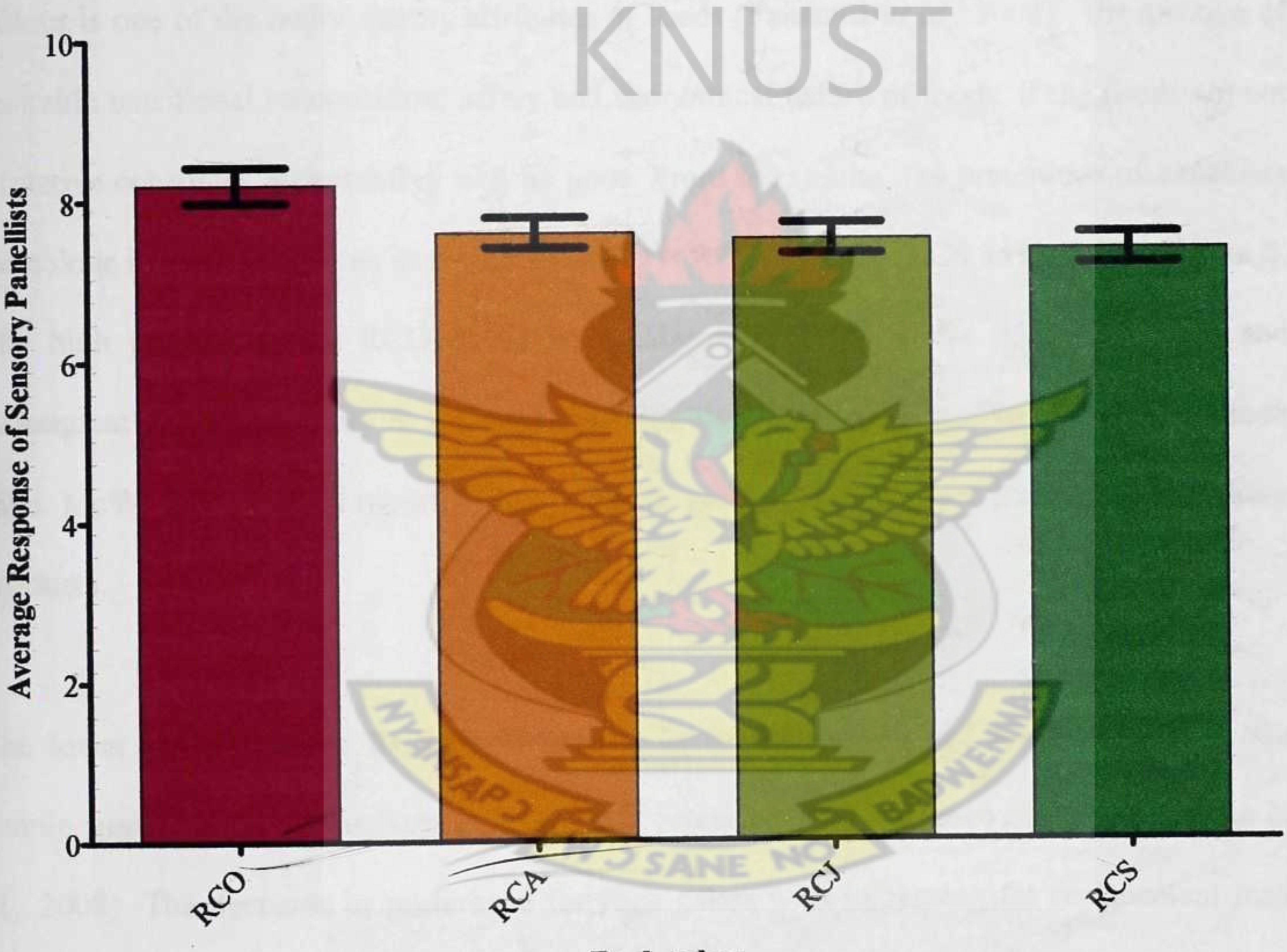

Figure 6: Effect of soursop-derived fat replacer on appearance of rock cakes

Figure 7: Photographs indicating appearances of rock cakes after baking

4.3.2 Colour

Colour is one of the major quality attributes of foods (Fennema *et al.*, 2008). Irrespective of desirable nutritional composition, safety and economical nature of foods, if the foods are not attractive consumer acceptability will be poor. From the results, the preference of panellists for colour in rock cakes was in the order: RCO > RCA > RCJ > RCS as shown in Figure 8. The high preference for RCO could be attributed to its high fat content (100%) and subsequently the fats ability to impart a desirable uniform, golden brown colour to the rock cake. McWilliams (1993) reported that uniform, golden brown crusts are desired in bakery products.

The lower preference for RCS could be due to excessive Maillard reaction between the simple sugars of the fat replacer and the flour proteins in the presence of heat (Fennema *et al.*, 2008). The decrease in preference for rock cakes with increasing fat replacement may also be due to excessive browning of fat mimetics under high heat (Schwenk and Guthrie, 1997). However, there were no significant differences ($p \geq 0.05$) in colour between all rock cakes. This may be due to the ability of the fat replacer to hide all defects in relation to colour attesting to its high potentiality as a fat replacer in pastries.

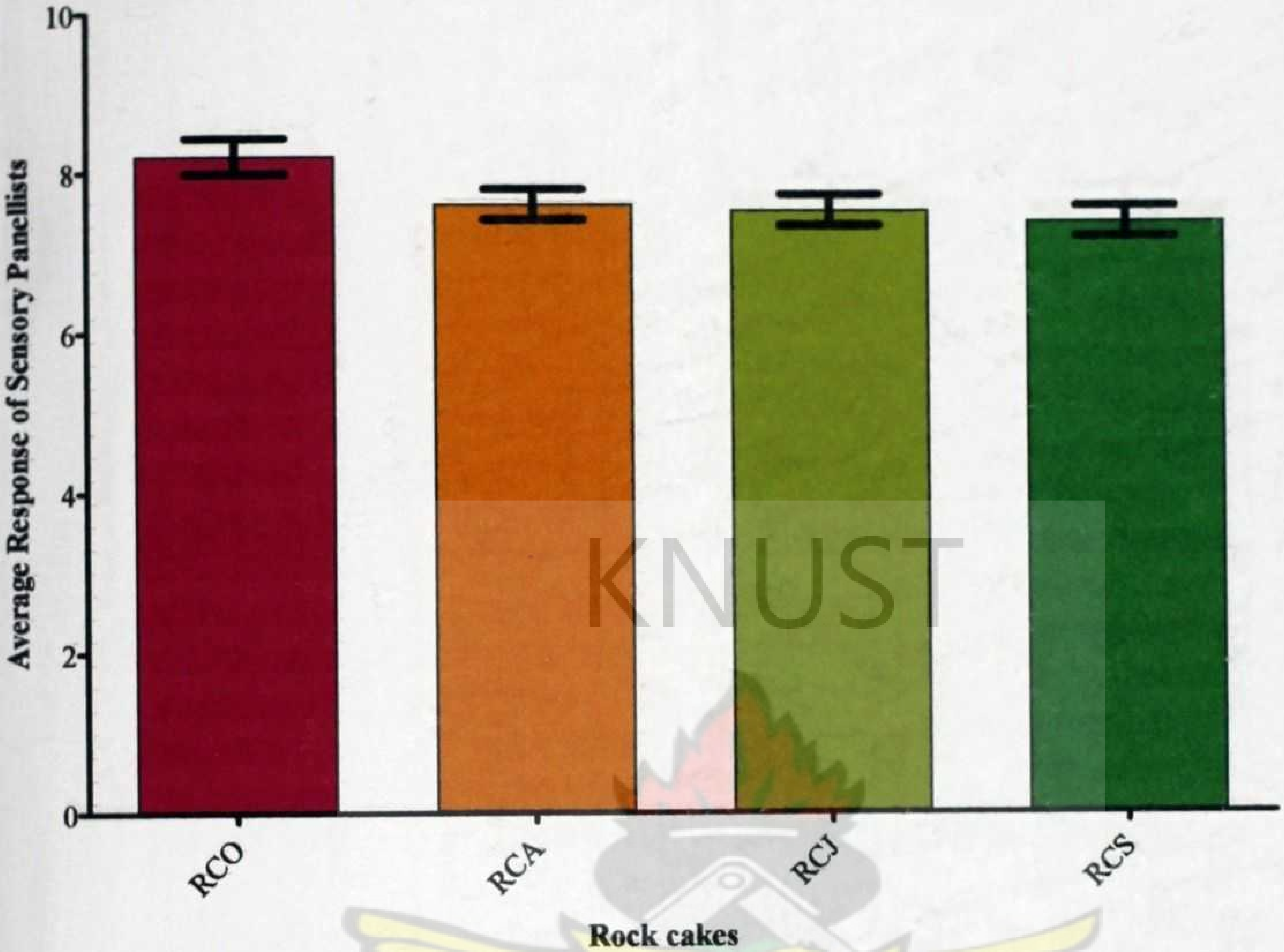

Figure 8: Effect of soursop-derived fat replacer on colour of rock cakes

4.3.3 Aroma

Preference of panellists for aroma was in the order: RCO > RCJ > RCS > RCA as shown in Figure 9. RCO was the most preferred while RCA was least preferred. The low preference for rock cakes with replacements may be due to their low fat content and high percentage of soursop fat replacer. Studies by Penfield and Campbell (1990) showed that fat imparts aroma when used in baked products and this is corroborated by RCO being the sample with the highest rating (7.93) for aroma as shown in Appendix 3B. Despite this trend of preference, there were no significant differences ($p \geq 0.05$) between fat replaced rock cakes and full fat rock cake. This may be due to the ability of the soursop fat replacer to bind more to the fat and hide any defects in relation to aroma, attesting to its potential as a fat replacer.

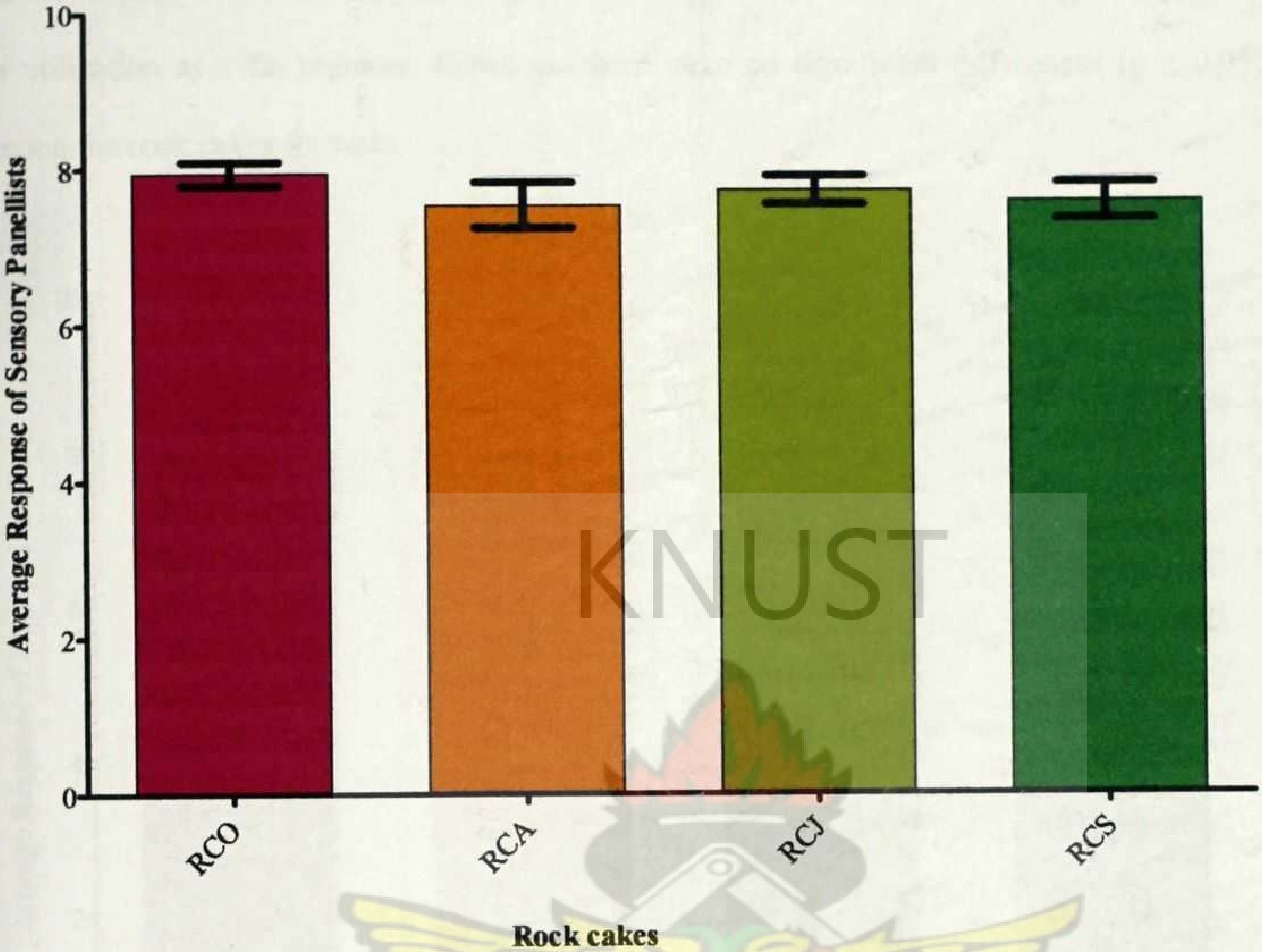

Figure 9: Effect of soursop-derived fat replacer on aroma of rock cakes

4.3.4 Taste

Taste is one of the most important factors consumers consider when shopping for food (Bruhn *et al.*, 1992). From Figure 10, the preference of panellists for the taste of rock cakes was in the order: RCO > RCJ > RCA > RCS. The results show that RCO was the most preferred as far as taste was concerned whereas RCS which had 60% of fat replacement was rated as the least preferred. The high preference of RCO compared to RCJ, RCA and RCS confirms fats act as flavour carriers to enhance the perception of taste (Bennion, 1995). The high amount of soursop fat replacer in the fat reduced rock cakes masked the taste imparted by fat but rather introduced an astringent taste. Sandrou and Arvanitoyannis (2000) reported that fat absorbs many flavour compounds and increases flavour by reducing the sharpness of acid ingredients. About 40% of the panellists stated they felt a sharp and biting after-taste in the fat reduced rock cakes and this may be due to the unripened state of the soursop prior to its utilization as a fat replacer. However, there were no significant differences ($p \geq 0.05$) among the rock cakes for taste.

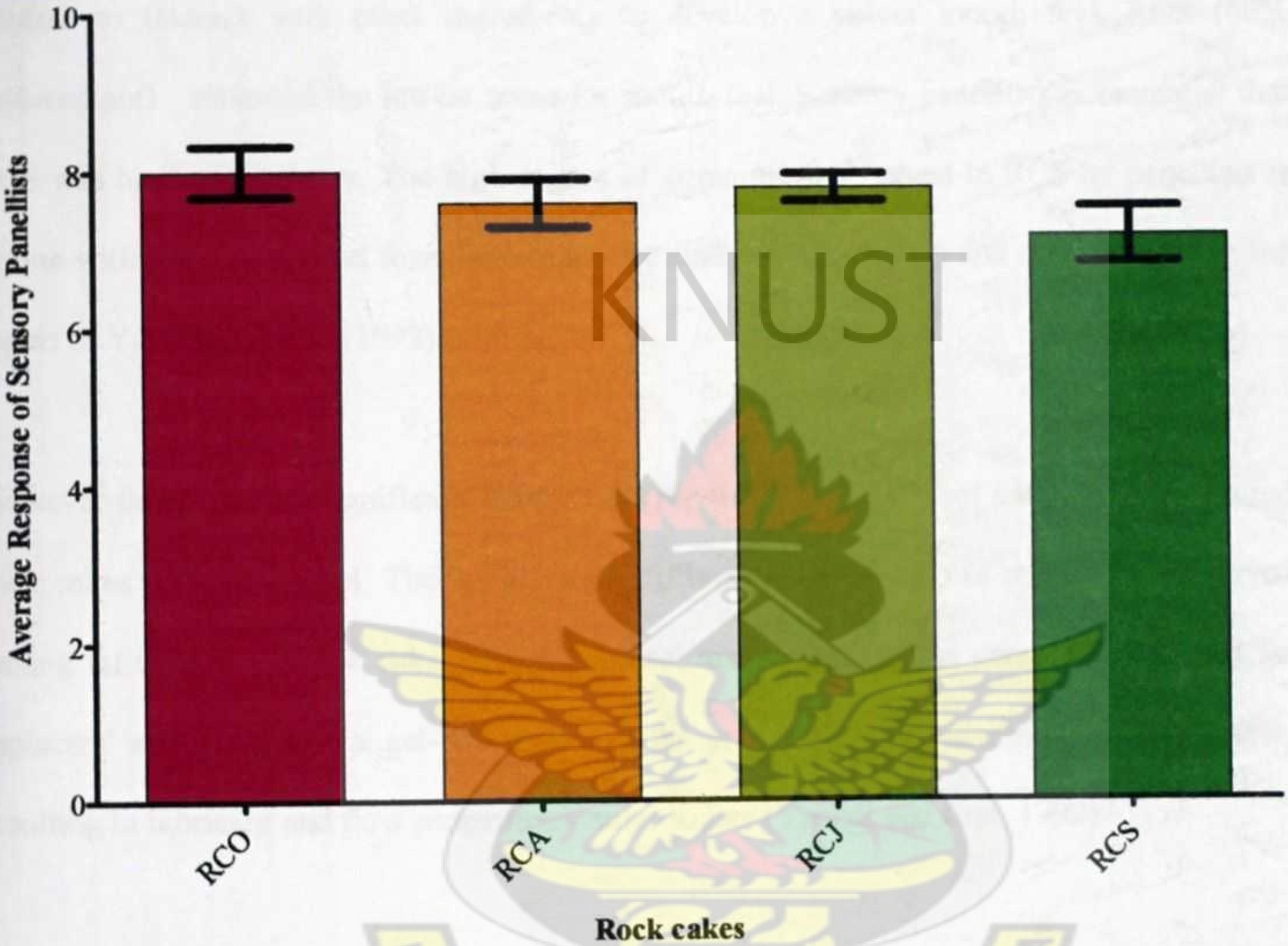

Figure 10: Effect of soursop-derived fat replacer on taste of rock cakes

4.3.5 Mouth Feel

The panellists mean scores of rock cakes mouth feel are displayed in Figure 11. RCO recorded the highest score for mouth feel followed by RCJ, RCA, and RCS respectively. RCO (full fat rock cake) had a high value for mouth feel because of the ability of the high fat content to interact with other ingredients to develop a velvet mouth feel. RCS (60% replacement) recorded the lowest score for mouth feel. Sensory panellists commented that RCS was hard and gummy. The high degree of gumminess observed in RCS by panellists is in line with results obtained from texture profile analysis (Figure 19) and this agrees with the report of Yackel and Cox (1992).

However there were no significant differences ($p \geq 0.05$) in mouth feel among fat substituted rock cakes and the control. The insignificant differences ($p \geq 0.05$) in mouth feel observed among fat substituted rock cakes and the control may be due to the carbohydrate-based fat replacers' ability to form a gel-like matrix in the presence of considerable levels of water, resulting in lubricant and flow properties similar to fats (Yackel and Cox, 1992).

The ability of the soursop fat replacer to form a gel-like matrix in the presence of water may be attributed to pectin in the fat replacer which provided texture and body to the fat reduced rock cakes due to the ability of the hydroxyl groups to bond to water through hydrogen bonding (Fennema *et al.,* 2008). Schwenk and Guthrie (1997) reported that fat mimetics imparts desirable mouth feel and lubricity to food systems by binding to water.

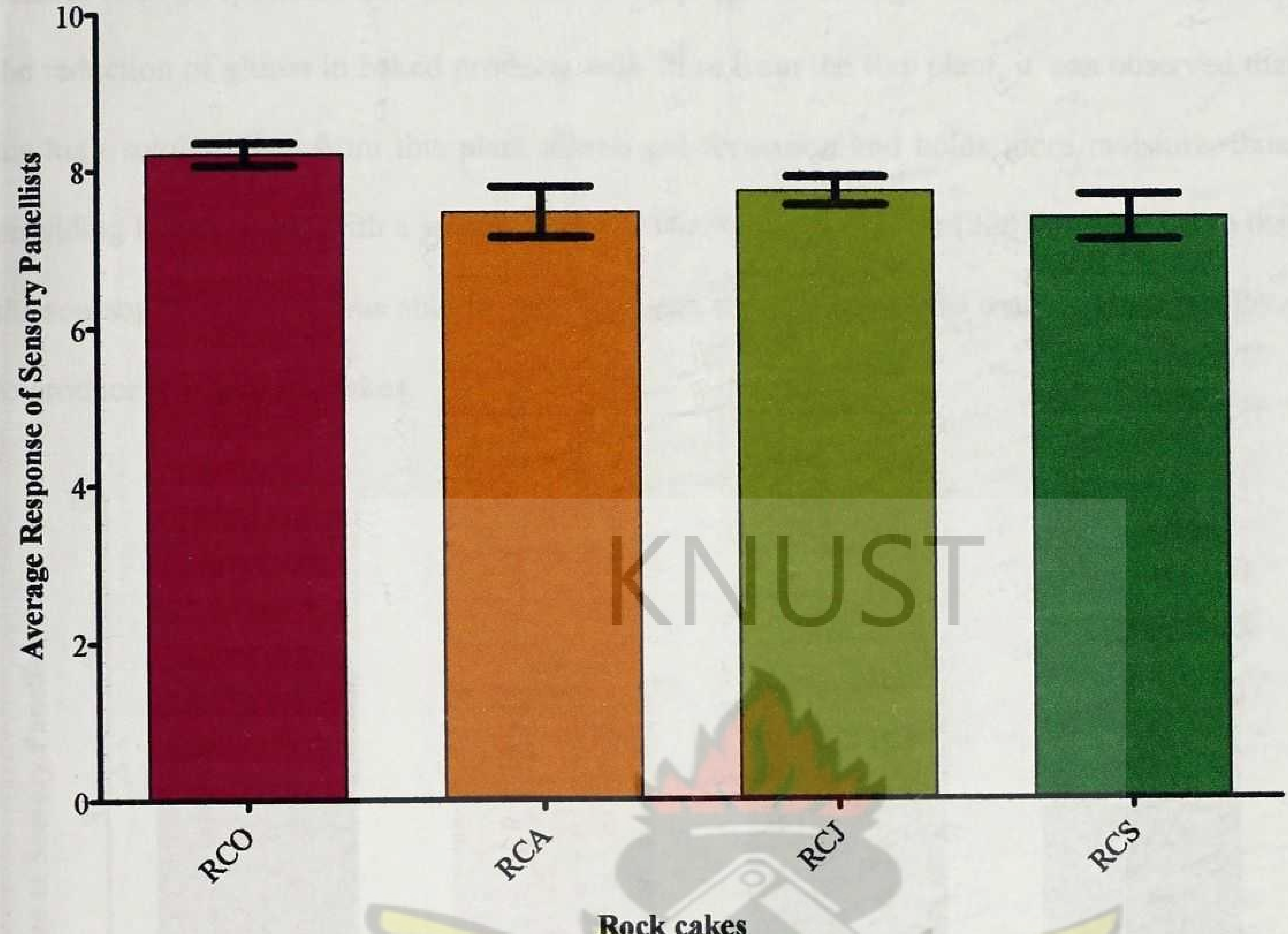

Figure 11: Effect of soursop-derived fat replacer on mouth feel of rock cakes

4.3.6 Sponginess

During baking, carbon dioxide is released by a chemical reaction of sodium bicarbonate found in the baking powder. The carbon dioxide forms bubbles that are entrapped by gluten in the flour causing the dough to rise and giving the baked product a soft and spongy texture (Fenster, 2007). Panellists score for sponginess of rock cakes in increasing order of occurrence was as follows: RCO > RCJ > RCA > RCS as depicted in Figure 12. No significant differences ($p \geq 0.05$) in sponginess were found to exist between the full fat rock cake (RCO) and the three reduced-fat rock cakes (RCJ, RCA and RCS). This may be attributed to the high water holding capacity (455.31%) of the fat replacer which provided the fat replaced rock cakes with a spongy texture.

Fenster (2007) reported a similar trend in baked products. Though Fenster (2007) worked on the reduction of gluten in baked products with fibre from the flax plant, it was observed that the high soluble fibre from this plant allows gel formation and holds more moisture, thus, providing baked goods with a spongy texture. The report of Fenster (2007) may indicate that the soursop fat replacer was able to associate with the baking powder and gluten of the flour to produce spongy rock cakes.

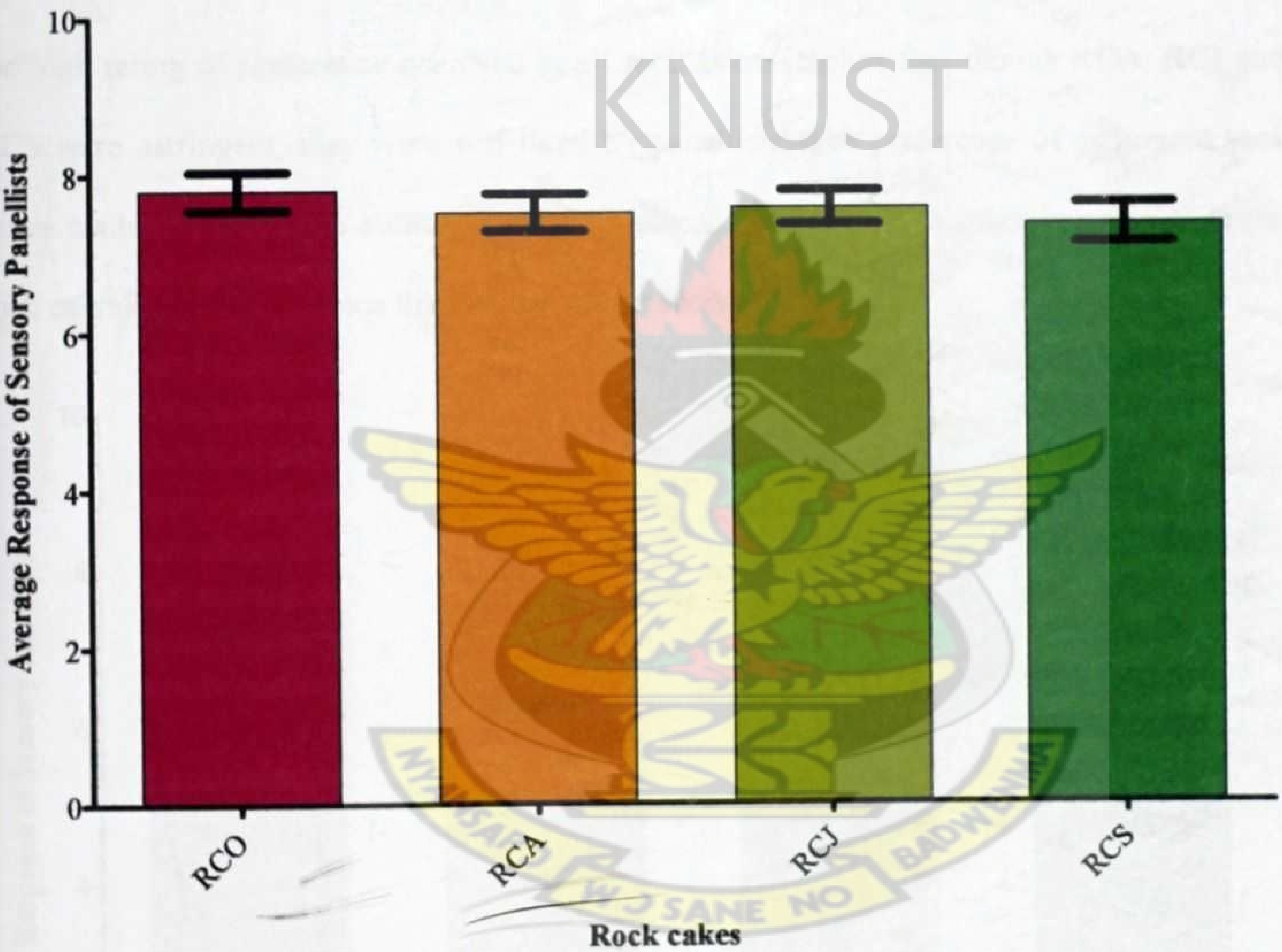

Figure 12: Effect of soursop-derived fat replacer on sponginess of rock cakes

4.3.7 Astringency

Astringency is a sensory attribute that is described as a drying-out, roughening, and puckery sensation felt in the mouth (Colona *et al.*, 2004). In general there was a decrease in preference for astringency with increasing fat replacement (Figure 13). Significant differences ($p \leq 0.05$) were observed between RCO and RCA, RCO and RCJ, and RCO and

RCS. However no significant differences ($p \geq 0.05$) in astringency existed among the fat reduced rock cakes (RCA, RCJ and RCS). The perception of astringency in fat reduced rock cakes may be due to the presence of polyphenolic compounds in unripe soursop used to prepare the fat replacer. A report by Colonna *et al.* (2004) stated that, astringency in foods such as unripe fruits, red wine, green and black teas, and soy-based foods is due to the presence of polyphenolic compounds. RCO was the most preferred because it had no fat replacer, followed by RCA and RCJ with RCS being the least preferred. Despite this trend, the high rating of preference observed in all rock cakes implies that though RCA, RCJ and RCS were astringent, they were still liked by panellists. The preference of astringent rock cakes could be due to the ability of the fat replacer to bind well to other ingredients in the rock cake formulation, hence limiting its perceived astringent taste.

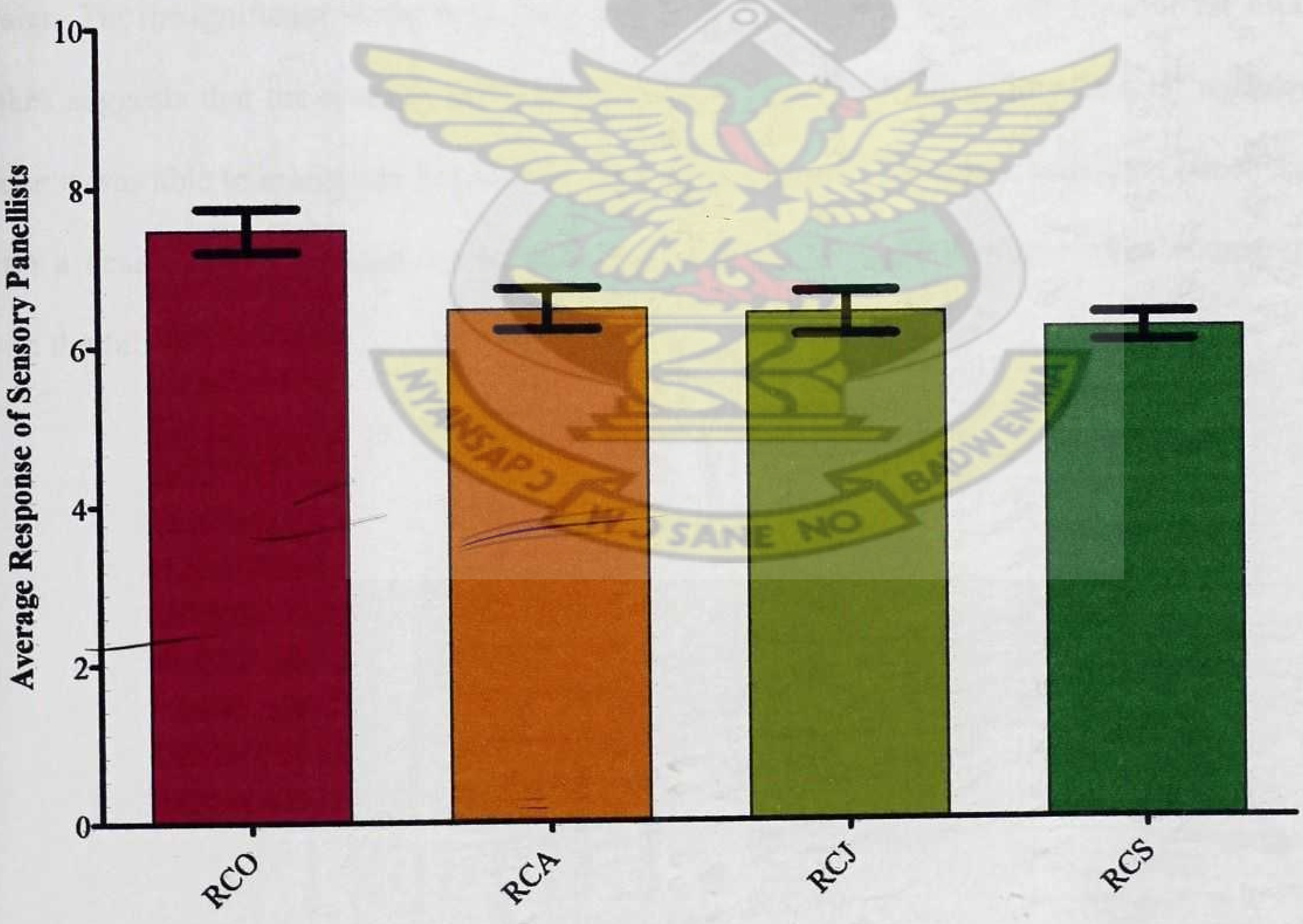

Figure 13: Effect of soursop-derived fat replacer on astringency of rock cakes

4.3.8 Overall Acceptability

From Figure 14, RCO was best accepted with a rating score of 8.00. Preference for rock cakes by panellists was in the order: RCO > RCJ > RCA > RCS. The high preference for RCO (full fat rock cake) was due to its high fat content which imparted tenderness, lubricity, flavour, colour, moistness and a smooth mouth feel. Despite this response, no significant differences existed between fat replaced and full fat (control) rock cakes. This may be due to the relatively high water holding capacity (425.30%) of the fat replacer providing an overall good sensory profile.

Nonaka (1997) reported that maltodextrin (carbohydrate-based fat replacer) provides a pleasing sensory profile of moisture, lubricity, texture, and taste in baked products by holding water. The insignificant differences between fat reduced rock cakes and the full fat rock cakes suggests that the soursop derived fat replacer has a high potentiality as a fat replacer since it was able to mimic the functions of fat in the replaced rock cakes, providing panellists with a desirable and reduced fat product without sacrificing any attribute when compared with the full fat rock cake.

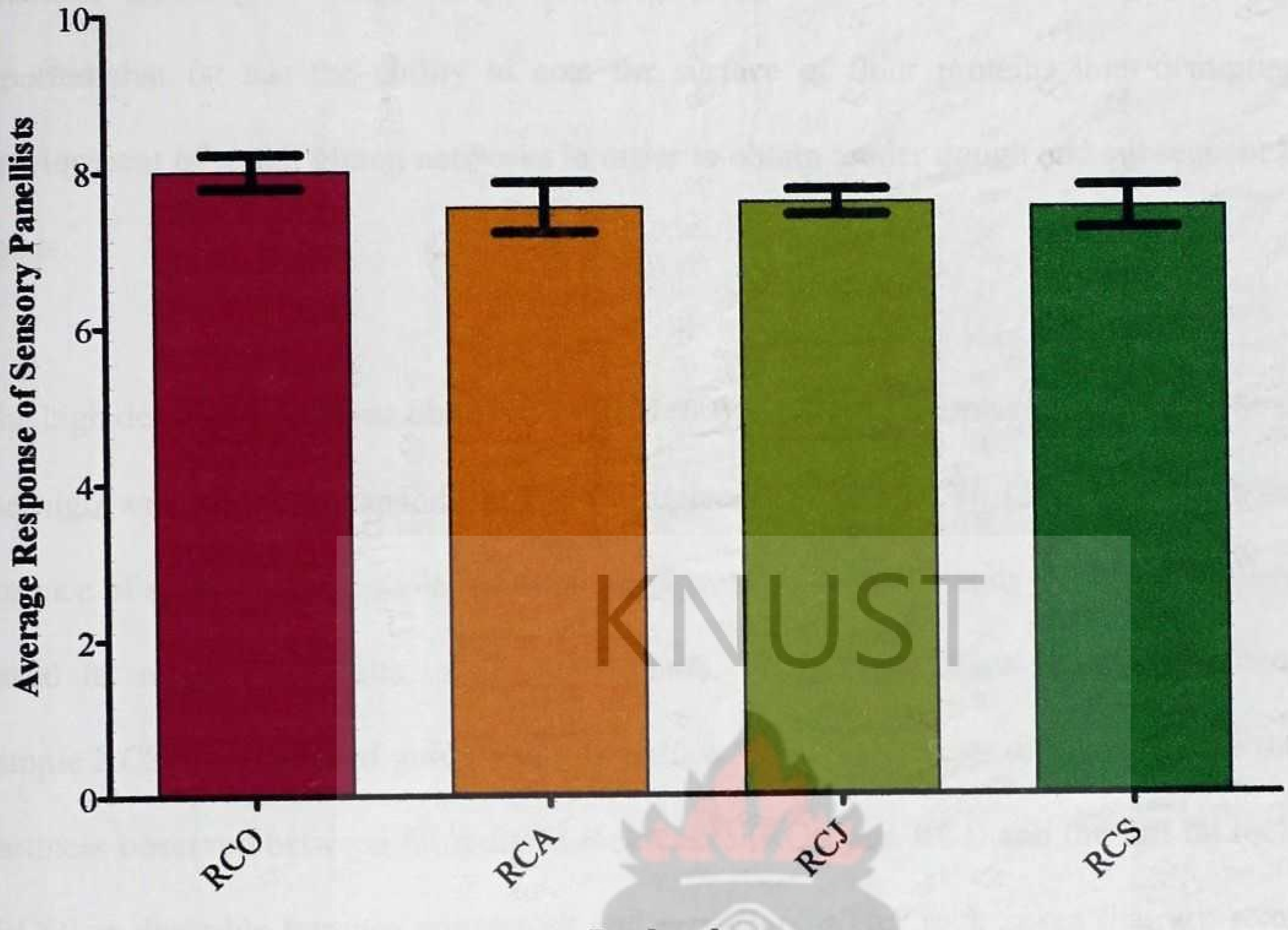

Figure 14: Effect of soursop-derived fat replacer on overall acceptability of rock cakes

4.4 Texture Evaluation on Rock Cakes

In the study, results obtained from texture profile analysis of rock cakes are shown in figures 15 to 22.

4.4.1 Hardness

There were no significant differences ($p \geq 0.05$) in hardness among the following pairs: RCO and RCA, and RCO and RCJ, RCA and RCJ. However, there was significant difference ($p \leq 0.05$) between RCO and RCS, RCA and RCS, RCJ and RCS. In general, there was an increase in hardness with increasing fat replacement. From Figure 15, hardness of rock cakes was in the order: RCS < RCJ < RCA < RCO. The increase in hardness with increasing fat replacer was due to the insufficient amounts of fat to inhibit development of tough gluten networks resulting in harder dough and subsequent rock cakes. Chysirichote *et al.* (2010) reported that fat has the ability to coat the surface of flour proteins thus disrupting the development of tough gluten networks in order to obtain tender dough and subsequent baked goods.

The high degree of hardness observed in RCS (60% soursop fat replacer) could also be due to the high water holding capacity of the fat replacer. Zoulias *et al.* (2002) reported that the absence of sufficient fat coupled with the high water holding capacity of some carbohydrate-based fat replacers' results in dough hardness. Sensory panellists also commented that, sample RCS was hard and gummy-like in nature. The insignificant differences ($p > 0.05$) in hardness observed between fat reduced rock cakes (RCA and RCJ) and the full fat rock cake (RCO) is desirable because consumers and producers prefer rock cakes that are semi-hard compared to soft rock cakes. The ability of the fat replacer to mimic functions of fat and produce fat reduced rock cakes (RCA and RCJ) similar to the full fat rock cake (RCO) again attests to its high potentiality as fat replacer.

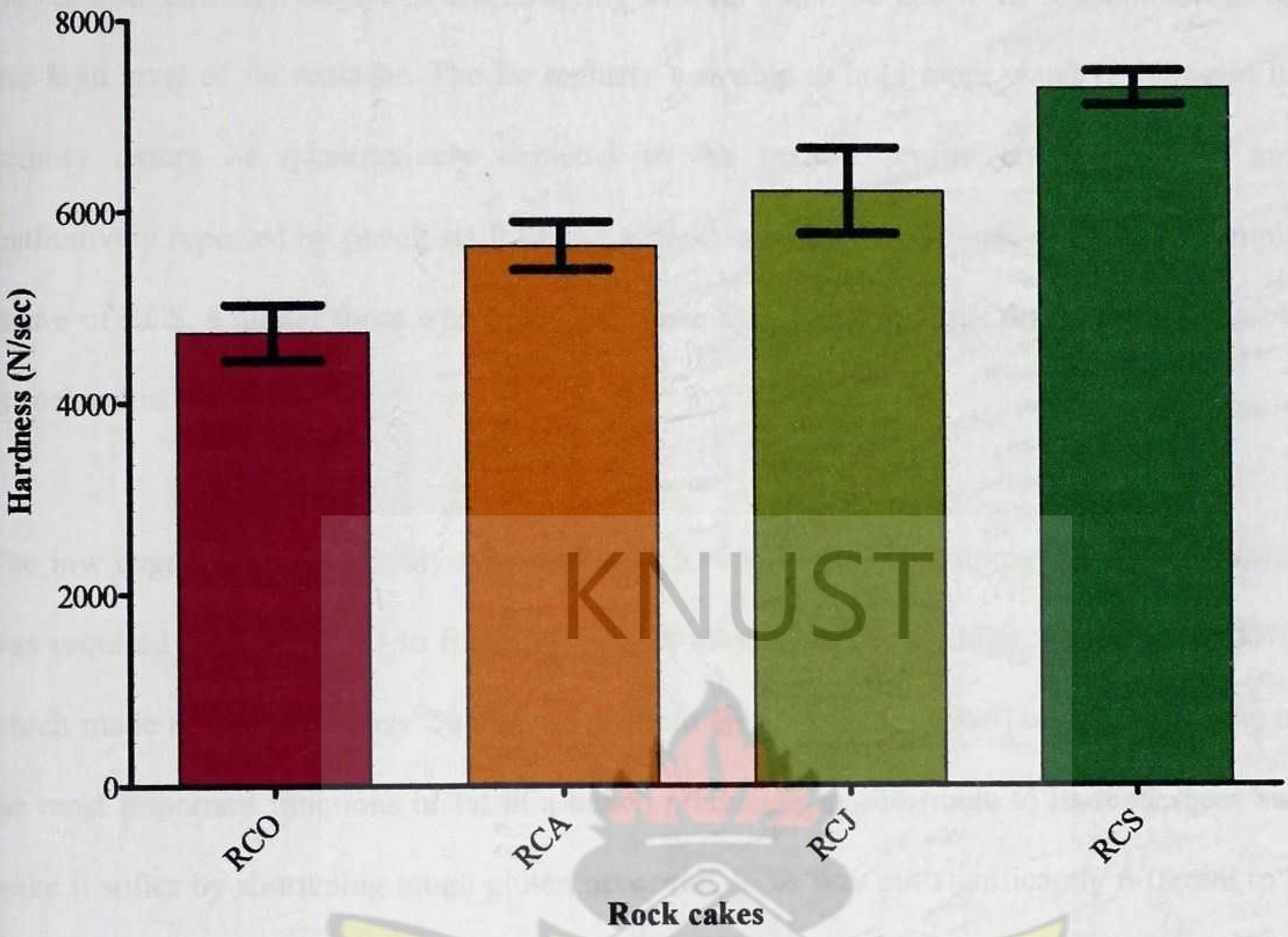

Figure 15: Effect of soursop-derived fat replacer on hardness of rock cakes

4.4.2 Fracturability

Fracturability is defined as the force with which a material fractures or deforms (Szczesniak *et al.,* 1963). Fracturability of the rock cakes was in the increasing order: RCO < RCA < RCJ < RCS. The increase in fracturability with increasing fat replacement suggests that the force needed to fracture the rock cakes increased as the level of fat replacer increased. Significant differences ($p \leq 0.05$) were observed between RCO and RCJ, RCO and RCS, RCA and RCS, RCJ and RCS. However, no significant differePnce ($p \geq 0.05$) existed between RCO and RCA, RCA and RCJ.

The high degree of fracturability observed in RCS indicates that it required the highest amount of force to cause its fracture when compared to the other fat reduced rock cakes and the control. The high degree of fracturability in RCS could be due to its low amount of fat and high level of fat replacer. The fat replacer was able to hold more water resulting in its gummy nature as quantitatively depicted in the texture profile analysis (TPA) and qualitatively reported by panellists from the sensory evaluation. Because of the high gummy nature of RCS, a higher force was needed to cause its fracture and this feature is undesirable in rock cakes.

The low degree of fracturability observed in RCO implies that a minimum amount of force was required to cause RCO to fracture and this may be due to its high fat content (100%) which made it tender for easy fracturing. Penfield and Campbell (1990) reported that one of the most important functions of fat in a baked product is to contribute to its tenderness and make it softer by shortening tough gluten networks. RCA was not significantly different ($p \geq 0.05$) from RCO though it had a lesser amount of fat (80%). This implies that the same force may be needed to cause fracturabilty in both RCO and RCA.

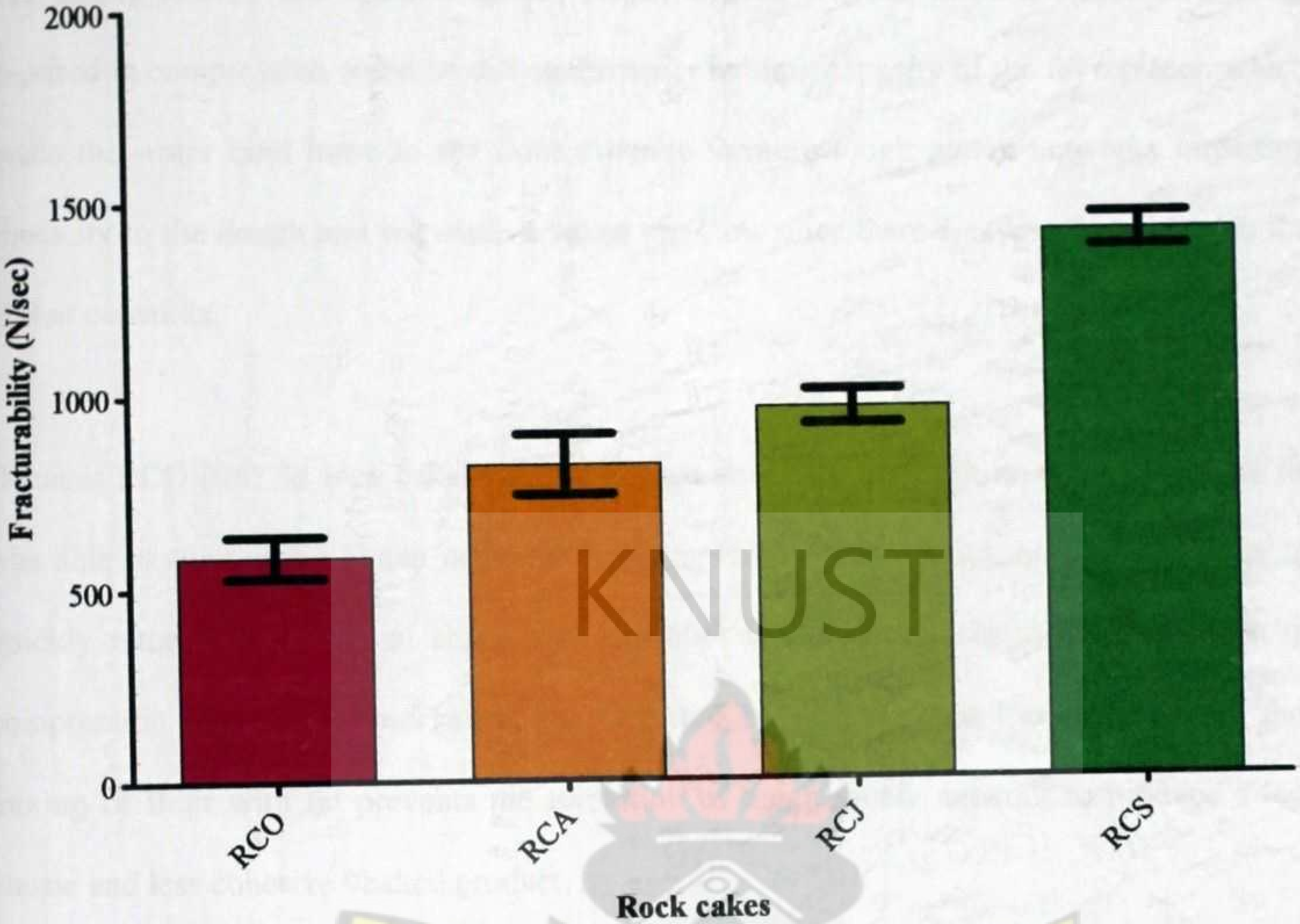

Figure 16: Effect of soursop-derived fat replacer on fracturability of rock cakes

4.4.3 Springiness

Springiness is the degree to which a product returns to its original shape once it has been compressed (Szczesniak *et al.*, 1963). The results showed an increase in springiness with increasing fat replacement as depicted in Figure 17. Texture profile analysis for springiness showed significant differences ($p \leq 0.05$) between rock cakes with the exception of RCO and RCA, and RCS and RCJ. High values (Appendix 4B) of springiness recorded in RCJ and RCS indicate that RCJ and RCS were highly elastic due to their low fat contents. Thus, RCJ and RCS were stretchy and flexible to quickly return to their original shape and size after being exposed to a 50% compression at a speed rate and time of 1.0 mm/sec and 2 sec respectively.

The ability of RCJ and RCS to quickly return to their original shape and size after being exposed to compression could be due to the water holding capacity of the fat replacer, which made the water bind more to the flour proteins forming tough gluten networks imparting elasticity to the dough and subsequent baked products since there was less fat to shorten the gluten networks.

Because RCO (full fat rock cake) had the highest amount of fat with no fat replacer, the fat was able to shorten the gluten networks resulting in a tender product, hence its inability to quickly return to its original shape and size after being exposed to the same amount of compression. A similar observation was reported by Penfield and Campbell (1990) that mixing of flour with fat prevents the formation of tough gluten network to produce a less elastic and less cohesive 0baked product.

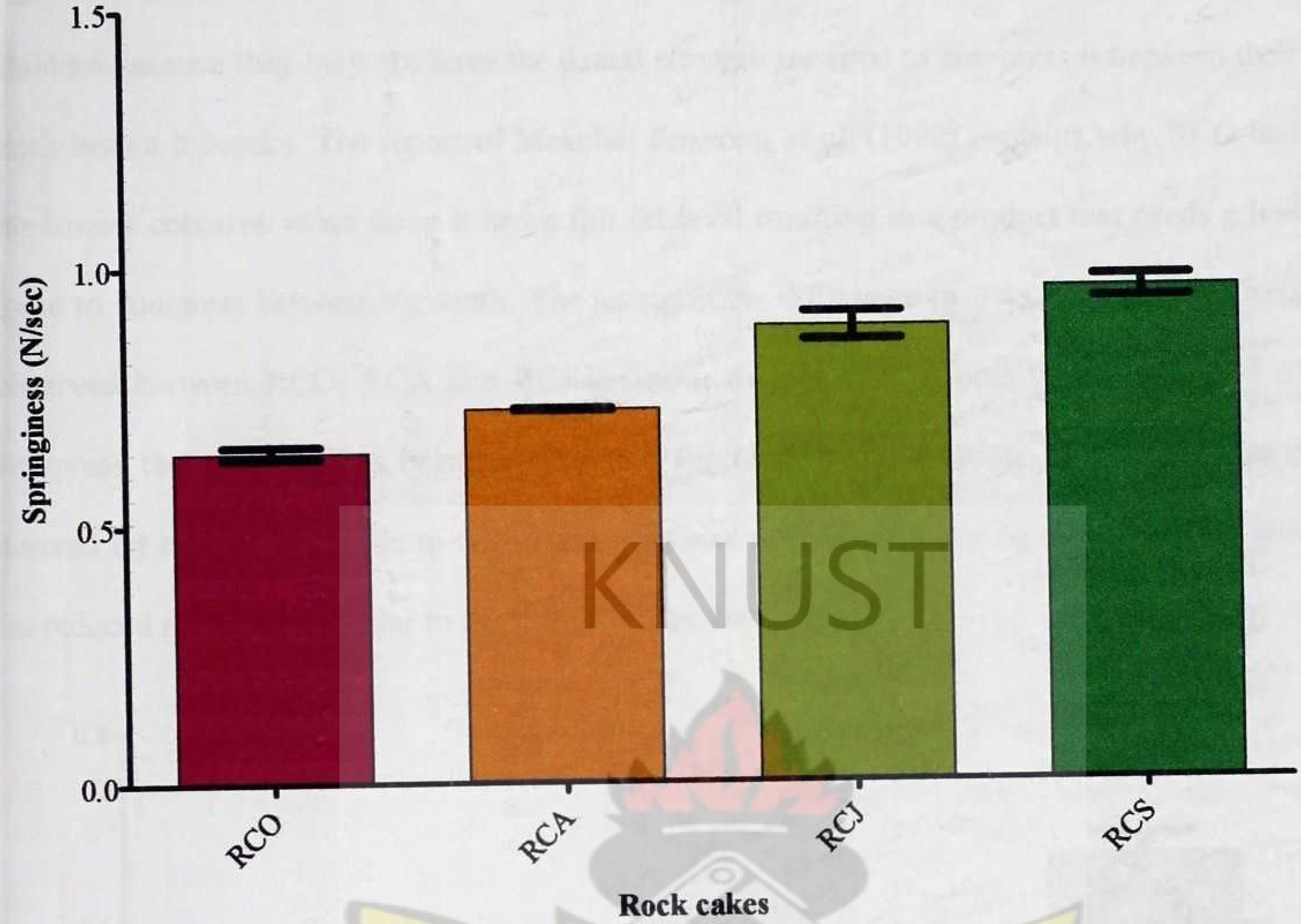

Figure 17: Effect of soursop-derived fat replacer on springiness of rock cakes

4.4.4 Cohesiveness

Cohesiveness is the degree to which a substance is compressed between the teeth before it breaks (Szczesniak *et al.*, 1963). From Figure 18, there was increase in cohesive properties of rock cakes with increasing fat replacement. Significant differences ($p \leq 0.05$) existed between the following pairs of rock cakes: RCO and RCS, RCA and RCS, and RCJ and RCS. However there was no significant difference ($p \geq 0.05$) among RCO, RCA and RCJ. The high cohesive property of RCS could be due to the low amount of fat in its formulation.

Mache- Rezzoug *et al.* (1998) reported that the mixing of flour with fat prevents the formation of tough gluten network to produce a less elastic and less cohesive baked product. Hence RCS will require a greater force to compress it between the teeth before it breaks. The high cohesive property observed in RCS is an undesirable sensory attribute especially for children because they may not have the dental strength required to compress it between their teeth before it breaks. The report of Maache- Rezzoug *et al*. (1998) explains why RCO had the lowest cohesive value since it had a full fat level resulting in a product that needs a less force to compress between the teeth. The insignificant difference ($p \geq 0.05$) in cohesiveness observed between RCO, RCA and RCJ indicates that, a similar force will be required to compress these rock cakes between the teeth for efficient mastication. Thus, the soursop derived fat replacer was able to mimic the functions of fat in tenderizing and producing soft fat reduced rock cakes similar to the full fat rock cake.

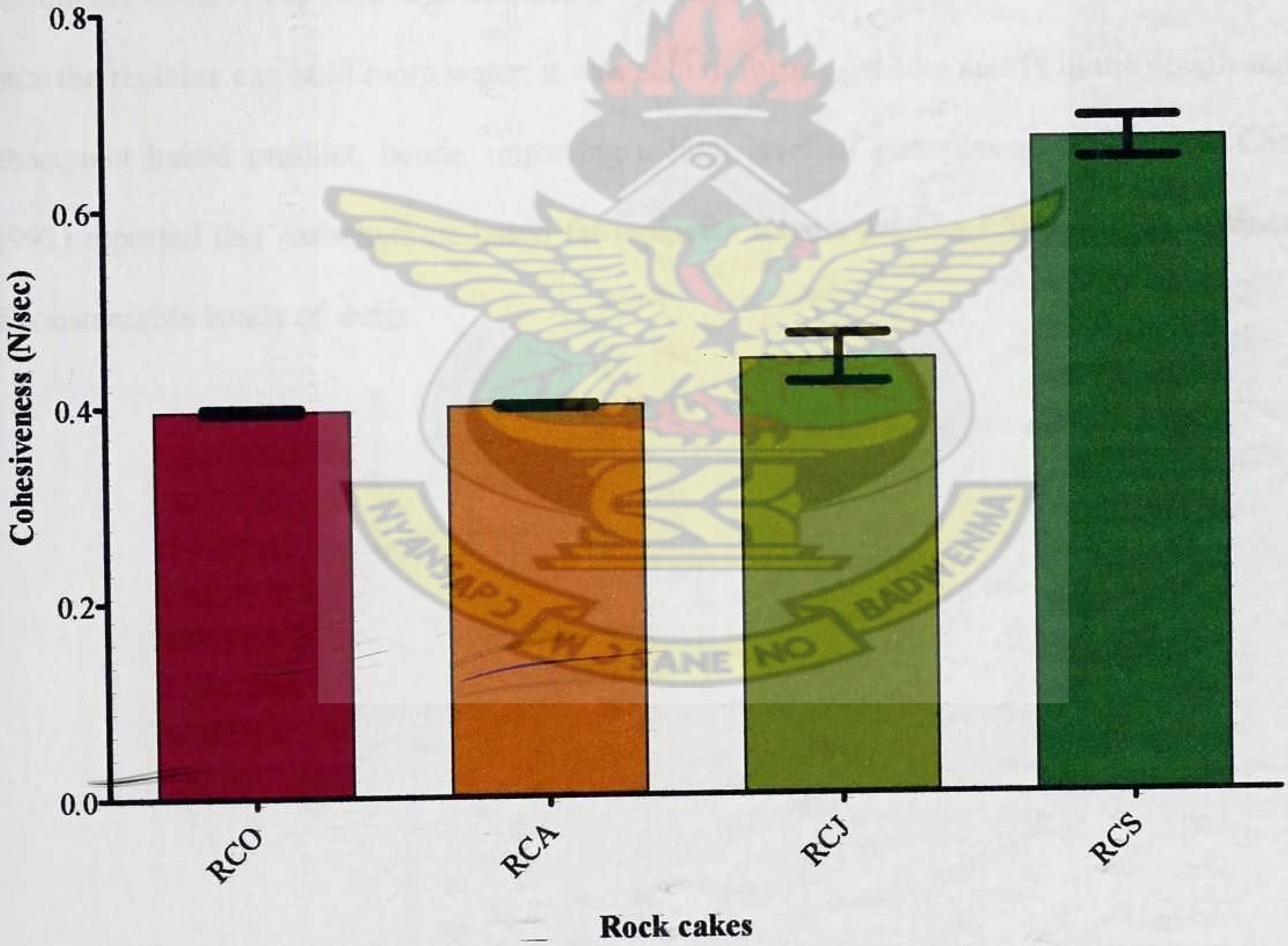

Figure 18: Effect of soursop-derived fat replacer on cohesiveness of rock cakes

4.4.5 Gumminess

Gumminess is the energy required to disintegrate a semi-solid food to a state ready for swallowing (Szczesniak *et al.*, 1963). From Figure 19, there was an increase in gumminess of rock cakes with increasing fat reduction. RCS had the highest score (4494 N/sec) for gumminess while RCO had the lowest score (1480 N/sec). Although there were significant differences ($p \leq 0.05$) between RCO and RCS, RCA and RCS, and RCJ and RCS, no significant difference ($p \geq 0.05$) existed between RCO and RCA, RCO and RCJ, and RCA and RCJ (Appendix 4B). The observation of RCS being the gummiest is consistent with comments made by sensory panellists during sensory evaluation. The high degree of gumminess observed in RCS was because it had the highest level of replacement (60%) and since the replacer can hold more water, it was able to form a gel-like matrix in the dough and subsequent baked product, hence, imparting a high level of gumminess. Yackel and Cox (1992) reported that carbohydrate-based fat replacers form a gel-like matrix in the presence of considerable levels of water.

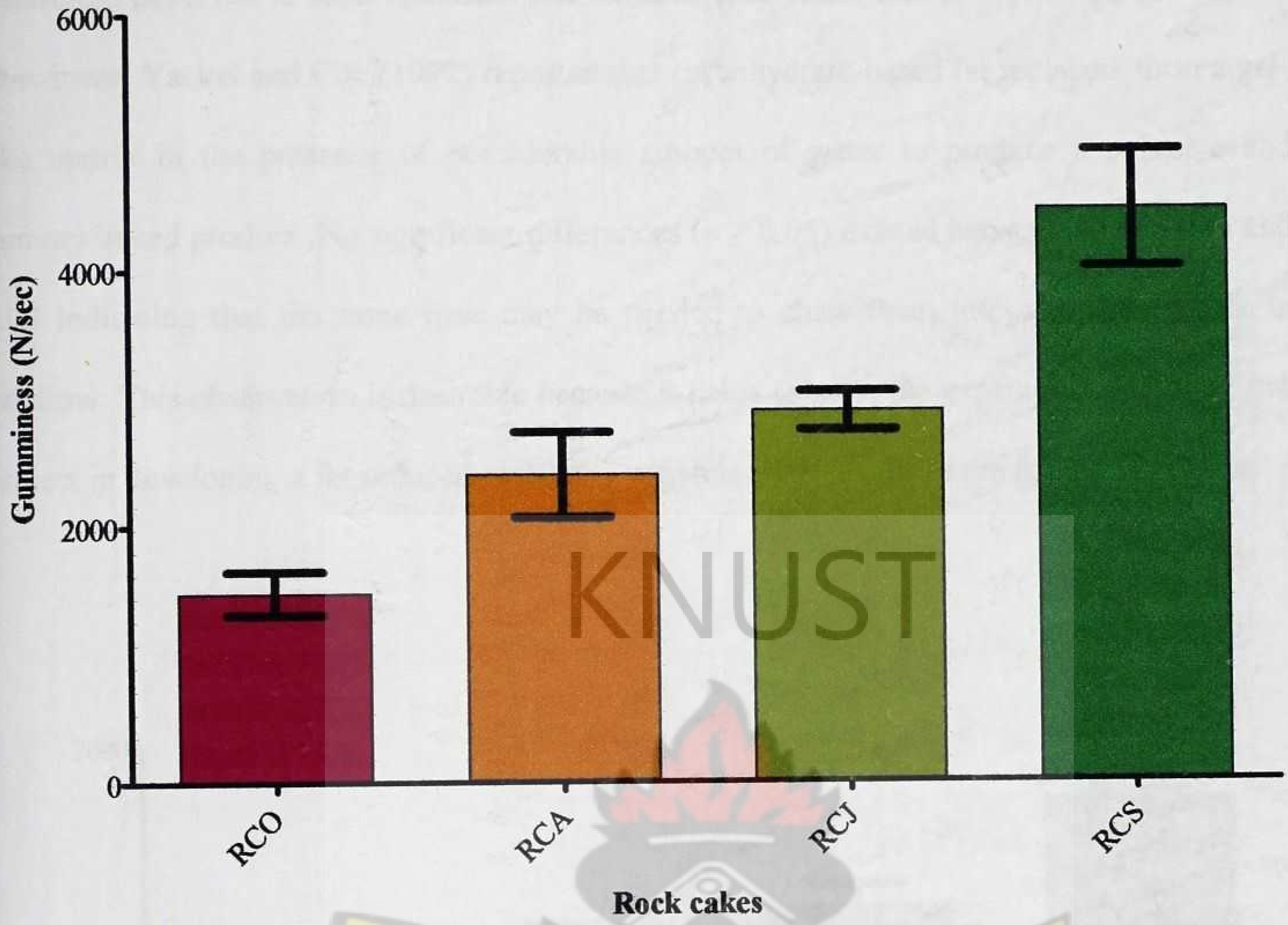

Figure 19: Effect of soursop-derived fat replacer on gumminess of rock cakes

4.4.6 Chewiness

Chewiness is the length of time required to chew a sample to a consistency suitable for swallowing (Szczesniak *et al.*, 1963). From Figure 20, there was an increase in chewiness with increasing fat reduction. Significant differences ($p \leq 0.05$) in chewiness were observed between the following pairs of rock cakes: RCO and RCS, RCA and RCS, and RCJ and RCS. RCO recorded the least score (1388 N/sec) for chewiness with RCS recording the highest score (1852 N/sec) as depicted on Appendix 4B.

The high degree of chewiness observed in RCS was due to its high fat replacement resulting in its hard, cohesive, springy and gummy nature which made chewing difficult. Therefore, more time will be needed to chew RCS into a state ready for swallowing. The high degree of chewiness observed in RCS is undesirable because rock cakes do not require a high level of chewiness. Yackel and Cox (1992) reported that carbohydrate-based fat replacers form a gel-like matrix in the presence of considerable amount of water to produce a cohesive and gummy baked product. No significant differences ($p \geq 0.05$) existed between RCO, RCA and RCJ indicating that the same time may be needed to chew them into a state desirable to swallow. This observation is desirable because it helps to meet the expected outcome of this project in developing a fat reduced rock cake which is very similar to the full fat rock cake.

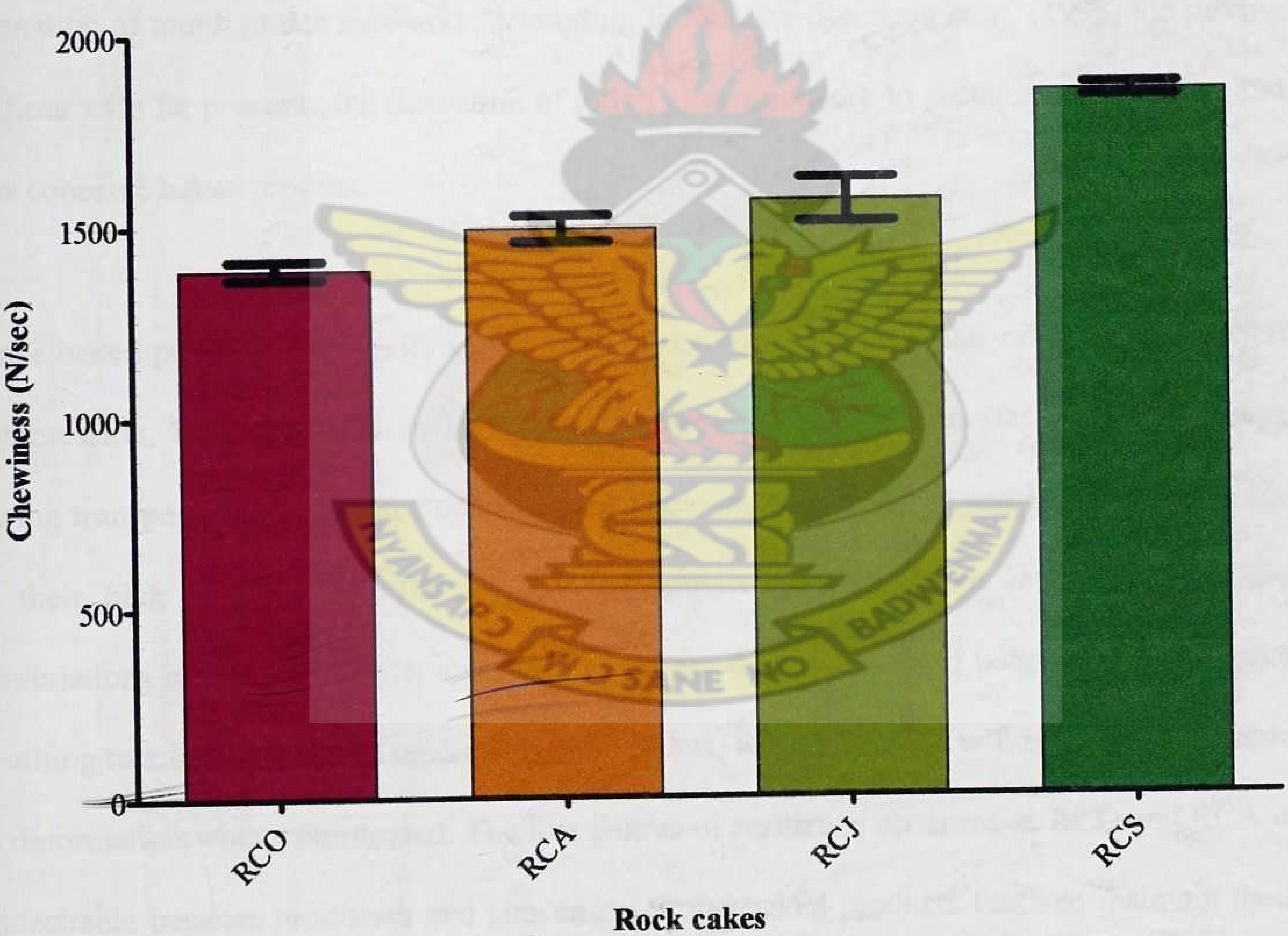

Figure 20: Effect of soursop-derived fat replacer on chewiness of rock cakes

4.4.7 Resilience

The speed with which a baked product returns to its original shape after compression is termed resilience (Szczesniak *et al.,* 1963). From Figure 21, there was an increase in resilience with increasing fat reduction. There were significant differences ($p \leq 0.05$) between RCO and RCJ, RCO and RCS, RCA and RCS, RCJ and RCS. However, no significant difference existed between RCO and RCA, RCA and RCJ. RCJ and RCS recorded high values for resilience with RCO and RCA recording the lowest resilience values (Appendix 4B). The high degree of resilience observed in RCJ and RCS may be due to their high level of soursop-fat replacer which imparted an elastic and hard baked product through the formation of tough gluten networks. According to Maache- Rezzoug *et al*. (1998) the mixing of flour with fat prevents the formation of tough gluten network to produce a less elastic and less cohesive baked product.

Since baked products are ideally expected to return completely to their original shapes after compression, RCJ and RCS will possess an enhanced resistance to stacking and packing during transportation. The low degree of resilience observed in RCO and RCA could be due to their high level of fat, 100% and 80% respectively. The high level of fat in the formulations of RCO and RCA was able to prevent the formation of tough gluten networks resulting in a less elastic and tender rock cake. Thus, RCO and RCA will be more vulnerable to deformation when compressed. The low degree of resilience observed in RCO and RCA is undesirable because producers and consumers prefer baked products that can maintain their original shape after compression during storage, transport, on the shelf, when squeezed by the consumer or once in the shopping bag.

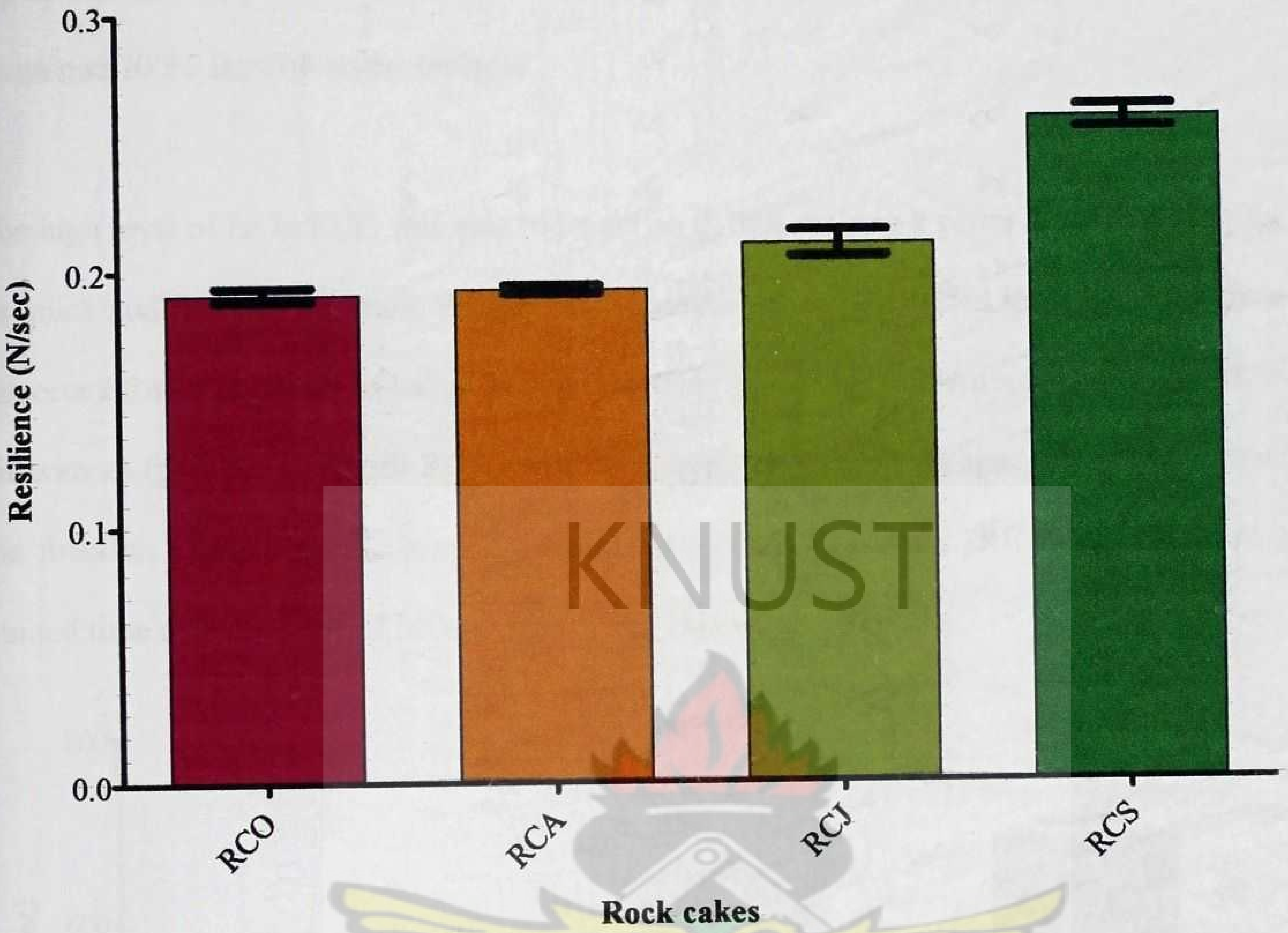

Figure 21: Effect of soursop-derived fat replacer on resilience of rock cakes

4.4.8 Modulus of Deformation (MD)

In general there was an increase in MD with increasing fat replacement as depicted in Figure 22. Significant differences ($p \leq 0.05$) existed between the following rock cake pairs: RCO and RCJ, RCO and RCS, RCA and RCS, and RCJ and RCS. However, there were no significant differences between RCO and RCA, and RCA and RCJ. RCS recorded the highest value (683.80 N/sec) for MD while RCO had the least value (283.20 N/sec). The extended time and high level of MD observed in RCS is due to its low percentage of fat (40%) and high percentage of fat replacer (60%). High percentage of soursop fat replacer in RCS accounted for its high MD because the replacer was able to hold more water resulting in an elastic, gummier and less fractured rock cake; hence a greater force was needed to deform the macro-structure of RCS. The high degree of MD observed in RCS is undesirable and not typical of rock cakes. RCO required a limited time and a low level of deformation because it contained 100% fat with no fat replacer.

The high level of fat in RCO was able to tenderise it, thus making it softer and accounting for its quick and easy deformation. Penfield and Campbell (1990) reported that one of the most important functions of fat in baked goods is to contribute to its tenderness. The insignificant differences ($p \geq 0.05$) between RCO and RCA implies that the fat replacer was able to mimic the function of fat in tenderising the dough to produce a product (RCA) that required a limited time and low level of MD as desired and typical of rock cakes.

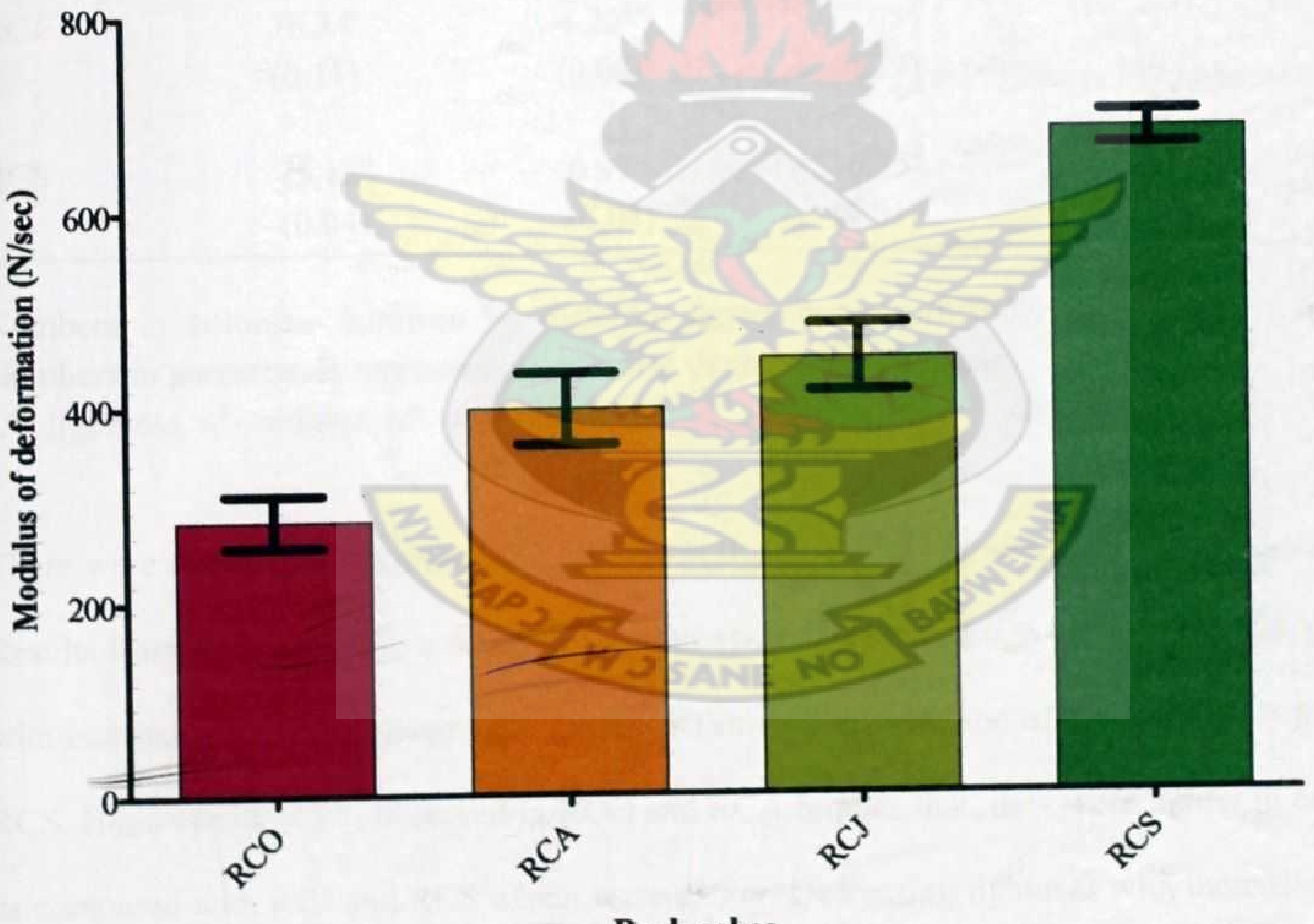

Figure 22: Effect of soursop-derived fat replacer on modulus of deformation of rock cakes

4.5 Effect of fat reduction on the CIE L*, a*, b* colour parameters of rock cakes

The colorimetric properties of fat reduced rock cakes before and after baking are presented in Tables 4 and 5.

Table 4- Mean and standard deviation CIE L*, a*, b* colour parameter values of rock cakes dough before baking

Rock cakes	L*(lightness)	a*(redness)	b*(yellowness)
RCO	78.55[a] (0.05)	2.11[a] (0.08)	20.68[a] (0.16)
RCA	77.42[b] (0.06)	1.85[ba] (0.04)	17.86[b] (0.09)
RCJ	76.34[c] (0.11)	1.22[bc] (0.06)	17.05[c] (0.29)
RCS	75.18[d] (0.04)	0.97[c] (0.03)	16.35[d] (0.01)

Numbers in columns followed by different letters are significantly different ($p \leq 0.05$)
Numbers in parentheses represent the standard deviation of the mean.
L*- lightness, a*- redness, b*- yellowness

There were significant differences ($p \leq 0.05$) in lightness, L*, between dough of rock cakes. Results from Table 4 shows a decrease in lightness, L*, for the dough of unbaked rock cakes with increasing fat replacement. The results in Table 4 depict a trend of RCO > RCA > RCJ > RCS. High values of L*, observed in RCO and RCA implies that, they were lighter in colour as compared with RCJ and RCS which were darker. Decreasing lightness with increasing fat reduction demonstrates that, dough of rock cakes got darker with increasing soursop-fat replacement. The decrease in lightness with increasing fat reduction could be due to the different amounts of fat used in the formulation of rock cakes dough. Increase in darkness with increasing soursop fat replacer could also be due to the impartation of the colour of the soursop fat replacer on the dough as its addition increases.

Redness value, a*, of rock cakes dough decreased with increasing fat replacement in the order of RCO > RCA > RCJ > RCS as depicted in Table 4. Significant differences ($p \leq 0.05$) in redness existed between rock cakes dough of RCO and RCJ, RCO and RCS, and RCA and RCS. However, no significant differences ($p \geq 0.05$) existed between RCO and RCA, RCA and RCJ, and RCJ and RCS. The decreasing a* values with increasing fat replacement observed in rock cakes dough implies that, dough of rock cakes decreased in redness with increasing soursop fat replacer.

The yellowness, b*, of rock cakes dough decreased with increasing soursop fat replacement in the order of RCO > RCA > RCJ > RCS as depicted in Table 4. Significant differences ($p \leq 0.05$) existed between dough of rock cakes. RCO recorded the highest yellowness value (20.68) whereas RCS recorded the least value (16.35). The high yellowness, b*, observed in RCO dough could be due to its high fat content (100%) whereas the low b* observed in RCS could be due to its low fat and high soursop fat replacer content. This implies that the colour of rock cakes dough shifted from yellow to blue on the colour wheel (Praznik, 2002).

Table 5. Mean and standard deviation CIE L*, a*, b* colour parameters values of baked rock cakes crust

Rock cakes	L*(lightness)	a*(redness)	b*(yellowness)
RCO	68.62[a] (0.01)	7.68[a] (0.23)	17.27[a] (0.36)
RCA	65.89[b] (0.04)	6.92[b] (0.06)	17.27[a] (0.05)
RCJ	62.92[c] (0.03)	5.75[b] (0.04)	13.93[b] (0.06)
RCS	61.54[d] (0.08)	5.44[c] (0.11)	13.90[b] (0.15)

Numbers in columns followed by different letters are significantly different ($p \leq 0.05$)
Numbers in parentheses represent the standard deviation of the mean.
L*- lightness, a*- redness, b*- yellowness.

Results from Table 5 showed a decrease in lightness, L*, for the crusts of baked rock cakes with increasing fat replacement. The results depicts a trend of RCO > RCA > RCJ > RCS. Significant differences ($p \leq 0.05$) were observed between the crusts of rock cakes (Appendix 6E). The high value of lightness, L*, observed in RCO could be due to its high fat content (100%). The decrease in lightness with increasing fat replacement implies that the rock cakes got darker with increasing fat replacement.

The observation of increasing darkness with increasing fat replacement could be due to the ability of soursop fat replacer in masking the lightness attribute imparted by fat as its addition was increasing during rock cakes formulation. A similar trend of decreasing lightness with increasing fat replacement was reported by Chysirichote *et al.* (2010). Chysirichote *et al.* (2010) reported a decrease in lightness, L*, with increasing maltodextrin fat replacement in the crust of Flaky Chinese pastry.

Significant differences ($p \leq 0.05$) in redness of crusts existed between rock cakes with the exception of RCA and RCJ which were not significantly different from each other. Redness value, a*, of rock cakes crusts decreased with increasing fat replacement in the order of RCO > RCA > RCJ > RCS as depicted in Table 5. Chysirichote *et al.* (2010) reported a decrease in redness, a*, with increasing maltodextrin and inulin fat replacement in the crust of Flaky Chinese pastry. However, Paintsil (2008) reported an increase in redness, a*, with increasing papaya fat replacement in the crust of rock buns due to the presence of carotenoid pigment in the papaya fat replacer.

No significant differences ($p \geq 0.05$) were observed in yellowness, b*, between the following pairs of rock cakes crusts: RCO and RCA, RCJ and RCS. However significant differences ($p \leq 0.05$) existed between crusts of RCO and RCJ, RCO and RCS, RCA and RCJ, RCA and RCS. RCO and RCA recorded the highest yellowness value (17.27) with RCJ and RCS recording the least values of 13.93 and 13.90 respectively. The high yellowness observed in RCO and RCA was due to their high fat content which imparted the uniform golden brown colour desired in rock cakes (Penfield and Campbell, 1990). Decrease in yellowness with increasing fat reduction in rock cakes confirmed the results obtained from sensory evaluation where the preference of panellists to rock cakes was decreasing with increasing fat reduction with respect to colour. RCJ and RCS recorded low yellowness values because of their low fat content and high soursop fat replacer. Chysirichote *et al.* (2010) reported a decrease in yellowness, b*, with increasing maltodextrin and inulin fat replacement in the crust of Flaky Chinese pastry.

CHAPTER FIVE

5.0 CONCLUSION

Comparison of fat and moisture contents among fat-reduced rock cakes and the full-fat rock cake (control) showed a decrease in both parameters with increase in soursop fat replacer. With respect to sensory evaluation, no significant difference ($p \geq 0.05$) existed between the full-fat rock cake (control) and fat-reduced rock cakes in all sensory attributes with the exception of astringency. Untrained sensory panellists preferred the full-fat rock cake (control) to the fat-reduced rock cakes with the degree of liking between "like very much" to "like moderately". Colorimetric properties of rock cakes dough and crust decreased with increasing fat reduction. RCO (control) recorded the highest values for all colorimetric properties with RCS (60% fat reduced rock cake) recording the least values for colorimetric properties. The study on texture showed that fat-reduced rock cakes were comparable and even better than the full-fat rock cake (control) up to a 40% fat reduction level. Textural properties of rock cakes above 40% fat reduction were not desirable.

The application of soursop as a fat replacer resulted in satisfactory rock cakes. Rock cakes produced from soursop fat replacer at a 40% substitution level were comparable to the full-fat rock cake (control) in terms of sensory properties and also better than the full-fat complements with respect to textural properties.

5.1 Recommendation

From this study, it is recommended that, future research should concentrate on the following areas;

- Investigating the combinations of soursop and other carbohydrate-based fat replacers in order to find a replacement system that will most effectively produce better sensory attributes.
- Investigating the effects of soursop fat replacement on product quality in baked goods such as bread and cakes.

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APPENDICES

APPENDIX 1- FORMULAE USED FOR CALCULATIONS

a) $\% \text{ moisture} = \frac{W2 - W3}{W2 - W1} \times 100$

Where: W1 = Weight of crucible

W2 = Weight of crucible + Sample

W3= Weight of crucible + Dry sample

b) $\% \text{ Ash} = \frac{W3 - W1}{W2 - W1} \times 100$

Where: W1 = Weight of porcelain crucible
W2 = Weight of porcelain crucible + sample
W3 = Weight of porcelain crucible + Ash

c) $\% \text{ Total nitrogen } (\% N) = \frac{X \text{ moles}}{1000 \text{ cm3}} \times \frac{(Vs - Vb) \text{ cm3}}{\text{mg}} \times \frac{14 \text{ g}}{\text{moles}} \times 100$

$\% \text{ Protein} = \% N \times 6.25$

Where: mg = Mass of sample
X = Normality of acid, HCL
Vs = Titration value of sample
Vb = Titration value of blank
6.25 = Protein conversion factor

d) $\% \text{ Fat} = \frac{W2 - W1}{W3} \times 100$

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

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

APPENDIX 2A – ANOVA FOR PERCENT FAT AND MOISTURE OF ROCK CAKES

Parameter	Source of variation	Sum of squares	Df	Mean square	F-ratio	P-value
Fat						
	Between groups	169.50	3	56.49	1886	0
	Within groups	0.12	4	0.03		
	Total (Corr)	169.60	7			
Moisture						
	Between groups	134.40	3	44.81	315.50	0
	Within groups	0.57	4	0.14		
	Total (Corr)	135.0	7			

APPENDIX 2B: TABLE FOR MEAN PERCENT FAT AND MOISTURE VALUES OF FORMULATED ROCK CAKES

Parameter	Formulated Rock Cakes			
	RCO	RCA	RCJ	RCS
Fat Content (g/100 g)	17.30 (0.18)	12.44 (0.28)	8.82 (0.11)	4.81 (0.04)
Moisture Content (g/100 g)	24.05 (0.29)	20.98 (0.33)	15.49 (0.61)	13.89 (0.09)

Numbers in columns followed by different letters are significantly different ($p \leq 0.05$)
Numbers in parentheses represent the standard deviation of the mean.
Rock cake Treatments: RCO = control (100% fat)
RCA = 20% soursop fat replacement
RCJ = 40% soursop fat replacement
RCS = 60% soursop fat replacement

APPENDIX 3A: QUESTIONNAIRE FOR SENSORY EVALUATION OF ROCK CAKES

ACCEPTABIITY TEST

Name: ……………………………………………

Product: Rock Cakes

Sample code:………………………………………

Date:…………………………………………………

Please examine these samples and evaluate them in terms of appearance, colour, aroma, taste, mouth feel, Texture (sponginess), astringency and overall acceptability. Please remember to wash your mouth and chew your cream crackers after each tasting.

No	Interpretation	Appearance	Colour	Aroma	Taste	Mouth feel	Texture (sponginess)	Astringency	Over accep
9	Like extremely								
8	Like very much								
7	Like moderately								
6	Like slightly								
5	Neither like nor dislike								
4	Dislike slightly								
3	Dislike moderately								
2	Dislike very much								
1	Dislike extremely								

Comments please:
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Would you buy this product? Yes No

APPENDIX 3B: TABLE FOR MEAN VALUES AND STANDARD DEVIATION OF SENSORY ATTRIBUTES

Rock cakes	App	Col	Aro	Tas	Mtf	Spo	Ast	Overall
RCO	8.20[a] (0.86)	8.27[a] (0.88)	7.93[a] (0.59)	8.00[a] (1.25)	8.20[a] (0.56)	7.80[a] (0.94)	7.467[a] (1.06)	8.00[a] (0.85)
RCA	7.60[a] (0.74)	7.53[a] (0.74)	7.53[a] (1.13)	7.60[a] (1.18)	7.47[a] (1.25)	7.53[a] (0.92)	6.47[b] (0.99)	7.53[a] (1.25)
RCJ	7.53[a] (0.74)	7.67[a] (0.82)	7.73[a] (0.70)	7.80[a] (0.68)	7.73[a] (0.70)	7.60[a] (0.83)	6.40[b] (1.06)	7.60[a] (0.63)
RCS	7.40[b] (0.74)	7.60[a] (0.74)	7.60[a] (0.91)	7.20[a] (1.37)	7.40[a] (1.12)	7.40[a] (0.99)	6.20[b] (0.68)	7.53[a] (1.06)

Numbers in columns followed by different letters are significantly different ($p < 0.05$)
Numbers in parentheses represent the standard deviation of the mean.
App- Appearance, Col- Colour, Aro- Aroma, Tas- Taste, Mtf- Mouth feel, Spo- Sponginess, Ast- Astringency, Overall- Overall acceptability.
Rock cake Treatments: RCO = Control (100% fat)
RCA = 20% soursop fat replacement
RCJ = 40% soursop fat replacement
RCS = 60% soursop fat replacement

APPENDIX 3C: ANOVA TABLE FOR SENSORY EVALUATION OF ROCK CAKES

Attribute	Source of variation	Sum of squares	Df	Mean square	F-ratio	P- value
Appearance	Between groups	5.65	3	1.83	3.16	0.03
	Within groups	33.33	56	0.60		
	Total (Corr)	38.98	59			
Colour	Between groups	5.13	3	1.71	2.69	0.05
	Within groups	35.6	56	0.64		
	Total (Corr)	40.73	59			
Aroma	Between groups	1.40	3	0.47	0.63	0.59
	Within groups	41.20	56	0.74		
	Total (Corr)	42.60	59			
Taste	Between groups	5.25	3	1.75	1.32	0.28
	Within groups	74.40	56	1.33		
	Total (Corr)	79.65	59			
Mouth feel	Between groups	5.93	3	1.98	2.19	0.09
	Within groups	50.67	56	0.90		
	Total (Corr)	56.60	59			
Sponginess	Between groups	1.25	3	0.42	0.49	0.69
	Within groups	47.33	56	0.85		
	Total (Corr)	48.58	59			
Astringency	Between groups	14.47	3	4.82	5.25	0.00
	Within groups	51.47	56	0.92		
	Total (Corr)	65.93	59			
Overall acc	Between groups	2.27	3	0.76	0.79	0.50
	Within groups	53.07	56	0.95		
	Total (Corr)	55.33	59			

APPENDIX 4A: ANOVA TABLE FOR TEXTURE PROFILE ANALYSIS OF ROCK CAKES.

Attribute	Source of variation	Sum of squares	Df	Mean Square	F-ratio	P-value
Hardness						
	Between groups	4.57×10^{8}	3	1.52×10^{8}	67.59	0.00
	Within groups	1.80×10^{7}	8	2.26×10^{6}		
	Total (Corr)	4.74×10^{8}	11			
Fracturabilty						
	Between groups	1.12×10^{6}	3	37303	38.80	0.00
	Within groups	76914	8	9614		
	Total (Corr)	1.19×10^{6}	11			
Springiness						
	Between groups	0.01	3	0.00	18.54	0.00
	Within groups	0.00	8	0.00		
	Total (Corr)	0.02	11			
Cohesiveness						
	Between groups	0.00	3	0.00	26.19	0.00
	Within groups	0.00	8	6.93×10^{-5}		
	Total (Corr)	0.00	11			
Gumminess						
	Between groups	9.98×10^{7}	3	3.33×10^{7}	70.55	0.00
	Within groups	3.77×10^{6}	8	471443		
	Total (Corr)	1.04×10^{8}	11			
Chewiness						
	Between groups	5.19×10^{7}	3	1.73×10^{7}	80.53	0.00
	Within groups	1.72×10^{6}	8	214628		
	Total (Corr)	5.36×10^{7}	11			
Resilience						
	Between groups	0.01	3	0.00	76.55	0.00
	Within groups	0.00	8	4.08×10^{-5}		
	Total (Corr)	0.01	11			
Modulus of deformation						
	Between groups	255568	3	85189	31.94	0.00
	Within groups	21337	8	2667		
	Total (Corr)	276904	11			

APPENDIX 4B: TABLE FOR MEAN AND STANDARD DEVIATION VALUES OF TEXTURE PROFILE ANALYSIS

Rock cakes	Har	Fra	Adh	Spr	Coh	Gum	Chw	Res	Mod
RCO	4730[a] (0.05)	583.00[a] (0.01)	3.12[a] (1.03)	0.64[a] (0.02)	0.39[a] (0.00)	1480[a] (1.04)	1388[a] (0.01)	0.19[a] (0.00)	283.20[a] (0.04)
RCA	5641[a] (0.11)	820.10[ab] (0.07)	1.69[a] (0.00)	0.73[a] (0.00)	0.40[a] (0.00)	2406[a] (0.02)	1494[a] (1.06)	0.19[ab] (0.00)	397.7[ab] (1.25)
RCJ	6217[ab] (0.10)	965.30[b] (0.15)	1.58[a] (1.30)	0.89[b] (0.01)	0.44[a] (0.01)	2909[a] (1.00)	1567[a] (1.50)	0.21[b] (0.00)	449.10[b] (1.15)
RCS	7303[b] (1.15)	1420.00[c] (0.12)	10.13[b] (0.12)	0.96[b] (0.02)	0.67[b] (0.00)	4494[b] (0.91)	1852[b] (0.85)	0.26[c] (0.01)	683.80[c] (1.05)

Numbers in columns followed by different letters are significantly different ($p < 0.05$)
Numbers in parentheses represent the standard deviation of the mean.
Har- Hardness, Fra- Fracturability, Adh- Adhesiveness, Spr- Springiness, Coh- Cohesiveness, Gum- Gumminess, Res- Resilience, Mod- Modulus of deformation.

Rock cake Treatments: RCO = Control (100% fat)
RCA = 20% soursop fat replacement
RCJ = 40% soursop fat replacement
RCS = 60% soursop fat replacement

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

Attribute	Source of variation	Sum of squares	Df	Mean Square	F-ratio	P-value
Lightness						
	Between groups	18.83	3	6.28	1324	0.00
	Within groups	0.04	8	0.00		
	Total (Corr)	18.87	11			
Redness (a*)						
	Between groups	3.38	3	1.13	381.9	0.00
	Within groups	0.02	8	0.00		
	Total (Corr)	3.40	11			
Yellowness (b*)						
	Between groups	32.44	3	10.81	359.4	0.00
	Within groups	0.24	8	0.03		
	Total (Corr)	32.68	11			

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

Attribute	Source of variation	Sum of squares	Df	Mean Square	F-ratio	P-value
Lightness (L*)						
	Between groups	89.81	3	29.94	1420	0.00
	Within groups	0.02	8	0.00		
	Total (Corr)	89.83	11			
Redness (a*)						
	Between groups	17.23	3	5.74	328.7	0.00
	Within groups	0.14	8	0.02		
	Total (Corr)	17.37	11			
Yellowness (b*)						
	Between groups	33.84	3	11.28	282.0	0.00
	Within groups	0.32	8	0.04		
	Total (Corr)	34.16	11			

APPENDIX 6A: TABLE FOR BONFERRONI'S MULTIPLE COMPARISM TESTS ON FAT AND MOISTURE CONTENTS OF ROCK CAKES

Attribute	Rock Cakes	Mean Diff	T-statistic	Significant ($P \leq 0.05$)
Fat				
	RCO vs RCA	4.86	28.08	Yes
	RCO vs RCJ	8.48	49.00	Yes
	RCO vs RCS	12.49	72.17	Yes
	RCA vs RCJ	3.62	20.92	Yes
	RCA vs RCS	7.63	44.09	Yes
	RCJ vs RCS	4.01	23.17	Yes
Moisture				
	RCO vs RCA	3.07	8.13	Yes
	RCO vs RCJ	8.56	22.70	Yes
	RCO vs RCS	10.16	26.96	Yes
	RCA vs RCJ	5.49	14.57	Yes
	RCA vs RCS	7.09	18.83	Yes
	RCJ vs RCS	1.61	4.26	No

APPENDIX 6B: TABLE FOR BONFERRONI'S MULTIPLE COMPARISM TESTS ON SENSORY ATTRIBUTES OF ROCK CAKES

Attribute	Rock cake	Mean Diff	T-statistic	Significant ($P \leq 0.05$)
Colour				
	RCO vs RCA	0.73	2.52	No
	RCO vs RCJ	0.60	2.06	No
	RCO vs RCS	0.67	2.29	No
	RCA vs RCJ	0.13	0.46	No
	RCA vs RCS	0.06	0.23	No
	RCJ vs RCS	0.07	0.23	No
Appearance				
	RCO vs RCA	0.60	2.13	No
	RCO vs RCJ	0.67	2.37	No
	RCO vs RCS	0.80	2.84	Yes
	RCA vs RCJ	0.67	0.24	No
	RCA vs RCS	0.20	0.71	No
	RCJ vs RCS	0.13	0.47	No
Aroma				
	RCO vs RCA	0.40	1.28	No
	RCO vs RCJ	0.20	0.64	No
	RCO vs RCS	0.33	1.06	No
	RCA vs RCJ	-0.20	0.64	No
	RCA vs RCS	-0.07	0.21	No
	RCJ vs RCS	0.13	0.43	No
Taste				
	RCO vs RCA	0.40	0.95	No
	RCO vs RCJ	0.20	0.48	No
	RCO vs RCS	0.80	1.90	No
	RCA vs RCJ	-0.20	0.48	No
	RCA vs RCS	0.40	0.95	No
	RCJ vs RCS	0.60	1.43	No
Mouth feel				
	RCO vs RCA	0.27	0.79	No
	RCO vs RCJ	0.20	0.59	No
	RCO vs RCS	0.40	1.19	No
	RCA vs RCJ	-0.07	0.19	No
	RCA vs RCS	0.13	0.39	No
	RCJ vs RCS	0.20	0.59	No

APPENDIX 6B: TABLE FOR BONFERRONI'S MULTIPLE COMPARISM TESTS ON SENSORY ATTRIBUTES OF ROCK CAKES CONTINUED

Attribute	Rock cake	Mean Diff	T-statistic	Significant ($P \leq 0.05$)
Astringency				
	RCO vs RCA	1.00	2.86	Yes
	RCO vs RCJ	1.07	3.05	Yes
	RCO vs RCS	1.27	3.62	Yes
	RCA vs RCJ	0.07	0.19	No
	RCA vs RCS	0.27	0.76	No
	RCJ vs RCS	0.20	0.57	No
Sponginess				
	RCO vs RCA	0.27	0.79	No
	RCO vs RCJ	0.20	0.59	No
	RCO vs RCS	0.40	1.19	No
	RCA vs RCJ	-0.07	0.19	No
	RCA vs RCS	0.13	0.39	No
	RCJ vs RCS	0.20	0.59	No
Overall Acceptability				
	RCO vs RCA	0.47	1.31	No
	RCO vs RCJ	0.40	1.13	No
	RCO vs RCS	0.47	1.31	No
	RCA vs RCJ	-0.07	0.19	No
	RCA vs RCS	0.0	0.0	No
	RCJ vs RCS	0.07	0.19	No

APPENDIX 6C: TABLE FOR BONFERRONI'S MULTIPLE COMPARISM TESTS ON RHEOLOGICAL PROPERTIES OF ROCK CAKES

Attribute	Rock cake	Mean Diff	T-statistic	Significant ($P \leq 0.05$)
Hardness				
	RCO vs RCA	-910.9	2.09	No
	RCO vs RCJ	-1487	3.41	No
	RCO vs RCS	-2573	5.81	Yes
	RCA vs RCJ	-576.0	1.32	No
	RCA vs RCS	-1662	3.81	Yes
	RCJ vs RCS	-1086	2.49	No
Fracturability				
	RCO vs RCA	-237.1	2.96	No
	RCO vs RCJ	-382.3	4.78	Yes
	RCO vs RCS	-837.4	10.46	Yes
	RCA vs RCJ	-145.2	1.81	No
	RCA vs RCS	-600.3	7.49	Yes
	RCJ vs RCS	-455.1	5.68	Yes
Springiness				
	RCO vs RCA	-0.08	3.23	No
	RCO vs RCJ	-0.24	9.48	Yes
	RCO vs RCS	-0.32	12.31	Yes
	RCA vs RCJ	-0.16	6.25	Yes
	RCA vs RCS	-0.23	9.08	Yes
	RCJ vs RCS	-0.07	2.83	No
Cohesiveness				
	RCO vs RCA	-0.00	0.17	No
	RCO vs RCJ	-0.05	2.17	No
	RCO vs RCS	-0.27	11.88	Yes
	RCA vs RCJ	-0.05	1.99	No
	RCA vs RCS	-0.27	11.71	Yes
	RCJ vs RCS	-0.22	9.71	Yes
Gumminess				
	RCO vs RCA	-925.8	2.14	No
	RCO vs RCJ	-1429	3.30	No
	RCO vs RCS	-3014	6.96	Yes
	RCA vs RCJ	-503.4	1.16	No
	RCA vs RCS	-2088	4.82	Yes
	RCJ vs RCS	-1585	3.66	Yes

APPENDIX 6C: TABLE FOR BONFERRONI'S MULTIPLE COMPARISM TESTS ON RHEOLOGICAL PROPERTIES OF ROCK CAKES CONTINUED

Attribute	Rock cake	Mean Diff	T-statistic	Significant ($P \leq 0.05$)
Chewiness				
	RCO vs RCA	-106.7	2.06	No
	RCO vs RCJ	-179.7	3.47	No
	RCO vs RCS	-463.9	8.95	Yes
	RCA vs RCJ	-72.98	1.41	No
	RCA vs RCS	-357.3	6.89	Yes
	RCJ vs RCS	-284.3	5.48	Yes
Resilience				
	RCO vs RCA	-0.00	0.38	No
	RCO vs RCJ	-0.02	3.83	Yes
	RCO vs RCS	-0.07	13.29	Yes
	RCA vs RCJ	-0.02	3.45	No
	RCA vs RCS	-0.07	12.91	Yes
	RCJ vs RCS	-0.05	9.46	Yes
Modulus of Deformation				
	RCO vs RCA	-114.5	2.72	No
	RCO vs RCJ	-165.9	3.93	Yes
	RCO vs RCS	-400.6	9.50	Yes
	RCA vs RCJ	-51.38	1.22	No
	RCA vs RCS	-286.1	6.79	Yes
	RCJ vs RCS	-234.8	5.57	Yes

APPENDIX 6D: TABLE FOR BONFERRONI'S MULTIPLE COMPARISM TESTS ON CIE L*, A*, B* COLOUR PARAMETERS OF ROCK CAKES DOUGH

Parameter	Rock cake	Mean Diff	T-statistic	Significant ($P \leq 0.05$)
L*(lightness)				
	RCO vs RCA	2.37	69.00	Yes
	RCO vs RCJ	7.80	164.8	Yes
	RCO vs RCS	5.07	142.1	Yes
	RCA vs RCJ	4.43	102.4	Yes
	RCA vs RCS	2.70	69.15	Yes
	RCJ vs RCS	-1.73	49.03	Yes
a*(redness)				
	RCO vs RCA	0.26	1.23	No
	RCO vs RCJ	0.89	4.21	Yes
	RCO vs RCS	1.14	5.38	Yes
	RCA vs RCJ	0.63	2.99	No
	RCA vs RCS	0.88	4.16	Yes
	RCJ vs RCS	0.25	1.18	No
b*(yellowness)				
	RCO vs RCA	2.82	19.89	Yes
	RCO vs RCJ	3.63	25.63	Yes
	RCO vs RCS	4.33	30.55	Yes
	RCA vs RCJ	0.81	5.74	Yes
	RCA vs RCS	1.51	10.66	Yes
	RCJ vs RCS	0.69	4.91	Yes

APPENDIX 6E: TABLE FOR BONFERRONI'S MULTIPLE COMPARISM TESTS ON CIE L*, A*, B* COLOUR PARAMETERS OF ROCK CAKES CRUSTS

Parameter	Rock cake	Mean Diff	T-statistic	Significant ($P \leq 0.05$)
L*(lightness)				
	RCO vs RCA	2.74	73.00	Yes
	RCO vs RCJ	7.08	188.8	Yes
	RCO vs RCS	5.71	152.2	Yes
	RCA vs RCJ	4.34	115.8	Yes
	RCA vs RCS	2.97	79.22	Yes
	RCJ vs RCS	-1.37	36.63	Yes
a*(redness)				
	RCO vs RCA	2.77	25.63	Yes
	RCO vs RCJ	2.93	27.15	Yes
	RCO vs RCS	1.24	11.52	Yes
	RCA vs RCJ	0.16	1.51	No
	RCA vs RCS	-1.52	14.11	Yes
	RCJ vs RCS	-1.69	15.63	Yes
b*(yellowness)				
	RCO vs RCA	0.00	0.02	No
	RCO vs RCJ	3.38	20.68	Yes
	RCO vs RCS	3.34	20.48	Yes
	RCA vs RCJ	3.37	20.66	Yes
	RCA vs RCS	3.34	20.46	Yes
	RCJ vs RCS	-0.03	0.20	Yes