PRODUCTION, QUALITY AND POSSIBLE USES OF CASHEW GUM

By

ESTHER GYEDU-AKOTO (MPhil Food Science)

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DECLARATION

I hereby declare that this submission is my own work towards the PhD and that, to the best of my knowledge, it contains no material previously published by any other person no material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Esther Gyedu-Akoto (PG8895205) 12/10/09
Student — Signature — Date

Certified by:

Dr. I. Oduro 14/10/09
Supervisor — Signature — Date

Prof. W.O. Ellis 12-10-09
Supervisor — Signature — Date

Prof. J.H. Oldham 12-10-2009
Supervisor — Signature — Date

Dr. F.M. Amoah 12/10/09
Supervisor — Signature — Date

Certified by:

Mrs. F.O. Mensah 14/10/09
Head of Dept. — Signature — Date

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ABSTRACT

The cashew tree gum is seen as a promising plant exudate for the food industry in Ghana, however, there is a lack of understanding of its basic physico-chemical, rheological and toxicological properties thus limiting its utilization in foods. The long term strategy for promoting the use of cashew gum in the food industry is therefore to understand and exploit the agricultural production, harvesting, physico-chemical and rheological properties of the gum. An initial study of cashew gum yield trends per tree and picking in relation to age of tree and the location of tree was conducted at four cashew growing districts (Sampa, Wenchi, Bole, Damango and Jirapa) in Ghana for a period of 24 months. This was to develop cashew gum production for the food industry and to generate extra income for cashew farmers. Trees used in the study were of two age groups, 10 years and below and above 10 years. Yield trends in relation to rainfall were also compared. The results showed that age and location of cashew trees have no significant effect on the production of gum.

The physico-chemical and rheological properties of cashew gum collected from the four cashew growing districts were studied to help promote the utilization of cashew gum in the food industry. The gums collected from trees of the two different age groups were compared to gum Arabic in terms of pH, total ash, protein content, total sugars, total phenols, moisture content and insoluble matter. Gum from mature trees was generally found to have higher levels of protein, moisture, sugars and phenols than that from young trees, with the exception of pH which was lower in gums from mature trees. The predominant minerals in cashew tree gum were Ca, K, Na and Fe. Gelation properties of cashew gum showed that the gum gelled at a higher concentration of 80%. A study of the viscosities of aqueous gum solutions showed that the concentration increased with viscosity while an increase in temperature reduced the viscosity. Gum produced during the rainy season was less viscous than that produced in the dry season. Viscosities of gum reduced slightly after 6 and 12 months storage. The results showed that location, maturity and storage had no significant effects on the viscosity of cashew gum.

Toxicological evaluation (acute toxicity) of cashew gum showed that the median lethal dose (LD_{50}) for cashew gum was more than 30 g/kg b.w. Due to the limited supply and high cost of gum Arabic, cashew gum was assessed as a quick coating agent in the production of chocolate pebbles, using gum from both young and mature cashew trees. Pebbles produced with cashew gum samples were compared with those produced with gum Arabic. Although chemical parameters determined showed significant differences among the three products ($p < 0.05$), sensory analysis did not. The overall acceptability of the products were similar and the mean scores were 7.4, 6.8 and 7.1 for pebbles produced with gum Arabic, that produced with cashew gum from young and mature trees respectively. The optimum formulations for the production of pineapple jam and cashew juice drink with cashew gum as gelling agent and stabilizer were determined using response surface methodology (RSM). Cashew gum was found to be suitable as a clarifying agent rather than a stabilizer in cashew juice and a fat replacer in baked dough nuts.

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CHAPTER 1

INTRODUCTION

The cashew tree is a fast growing evergreen tropical tree, which is highly frost sensitive and found in a wide spectrum of climatic regions spanning between the 25 °N and S latitudes. In Ghana cashew production is scattered throughout the country with the major production area concentrated in the coastal savannah, transitional savannah and the northern savannah zones. However, in the coastal savannah area, most of the trees have been cut down and developed for human habitation. Thus, this work was concentrated in the transitional and northern savannah zones. Cashew can withstand high ambient temperatures the mean being 25 °C and annual rainfall of production in the range of 1000 to 2000 mm (Waite and Jamieson, 1986). It is drought tolerant and has a well-developed root system. It grows well in sandy soils generally unsuitable for other fruit trees (Shomari and Topper, 2003).

Cashew apples and cashew nuts are excellent sources of nutrition. The apple contains five times more vitamin C (Barros *et al., 2001*) than an orange, contains more calcium, iron and vitamin B1 than other fruits such as citrus, avocados and bananas. However, it is highly perishable and can be eaten fresh or juiced. In Brazil, fresh cashew apples are packed in trays and marketed in retail fresh produce outlets (Filgueira and Alves, 2001). Currently, in Ghana; the apples are normally left on the farm floor to rot. Thus, there is the need to search into the possible uses of cashew apples. By-products of cashew include the shell liquid from the nut and the gum from the tree. Shell liquid represents about a quarter of the mass of an unshelled nut. This fluid, which is a mixture of anacardic acid and cardol is the main by-product (Anon, 1978). The gum, which is produced in appreciable amounts by the cashew tree represents non-conventional alternatives for the farmers (Smith and Montgomery, 1959).

Gums taken from the exudates and extracts of plants have been given a strong impulse due to the many potential uses in industries and to the excellent international market value. About half a billion kilograms of gum are consumed in the United States each year where the growth in demand exceeds 8% per year (FAO, 2002). In Ghana about 10 tonnes of gum is used annually by industries such as Nestle Ghana Limited, PZ Cussons Limited, Coca Cola Bottling Company, Dannex Pharmaceutical Company and Cocoa Processing Company (Frimpong-Mensah, 2000). Hitherto however, most of these industries use gum Arabic which is mostly imported into the country.

Cashew gum is a plant exudate similar to gum Arabic and can be used as a substitute of liquid glue for paper, as agglutinant for capsules and pills in the pharmaceutical and cosmetic industries and in food industry as a stabilizer of juices (Glicksman, 1969). It can also be utilized in the making of cashew wines. Thus cashew gum extraction can represent one more source of revenue for the producer, in addition to the cashew nut. Since cashew trees thrive well in the transitional and savannah zones in Ghana where most tree crops may not thrive well, the need to explore the agricultural production and end use of gum from cashew trees in Ghana cannot be overemphasized.

Purpose of study

There is an expanding local market for natural gums within the food industry in Ghana and this has necessitated the need to replace imported synthetic substitutes with locally produced natural gums. In the light of these, this study was carried out with the aim of developing cashew gum through the production and end use of the gum by the study of environmental and physico-chemical factors affectinggum production as well as the physico-chemical and rheological properties of the gum.

Objectives

1. To study the agricultural production of cashew gum in Ghana (tree age, location and seasonal effects on gum yield).
2. To study the physico-chemical and rheological properties of cashew gum and to determine its safety levels.
3. To evaluate the utilization of cashew gum in product development; such as
    i. a coating agent in chocolate pebbles production.
    ii. a clarifying agent in cashew apple juice.
    iii. a gelling agent in pineapple jam production.
    iv. A fat replacer in baked dough nuts.

CHAPTER 2

LITERATURE REVIEW

2.1 Cashew - *Anacardium occidentale* L.

2.1.1 Taxonomy

Cashew, *Anacardium occidentale* L., is a member of the Anacardiaceae family allied with mango, pistachio, poison ivy and poison oak. The family contains about 73 genera and about 600 species. *Anacardium* contains 8 species native to tropical America, of which cashew is the most important economically. Trees within the Anacardiaceae family are known for having resinous bark and caustic oils in their leaves, bark, and fruits which cause some form of dermatitis in humans. Hence it is ironic that two of the most delectable nuts and one of the world's major fruit crops come from this family. The cashew industry, in particular, had to overcome severe limitations imposed by caustic oils in the nut shell. Today, the caustic substance, cashew nut shell liquid, which made the domestication of the plant difficult, is a valued by-product of cashew nut production (Rosengarten, 1984).

2.1.2 Cultivars

Cashew is one of the few fruit crops normally grown from seed, and few improved cultivars exist in commercial production. Yellow and red apple forms exist naturally, and do not appear to hybridize readily, but each is genetically variable in its own right and is not recognized as a cultivar. Several cultivars have been selected in India which show variations in kernel oil and shell oil content (Prahbu and Pillas, 2001). Brazil has also produced dozens of dwarf clones, some yielding twice as much as seedling trees, with higher percent kernel (38% more) and good cracking characteristics (<2% broken kernels) (Barros *et al.*, 2001).

2.2 Origin and cultivation of cashew

Cashew is native to North-Eastern Brazil, in the area between the Atlantic and the Amazon rainforests (Barros *et al.*, 2001). The area is a predominantly savannah woodland or thorn scrub, and includes the almost desert-like Caatinga. Although cashew will grow in tropical wet forests, they rarely produce any nuts and production is far greater in areas with a distinct wet and dry season, such as its native region in Brazil, India and East Africa.

The Portuguese introduced the tree to Africa and India in the sixteenth Century shortly after its discovery in 1578 (Johnson, 1973). It was planted in India initially to check erosion, and uses for the nut and pseudo fruit (cashew apple) were developed much later. The trees were well adapted to the region and became naturalized. Trees also became naturalized in Central America and the Caribbean islands. Nut domestication pre-dated the arrival of Europeans to Brazil, although international nut trade did not occur until the 1920s (Nair, 1996). Native South Americans discovered that roasting nuts in fire would remove the caustic oil in the shell, allowing the nut to be cracked and consumed without any ill effects (Duke, 1983). The roasting practice was either not known or not appreciated outside the native region, and as a result the cashew apple was the first product consumed, with the nut being discarded. Natives also knew of many medicinal uses for the apple juice, bark, and caustic seed oil that were later exploited by Europeans (Duke, 1983). India developed more refined methods for removing the caustic shell oil, and this country is given credit for developing the modern nut industry. India led the world in cashew production for many years until recently, when production in Vietnam surged about 3-fold in a few years. In its native region Brazil, cashew nut production ranks in the top 5 of the world, and virtually all cashew apples and juice products come from this country. Preliminary data indicate that cashew nut production surpassed almond in 2003, and thus cashew is now ranked the first nut crop in the world (FAO, 2002). Average yields worldwide are about 780 kg/ha and the world production of cashew nuts stands at about 2.7 million MT per year (UNCTAD, 2007). In Ghana, the average yield in Ghana currently stands at 350-400 kg/ha with an annual production of 22,000 MT (CDP, 2007).

2.3 Medicinal properties and non-food usage

Cashew has been found to have medicinal and non-food uses from the bark, leaves, and apple juice. Bark teas were used for treating diarrhoea, and the caustic shell oil was used to treat skin infections, warts, worms, and botfly larvae beneath the skin (Davis, 1999). Teas and fruit juices from cashew are known to have antimicrobial, anti-inflammatory, astringent, diuretic, hypoglycemic, and other medicinal properties. The active ingredients are thought to be tannins, anacardic acid, and cardol in the cashew fruits (Davis, 1999). Modern uses of shell oil and fruit juice include facial peels, scalp conditioners and shampoos. Clinical studies have shown anti-inflammatory properties of tannins, and antimicrobial properties of anacardic acid against several micoorganisms, including *Escherichia coli* and *Helicobacter pylori* (Morton, 1987). Leaf extracts have also shown hypoglycemic activity in rodents and a reduction in artificially induced diabetes (Morton, 1987). Cashew apples which contain up to 5 times the amount of vitamin C as in citrus and high amounts of minerals have also been found to be used in the cure of scurvy and diarrhoea (Behrens, 1996).

Cashew nut shell liquid (CNSL), which is sandwiched in a honeycomb layer of tissue between the two walls of the nut shell has industrial uses such as automobile brakes, adhesives, paints and varnishes, insecticides, electrical insulation, and anti-microbials (Ohler, 1979). The shell oil is highly caustic, causing moderate to severe skin irritation. When wood is burned or nuts roasted, contact with or breathing of the fumes can cause skin and eye irritation, inflammation, and poisoning. In addition to CNSL, resins and gums from fruit, stems or bark are used as a varnish for books, wood, and flooring as a protection from ants and other insects (Duke, 1983).

2.4 Cashew production

World production of cashew nuts stands at about 1,870,284 MT (FAO, 2002) from 32 countries. This has doubled since 1994, with most countries experiencing substantial increases, particularly Vietnam. India pioneered the modern processing of nuts, and had been consistently the world's leading producer for decades prior to 2002. Cashew is now ranked as the first nut crop in the world, since its production surpassed that of almond in 2003 by over 300,000 MT.

Cashew occupies over 5.0 million hectares of land area in the world, which is extremely high given the level of production. This reflects the low intensity of production in most areas. A large quantity of nuts is harvested from the wild or naturalized stands of trees (Topper, 2002). Average yields worldwide are about 150 kg/ha. In its native land of Brazil, yields are only about 55 kg/ha. Cashew yields in Vietnam stand at 560 kg/ha, reflecting the intensive management of the crop in that country. Thus, Vietnam produces over three times the total production of Brazil on only 36% of the land area (Topper, 2002). The adoption of high yielding, dwarf cultivars of cashew could easily reduce land area by 50% while allowing increased production to meet rising world demand (Barros *et al.*, 2000). Table 2.1 shows the ranking of world production of cashew nuts among major producing countries.

Table 2.1: Top 10 countries in world cashew production

No.	Country	%World production	No.	Country	%World production
1.	Vietnam	28	6.	Indonesia	4
2.	India	25	7.	Guinea Bissau	4
3.	Nigeria	10	8.	Cote D'Ivoire	4
4.	Brazil	8	9.	Mozambique	3
5.	Tanzania	6	10.	Benin	2

*Source: Multiple Sources, FAO Statistical Database

Cashew gives two additional products of commercial value from the fruit. These are cashew apples and cashew nut shell liquid. The cashew apple is the juicy, swollen peduncle of the fruit. The juice is astringent and loaded with tannin, particularly in red cashew apples. The cashew nut shell has an inner and outer wall, separated by a honeycomb tissue infused with caustic oil. Cracking of the nuts when fresh results in the oil contaminating the kernel. Nuts are therefore roasted to drain off the oil before they are shelled. The nuts are about 22-30% kernel by weight (Azam-Ali and Judge, 2001).

2.5 Natural Gums

Natural gums consist of plant/tree exudates, seed gums, microbial gums and seaweed gums (Glicksman, 1969). Seed gums are derived from ground endosperm of seeds. They are highly viscous at low concentrations (Duke, 1981). Collection and processing of seed gums include the drying and crushing of harvested pods to separate seeds from pod husk. The seeds are dehulled and the germ separated from the endosperm. The pieces of endosperm are then ground to the required particle size to get the gum. Further processing involves either chemical modification of the gum or blending with other gums to produce a final product with a range of physical and functional properties designed to suit the end-user's requirements. Microbial gums are extracellular polysaccharides from microorganisms produced from nutritive media. Xanthan gum is the only microbial gum permitted for use in foods. It has high viscosity at low shear and yield value (Belitz *et al.*, 2004).

Seaweed gums are gelatinous products isolated from seaweed, mainly red and brown algae, by hot water or alkali extraction process followed by drying or isolate precipitation. They include agar, carrageenan and alginate (Belitz *et al.*, 2004). Industrial gums extracted from seaweeds fall into three categories: alginates (derivatives of alginic acid), agars and carrageenans. The first is extracted solely from brown seaweeds whilst the last two are extracted only from red seaweeds. There are a number of artificial products reputed to be suitable replacements for seaweed gums but none have the exact gelling and viscosity properties of seaweed gums and it is very unlikely that seaweeds will be replaced as the source of these polysaccharides in the near future (Belitz *et al.*, 2004).

2.5.1 Chemistry of gums

The term 'gum' has been loosely applied to many substances, both hydrophilic and hydrophobic, that have gummy characteristics. However, in strict terms, gums are confined to hydrophilic substances that give viscous solutions or dispersions when treated with hot or cold water. The structures of gums are made up of heterogeneous complex mixtures of closely related polysaccharides (Belitz *et al.*, 2004). The basic structure of gums consists of arabinose, rhamnose, galactose and glucoronic acid. They are best known as powerful thickeners but perform an extraordinary number of other functions essential to food quality. They impart food texture and structure, and they play a role in flavour release, appearance and shelf stability (Glicksman and Sand, 1973). In recent years, gums have been recognized as healthy sources of fibre as well (Hundley, 2002).

2.5.2 Plant/tree exudates

These are exudates from various plant species and are obtained as a result of tree bark injury. They are normally collected as air-dried droplets with diameters from 2-7cm.

Plant exudates are excreted from tree species belonging to families of *Burseraceae, Mimosaceae* and *Sterculiacea*, which grow in the wild. Almost 100% of existing gum bearing trees is naturally or wildly grown under arid, warm or hot, very sloppy and rugged topographic conditions. This type of gum includes gums Arabic, karaya, tragacanth and cashew gum (Fitwi, 2000).

2.5.2.1. *Production and collection procedures of plant exudates*

Exudates from the stem and branches of a tree are produced as large nodules during a process called gummosis to seal wounds in the bark of the tree. The major commercial processes involved in the production of these gums are collection, sorting, processing, quality control and end-use marketing (Chihongo, 2000). They are mostly not processed in countries of production but exported to overseas markets for processing. The only spray dried gum production facility in Africa started in Nigeria, in 1999 (Okoro, 2000). The processing plant has a capacity of 2000 tonnes per annum of spray dried gum which is currently being distributed all over the world. Gums are naturally produced by exudation from trees resulting from natural damage on the trees by natural agents or individuals and animals on casual basis (Fitwi, 2000). Several techniques are now being used to artificially induce the production of gum to guarantee viability and improvement of the quality of the commercial product. These techniques involve systematically controlled tapping and collection procedures. The flow diagram in Figure 2.1 shows the steps involved in the collection and sorting of plant exudates to the point of grading.

2.5.2.2 Sorting and grading of gum

Gums could be graded physically based on their colour, size and brightness. They could also be graded in terms of solubility, viscosity, bark and foreign matter (BFOM) and total ash content (Immeson, 1992). All these gradings could be done when the gum is in their natural as well as powdered form. The quality of gum is usually assessed by its moisture content, optical rotation and the amount of foreign matter. Commercial gum Arabic for instance, must have moisture content between 12-14%, optical rotation between -25 and -35 and foreign matter content must be less than 3-5%. The microbiological count for *Salmonella*, *Escherichia coli* and *Staphylococcus aureus* must also be negative (FAO, 1992).

2.5.3 Acacia gum

Acacia gum is obtained from the genus Acacia, which belongs to the family *Leguminosae*. The acacia tree originates from Africa. All gum-yielding acacias exhibit the same habit and general appearance. The acacia tree is a spiny shrub, which prefers sandy or sterile regions, with dry climate during the greater part of the year. In sub-Saharan Africa about the middle of November, after the rainy season, the tree exudes spontaneously from the trunk and principal branches, but the flow is generally stimulated by incisions in the bark (Yaddou, 2000). In about fifteen days the gum thickens and hardens on exposure to the air. They usually form round or oval tears, white or red, depending on whether the specie is a white or red gum tree. The gum harvest from the various species of acacia lasts ~~about five~~ weeks.

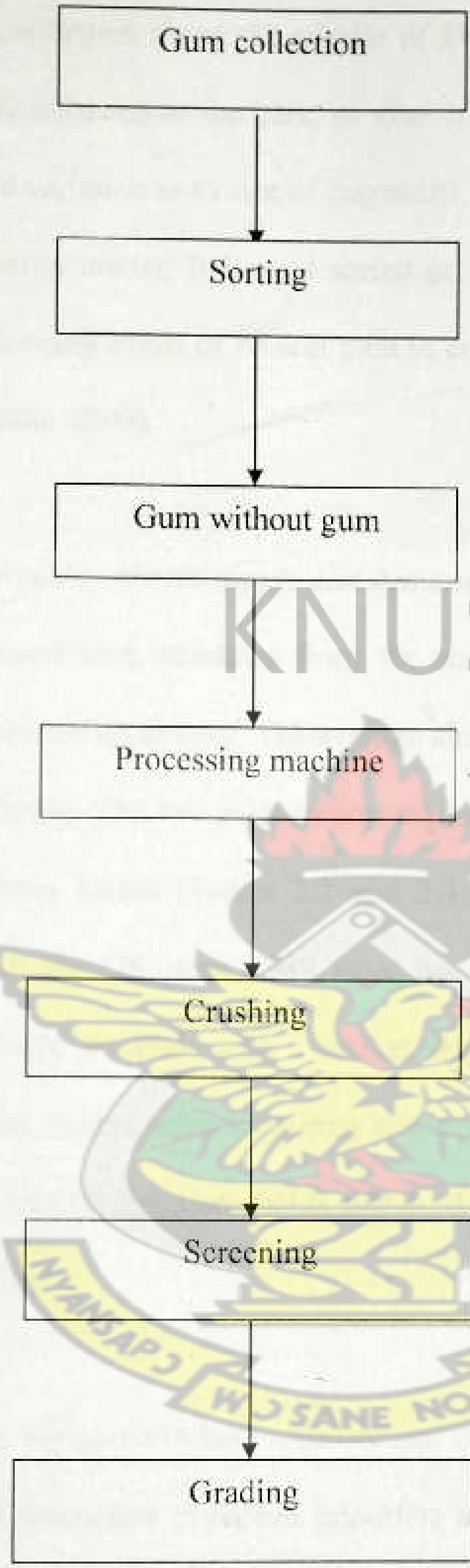

Figure 2.1: Steps involved in the collection and sorting of plant exudates (Immeson, 1992)

Harvesting of the gum begins about the middle of December. The masses of gum are collected, either while adhering to the bark, or after it falls to the ground. The unsorted gums show the widest variation as to size of fragments, whiteness, clearness and freedom from adhering or foreign matter. It is next sorted or 'picked' in accordance with these differences. There are many kinds of Acacia gum in commerce but the most common is the gum Arabic (Yaddou, 2000).

2.5.3.1 *Gum Arabic - World supply and demand trends*

Gum Arabic is prepared from exudates from the stem and branches of sub-Saharan *Acacia Senegal* and *Acacia seyal* trees. The average annual yield per tree is between 0.9-2.0 kg (Belitz *et al.*, 2004). The two main import markets for gum Arabic are the United States and the European Union (Tables 2.2 and 2.3) (GASID, 2005). The two most important exporters to the US since 1989 have been Sudan and France. These two countries have dominated the trade with a market share of 85-95%. France mostly re-exports processed gum Arabic after importing crude gum arabic mainly from African producing countries. United Kingdom holds the third place with a 3-4% share of the market (GASID, 2005).

The European market, measured in both quantity and value, is 3-4 times bigger than the US market. The most important European importers are France, United Kingdom and Germany. Together they import over 70% of gum arabic to Europe from sub-Saharan Africa. The major exporters from Africa are Sudan and Nigeria who are responsible for

60-70% of the gum Arabic exported to Europe. Chad, Cameroon and Mexico are also important exporters with a combined market share of a little over 20%.

Table 2.2: US total imports of gum arabic by quantity and value from 1989- 1994.

Year	Quantity (tonnes)	Value (US$ million)
1989	6,250	18.4
1990	9,304	16.4
1991	8,273	20.0
1992	5,802	18.2
1993	5,508	17.1
1994*	7,500	Not available

*Estimate based on supplier survey.
Source: National Trade Data Bank, 1995. Department of Commerce.

The market data indicates that the European market would be easier to penetrate than the US market for exporting crude gum Arabic. This assumption is based on the fact that 40% of the gum Arabic imported to the US is processed. The US market is dominated by Sudan and France with a combined market share of over 90%. On the other hand the top five exporters have roughly an 80-85% market share of the EU market.

Table 2.3: EU import totals of gum Arabic by quantity and value 1990- 1993

Year	Quantity (tones)	Value (US$ million)
1990	27,631	65.9
1991	32,118	75.8
1992	27,387	78.9
1993	23,202	75.7

*Source: EUROSTAT, 1994. Monthly EU External Trade.

2.5.3.2 *Structure and properties*

The gum is a complex and variable mixture of arabinogalactan, oligosaccharides, polysaccharides and glycoproteins. The main structural units are L-arabinose, L-rhamnose, D-galactose and D-glucoronic acid. Depending on the source, the glycan components contain a greater proportion of L-arabinose relative to D-galactose for *Acacia seyal* or D-galactose relative to L-arabinose for *Acacia senegal*. Gum arabic occurs as neutral or a weakly acidic salt. It consists principally of *Arabin*, a compound of Arabic acid with calcium, varying amounts of magnesium and potassium salts of the same acid being present. The gum also contains 12 to 17% of moisture and a trace of sugar. It yields 2.7 to 4% of ash, consisting almost entirely of calcium, magnesium and potassium carbonates. It is highly soluble in water and solutions of up to 50% can be prepared. It is insoluble in alcohol and ether, but soluble in diluted alcohol in proportion to the amount of water present. It has a pH range between 4.0-4.8 (Belitz *et al.*, 2004).

During the time of the gum harvest, the Moors of the desert are said to live almost entirely on it, and it has been proved that 170g of gum Arabic is sufficient to support an adult for twenty-four hours. It is purported that the Bushman Hottentots have been known in times of scarcity to sustain themselves on it for several days. In many cases of ailment, it is considered that a solution of gum arabic may for a time constitute the exclusive drink and food of the patient (Food Resource, 2005).

2.5.3.3 Functionality

Gum Arabic is a useful hydrocolloid emulsifier, texturizer and film former, widely used in the drinks industry to stabilize flavours and essential oils. It is an ideal carrier in flavour encapsulation because of its natural emulsifying and surface-active properties, good retention of volatile flavour components, high solubility in water and acid stability. Additional advantages include its bland flavour, low hygroscopicity and ability to protect flavours from oxidation. A study on the development and evaluation of acacia gums for the encapsulation of flavours showed substantial differences between various types of acacia gums. The gums tested protected orange oil against oxidation more effectively than modified starch (Food Resource, 2005).

In confectionery, gum Arabic retards sugar crystallization, emulsifies and distributes fat particles in caramel and toffees. It also functions as a binder and structure builder in cough drops and lozenges, and in panned sugar confections, it serves as a coating agent and film-former. In snack foods and bakery products, it serves as a lubricant and binder in extruded snack cereals and provides adhesion of dry flavours in peanuts and related products. In low-fat cakes and muffin mixes, gum Arabic functions as a partial oil replacer as well as a moisture binder. In nutraceuticals it is also used in meal replacers, nutritional beverages and weight loss products because of its high solubility, low viscosity and high soluble dietary fibre content (Food Resource, 2005).

2.5.4 Gum tragacanth

Gum tragacanth, like gum arabic, has an ancient history. It is an exudate of the Astragalus genus of plants of the *Leguminosae* family which has been described several years before Christ. These plants are grown in the Middle East. The name tragacanth, from the Greek words tra gos (goat) and akantha (horn), probably refers to the curved shape of the ribbons, the best grade of commercial gum. It is also available in flakes, and each grade is grown from a specific shrub. The gum exudes spontaneously from breaks or wounds inflicted in the bark of the shrubs. It is usually collected by hand by the natives and carried to collecting and sorting centers where it is graded into several grades of ribbons and flakes and exported (Immeson, 1992). Gum tragacanth, recognized officially in the United States Pharmacopoeia since 1820, is currently defined as "dried gummy exudation from *Astragalus gummifer Labillardiere* or other Asiatic species of Astragalus" (FDRL, 1972).

2.5.4.1 Structure and properties

Tragacanth gum is available in flattened, lamellated, frequently curved fragments or straight or spirally twisted linear pieces from 0.5 mm to 2.5 mm in thickness. It is white to cream in colour, translucent, horny in texture and has no odour. It consists of a water-soluble fraction tragacanthin, which gives a colloidal hydrosol solution, and an insoluble bassorin component, which swells to a gel-like state. Gum tragacanth solutions are acidic, usually in BeMiller the pH range of 5-6. The structural units of traganthin are D-galacturonic acid, D-xylose, L-fucose and D-galactose. Those of bassorin are L-arabinose, D- galacturonic acid, D-galactose and L-rhamnose (Belitz *et al.*, 2004).

2.5.4.2 *Functionality*

The ability of tragacanth to swell in water to give thick, viscous dispersions or pastes has accounted for many of its uses in the pharmaceutical and food industries. As with most other gums, viscosity is the most important property of the gum tragacanth solution. Compared to other gums, however, tragacanth is fairly stable over a wide pH range down to extremely acidic conditions at about pH 2. For this reason, it has been widely used in food products such as salad dressings, where stable viscosities at low pHs are required (BeMiller and Whistler, 1993).

2.5.5 Gum karaya

Karaya gum, sometimes known as Sterculia gum, is the dried exudation of the *Sterculia ureus* tree and other species of Sterculiaceae family. This large and bushy deciduous tree is native to India. It is leafless in the cold season and young leaves sprout in the hot season (Fitwi, 2000). The best quality gum is collected during April, May and June i.e. in summer. During this time, as the weather gets warmer the yield increases. The gum collected during the monsoons has low viscosity. In September, after the monsoon, the collection cycle is repeated. This yield usually gives less viscous solutions than the gum collected in summer. The locals tap the trees by making incisions up to one square foot in dimension on the trunk. The gum begins to exude immediately and the exudation continues for several days. The maximum amount of exudation occurs within the first 24 hours. The gum is in the form of huge irregular tears (Fitwi, 2000).

2.5.5.1 *Structure and properties*

Karaya gum is a complex polysaccharide of high molecular weight. It contains calcium and magnesium salts and on hydrolysis yields galactose, rhamnose and galacturonic acid. Karaya gum occurs as a partially acetylated derivative. The acid number has been found to vary from 13.4 to 22.7. The variation in acid number is influenced not only by the source of the sample but also by its age. The gum has a peculiar property of splitting off free acetic acid and this loss is loosely correlated with the particle size. Trimethylamine has also been identified in the hydrolysed products. Karaya gum contains 12% to 14% moisture and less than 1% acid insoluble ash. The pH of a 1% Karaya gum solution is 4.6 (Belitz *et al.*, 2004).

The highest-grades of Karaya gum are white, translucent and almost free of bark. The lower grades vary from light yellow to brown and may contain as much as 3% of insoluble impurities. Powdered karaya gum is white to greyish white. Karaya gum, like gum Tragacanth, does not dissolve in water to give a clear solution but rather forms a colloidal sol. Powdered karaya swells in cold water to an extent that a 3 to 4% solution will produce a heavy gel of uniform smoothness and texture. For higher concentrations it is necessary to cook the gum under steam pressure to make it soluble. It yields a thick, syrup-like liquid. Karaya gum will form viscous solutions in hydro-alcoholic solutions ranging up to 60% alcohol concentration. The viscosity of Karaya gum is largely dependent on its freshness, that is, how recently it was gathered from the trees. The viscosity is affected by conditions of climate and growth. Viscosity is also affected by storage. Powdered Karaya gum will show a decrease in viscosity after storing over 6 months and the viscosity loss in storage can be minimized by the addition of preservatives like benzoates, sorbates, phenols and related compounds (Whistler and BeMiller, 1993).

2.5.5.2 *Functionality*

Gum karaya is a soluble fibre, which aids in the intestinal processes of the digestive system. It is therefore used as a bulk laxative. It is used in ground meat products as it provides good water holding and binding properties to yield finished products. In the paper industry, it is used in the manufacture of long fibered, lightweight papers and also used in textile industry as a thickening agent for dyes. It is a good emulsion stabilizer for French style salad dressings, whipped cream products, meringue toppings and aerated dairy foods. It is also used as a binder for making low calorie dough-based products such as pasta, bread and other bakery products (Whistler and BeMiller, 1993).

2.5.6 Cashew gum

Cashew gum can be obtained by natural exudation or by means of incisions on the trunk and branches of the cashew tree. It presents a great potential for industrialization, since it can be used in the paper, pharmaceutical, cosmetic and food industries as a stabilizer, suspension agent, as well as a flavour encapsulator (Lima *et al.*, 2001). Since much has not been done on the utilization of cashew gum in the food industry, there is the need to study how cashew gum will perform in some food systems such as chocolate pebbles, juices and jams.

2.5.6.1 Structure and properties

The gum from the cashew tree occurs in the form of pale yellow to reddish stalactic masses, which are soluble in water. The gum is a complex polysaccharide of high molecular mass comprising 61% galactose, 14% arabinose, 7% rhamnose, 8% glucose, 5% glucuronic acid and 2% other sugar residues. Elementary analysis revealed water content 7.4%, total protein measured about 0.5%, total lipids 0.06 %, fibres 0.95% and ash 0.95%, the total carbohydrate was 98 % (Lima *et al.*, 2002).

2.5.6.2 Functionality

Due to its insecticidal and good adhesive properties, cashew gum is used primarily in industrial application for binding books, as adhesives for envelopes, labels, stamps and posters. Research already exists on its utilization in the making of inks and varnishes.

2.6 Gum production

Gum production varies from tree specie to specie and this was shown by Vassal and Mouret (1989) who assessed the growth and production of gum in 1986 from nineteen Acacia trees. The assessment was done three years after cultivation of the plants. Ten out of the nineteen species had satisfactory gum exudates in terms of quantity and quality. *A. mearnsii* performed particularly well, with about 130 g of gum from two summer harvests. Studies on the physico-chemical properties of the gum were found to be similar to those of *A. senegal*, which is known to give high quality gum.

McReynolds and Gansel (1985) also studied the production of gum from Acacia trees planted Florida as part of a progeny test. The results showed that offspring of parents both with high gum production gave an average yield of 8.2 kg/tree per annum (p.a.) over a period of 8 years. Yield from progeny of average wind-pollinated parents was 5 kg/tree p.a., and yields from other progenies such as high wind pollinated parents and high wind X average wind pollinated or average wind X average wind pollinated parents were intermediate. Results also showed that average wood volumes of the different groups of progeny were not significantly different. However, results from the most reliable data groups (high X high and high X average) suggested that using improved strains can increase wood volume by about 10% and gum yield by more than 30% (where X means cross).

Lima *et al.* (2001) evaluated the influence of chemical stimulants in the extraction of gum from cashew tree as well as its interference on future gum productions. They used Sulphuric acid concentrations of 0, 15, 30 and 45%, combined with 2-chloroethylphosphonic acid concentrations of 0, 5, 10, 15 and 20% and 5% dimethyl sulphoxide in a factorial design for the study. They observed a general increase in gum exudation from the trees in all months following the stimulant applications. However, a 15% concentration of 2-chloroethylphosphonic acid allowed the highest rate of gum exudation.

Although some work has been done on gum production from different *Acacia* species in a particular location very little has been done on trees from different locations. Little work has also been done on cashew gum production and the determination of its average yield per annum and this has led to the study on the production of gum from cashew trees of different age groups and from different locations in Ghana.

2.7 Physico-chemical and rheological properties of gums and their applications in foods

The use of gums in numerous industries especially in the food industry has increased widely in these last decades (Diego and Navaza, 2003) and this is due to their numerous characteristics such as the gelling, stabilizing and thickening properties. These functions and the physico-chemical properties of gums are used to determine their quality and performance during processing and this has led to several investigations into them.

Investigations by Aslam *et al.* (1978) on the properties of *Khaya grandifoliola* gum revealed that the gum has only limited solubility in water. Analysis of the gum showed that approximately 50% was in the free acid form and the remainder was largely the calcium salt. The gum dissolves in sodium carbonate solution with removal of calcium ions and this significantly alters the viscosity of the solution but may be controlled by the addition of calcium ions. Elfak *et al.* (1977) also reported that the intrinsic viscosity of guar gum solution was greater than that of locust bean gum but the interaction coefficient of guar gum solution was less than that of locust bean gum. They also showed that the addition of glucose, sucrose or glucose syrup increased the apparent viscosity and the interaction coefficient of the solutions but reduced the intrinsic viscosity. Addition of glucose, sucrose and glucose syrup to dilute solutions of carrageenan and sodium carboxymethylcellulose also increased the apparent viscosities and lowered the intrinsic viscosities of the solution (Elfak *et al.*, 1977).

Evaluation of the physical properties of aqueous solution of African *Albizia zygia* gum has shown that approximately 80% of the gum is soluble in cold water with the remainder dispersed as fine particles of gel (Ashton *et al.* 1975). The viscosity of the solution increased with concentration. However, above 1.5% concentration, the solutions exhibited shear thinning. Examination of ice cream samples with *A. zygia* gum used as total or partial replacement of existing commercial stabilizers showed that *A. zygia* gum has little stabilizing effect compared with locust bean gum and sodium carboxymethylcellulose (CMC7HF). Studies on the viscosity of aqueous solutions of gum ghatti have also shown that the gum contains both a soluble and an insoluble gel (Jefferies *et al.*, 1977). Maceration of the gel in water gave a perfectly stable dispersion, which behaved as a solution. The viscosity of the gel dispersion was about 10-30 times that of the soluble gum. The proportion of gel in four commercial batches of gum ghatti varied from 8-23% and the viscosity of the whole gum dispersion depended largely on the proportion of gel. Blending to a fixed proportion of gel can closely control the viscosity of gum ghatti (Jefferies *et al.*, 1977).

The effects of guar gum (G), locust bean gum (L) and xanthum gum (X) were studied in a low fat frozen dairy dessert using seven stabilizer combinations (G, L, X, GL, GX, LX and GLX) (Muncy and White, 1991). Dessert samples with X, GX or GL had the highest body/texture scores and those with X, G or GX had the highest flavour scores. X increased the viscosity significantly when used alone or in combination. The seven stabilizer combinations showed no significant difference in meltdown resistance when compared with a control ice cream. The GL system, when used with microcrystalline cellulose, provided desirable mix viscosity, and acceptable flavour and body/texture scores in the low-fat frozen dairy desserts (Muncy and White, 1991).

Studies on the rheological properties of gum and milk protein interactions using three different gums kappa-carrageenan, guar and xanthan at three different concentrations (.05, 0.10 or 0.20%) showed that the gums in dried skim milk solutions were more viscous than gums in water solutions when compared at equivalent gum concentrations. (Schmidt and Smith, 1992). The flow behaviour index values indicated that, at low gum concentration, the solutions possessed Newtonian flow behaviour; however, at higher concentration, the flow behaviour was pseudoplastic. Effects of stabilizer types on the rheological properties of buffalo whipped cream showed that the addition of 0.05% stabilizer containing 0.04% sodium alginate and 0.007% carrageenan slightly increased viscosity and markedly reduced serum leakage. The addition of 0.5% Palsgaard 5822 emulsifier also enhanced the rheological properties. Carboxymethylcellulose and a commercial guar gum/xanthan gum/locust bean gum mix were found to be unsuitable for use as stabilizers in whipped cream production (Ghita *et al.*, 1992).

Studies on cottage cheese dressings prepared from 5 different blends of gums using guar, locust bean, xanthan and kappa-carrageenan showed that dressings containing guar and xanthan gums had highest initial viscosities and those with high kappa-carrageenan ratios had the lowest (Parker and Hicks, 1991). Dressings containing xanthan gum had the greatest loss in viscosity over time and had highest initial curd absorption rates; syneresis (wheying off) increased as xanthan gum concentration increased. The amount of dressing that flowed away from the dressed curd after 24 hours was equal for all dressings. Drip loss also decreased with increasing storage time.

Pamplona and Zarrudo (1989) studied the physico-chemical components of *Leucaena leucocephala* seed gum using three different seed varieties (K-28, Cunningham and the indigenous Copil No. 2). The fat-free seeds yielded 35.0% hot-water soluble matter, which contained 22.5% total sugars, 19.2% proteins, 0.33% tannins and 14.9% ethanol precipitated gum. Paper and high-pressure liquid chromatographic analysis of the acid gum hydrolysate showed the presence of mannose and galactose in the molar ratio 1.3:1.0. The gum isolate had an intrinsic viscosity of 7.7 eta and a 1000 ppm aqueous solution had 2.29 cP viscosity. Investigations on the viscosity of xanthan gum solutions at low shear showed that all solutions were pseudoplastic (Zatz and Knapp, 1984). Solutions containing 0.3-0.5% gum exhibited a highly ordered phase at very low shear. Viscosity, the degree of pseudoplasticity and the value of the transition from soft gel to pseudoplastic behaviour were directly related to gum concentration. The effect of the addition of salt on the viscosity depended on the xanthan gum concentration. The viscosity of a 0.3% gum solution was practically unaffected by the salts whilst higher gum concentrations exhibited a viscosity increase in the presence of salt. However, concentrations less than 0.3% exhibited viscosity decrease. No major differences were observed between sodium chloride, calcium chloride and sodium citrate in their influence on xanthan gum viscosity (Zatz and Knapp, 1984).

Studies on cashew and acacia gums have shown that they have similar rheological and organoleptic properties (Owusu *et al.*, 2005). They were both cream to white in colour, odourless, translucent and glassy in form. They were also gritty in texture. Solutions of both gums showed an increase in viscosity with concentration but the increase with gum Arabic was more gradual showing that cashew gum has a slightly better thickening ability. There was also no significant effect of pH, temperature changes or storage time on the viscosities of both gums. Cashew gum also showed a better stabilizing effect than gum Arabic. Mothe and Correia (2004) studied the rheological properties of cashew/zanthan gum blends in cashew juice and found out that juice without any gum had the lowest viscosity. That with cashew gum exhibited slight increase in viscosity whilst juice with xanthan gum had the highest viscosity. Juice with gum blends had viscosity similar to that with zanthan gum. The use of cashew gum polysaccharides to construct a kind of chromatographic matrix (hydrogel) has become a useful tool for modern biotechnology in underdeveloped countries (Lima *et al.*, 2002) and it has been found to be an efficient method for detection and elucidation of galactose-specific lectins.

A lot of work has been done in terms of physico-chemical and rheological properties of gums. However, some main concerns of gum production, processing and use involve accurate identification of the source of each product and quality assurance. Gums from different acacia species have been found to be of different qualities. Out of 130 acacia species 17 have been found to produce commercial acacia gum (Chikamai, 2005). There is a paucity of data in this respect when it comes to cashew gum. Thus, there is the need to evaluate the properties of gum from cashew trees of different ages and locations in Ghana.

2.8 Toxicological evaluation of natural gums

Any substance, which on entering the body interferes with normal physiological functions, is considered foreign. There may be beneficial effects as well as toxic effects of such substances. Naturally occurring toxicants can be found in foods from both plant and animal sources and this has led to the recognition of food and nutrition toxicology. Some food additives including gums may also be toxic above certain concentrations while others, even in their small concentrations may be mutagenic. Over 2,000 food additives are in use but very few have had full-scale toxicological testing. However, most gums have been evaluated under the FAO/WHO Joint Expert Committee of Food Additves (JECFA). The JECFA safety evaluations include toxicological tests, consideration of natural or artificial additives, derivation of acceptable daily intake (ADI) level and other related information (Walker, 2005).

2.8.1 Short-term studies (acute toxicity)

In short term studies, test organisms are exposed to the substance for a short period of time to measure the concentration that will have a significant effect on them. Data from these tests can be used to screen or rank toxicity and to assess the potential for effects in the environment. Short term studies have shown that karaya gum does not disintegrate appreciably in the alimentary tract. In a study of 10 dogs, 95% of the orally administered gum was recovered in the faeces and it absorbs a large quantity of water and therefore acts as a laxative. It tends to increase faecal nitrogen excretion, does not affect starch digestion in the dog and does not inhibit the utilization of vitamin A in rats (FAO, 1980). The caloric value determined in groups of 10 rats fed for one week 5 g basal diet with either 1 g and 3 g cornstarch or 1 g and 3 g karaya gum supplements showed that 1 g level karaya gum had 30% of the caloric value of cornstarch. At the 2 g level growth was very depressed. The intestines were enlarged in all rats on gum (FAO, 1980).

Examination of the intestines of rats fed with 1 g of karaya gum per day for 91 days showed no gross abnormalities and there was no interference with normal growth (FAO, 1980). Feeding three dogs with 5 g unprocessed karaya gum daily for 30 days resulted in more frequent defaecations and increase in faecal bulk and moisture. There was no obvious gastro-intestinal irritation. Fifty human subjects who ate 4-6 g karaya gum in ice cream showed no allergic reactions (FAO, 1980). Out of 46 female and 43 male subjects who took karaya gum granules for one week at levels equivalent to 7 g per day, seven had abdominal discomfort. Ingestion or inhalation of karaya gum was also reported to have caused allergy (FAO, 1980). Sixteen cases of allergic sensitivity to inhalation of the gum used as a wave set, and to oral ingestion as a laxative were reported. Symptoms included hay fever, asthma, dermatitis and gastro-intestinal distress. In a comparison with carob bean gum as a laxative in 10 human subjects karaya gum was found to be transformed to a gelatinous state at a higher level in the intestine and to be transported more rapidly through the intestinal tract (FAO, 1980).

Groups of newly weaned rats (10 per group) fed with a soybean-corn meal diet containing 2% tragacanth gum for 37 days showed that tragacanth gum had no effect on the digestibility of the diet, nor was there any significant effect on growth (Vohra *et al*., 1979). Tragacanth gum was used in a 6-7 week feeding study to evaluate the effect on adaptive responses of nutritionally controlled parameters in rats by feeding a fibre-free diet containing increasing additions of polysaccharides (0, 10, 20, and 40%). In general, the supplements reduced growth rates due to lower energy intakes. None of the polysaccharides fed, however, decreased energy utilization. Similarly, all polysaccharides increased small intestine weights by up to about 30% without grossly altering mucosal protein or DNA per unit of length. Concerning the effect on the large intestine, tragacanth gum had a pronounced effect on caecum weight, which increased by factors of 1.8, 2.0, and 4.2 for additions of 10, 20, and 40%, respectively. The degree of the observed changes was determined mainly by the dietary concentration of the polysaccharide and its accessibility to bacterial degradation within the intestinal tract (Elsenhaus *et al.*, 1981). Groups of day-old broiler chickens (7 per group) fed with a soybean-corn diet containing 2% tragacanth gum for 24 days showed significant reduction in body weights and the digestibility of the diet (Vohra *et al*., 1979). Groups of day-old Japanese quail (10 per group) also fed with a soybean-corn diet containing 2% tragacanth gum for 36 days revealed that tragacanth gum did not significantly affect the growth of the quail or the digestibility of the diet (Vohra *et al.*, 1979). A study on the acute oral LD_{50} of 12 food-grade gums (sodium and calcium carrageenate, tragacanth, ghatti, locust bean, Arabic, guar, karaya, propylene glycol, alginate, furcellaran, agar agar, and sodium carboxymethyl cellulose) on 5 groups of 10 animals for 14 days showed that the LD_{50} values observed ranged from 2.6 to 18.0 g/kg, with most values in the 5 to 10 g/kg range. Generally, the rabbit was the most sensitive species and the rat and mouse the least sensitive (Bailey, personal communication to WHO, 1976).

Groups of 10 male and 10 female rats were fed in their diet with carob bean gum at levels of 0%, 1%, 2% or 5% for 90 days. General condition, behaviour, survival, growth, food intake, haematology, blood biochemistry and urinalysis showed no treatment-related differences between test and control groups. Gross and microscopic examination did not reveal any pathological changes attributable to ingestion of the gum. The increase in the relative weight of the caecum at the 2% level is not considered to be of toxicological importance (Til *et al.*, 1974). Groups of newly weaned Sprague-Dawley rats (10/group) fed with a soybean-corn meal diet containing 2% locust bean gum for 36 days showed that locust bean gum had no effect on the digestibility of the diet, nor was there any significant effect on growth (Vohra *et al.*, 1979).

In a study involving four groups of five male and five female Beagles fed on 0%, 1% 5% and 10% of a precooked mixture of locust bean and guar gum (proportions unknown) for 30 weeks, only at the 10% level were hypermotility and soft, bulky stools observed, probably of ~~no~~ toxicological significance. Also at the 10% level digestibility was reduced. No adverse haematological, urinary, gross histopathological and ophthalmological findings were noted (Cox *et al.*, 1974). Groups of 20-day-old chickens fed with diets containing 0.25%, 0.52%, 12% and 22% locust bean gum for three weeks showed growth depression which was dose related and marked at the 22% level of intake (Kratzer *et al.*, 1967). Groups of day-old broiler chickens (seven per group, breed not specified) fed with a soybean protein-corn based diet containing 2% locust bean gum for 24 days also revealed that average body weight of chickens and the digestibility of the diet reduced significantly by the inclusion of locust bean gum in the diet (Vohra *et al.*, 1979). A similar study on groups of day-old Japanese quail (10 per group) also showed that average body weight and digestibility of the diet significantly reduced by inclusion of locust bean gum in the diet (Vohra *et al.*, 1979). Acute toxicity tests carried out on rats showed that the LD_{50} is greater than 5000 mg/kg body weight (Maxwell & Newell, 1972).

A study carried out on an unspecified number of rats fed with diets containing 7.5 or 10% xanthan gum for 99-110 days showed no adverse effects on these animals (Vohra *et al.*, 1979). In a 91-day feeding study, a reduced rate of weight gain was found in groups of rats receiving 7.5 or 15% xanthan gum in the diet. Diets containing 3 or 6% gum did not reduce weight gain. No significant alterations in haemoglobin, red or white cell counts, or organ weights were observed in these rats. Histological examination of tissues from rats at the 15% level showed no pathological effects. At the highest-dose level the animals produced abnormally large faecal pellets, but diarrhoea did not occur. A paired-feeding test was used to compare the growth of rats ingesting a diet containing 7.5% xanthan gum and comparable rats restricted to the same intake of control diet. No differences in weight gain were found at the end of 18 days, indicating the absence of a growth-inhibiting factor (Vohra *et al.*, 1979).

Groups of 5 male and female weanling rats fed with 0, 2.5, 5.0, or 10.0% commercial xanthan gum product showed no significant pathological changes in the animals (Cox *et al.*, 1974). Diets containing a nutritionally adequate, high-maltose nutrient mixture and either 4% xanthan gum or 4% cellulose were fed *ad libitum* to male Wistar rats for 7 days. The feeding of this gum increased the combined weight of the small intestine and its contents by 110%. This effect was partially due to an enlarged cell mass and to extra dry matter in the contents; however, it was chiefly due to a 400% increase in intraluminal water. Xanthan feeding enhanced greatly the persistence of sugars beyond the proximal quarter of the small intestine and increased their total recovery in the first three-quarters of that organ by 150%. The xanthan-induced increase in intraluminal water in the small intestine was partially due to a slowed absorption of osmotically-active substances from the gut (Cox *et al.*, 1974).

The feeding of nutritionally adequate high-carbohydrate diets to starved rats causes an elevation of total liver lipid and of hepatic enzymes associated with lipogenesis. In an experiment of feeding rats with nutritionally adequate carbohydrate diets with or without xanthan gel (a suspension containing 4% xanthan gum) showed that xanthan gel lowered relative liver size, total liver lipid, G-6-P dehydrogenase, and malic enzyme activity. Another experiment of feeding rats with 0.8, 1.4 and 2.0% xanthan gum showed that at less than 2% of the dry diet ingredients, nutrient intake was lowered (Vohra *et al.*, 1979).

Acute toxicity tests carried out on rats, mice and dogs through different routes of administration showed different LD_{50} values (Table 2.4). Daily application of a 1% solution for 15 days to rat skin produced no signs of irritation and daily application of a 1% solution for five days to rabbit conjunctiva also produced no signs of irritation. Intradermal challenge tests in guinea pigs did not produce evidence of sensitization (Kratzer *et al*., 1967).

A study involving five albino rats which received single doses of xanthan gum by inhalation for one hour showed no signs of toxicity after a period of 14 days. The rats retained good physical appearance throughout and no gross changes were seen at autopsy (Kratzer *et al*., 1967).

2.8.2 *Long-term studies (chronic toxicity)*

Out of five rats fed with diet containing 20% karaya gum for two years three developed enlarged colon and ulceration. However, in another experiment where groups of rats fed with diets containing 10-25% karaya gum over their life span showed no caecal ulceration (FAO, 1980). Fermentations of 10 polysaccharides by species of the family of Enterobacteriaceae were examined. Karaya gum was not fermented by any of the strains tested. As food additive, karaya gum seems safe from destruction by facultative fermenters (Ochuba & von Riesen, 1980).

Table 2.4: LD_{50} of xanthan gum in rats, mice and dogs

Species	Route	LD_{50} mg/kg bw
Mouse	Oral	>1000
	i.p.	>50
	i.v.	100-250
Rat	Oral	>45,000
Dog	Oral	>20,000

*Source: WHO Food Additives Series, No. 13, 1978.
i.p.- intraperitonial   i.v.- intravenous

2.8.3 Clinical studies

Studies on 20 overweight persons, 30 to 50 years old, who took their normal diet with 15g guar gum added daily for 6 weeks showed a significant reduction in plasma total cholesterol, low-density lipoprotein cholesterol and total cholesterol to high-density lipoprotein (HDL) cholesterol ratio (Annison *et al.*, 1991). HDL cholesterol values were not affected by fibre intake. Transferring these results into recommendations for clinical application requires further research into dose and duration of intake. The effect of guar gum on patients with type-II diabetes mellitus was studied by Kim and Chang (1989) who found out that guar treatment significantly decreased blood glucose. Patients consumed a total of 5 g guar gum 30 minutes before each of 3 meals daily for 7 days and 3 weeks. In an oral glucose tolerance test, blood glucose values were significantly decreased at 120 and 180 minimum after guar treatment. Total lipid and triglycerides in blood were decreased and high-density lipoprotein cholesterol was significantly increased after guar treatment. HbA1C was reduced from 11.3 to 10.1%. The body weight, total cholesterol, insulin activity and the satiety ratings of the patients after guar treatment were not significantly changed.

The effect of some soluble non-starch polysaccharides (NSP), guar gum and acacia pycenantha gum on plasma cholesterol and triacylglycerols in rats was studied by feeding them with highly purified potato starch, which has a very high digestibility in vitro (>99%). All rats, including those fed on the control diet had very high contents of starch in their caeca indicating digestibility of the starch was low. Values of this "resistant" starch were highest in rats given the soluble NSP indicating that the gums caused some inhibition of starch digestion. The "resistant" starch does not have the biological activity of the gums, which depressed plasma cholesterol and/or triacylglycerol values. The reason for the very low digestibility of the starch is unclear as it is highly digestible in vitro. It is possible that gelatinizing the starch before diet formulation would have improved the digestibility (Annison *et al.*, 1991). A clinical study of a commercial preparation of locust bean grain as a laxative in doses of "two heaped teaspoonfuls" in 56 patients, some of whom took the preparation regularly for two years, resulted in no effects on the gastrointestinal tract, and no allergenic reaction (Holbrook, 1951).

Eight infants between the ages of 2.5-5 months were fed meals of sugared milk or sugared milk plus a 1% powder extract from locust bean. Addition of the carob supplement did not alter the duration of the gastrointestinal transit time of the meal. Physiological aerophagy was markedly suppressed by the supplement (Rivier, 1952). In patients with renal failure, ingestion of 25 g of locust bean gum/day had a laxative effect, decreased high blood pressure, and caused a fall in serum urea, creatinine, and phosphorus by the second week of treatment (Eastwood *et al.*, 1984). Following a 7-day control period, 5 healthy men ingested 9.9 g tragacanth gum daily (3 × 3.3 g-portion gelled in 200 ml water) for 32 days. The tragacanth gum was well-tolerated and no adverse effects were reported in any of the volunteers. Tragacanth gum had no significant effect on any of the parameters measured with the exception that intestinal transit time decreased, and faecal wet- and dry-weights were increased in all subjects at the end of the test period. Four subjects also showed an increase in faecal fat concentration (Eastwood *et al.*, 1984).

2.8.4 Studies on teratogenicity

Teratogenical experiments with four species of animals (rats, mice, hamsters and rabbits) did not indicate any teratogenic effects on mice at 280 mg/kg body weight and 1300 mg/kg, although 5 out of 21 dams died at the latter dose. Up to 1300 mg/kg in rats, up to 1000 mg/kg in hamsters and at 196 mg/kg in rabbits no teratological effects were seen. At 910 mg/kg in rabbits, most of the pregnant dams died (Morgareidge, 1972). In one study, locust bean gum was injected via the air cell and yolk or albumen routes into fertile eggs prior to and after 96 hours of incubation. Eggs were candied at 48-hour intervals and dead embryos were examined for stage of development and defects. Anophthalmia, phocomelia, micromelia and torticollis occurred at hatching (Naber & Smothers, 1975). Intra-peritoneal (i.p.) injection of 1 ml of 1% aqueous mucilage of Persian tragacanth gum (single dose or 5 doses of 0.2 ml each) into mice between days 11 and 15 of gestation caused the death of all foetuses. Oral or subcutaneous (s.c.) administration had no effect. All samples were found to be contaminated with *Enterobacter spp.* and the embryotoxic effects were attributed to bacterial metabolites (Frohberg *et al*., 1969). Tragacanth gum showed no evidence of maternal toxicity or teratogenicity after oral administration as a suspension in corn oil to pregnant mice, hamsters, rats and rabbits at different levels and different days of gestation (Table 2.5).

The studies with pregnant rats and rabbits resulted in significant maternal mortality in rats at the 1200 mg/kg body weight dose level and in rabbits at dose levels of 150 and 700 mg/kg body weight. At autopsy, the gross and pathological findings showed marked haemorrhage in the mucosa of the small intestine. Offspring from animals surviving in the high-dose group as well as those in other test groups showed no compound-related abnormalities in the soft or skeletal tissues (FDRL, 1972). Maternal toxicity observed in rats and rabbits, at the highest levels tested, may have been due to the mode of administration (suspended in corn oil), rather than to any innate toxicity of the gum.A study was also done using a chick embryo test system. Tragacanth gum dissolved in 0.12 N HCl was injected either into the air sac or the yolk of fertile chicken eggs at dose levels up to 7 mg/kg. The administration of tragacanth gum did not result in a significant increase in mortality. All hatched chicks appeared normal. Abnormalities observed in eggs that failed to hatch were 22% test, 14% solvent-control, and 3.41% flock background (Bodder, 1974).

Table 2.5: Oral administration of tragacanth gum to mice, hamsters, rats and rabbits

Species	Dose levels (mg/kg bw/day)	Gestation days
Mice	Up to1200	6-16
Hamsters	Up to 900	6-10
Rats	Up to 1200	6-15
Rabbits	Up to 700	6-8

*Source: WHO Food Additives Series, No. 13, 1978

2.8.5 Studies on mutagenicity

Tragacanth gum was evaluated for genetic activity in the following *in vitro* microbial assays, with and without activation: *Salmonella typhimurium* (strains TA1535, TA1537, TA1538, TA98, and TA100) and *Saccharomyces cerevisiae* strain D_4. No mutagenic activity was observed in any of these assays (Litton Bionetics, 1977). Tragacanth gum was not mutagenic in a number of tests using mammalian systems. These included:

(a) Host Mediated Assay *in vivo* in rats and mice using *Salmonella typhimurium* strain TA1530 and G46 or mitotic recombination frequency in *S. cerevisiae* D_3,

(b) A cytogenic study *in vivo* of rat bone-marrow cells,

(c) An *in vitro* study with human lung cells (wt. 38) in tissue culture (Litton Bionetics, 1972).

Mutagenic tests on rats and mice using three different methods gave negative results. There was no measurable mutagenic response in recombination frequency for *Saccharomyces cerevisiae* in host-mediated assay at 5 g/kg *in vitro*. No adverse effects were seen on chromosomes in rat bone marrow or human lung cell cultures. The dominant lethal test in rats was negative (Maxwell & Newell, 1972). Carob (locust) bean gum was evaluated for genetic activity in microbial assays with and without the addition of mammalian metabolic activation preparations. Indicator organisms used were *Saccharomyces cerevisiae* and *Salmonella typhimurium*, strains TA-1535, TA-1537 and TA-1538. Mammalian metabolic activation preparations were from mouse (ICR adult), rat (Sprague-Dawley adult) and monkey (*Macaca mulatta* adult). Carob (locust) bean gum did not exhibit genetic activity in any of the assays employed (Brusick, 1975).

2.8.6 Special studies on sensitization

Although there are only a few reports on sensitization to tragacanth gum, the available information indicates that tragacanth gum is a powerful allergen capable of causing extremely severe reactions. Allergic reactions may occur as a result of inhalation or oral ingestion. The immunogenicity of tragacanth gum was demonstrated in an *in vivo* test using a footpad-swelling test in mice. Purification of the gum led to a marked reduction of the immune response (Strobel *et al.*, 1982).

2.8.7 Special study on reproduction

A three-generation reproduction study was carried out using groups of 10 male and 20 female rats in the first generation and 20 male and 20 female rats in subsequent generations. Dosage levels of 0, 0.25, and 0.5 g/kg body weight./day were administered in the diet. Criteria evaluated were survival, body weight, general appearance, behaviour, the number of litters produced, number of live births and still births, physical condition of the young, weight at birth and weaning and survival of the young. Females that had fewer than two litters were examined to determine whether there was foetal resorption. Malformations in offspring were recorded and gross and micropathological examinations were made on the offspring of the second and third generations. No adverse effects attributable to xanthan gum were found in this study (Maxwell & Newell, 1972).

Groups of 50 male and 50 female Osborne-Mendel rats (approximately 21 days of age) were maintained on diets containing 0, 0.006, 0.06, 0.6 and 6.0% tragacanth gum. After 13 weeks on the test diets, the rats were bred to produce an F_1 generation. The offspring were weaned at day 21 and placed on their respective diets. The animals in the F_0 generation were maintained on the test diets for a total period of 27 weeks. Groups of 50 male and 50 female rats of the F_1 generation were maintained on the test diets for approximately 20 weeks. Results from this study revealed that both male and female rats in the 6% group showed significantly lower body weights, as well as decreased food efficiency, than the controls. Lower body weights were also observed in the F_1 generation, particularly in the males and haematological measurements showed no compound-related effects. Only minor effects were noted in the various clinical chemistry parameters. Reproduction data were comparable for test and control animals. Histological studies did not show any compound-related effects. Enlarged livers were noted in the 6% group, but the enlargement was not associated with any significant change in liver composition or with histological changes. The ATP/ADP ratio in liver preparations for F_0 animals was markedly decreased, but this effect was not observed in the F_1 animals (Graham *et al.*, 1985). Although full-scale toxicological tests have been done on most gums none has been done for cashew gum, hence the need to study the acute toxicity of cashew gum to establish its safety in terms of end use.

2.9 Uses of cashew gum

As mentioned earlier, gums have been used extensively in foods as emulsifiers, stabilizers, texturizers, binders and film-formers. However, very little has been done in terms of the utilization of cashew gum. Hence, the need for investigations into the utilization of cashew gum in product development such as fruit juices and preserves and chocolate products.

2.9.1 Fruit juice production trends

Over the past several decades there has been a growing trend towards adding value to raw agricultural products. As populations have become more urban, this trend has accelerated. The need for stable, convenient foods has increased along with the demand for exotic produce for international cuisine. Within the globalization of the food industry, the demand for quality juice and juice type beverages has markedly expanded. Traditionally, only a handful of fruit and vegetable juices have served this market as large multinational companies or their affiliates, have captured the majority of the national and the international juice trade. Juices such as orange, grape, pineapple, apple, tomato and blends are well established in developed countries. In recent times, minor, tropical juices such as cashew juice are attracting new attention (FAO, 1999).

2.9.2 The value of juices

The global market for juice and juice products was estimated to be about 50 billion litres in the late 1990s. In the United States of America alone, the retail commercial value of the almost 20 billion litres of juice and juice products exceeded US$18 billion, roughly 3% of a total food sales expenditure of US$630 billion. World trade has accelerated over the last decade with developing countries achieving over 60 percent of fruit juice exports. Brazil, the largest citrus producer, accounts for about 25% of world production (FAO, 1999).

In Ghana, the total production of soft drinks including fruit juices from 1991 to 1993 is shown in table 2.6. Lall *et al.* (1994) also reported on the total product sales of fruit juices in 1991 for both State-owned companies and Local African-owned companies in Ghana (Table 2.7). Thus, the total product sales for 2005 can be estimated using the same growth rates (1.5 and 30.3%) as $793,620.00 and $22,107,252.00 for State-owned companies and Local African-owned companies respectively. Developing juices from minor fruits such as cashew which is currently abundant in Ghana will contribute towards the development of the national economy.

Table 2.6: Production of soft drink in Ghana from 1991 to 1993

Year	Production (million L)
1991	12.96
1992	16.56
1993	23.76

*Source: Oti Boateng, 1994

Table 2.7: Total product sales of fruit juices in Ghana in 1991

Company type	Sales/Rate
State-Owned Companies	$644,300.00
Sales Growth Rate	1.5%
Local African-Owned companies	$543,700.00
Sales Growth Rate	30.3%

A study of the food markets the world over, suggest that juices of all types and in all forms have an important role in both food nourishment and enjoyment. This trend has certainly accelerated over the last half decade.

2.9.3 Cloudiness of fruit juices

Fruit juices and juice drinks are generally sold as either clear (clarified) commodities or as cloudy products of variable density. However, for some juices, there may be market demand for both clarified and cloudy forms. However, citrus juices and juice drinks are almost always processed to contain a dense cloud suspension (Baker and Cameron, 1999). Juice cloud may be characteristic of cultivar, and its density and colour intensity are specific qualities influencing juice grading and market acceptability. Juice cloud provides turbidity, flavour, aroma and the characteristic colour of juices. Loss of juice cloud through clarification results in a watery serum containing few characteristic flavour notes. That is why juice with solids in suspension is a better product to commercialize. Freshly extracted juices contain a continuum of particulate sizes, from coarse pulp fragments to submicron particles. Those of larger sizes tend to settle on standing, while those below 2μm in diameter constitute stable cloud (Baker and Cameron, 1999).

One of the main requirements for cloudy juices is that they retain a stable appearance throughout their intended shelf life (Siebert, 1999). Cloudy juices should remain constant in appearance until they are consumed, neither becoming more cloudy nor clarifying through sedimentation of cloud material. The intensity of turbidity and its qualitative nature are of special interest. Orange juice cloud, for instance, contains 52% proteins, 4.5% pectin, 25% lipid, 2% hemicellulose, 1.5% cellulose, 5.7% nitrogen and 2% ash (Klavons *et al.*, 1994). Cloud of commercial lemon concentrates also contains 29.8% protein and 4.1% pectin.

Cashew juice can be produced as both clarified and non-clarified juices for commercialization. Compared with clarified juice, the non-clarified juice which contains solids in suspension retains larger amounts of substances such as proteins, sugars, and tannins which are associated with the smell and flavor of the apples. This therefore makes the non-clarified juice a better product to commercialize (Mothe and Corella, 2004). Sediments formed in the unclarified cashew juice however tend to settle on standing making the product unattractive to the consumer, and this has led to the search for a suitable juice stabilizer and the potential of cashew gum to meet this condition. The steps involved in the production of cashew juice and where gum would be added for stabilization is shown in Figure 2.2.

2.9.4 *Fruit preserves*

Fruit preserves such as jams and marmalades are mixtures of fruits and sugar, which have been boiled to produce a stable gel structure with attractive visual and eating qualities and mould-free storage life. The products should have characteristic colours, flavours and textures and be easily spreadable. Commercial preserves contain about 25-30% small fruits, and are consequently, low in fruit content. They may also contain varying levels of artificial additives such as gelling agents, colours and flavours. Teagasc (2005) observed that home produced preserves should contain at least 50% fruit and have a characteristic fruity flavour. It should not be too sweet, too stiff nor rubbery and should contain no artificial additives. The market for good quality home produced jams and marmalades continues to grow whereas that for commercially produced preserves is in decline. The main attractions of the home produced preserves are the absence of artificial additives and the significant fruity flavour (Teagasc, 2005). The basic principle of jam making is to have fruit, pectin, acid and sugar present in the correct proportions (Fig. 2.3). The setting of jam depends on the presence of pectin. The fruit is simmered and the pectin is released into solution. Fruits low in pectin may need an additional source of pectin before they will give a satisfactory set. Acid is necessary for pectin extraction, improving colour and flavour and preventing crystallization (Teagasc, 2005).

In Ghana, jam produced by the local food industries is mainly from fruits such as pineapples and oranges which contain low pectin leading to the use of commercial pectin which is highly expensive. At the Cocoa Research Institute of Ghana, efforts were made to extract pectin from cocoa sweatings on large scale but this was not feasible due to the high cost of absolute ethanol which was used in large quantities for the extraction. This has led to investigating into the utilization of cashew gum as a gelling agent in pineapple jam production.

2.9.5 Chocolate pebbles

Panned goods, generally called 'dragees' are obtained by building up coating, layer by layer, on centres, which are rotating in a pan (Fig. 2.4). Their smooth, regular and compact surface is obtained by frictional force, to which every centre is submitted by their rotation one upon another in a revolving pan. By proper adapted coating solution, the coating follows automatically the contours of the centre, which ensures that the finished dragees show the same shape (Fabry, 1992). Gum Arabic, which is used as a quick coating agent of the centres, is very expensive, thus, the need to search for a cheaper substitute.

Chocolate pebbles are dragees with the engrossing syrup being chocolate mass mixed with cocoa butter. The chocolate could be dark, milk or white and the centers normally used are peanuts, hazelnuts, almonds, raisins, croquant, marzepan sugar crust liquers and

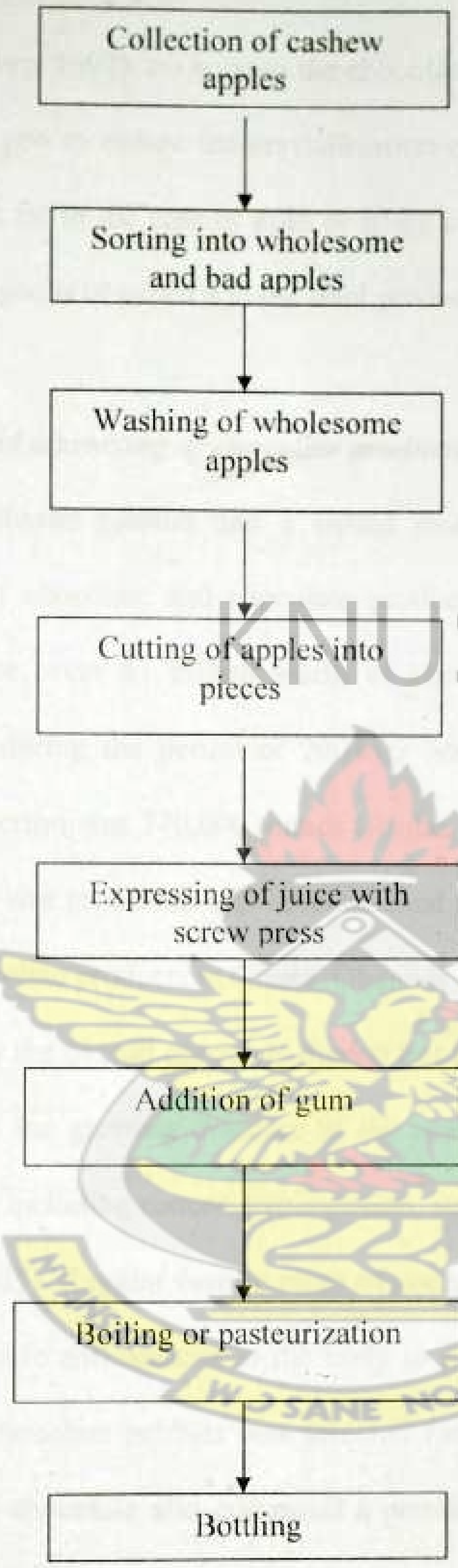

Figure 2.2: Steps involved in the preparation of stabilized cashew juice

expanded cereals (Fabry, 1992). As soon as the chocolate is distributed around the center, air is blown into the pan to ensure the crystallization of cocoa butter or the mixture of cocoa butter and milk fat in the case of milk or white chocolate. This is repeated until a reasonable size of dragee is obtained and the final product is polished.

2.9.6 Production and marketing of chocolate products

Chocolate is a worldwide passion and a famed mood-booster. Fulfilling consumer cravings, hundreds of chocolate and chocolate products are made in the US and for Valentine's Day alone, over $1 billion worth of chocolate is purchased. The world production of cocoa during the period of 2004/05 was 3,327,000 tonnes and that of Ghana for the same period was 740,000 tonnes (Arabe, 2006). About 95,000 tonnes out of the 740,000 tonnes was processed into semi-finished products such as cocoa mass and cocoa butter, and chocolate products in Ghana. Ghana is far from being a major consumer of chocolate. However the overall chocolate market has been growing slowly but steadily and this is because of the growing evidence of the health benefits of cocoa in fighting against many diseases including cancer, hypertension, stroke, diabetes, aging and erectile dysfunction (ARS, 2005). Regular consumption of cocoa products such as chocolates is believed to provide more antioxidants to the body to prevent such diseases and this is another reason why chocolate pebbles was selected for the study on the utilization of cashew gum. Ghana's chocolate also command a premium on the international market, hence the need to step up the production of chocolate based products to earn more revenue.

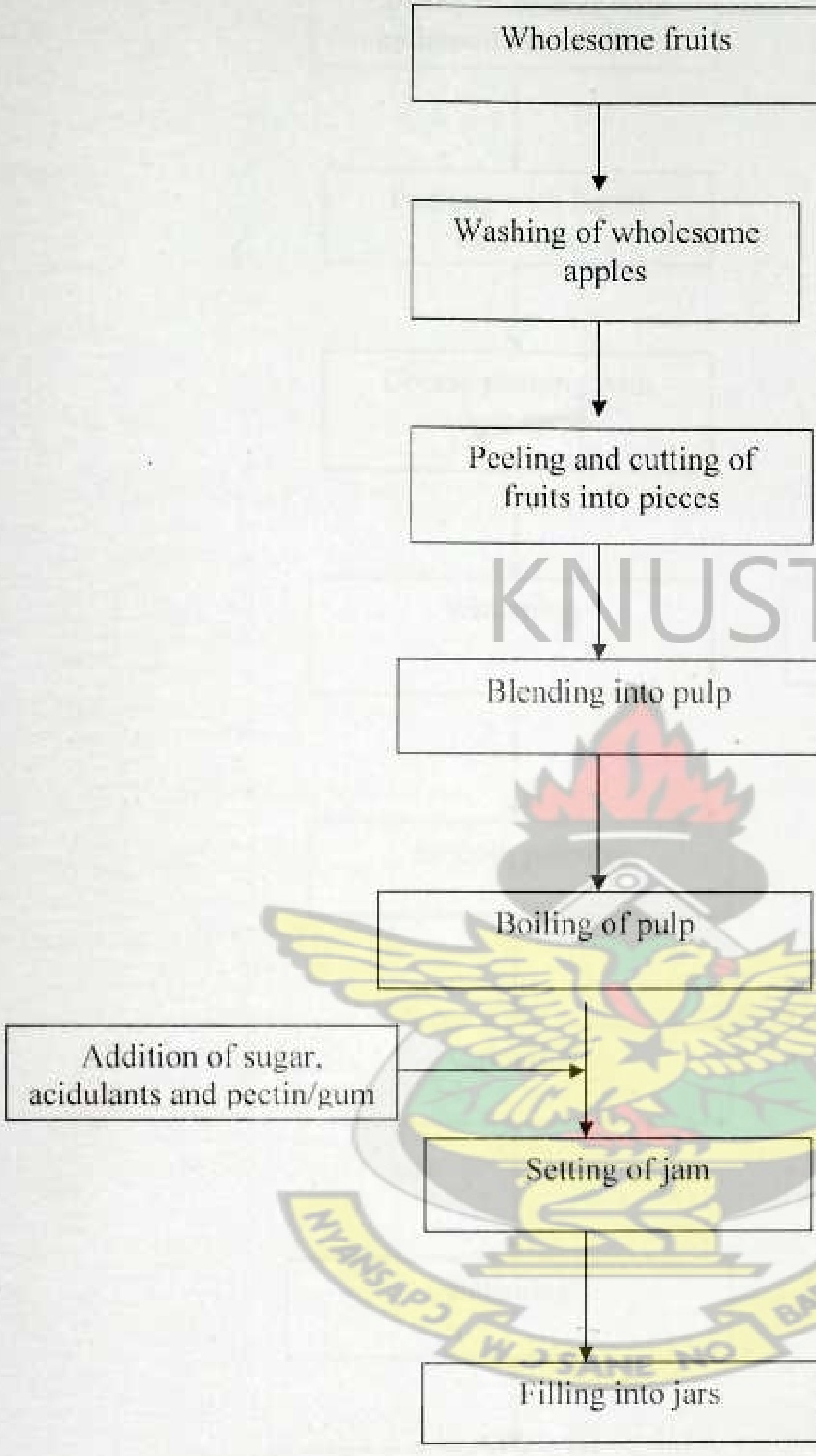

Figure 2.3: Steps involved in the preparation of jam

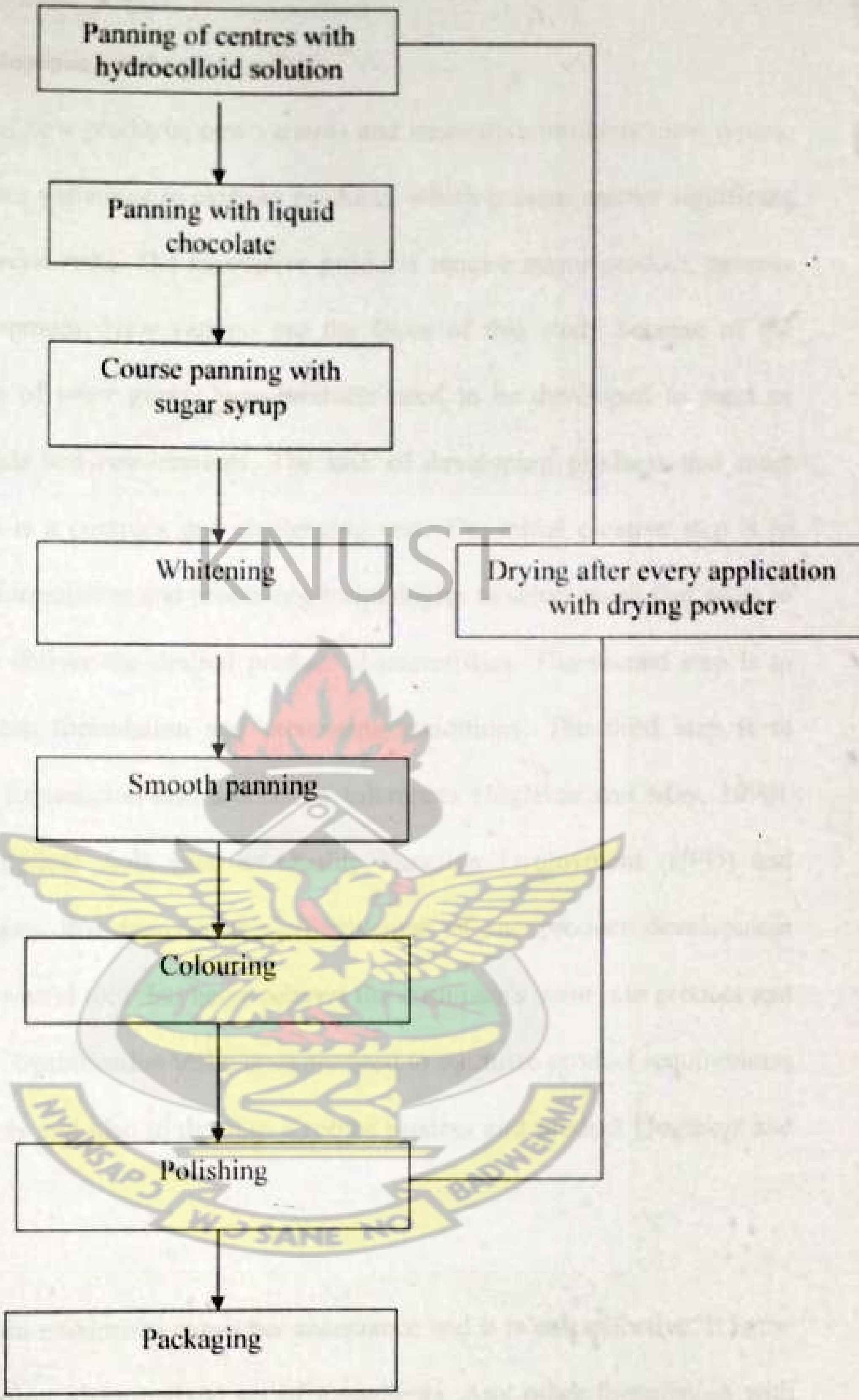

Figure 2.4: Steps involved in the preparation of chocolate pebbles

2.10 Product development and optimization

There are two types of new products, new variants and innovative products (new types). New variants are minor variations to existing products, which present neither significant technical nor commercial risks. The innovative products require major product, process and/or market development. New variants are the focus of this study because of the search for substitutes of other gums. New products need to be developed to meet or exceed customer needs and requirements. The task of developing products that meet customer expectation is a complex and challenging one. The initial creative step is to examine the various formulation and processing technologies to select those that seem to have the potential to deliver the desired product characteristics. The second step is to determine the optimum formulation and processing conditions. The third step is to generate appropriate formulation and processing tolerances (Joglekar and May, 1990). There are many analytical tools such as Quality Function Deployment (QFD) and Optimization techniques that increase the effectiveness of the product development process. QFD is a powerful tool that helps convert the customer's want into product and process requirements. Optimization techniques are used to optimize product requirements and process parameters and also to develop a robust process and product (Joglekar and May, 1990).

An optimal formulation maximizes consumer acceptance and it is cost effective. It is the best possible formulation given a fixed set of ingredients. Any other formulation with those ingredients will not perform better. The optimal formulation must fall within the cost-of-goods constraints so that the study is not only searching for just substitutes of conventional but cheaper ingredients. The four basic steps in optimizing a formulation are:

1. Ingredient screening which is the process of selecting the final set of ingredients for the finished product.
2. Identification of ingredients that, when varied, have a strong influence on the overall sensory properties and/or cost of the product (high-impact ingredients).
3. Design of test products, which is the process of the ingredient levels for the test products.
4. Consumer testing or sensory analysis (Fishken, 1983).

The food industry in the United States was once a sleepy commodity sector-safe but lacking investor appeal. It later saw a major evolution resulting in companies discovering the enormous returns that could be generated by adding value to commodity products in the form of convenience, nutrition, variety, economy and consistent quality. The companies also discovered that consumers would pay for value and this led to an unparalleled period of new product development (Fishken, 1983)

In 1975, a crisis in America's cranberry industry prompted serious thinking about product diversification among executives. By 1990, the company's product portfolio included over 30 fruit juice products, many of them combinations of cranberry with different fruits. They successfully pioneered the use of aseptically packaged juice drink and concentrate; expanded into cranberry and cranberry/fruit combination sauces; and developed and promoted a market for cranberry ingredients in the food service and processing industries. These investments boosted the company's sales from a plateau of $110 million in 1974 to approximately $900 million in 1989 (Anon, 1989). This example and others put into perspective the tremendous impact new products and process development have on the food industry. (Graf and Saguy, 1991)

2.11 Response Surface Methodology

Response surface methodology (RSM) consists of a set of statistical methods that can be used to develop improve, or optimize products (Myers and Montgomery, 1995). RSM typically is used in situations where several factors influence one or more performance characteristics, or responses. RSM may be used to optimize one or more responses, or to meet a given set of specifications. Results of RSM are either reported as a mathematical model or used to optimize the system response. Graphs plotted using RSM are called Response Surface plots or Contour plots (Gacula and Sighn, 1984). These plots are either two or three-dimensional in nature. This technique has been put to practical use in the field of quality engineering for purposes such as product process optimization especially in the United States. Conventional optimization technique, which is by repeating experimental analysis until an optimal solution is obtained, is time consuming and requires a huge amount of computer resources. This has led to the adoption of RSM. With RSM, experiments are generally performed with design of experiments to increase reliability of the response surface (Myers and Montgomery, 1995).

2.11.1 Response surface designs

These are the classic mixture approach in which the mixture components are the variables and the total amount of product is fixed, and the mathematical independent variable (MIV) or factorial approach where the mixture components are transformed into *x-1* independent-related variables. Each technique has advantages and disadvantages. In the classic mixture approach, the sum of the proportions must be one (Fig. 2.5), therefore the variables are not all independent. This allows the experimental region of interest to be defined more naturally, but the analysis of such experiments is more complicated. The MIV approach, with the variables independent, permits the use of classical factorial and response surface designs (Fig. 2.6), but has the undesirable feature that the experimental region changes depending on how the *x* mixture components are reduced to x-*1* independent factors.

The central composite design (CCD), an augmented factorial design, is commonly used in product optimization. A complete CCD experiment design allows estimation of a full quadratic model for each response. A schematic layout of a CCD for $k = 3$ independent variables is shown in Figure 2.6. The design consists of 2^k factorial points (filled circles) representing all combinations of coded values $x_k = \pm 1$, 2^*k (in this case, 6) axial points (hollow circles) at a distance $\pm a$ from the origin, and at least 3 centre points (hatched circles) with coded values of zero for each x_k. The value of a usually is chosen to make the design rotatable, but there are sometimes valid reasons to select other values.

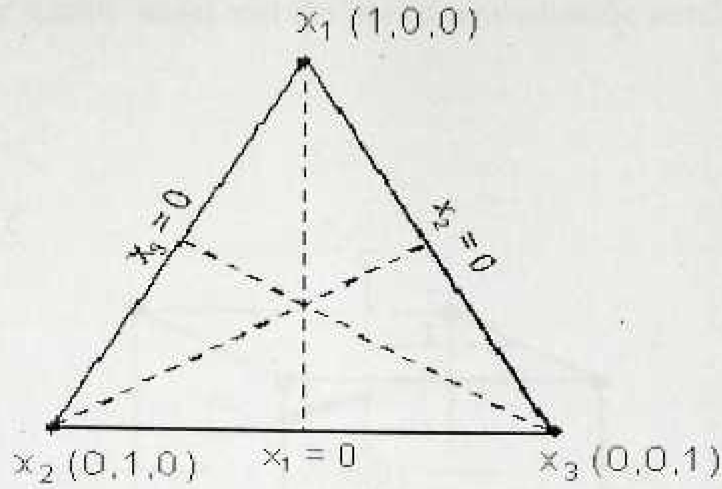

Figure 2.5: A triangular simplex region from a three-component mixture experiment

2.12 Sensory analysis

Sensory evaluation is a unique source of product information not easily obtained by other means and almost everyone has all the necessary sensory equipment with which to evaluate a product. Unlike physico-chemical properties of products, which make extensive use of elaborate and expensive instruments, many of which are automated and linked with computers, sensory evaluation relies solely on one's senses. In addition sensory evaluation uses limited numbers of people and concerns itself with measuring the responses of people to products in terms of its appearance, taste, texture and aftertaste, without benefit of label, pricing or other imagery (Stone and Sidel, 1995).

Applications of sensory analysis include setting of standards, quality control and assurance, product development and correlation with chemical, physical and instrumental measures (Pangborn, 1980). Some common misuse of sensory analysis also include trained judges asked to rate hedonic responses of products, confounding hedonic terms within intensity or quality scales and the use of non-scientific terminology (Pangborn, 1980).

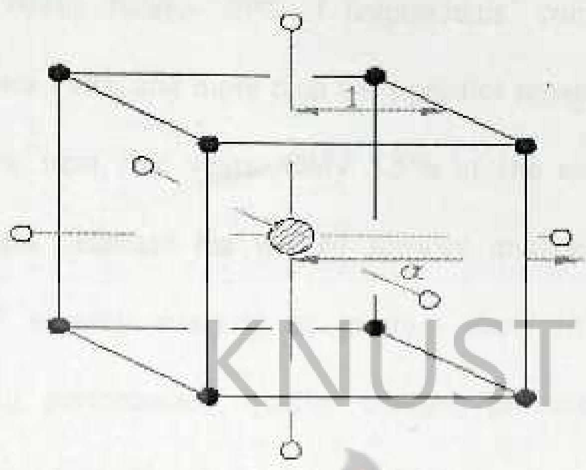

Figure 2.6: Schematic of a composite design for three factors

Product quality has a very important influence on consumer behaviour, particularly when it comes to selecting products to purchase and consume. The importance of the quality of a product can be determined by asking consumers what they think about the quality of a particular product. It must be noted that one can use the best quality ingredients, the most sophisticated production process, and the most thorough quality control procedures, but that does not guarantee that consumers will either recognize the quality of the product or be willing to purchase that product. (Stone *et al.*, 1991). Determination of product quality requires sensory descriptive and preference judgments. Descriptive judgments are obtained from a trained panel while preference judgments are obtained from appropriately recruited and qualified consumers. In addition to sensory analysis, products should be analyzed using physical and chemical methods.

Despite advances in texture analysis and the increasing use of electronic noses, technology still has not quite replaced human taste buds. In fact, sensory analysis has a solid future into the twenty-first century, according to a recent survey of 500 professionals (Miller, 1998). Nearly 70% of respondents' companies gave increased sensory analysis use since 1993, and more than 68% predict sensory analysis applications will increase within the next five years. Only 3.5% of the respondents thought that analytical devices would decrease the use of sensory analysis panels. Respondents evaluated the role of sensory analysis in product shelf life, competitor product performance, packaging performance, quality control, process control analysis and correlation with consumer data. The study showed that sensory analysis was ranked very important in product shelf life studies (68.6%), quality control measures 58.9% and evaluating competitor product performance 57%. Evaluating process control analysis and packaging performance measured 21.2% and 16.7% respectively. Packaging materials are being assessed for appearance by consumer panels, but the functional ability of packaging materials to maintain food flavour and texture over time is getting little attention (Miller, 1998).

In this study sensory analysis was conducted on each product developed to determine its quality and the optimum formulation.

CHAPTER 3

LOCATIONAL AND MATURITY EFFECTS ON CASHEW GUM PRODUCTION IN GHANA

3.1 ABSTRACT

A comparative study of cashew gum yield trends per tree and picking in relation to age of tree and the location of tree was conducted at five cashew growing districts (Sampa and Wenchi in the Brong Ahafo Region, Bole andDamango in the Northern Region and Jirapa in The Upper West Region) in Ghana for a period of 24 months. This was to develop cashew gum production for the food industry and to generate extra income for cashew farmers. Trees used in the study were of two age groups, those that were 10 years and below and those above 10 years. Yield trends in relation to rainfall were also compared. The minimum age of trees for the production of gum was found to be four years. Higher gum yields were obtained during the dry season from January to March when there was drought and the trees were under stress. Mature trees also produced more gums than younger trees. The average yield per tree varied from 13.7 to 276.0 g in young trees and 30.1 to 1237.1 g in mature trees in the first year and 37.8 to 115.2 g in young trees and 74.1 to 462.4 g in mature trees in the second year. Generally, less gum was produced by trees in year 2 and this was due to high rainfall in year 2. Organoleptic studies also showed that the gums were odourless and tasteless, comparing favourably to that of commercial gums such as gum Arabic. The study showed that age and location of cashew trees have no significant effect on the production of gum.

3.2 INTRODUCTION

The cashew tree, which grows in a wide spectrum of climatic regions, has been reported to produce appreciable amounts of gum (Smith and Montgomery, 1959). Natural gums are found under the bark of trees and are formed within plants by metamorphosis of the cells of the inner bark and their production have been found to be influenced by climatic conditions.

The two main ecological zones of Ghana are the closed forest area which covers about 34% of the country (8.22 million ha) and the savanna area which covers about 66% of the land area (15.62 million ha) (Nsiah-Gyabaah, 1996). The closed forest is floristically very rich and diverse and contains a large reserve of commercial timber species. About two-thirds of the country's human population and economic activities are concentrated in this zone. The savannah vegetation has evolved under conditions of annual bush fires, which has been increased by human activities. The vegetation consists of short grasses with scattered fire-tolerant trees. Ghana's forest-savanna zone lies in the area transitional between humid forest and dry savannah (Dickson and Benneh 1988). Since cashew thrives well in both the northern savanna and the transitional belts (CDP, 2007), this study was concentrated in those areas. Generally, the climate in Ghana is tropical and there are two main regimes of rainfall distribution. These are from March to July and from September to October (Dickson and Benneh 1988). Since natural gum production can be affected by the environment within which the trees are found, the study sought to determine the effect of location on the production of cashew gum.

This work was therefore carried out to study the effect geographical location and maturity of tree on the production of gum from cashew trees.

3.3 MATERIALS AND METHODS

3.3.1 Selection of cashew trees for gum collection (nested design)

To determine the effects of location and maturity on cashew gum production, farms were selected from two districts each within the Guinea Savannah (Bole and Jirapa) and the transitional belt zones (Wenchi and Sampa). Selection was done based on two different age groups. These are farms that were 10 years and below (young farms) and those above 10 years (mature farms). These age groups were used because cashew production was introduced into Ghana in the early 1990s and this made most of the farms fall within the ages of 5-20 years. Under each age group a maximum of five farms were selected and six trees selected from each farm randomly.

3.3.2 Collection of gum and yield determination

The trees were tagged and exudate masses were hand picked from the trees into polyethylene bags. Yield of gum per tree was determined by weighing the gums with a PB3001-L Mettler Toledo Balance (Switzerland) from each tree and finding the average. This was done for two years (2006 and 2007). The effects of location and maturity on the gum production were also determined. Data obtained was analyzed using Statgraphic Plus (windows version 3.0) programme for Kruskal-Wallis test and correlation to determine the relations and differences between gums obtained from the four locations and two age groups.

3.3.3 Sorting and grading of gum exudates

Gum exudates were sorted after collection to remove pieces of bark and other foreign matter. They were then sorted into three grades by picking in accordance with differences in colour and brightness.

3.3.4 Determination of colour

The colour of the different grades was determined by using the Minolta CR 310 chroma meter. The CIELAB colour parameters (L^*, a^* and b^*)were measured where

L^* indicates brightness/darkness on a scale of 100/0

a^* indicates red for positive values and green for negative values

b^* indicates yellow for positive values and blues for negative values

Three measurements were taken for each parameter with the instrument being standardized each time with a white ceramic plate. The hue angles, h^*, representing the degree of yellowness and the chroma, which is the brightness were calculated from the following equations:

$$h^* = \tan^{-1} (b^* / a^*)$$

$$\text{chroma} = (a^{*2} + b^{*2})^{1/2}$$

The values used are the means of three measurements. (Mabon, 1983);

3.3.5 Collection of rainfall data

Rainfall data during the experimental period were obtained from the Meteorological Departments of Wenchi, Bole and Wa (nearer to Jirapa) since there were no Meteorological stations in Sampa and Jirapa.

3.3.6 *Statistical analysis*

Data obtained was analyzed using Statgraphic Plus Programme for Correlation and Analysis of variance (ANOVA).

3.4 RESULTS AND DISCUSSION

3.4.1 *General observations during gum collection*

The selected farms were widely scattered making cashew gum collection highly labour intensive. It was observed that the gum exuded spontaneously from the trunk and principal branches of the trees around the middle of November, after the rainy season. The dry winds, which prevailed after the rainy season, caused the bark to crack and the gum flowed out. The exuded gum thickened and hardened within some few days on exposure to the air, usually in the form of round or oval tears or in straight or curled cylindrical pieces of various sizes (Plate 3.1). It was also observed that most of the trees produced white gums while a few produced amber coloured gums. The masses of gum were collected, either while adhering to the bark or after they fell to the ground.

3.4.2 *Yield determination for cashew gum during the dry and rainy seasons*

The study established that the youngest cashew tree to produce gum was four years and the oldest tree was nineteen years. Generally, higher cashew gum yields were obtained in all four districts within the Guinea savannah and the transitional belt zones during the dry season, January-March. For instance, the average cashew gum yield/tree for young trees varied from 13.7 g to 276.0 g in all the four districts during the dry season whilst virtually no gum was obtained in the rainy season (Tables 3.1 and 3.2). However, in mature trees some gum was collected in Sampa and Jirapa in

May and also in Sampa in August. This may be explained on the basis of drought, which put the trees under stress, a condition which according to Fitwi (2000) stimulates gum production in trees. A healthy plant will have all its system at full throttle but when under stress it begins to physiologically shut down. At Wenchi, yields were also high in July to August probably because of the reduction in rainfall during that period (Figure 3.1).

Plate 3.1: Tears of dried cylindrical gum on a cashew tree

3.4.3 *Yield determination for cashew gum from different locations and tree age groups*

Mature cashew trees were observed to produce more gum than the young trees within the first year of study. The average cashew gum yield/tree varied from 13.7 g at Bole, to 276.0 g at Wenchi in young trees and 30.1 g to 1237.1 g in mature trees both at Wenchi (Table 3.1). This may be due to the fact that the young plants are actively growing and therefore using their sap for growth. Also mature cashew trees are more proned to produce cracks for gum to ooze freely than in young trees. However, the difference between cashew gum yields from the two age groups was not significant. Similarly, results on yield data showed that location had no effect on gum yield. These findings were supported by the low correlation coefficient of (R) 7.1%, which showed no significant relation between the yield, age groups and the locations.

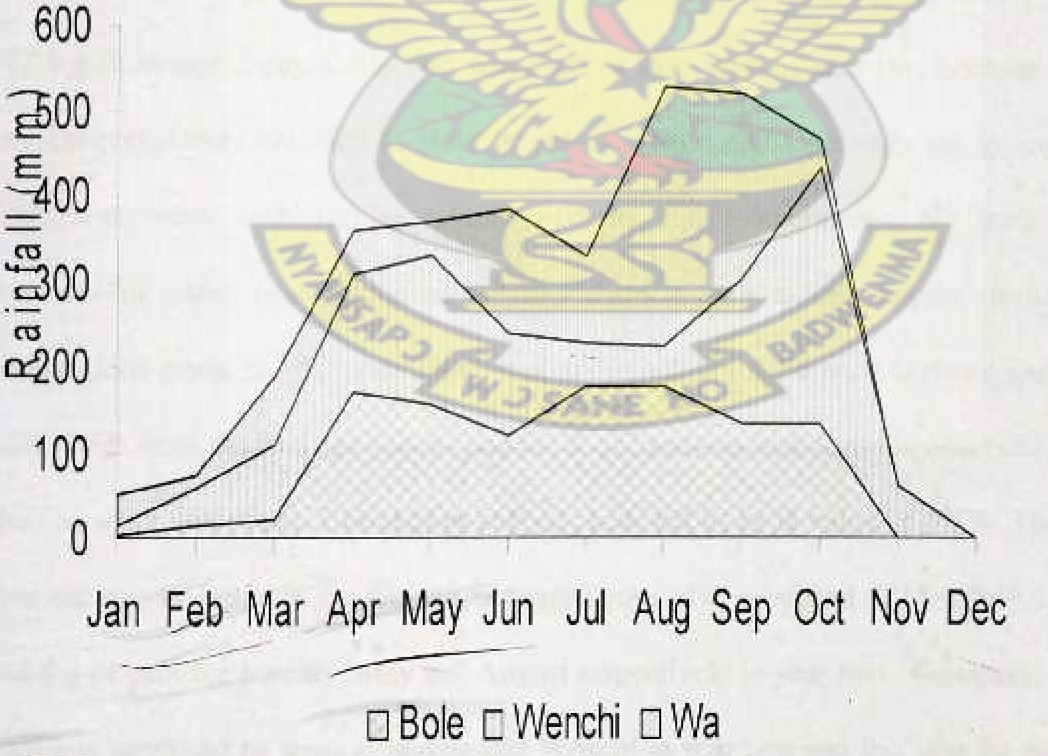

Fig 3.1: Rainfall pattern in the districts for the year 2006

The observed data showed that young trees from the transitional belt produced more gum than young trees within the Guinea savannah zone whereas mature trees from the Guinea savannah produced more gum than mature trees within the transitional belt. This may be due to the effects of variations in the climatic conditions of the two zones on the age of trees. A very old tree which according to local farmers was 45 years in Jirapa in the Guinea Savannah zone (Plate 3.2) produced 7664.1, 3270.1 and 497.7 g of gum for January, May and August respectively. Even though statistical analysis of the data showed that the age of the trees had no significant effect on gum yield, the observed data indicated that very old trees produced more gums. The annual yield of gum Arabic in comparison with cashew gum varied from 200 to 6700 g with the average yield/tree being 250 g per annum (Duke, 1981).

Results for year two are presented in Table 3.2 and the trend was similar to that in year one. The average yield/tree varied from 37.8 to 115.2 g in young trees and 74.1 to 462.4 g in mature trees. Collection was done at Damango in year two because only one collection was obtained at Bole in year 1. Bole and Damango are in similar ecological zones with similar rainfall patterns and temperatures. No gum was produced in young trees within all the four districts in May and August similar to observations made in year one. There was no significant difference between cashew gum yields from the two age groups and the four locations although the observed data showed some variations. Correlation analysis resulted in an R value of 5.6%. The 45 year old tree in Jirapa in the Guinea Savannah zone also produced 1215.3, 869.6 and 674.0 g of gum for January, May and August respectively in year two. Generally, less gum was produced by trees at Sampa and Wenchi in year two and this may be due to the high rainfall recorded in that year in those areas (Table 3.3). However, young trees in Jirapa produced more gum in January and March in year 2 than in year 1 and this may be due to the low rainfall distribution in Wa and its environs within that period (Table 3.3). There was no significant difference between gum yields for year 1 and that for year 2.

Plate 3.2: A 45 year old tree at Jirapa

Table 3.1: Average yield/tree (g) of cashew gum – Year 1

Location	Below 10 years				Between 10-20 years			
	Jan	Mar	May	Aug	Jan	Mar	May	Aug
Sampa	72.3 *(7.0)*	71.1 *(2.0)*	-	-	77.1 *(30.0)*	92.1 *(22.0)*	37.1 *(17.0)*	93.9 *(12.0)*
Wenchi	58.1 *(11.0)*	276.0 *(2.0)*	-	-	30.1 *(14.0)*	116.8 *(22.0)*	-	1237.9 *(5.0)*
Bole	13.7 *(10.0)*	-	-	-	84.4 *(5.0)*	-	-	-
Jirapa	24.8 *(11.0)*	56.0 *(8.0)*	-	-	150.0 *(19.0)*	152.5 *(18.0)*	346.7 *(4.0)*	-

(*Std dev. in italics)

Table 3.2: Average yield/tree (g) of cashew gum – Year 2

Location	Below 10 years				Between 10-20 years			
	Jan	Mar	May	Aug	Jan	Mar	May	Aug
Sampa	49.8 *(10.0)*	51.4 *(13.0)*	-	-	82.4 *(27.0)*	74.1 *(32.0)*	-	93.9 *(12.0)*
Wenchi	47.0 *(8.0)*	58.9 *(16.0)*	-	-	395.5 *(36.0)*	92.2 *(28.0)*	-	-
Damango	115.2 *(14.0)*	92.6 *(22.0)*	-	-	106.4 *(11.0)*	152.5 *(29.0)*	-	-
Jirapa	37.8 *(11.0)*	59.6 *(8.0)*	-	-	102.4 *(22.0)*	92.5 *(26.0)*	-	-

(*Std dev. in italics)

Table 3.3: Rainfall figures for Wenchi and Wa for 2006 and 2007

Month	Rainfall (mm) – 2006		Rainfall (mm) – 2007	
	Wenchi	Wa	Wenchi	Wa
January	9.4	35.9	11.2	0.0
February	42.0	13.8	35.6	0.0
March	86.1	78.0	87.2	17.4
April	139.5	50.3	131.9	156.0
May	174.1	41.0	168.6	198.0
June	119.7	143.4	147.2	72.4
July	50.7	100.9	130.0	121.8
August	47.7	304.7	140.3	186.7
September	170.5	219.4	232.6	103.3
October	299.7	33.4	226.2	113.3
TOTAL	**1,139.4**	**1020.8**	**1,310.8**	**968.9**

3.4.4 Sorting and grading

On the basis of colour and brightness, three different grades of cashew gum were obtained (Table 3.4). Grades 1 and 2 were whitish yellow in colour whilst the colour of grade 3 was amber and these conformed to the general physical properties of gums (Plates 3.3 and 3.4). The variation in the colour of gums depends on factors like storage time, the age or part of the tree that is tapped, duration of gum on tree before being picked and the presence of impurities (Fitwi, 2000). However, in this study, the variation in the colour of the grades obtained was due to the age of the part of the tree that was tapped and the presence of impurities. The hue angle (h*) representing the degree of yellowness varied from 0.34 to 1.50 whilst the chroma which is the brightness also varied from 11.92 to 15.94 (Table 3.5).

Organoleptic studies also showed that the gums were odourless and tasteless which confirms the general organoleptic properties of gums (Glicksman, 1969). The physical properties of grade 1 cashew gum were found to be glassy and transparent whilst grades 2 and 3 were translucent. Best quality gums are generally tasteless, whitish, yellowish or pale brown in colour and transparent or translucent in appearance (Robbins, 1988). The lower grades are generally more strongly coloured than the higher grades. This therefore indicates that grades 1 and 2 obtained after sorting are of better quality than grade 3.

Plate 3.3: Mixture of grades 1 and 2 cashew gum

Table 3.4: Physical and organoleptic properties of cashew gum

Grade	Colour	Shape and form	Optical property	Odour	Taste
1	Whitish yellow	Glassy	Transparent	odourless	tasteless
2	Whitish yellow	glassy	transluscent	odourless	tasteless
3	Amber	globular	translucent	odourless	tasteless

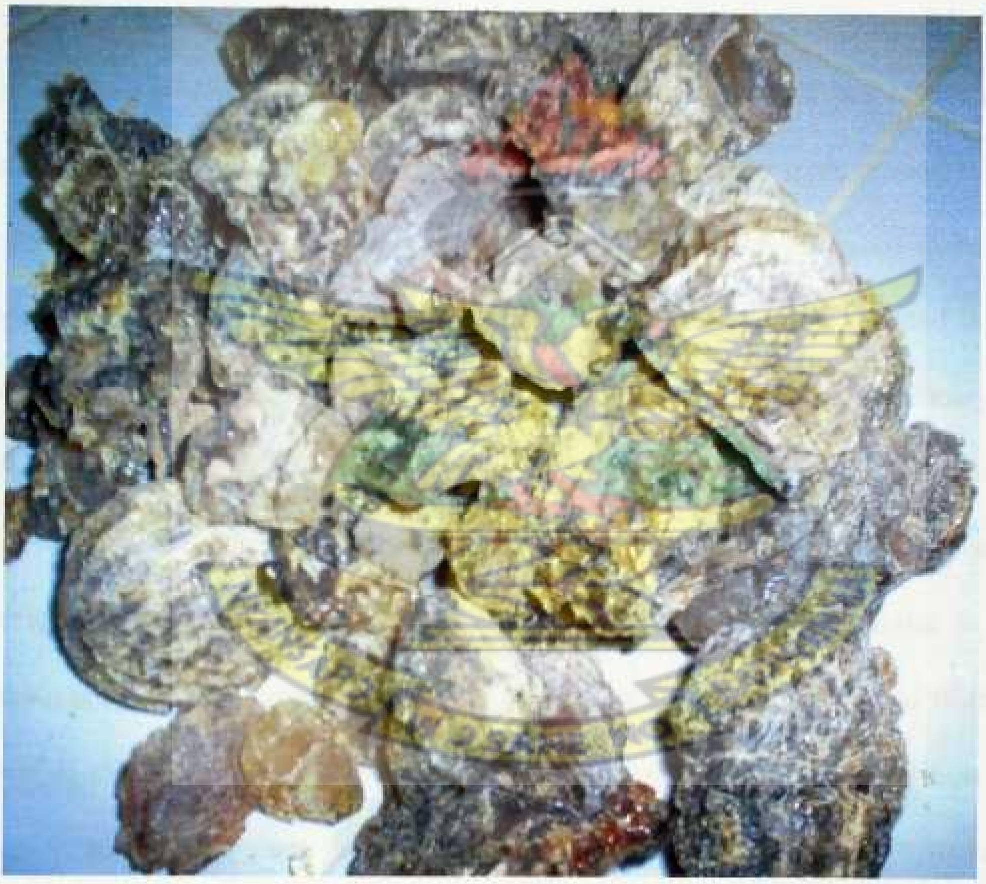

Plate 3.4: Grade 3 cashew gum

Table 3.5: Chroma and Hue angle values for the three grades

Grade	L	a*	b*	Chroma	Hue angle (h*)
1	88.32 *(1.50)*	1.06 *(0.10)*	15.86 *(1.43)*	15.94	1.50
2	38.45 *(3.16)*	10.96 *(0.94)*	4.62 *(0.34)*	11.92	0.34
3	60.21*(0.86)*	6.34 *(0.22)*	13.64 *(0.54)*	14.19	1.14

(*Std dev. in italics)

3.5 CONCLUSION

In conclusion, cashew trees as young as four years and as old as 45 years were found to produce gum. Observed data indicated that generally mature trees produced more gum than younger trees. Cashew trees in the transitional zone produced more gum relative to those in the Guinea savannah area. Drought also periods resulted in high cashew gum yields with average highest production occurring between January and March. Rainfall had a significant effect on gum production trends. Gums produced by cashew trees are of good quality in terms of colour, physical and organoleptic properties. They were whitish yellow to amber in colour, glassy or globular in form and transparent or translucent. They were also found to be colourless and tasteless, conforming to the general characteristics of gums. Thus, the potential for cashew gum production and development for the food industry in Ghana and also as a source of income for the cashew farmer is very high.

CHAPTER 4

PHYSICO-CHEMICAL PROPERTIES OF CASHEW GUM FROM FOUR CASHEW GROWING DISTRICTS IN GHANA

4.1 ABSTRACT

The physico-chemical properties of cashew gum collected from four cashew growing districts, Sampa, Wenchi, Bole and Jirapa in Ghana were studied to help promote the utilization of cashew gum in the food industry. The gum was collected from trees of two different age groups, those that were 10 years and below and those above 10 years. Physico-chemical properties of cashew gum were compared to those of gum Arabic. Parameters studied included pH, total ash, protein content, total sugars, total phenols, moisture content and insoluble matter content. The results of the study gave the following ranges for the various parameters evaluated: pH ranged from 3.8-4.2, total ash 0.5-1.2%, protein content 1.27-1.80%, total sugars 0.96-2.10 mg/g, total phenols 0.21-2.26%, moisture content 9.8-13.2% and insoluble matter 1.9-4.8%. Gum from mature trees was generally found to have higher levels of protein, moisture, sugars and phenols relative to that from young trees, with the exception of pH which was lower in gum from mature trees. There were variations in the physico-chemical properties of the cashew gum from the different locations and different tree age groups. The predominant minerals in cashew tree gum were Ca, K, Na and Fe and their nutritional benefits are discussed. This study showed that cashew gum possesses good physico-chemical properties and high levels of minerals and can therefore be used to improve or maintain the nutrional value of foods.

4.2 INTRODUCTION

Cashew gum is the exudate from *Anacardium occidentale* L., a tree that grows in many tropical and subtropical countries like Brazil, Cote d'Ivoire, Tanzania and Kenya. The use of cashew gum began in China centuries ago (Glicksman, 1969). Synthesis of the gum generally occurs in all organs of the plant with different qualitative composition, appearing to be genetically controlled and influenced by environmental conditions (Glicksman, 1969). The gum from the cashew tree occurs in the form of pale yellow to amber masses, which are soluble in water and its molecular structure is made up of galactose (72-73%), glucose (11-14%), arabinose (4.6-5%), rhamnose (3.2-4%) and glucuronic acid (4.7-6.3%) in mass. It is mainly composed of three types of galactan units within the core, linked by C-1 and C-3; C-1 and C-6 and C-1, C-3 and C-6. The glucose is present as a side chain, with up to five units long (Cunha *et al.*, 2007).

Williams and Phillips (2000) reported that variations in physico-chemical properties exist in natural gums from different tree species and also from the same tree species but of different ages as well as from different soil types. Some concerns have been raised on the production, processing and use of natural gums and these include the accurate identification of the sources of gums and their quality assurance. Therefore, there is the need to study the physico-chemical properties of cashew gums from different cashew growing areas to determine their quality and how they will perform during processing. This study was carried out to determine the pysico-chemical properties of cashew gum from the major producing areas in Ghana.

4.3 MATERIALS AND METHODS

4.3.1 Sample preparation

Cashew gum samples collected as natural gum exudates from the four cashew growing districts were dried in an oven at 30° C for two weeks and milled using Christy Disintegrator 43740 (Christy and Norris Ltd., Process Engineers, England).(Plate 4.1). The milled samples were stored in plastic containers prior to analysis.

Plate 4.1: Samples of milled gum

4.3.2 *Moisture content*

Moisture content was determined by weighing 2 g of each sample into porcelain crucibles and drying to a constant weight in an oven at 105° C. The moisture loss on drying was expressed as percentage of the weight of milled gum (British Pharmacopoeia, 1993).

4.3.3 *pH*

Aqueous solution of each gum sample was made by dissolving 2 g of each sample in 50 ml water and the pH measured with a glass electrode fitted to a Jenway 3020 pH meter (UK)(AOAC, 1990).

4.3.4 *Protein content*

Protein content was determined by weighing 1 g of each sample into a kjeldahl flask. 25 ml conc Sulphuric acid and a catalyst (a mixture of Selenium, Copper Sulphate and Potassium Sulphate in the ratio of 1:5:25) was added to the sample in the flask and digested on a heater for 30 min to get a clear solution. The solution was then allowed to cool and 50 ml 40% NaOH solution added to neutralize the acid (Kjeldahl's method). This was then distilled into a 25 ml Erlenmeyer flask containing 20 ml 2% Boric acid solution with a drop pf mixed indicator. The solution was then titrated 0.1 N H_2SO_4 to a faint pink colour. The nitrogen content was then calculated and multiplied by 6.25 (official N conversion factor to crude protein) to get the protein content.

4.3.5 *Total sugar concentration*

The total sugar concentration was determined using the phenol-sulphuric acid method (Dubois *et al.*, 1956). An aqueous solution of 1 g of each sample in 10 ml water was made and clarified with equal volumes of 0.3N $Ba(OH)_2$ and 5% $ZnSO_4$ solutions. The clarified solution was then filtered. The filtrate was deionised with Amberlite cation-anion exchange resins and filtered. 0.1 ml of the deionised solution was diluted with 0.9 ml distilled water to give a final dilution 1 in 100. Aliquots were then used for the colorimetric analysis after adding 1 ml of 10% phenol followed by 5 ml conc. Sulphuric acid. The absorbance was read at 490 nm and glucose was used as a standard for the calibration curve.

4.3.6 *Total phenolic compounds*

Extraction was done on 1 g of each sample adding 20 ml of 80% of aqueous acetone. Shaking was done using an electronic shaker (Edmund Bühler: 7400 Tulingen: KS10 and KL2 series) for 1 hour and sonicated for 30 minutes. Extraction was followed by filtration and evaporation of filtrate to dryness in a rotary vacuum evaporator. 10 ml distilled water was added to the dry residue and 0.1 ml of the extract solution was transferred to a 100 ml Erlenmeyer flask and the volume adjusted to 46 ml by the addition of distilled water. 1 ml Folin-Ciocalteu reagent was then added to the mixture, followed after 3 min by 3 ml Na_2CO_3 solution (20g/L). Subsequently the mixture was shaken mechanically for 2 hours and the absorbance measured at 760 nm using Shimadzu UV-20-02 Spectrophotometer (Shimadzu, Japan). Catechin was used as a standard for a calibration curve. The phenolic compound content was expressed as catechin equivalent.

4.3.7 Total ash content

The ash content was determined by weighing 2 g of each sample into porcelain crucibles and incinerating in a muffle furnace at 450° C for 2 hours until carbon-free ash was obtained. The weight of the ash was expressed as a percentage of the weight of milled gum (British Pharmacopocia, 1993).

4.3.8 Insoluble matter

The insoluble matter was determined by dissolving 5 g of each sample in 100ml water and adding 14 ml of 2 M HCl. The mixture was then boiled for 15 minutes with continuous stirring using a Stuart magnetic stirrer (UK) and then filtered through a No. 4 sintered glass filter. The residue obtained was then dried at 105° C to a constant weight. The weight of dried residue was expressed as a percentage of the initial sample weight (British Pharmacopoeia, 1993).

4.3.9 Minerals

Mineral content was determined using the wet ashing method. 1 g of each sample was digested with 25 ml conc. Nitric acid on a hot plate (in a fume chamber) for 30 min. The digest was then cooled and 1ml Perchloric acid (70% $HClO_4$) was added and digestion continued until solution was colourless. After digestion, the solution was cooled slightly and boiled for 10 min and then filtered hot through filter paper into 100 ml volumetric flask and made to the mark with distilled water. The solution was then used for the determination of Ca, Fe, K, Zn and Na contents using Atomic Absorption Spectroscopy (Unicam 929 AAS model, UK).

The data obtained were analyzed using Statgraphics Plus (Windows version 3.0) programme for analysis of variance (ANOVA).

4.4 RESULTS AND DISCUSION

4.4.1 pH

The pH of cashew gum ranged from 3.8 to 4.2 with gum from mature trees being more acidic than that from young trees (Figure 4.1). The pH of gum from mature trees varied from 3.8 to 3.9 and that for gum from young trees varied from 4.0 to 4.2. This may be due to high cationic composition of gums from mature cashew trees. Mhinzi and Mrosso (1995) observed that the high cationic composition of some acacia gums increased their acidity. The pH of cashew gum compared favourably with that of gum Arabic which is reported to be between 4.0 and 4.8 (Belitz *et al.*, 2004). The pH of gums from trees of the different age groups and also from the different locations were found to be significantly different ($p < 0.05$) from each other with some significant interaction between the locations and the ages of the trees ($p < 0.05$) (Appendix 2). These differences may be due to the mixed species of cashew trees found in the collection areas, the different soil composition of the different regions together with the varying climatic conditions. Thus, confirming the report of Phillips and Williams (2005) which stated that the physico-chemical properties of gums vary with tree species, age and soil type.

4.4.2 Ash content

The ash contents of cashew gum also ranged from 0.5 to 1.2% and these fall within the acceptable level of less than 4% reported for gum Arabic (Belitz *et al.*, 2000). Ash content is an important property considered as a purity parameter in the evaluation of gum quality (Immeson, 1992). The very low values of ash indicate that cashew gum collected is clean with insignificant amount of impurity. Gums from both young and mature trees from Sampa had the same ash content of 1.0% but those from mature trees in Jirapa had ash content of 1.2% whilst that from young trees was 1.0%. For Bole and Wenchi, gum from mature trees had lower ash contents, 0.5 and 0.8% respectively, than that from young trees (Figure 4.2). There were significant differences in the ash contents for gums from trees of the different age groups and also from the different locations ($p < 0.05$). These findings were supported by multiple comparison tests, which showed that gums from Sampa and Wenchi were significantly different from those from Bole ($p < 0.05$). These differences may also be due to the mixed species of cashew trees, the different soil composition of the different regions together with the varying climatic conditions. However, there were no interaction effects between the locations and the ages of the trees.

4.4.3 Protein content

The protein content of cashew gum ranged from 1.27 to 1.80%. It was observed that gum from young trees had higher protein content than those from mature trees at all locations with the exception of that from Wenchi where the young and the mature had the same protein level 1.41% (Figure 4.3). This may due to the fact that the young trees which are

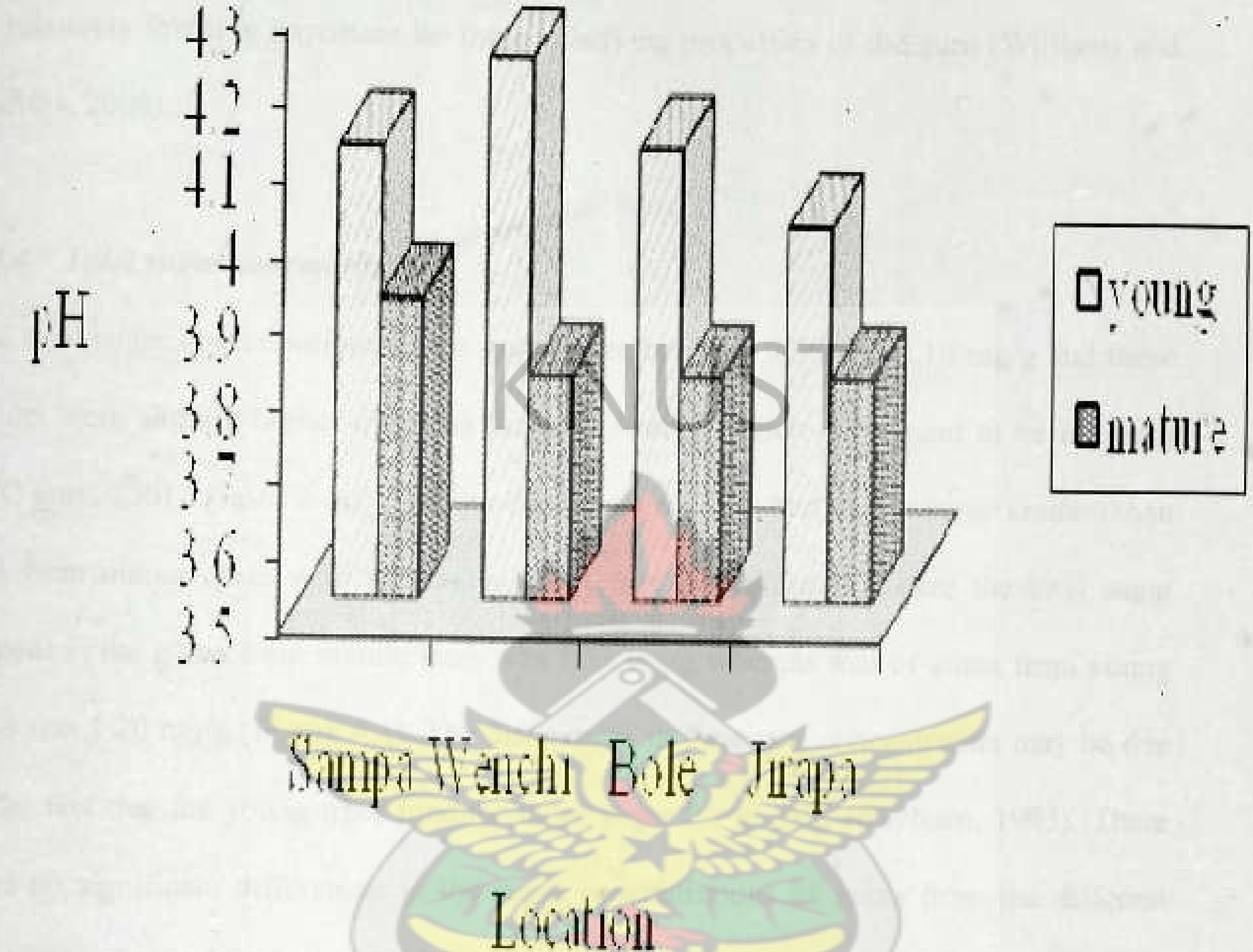

Fig 4.1: Effect of cashew tree maturity on pH of gum

actively growing synthesize more nutrients such as proteins (Rayburn, 1993). Gums from the two age groups showed significant differences ($p < 0.05$) but the differences in the locations were not significant. Although the protein content of cashew gum was found to be relatively low it is important for the emulsifying properties of the gum (Williams and Phillips, 2000).

4.4.4 Total sugar concentration

The total sugar concentrations of the gums were between 0.96 and 2.10 mg/g and these results were slightly higher than that for gum Arabic, which was found to be in traces (TIC gum, 2001). Cashew gum from young trees generally had higher sugar content than that from mature trees with the exception of that from Wenchi where the total sugar content in the gums from mature trees was 1.37 mg/g whereas that of gums from young trees was 1.20 mg/g (Figure 4.4). The differences in the sugar concentration may be due to the fact that the young trees produce more sugar for growth (Rayburn, 1993). There were no significant differences in the sugar concentrations of gums from the different locations and also from trees of different ages.

4.4.5 Total phenolic content

The total phenolic contents of the gums were between 0.21 and 2.26%. Gum from mature trees had higher phenolic content than that from young trees for all the locations (Figure 4.5). The total phenol content of gum from young trees varied from 0.21 to 0.35% whereas that for mature trees varied from 0.50 to 2.26%. The composition of phenolic

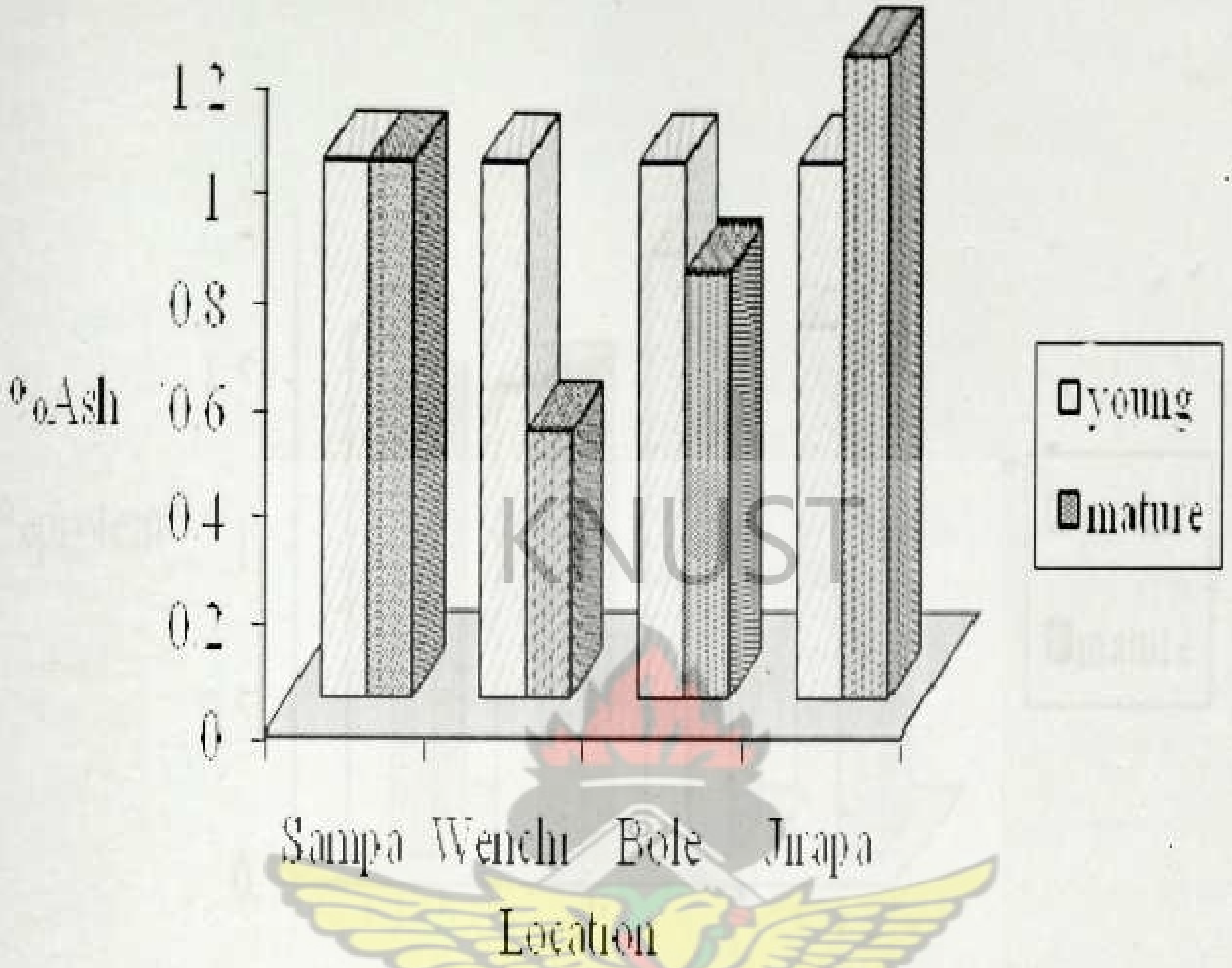

Fig 4.2: Effect of cashew tree maturity on ash content of gum

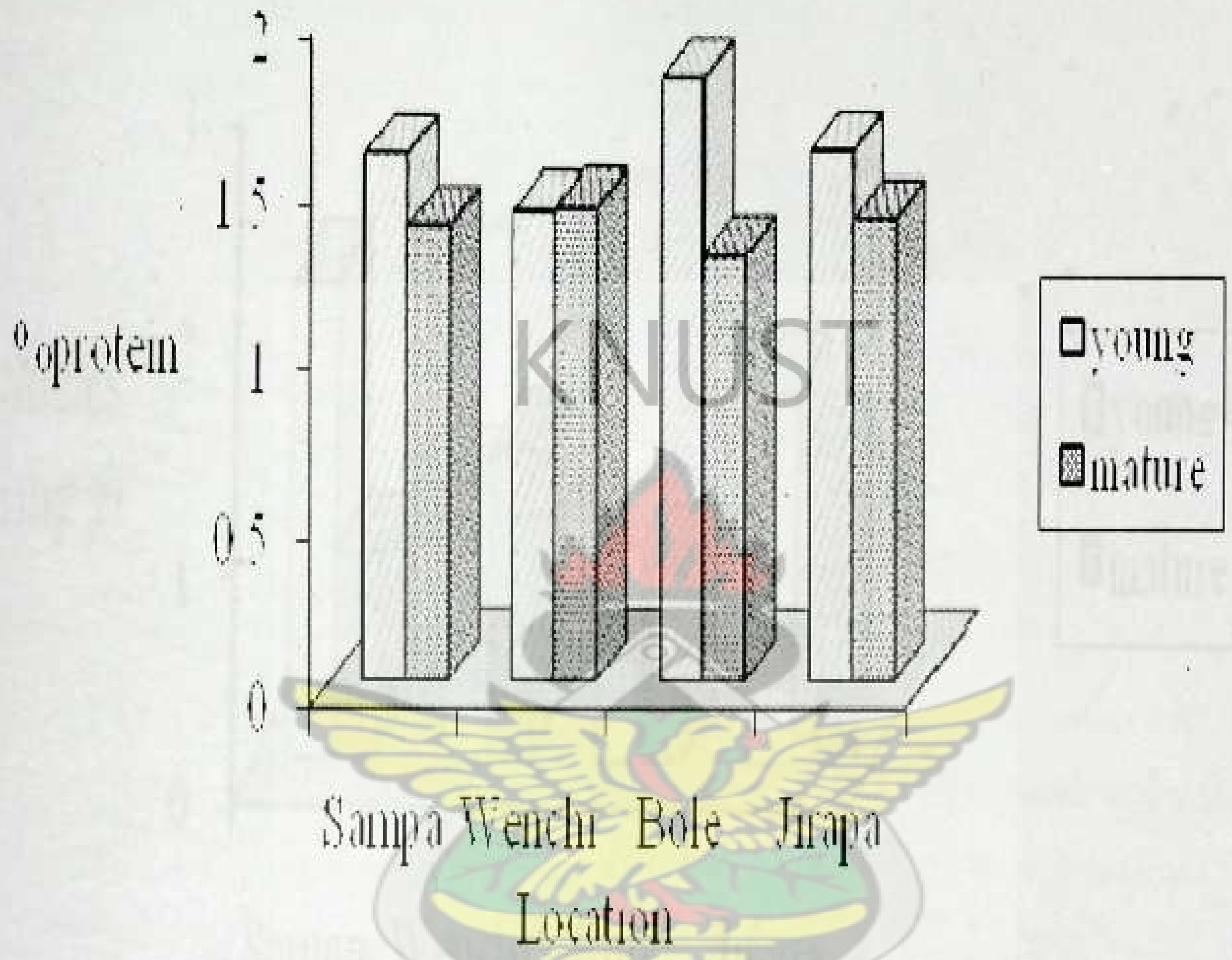

Fig 4.3: Effect of cashew tree maturity on protein content of gum

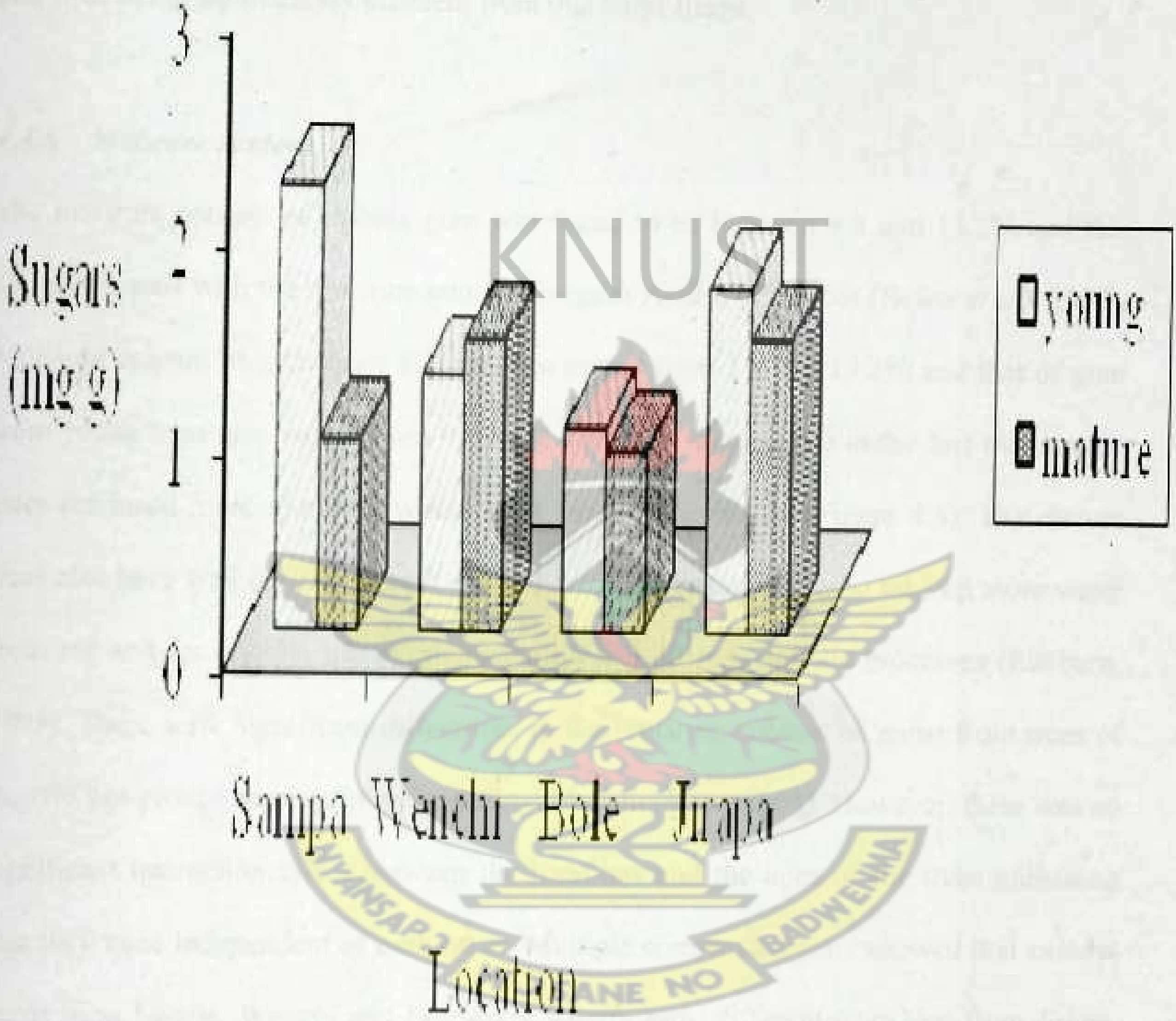

Fig 4.4: Effect of cashew tree maturity on sugar concentration of gum

constituents of plants is influenced by both internal and external factors such as genetic variations at species level, maturity and agronomic conditions (Kabuto *et al.*, 2000). The phenolic contents of gums from the different locations and from trees of different ages were significantly different ($p < 0.05$) with the phenolic contents of gums from Sampa and Bole being significantly different from that from Jirapa.

4.4.6 Moisture content

The moisture content of cashew gum was found to be between 9.8 and 13.2% and this compared well with the moisture content for gum Arabic (12-17%) (Belitz *et al.*, 2000). Moisture content of gum from mature trees varied from 11.3 to 13.2% and that of gum from young trees also varied from 9.8 to 11.8%. This may be due to the fact that mature trees produced more gum and would need longer time to dry (Figure 4.6). The mature trees also have well developed root systems which have the ability to take up more water from the soil for photosynthesis, transpiration and other metabolic processes (Rayburn, 1993). There were significant differences in the moisture content of gums from trees of the two age groups coming from the different locations ($p < 0.05$). However, there was no significant interaction effect between the locations and the ages of the trees indicating that they were independent of each other. Multiple comparison tests showed that cashew gums from Sampa, Wenchi and Bole were significantly different from that from Jirapa. Variations in the moisture content of gums from the different more water from the soil for photosynthesis, transpiration and other metabolic processes (Rayburn, 1993). There were significant differences in the moisture content for gums from trees of the two age groups coming from the different locations ($p < 0.05$). However, there was no interaction

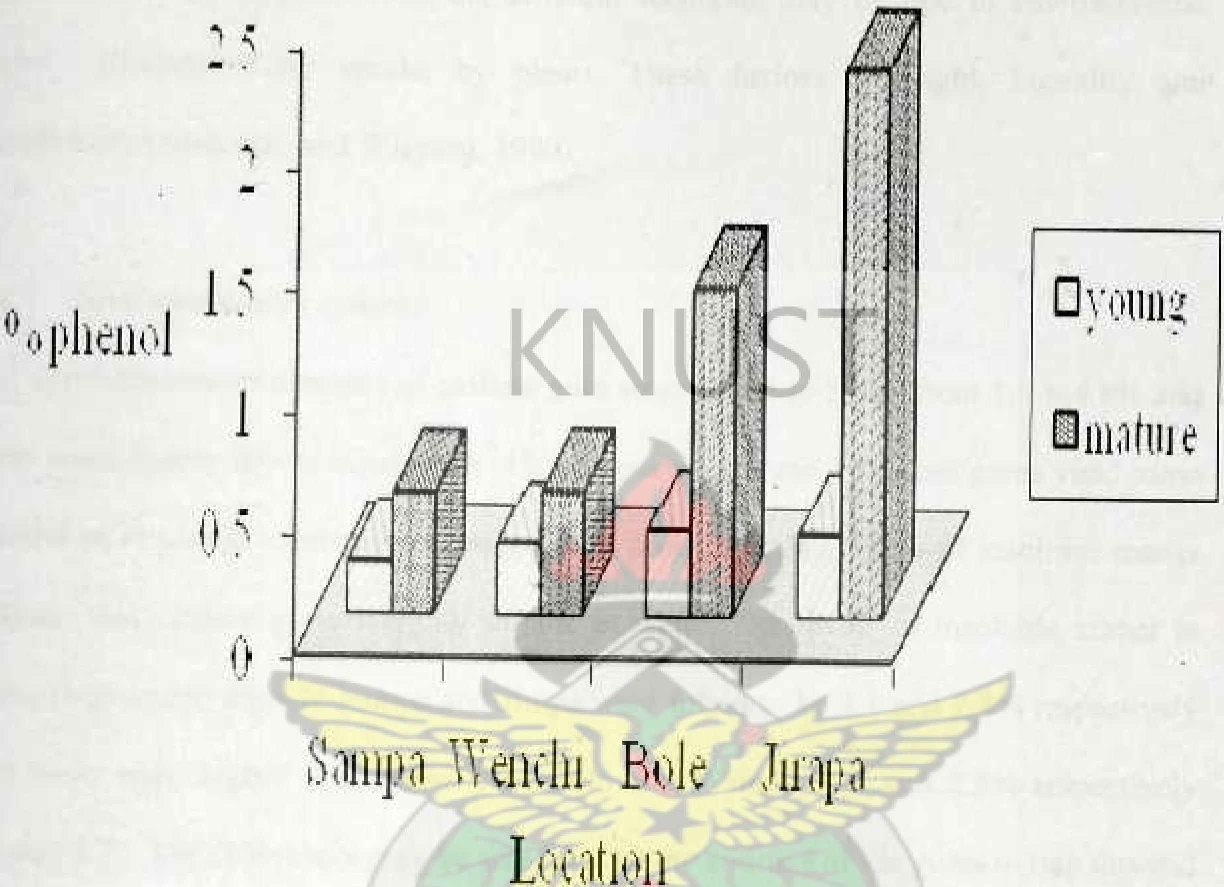

Fig 4.5: Effect of cashew tree maturity on phenolic content of gum

between the locations and the ages of the trees indicating that they were independent of each other. Multiple comparison tests again showed that cashew gums from Sampa, Wenchi and Bole were significantly different from that from Jirapa. Variations in the moisture content of gums from the different locations may be due to environmental factors affecting water uptake by plants. These factors are light, humidity and temperature (Anderson and Wieping, 1990),

4.4.7 Insoluble matter content

The insoluble matter contents of cashew gum were found to range from 1.9 to4.8% and these were mainly debris. Glicksman (1969) reported that most exudate gums yield some amount of insoluble residue when mixed with water. The low levels of insoluble matter indicate that cashew gum is highly soluble in water. The levels of insoluble matter in gums from young trees in Sampa and Jirapa were found to be 3.1 and 2.4% respectively and these were higher than those from Bole and Wenchi, 2.0 and 2.8% respectively (Figure 4.7). The differences may be attributed to the abilities of the gums to trap dirt and loose bark during and after exudation. Environmental factors such as the wind and sand can also add more dirt to the gums as well as the time of collection of gum. The longer the gum stays on the field the more dirt it traps. However the differences were not significant for the locations and the age groups of the trees.

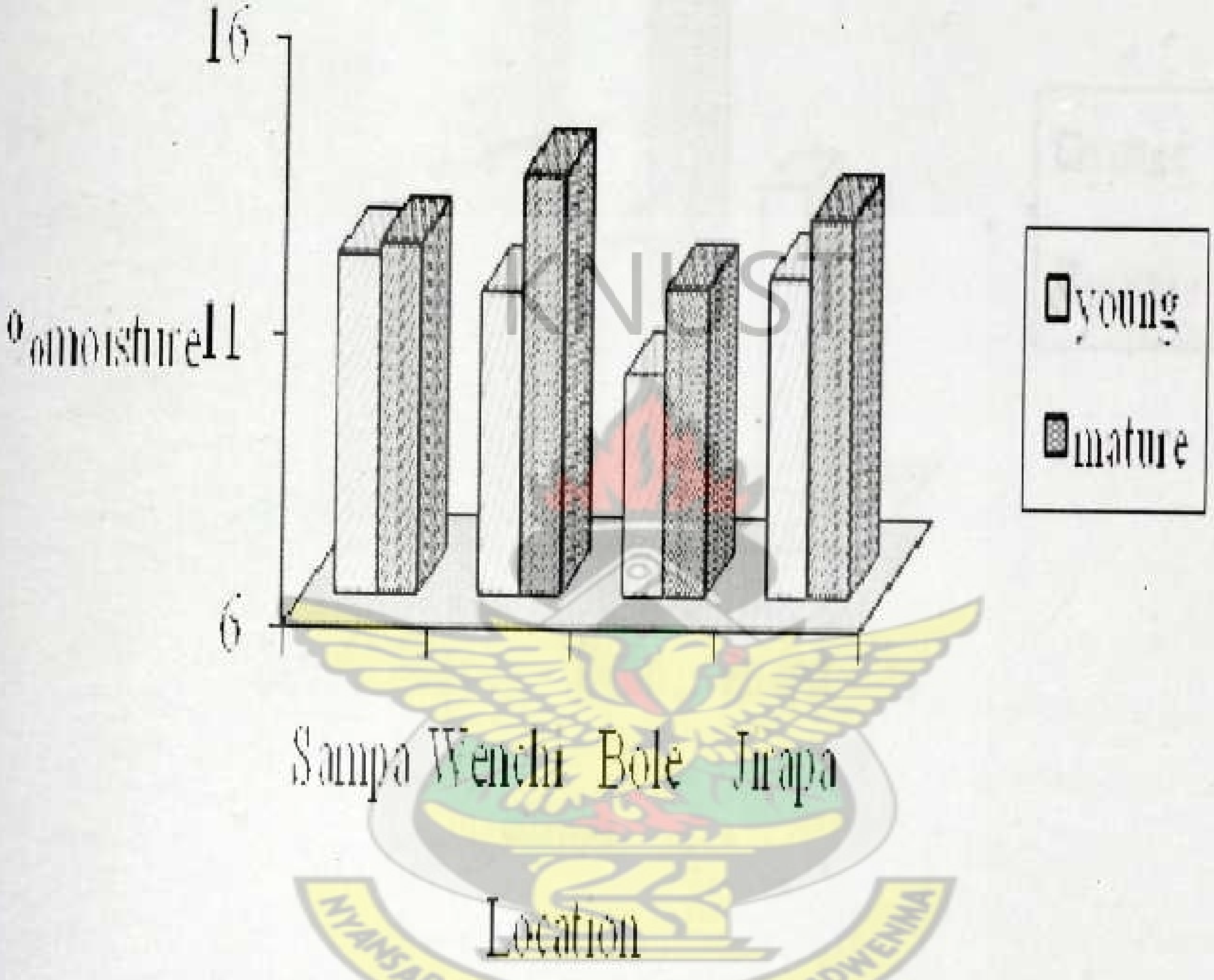

Fig 4.6: Effect of cashew tree maturity on moisture content of gum

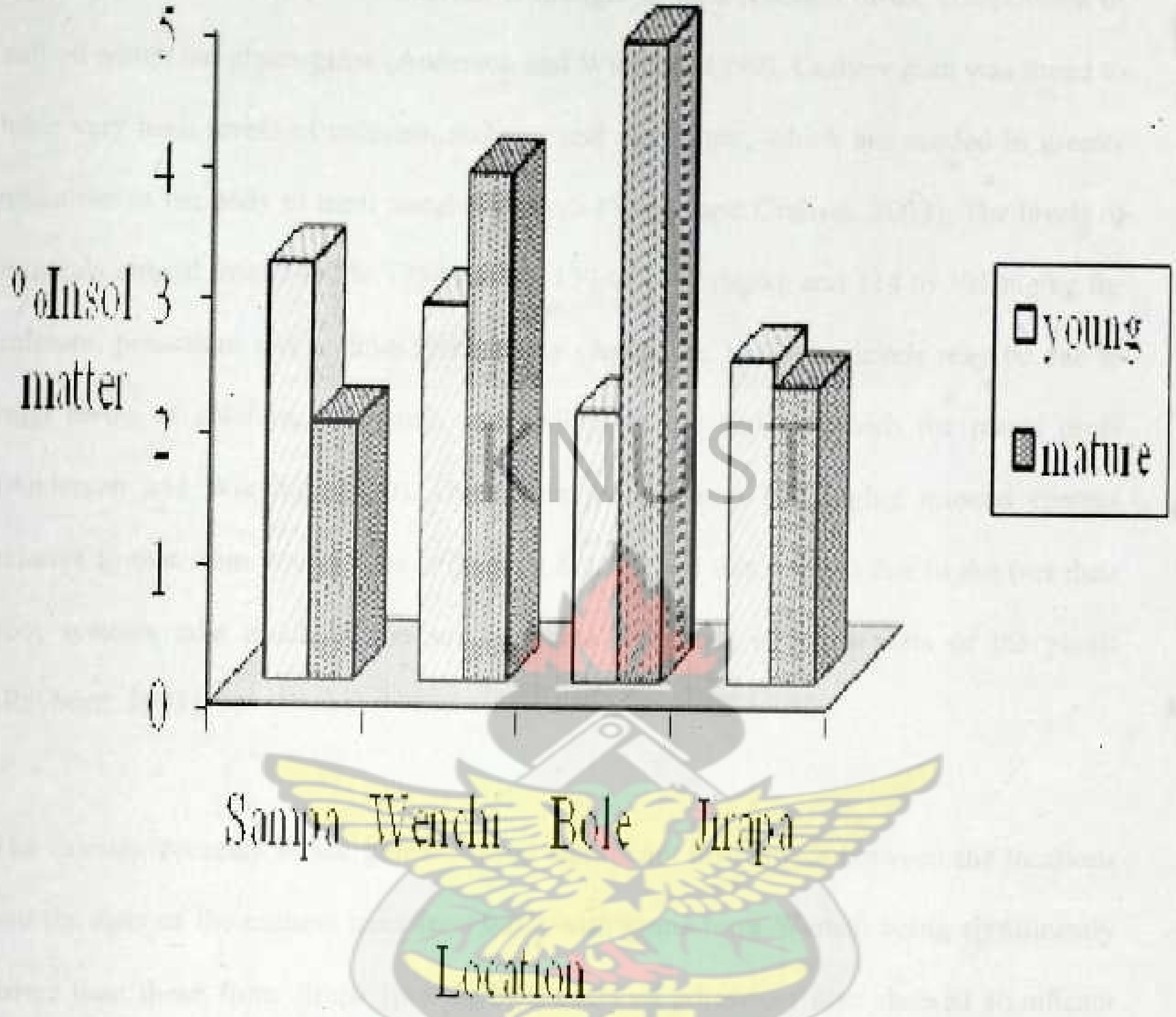

Fig 4.7: Effect of cashew tree maturity on insoluble matter content of gum

4.4.8 Mineral content

The mineral content of plant materials is thought to be a function of the composition of soil on which the plants grow (Anderson and Wieping, 1990). Cashew gum was found to have very high levels of calcium, sodium, and potassium, which are needed in greater quantities in the body to meet metabolic needs (Welch and Graham, 2003). The levels of minerals ranged from 1012 to 1750 mg/kg, 139 to 1397 mg/kg and 114 to 301 mg/kg for calcium, potassium and sodium respectively (Appendix 1). These levels may be due to high levels of calcium, potassium and sodium in the soil on which the plants grow (Anderson and Wieping, 1990). Gum from mature trees had higher mineral content relative to that from young trees (Figures 4.8-4.10) and this may be due to the fact their root systems take much of the soil nutrients and store in other parts of the plants (Rayburn, 1993).

The calcium contents of the gums showed significant differences between the locations and the ages of the cashew trees ($p < 0.05$) with gums from Wenchi being significantly lower than those from Jirapa ($p < 0.05$). Levels of potassium also showed significant differences between the locations and the ages of the trees ($p < 0.05$) with gums from Sampa, Wenchi and Bole being significantly lower than those of Jirapa. However, there were no significant differences between gums from trees of the different ages and from the locations in terms of the sodium content. Sodium and potassium contents of the gums tend to increase from the transitional belt to the Guinea savannah zone (Figures 4.9 and 4.10). For instance, potassium contents of cashew gum from Sampa and Wenchi ranged from139 to 386 mg/kg and those of gum from Bole and Jirapa were between 275 and

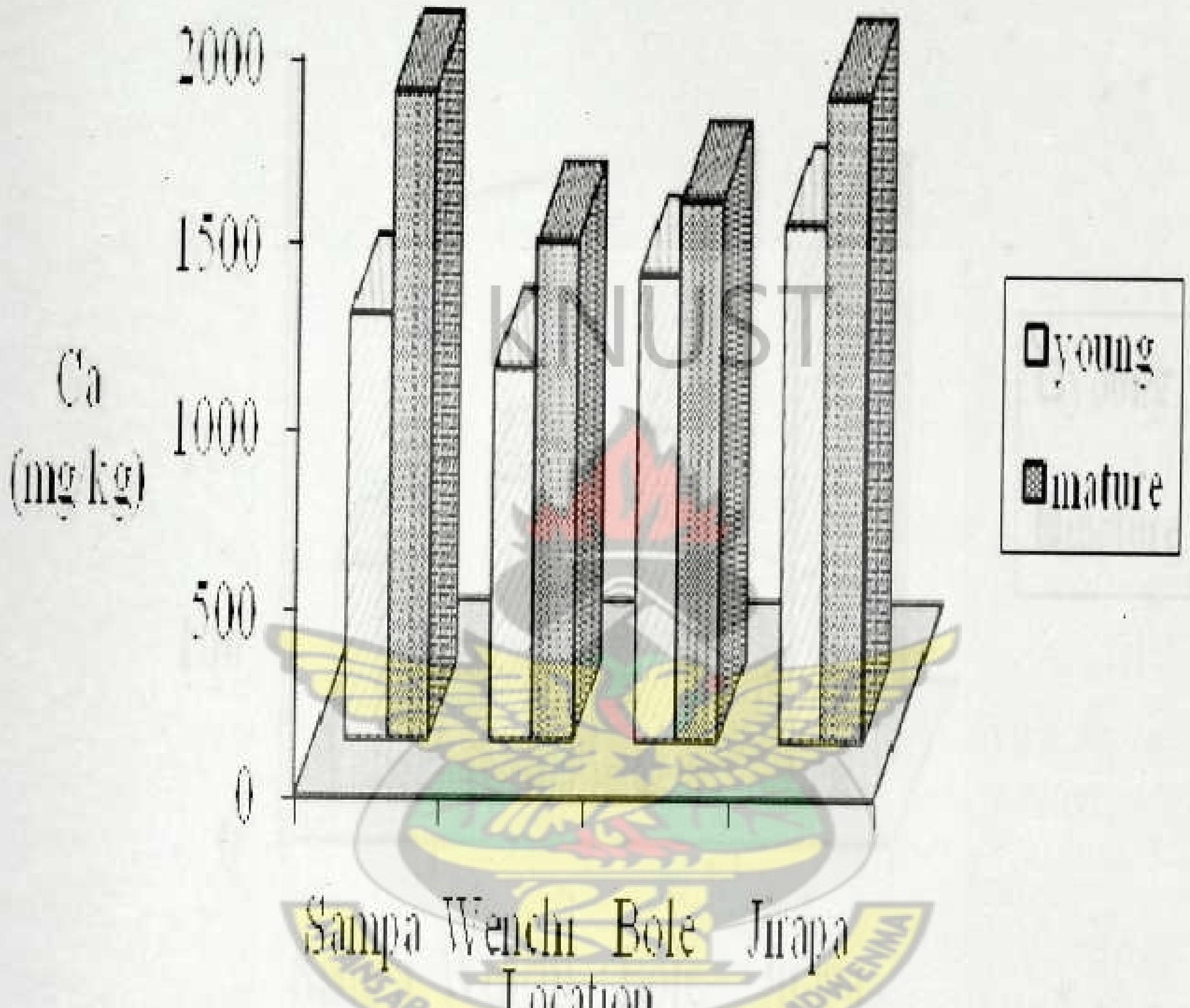

Fig 4.8: Effect of cashew tree maturity on calcium content of gum

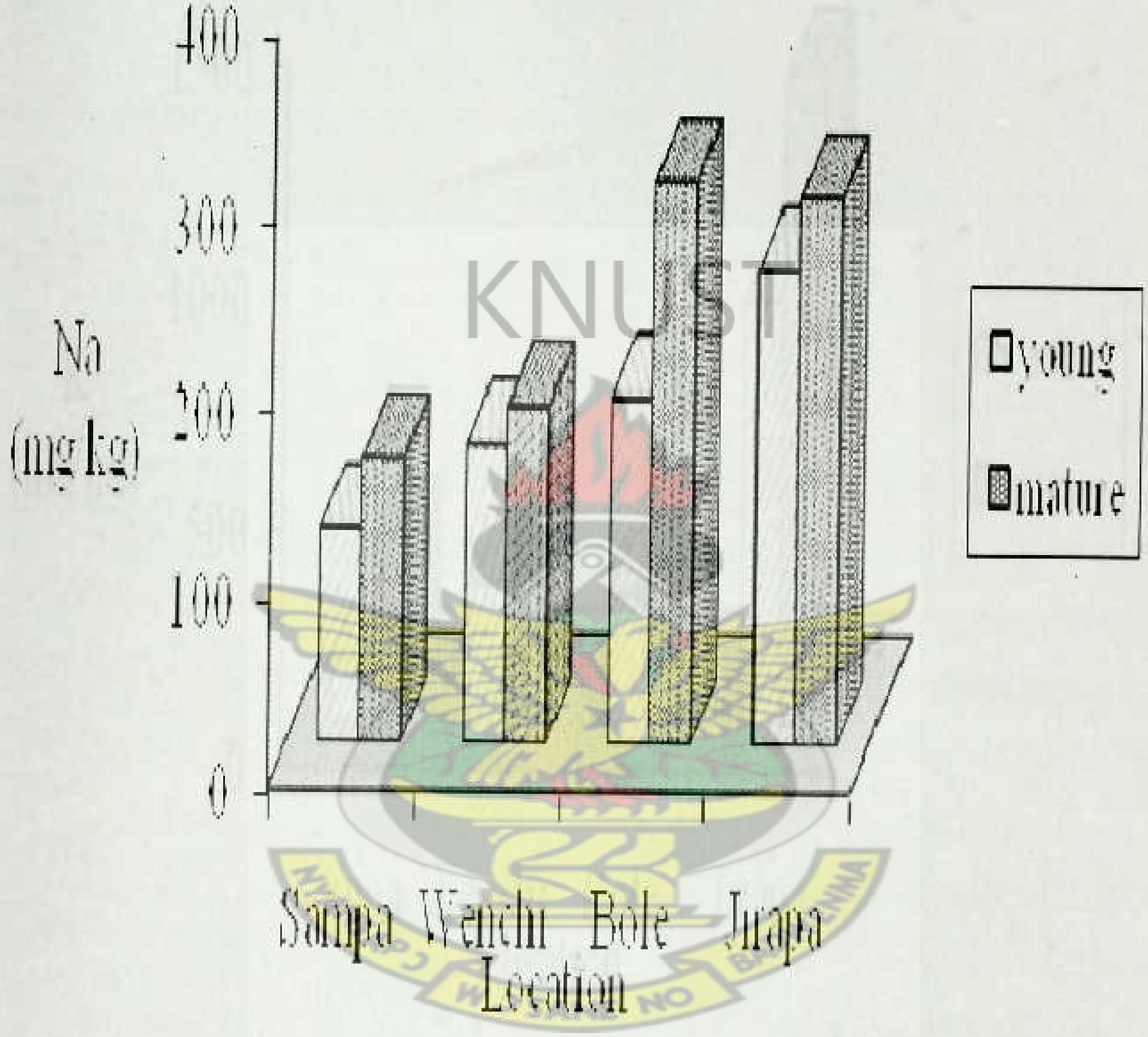

Fig 4.9: Effect of cashew tree maturity on sodium content of gum

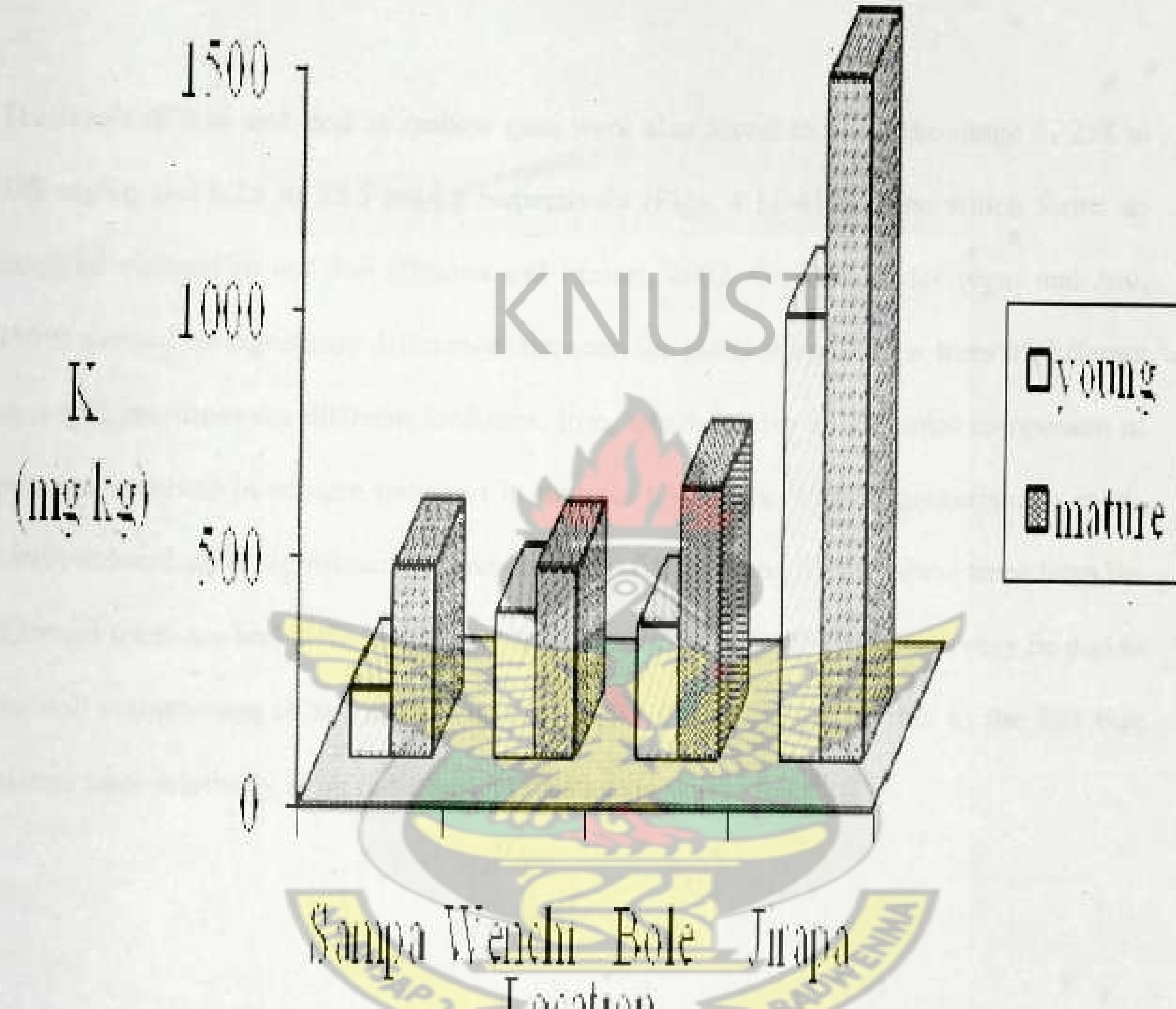

Fig 4.10: Effect of maturity on potassium

1397 mg/kg (Appendix 1). This is an indication of high levels of potassium and sodium in the soils of the Guinea savannah zone. The high levels of minerals which are normally found in their ionic state also account for the acidity of cashew gum (Mhinzi and Mrosso 1995).

The levels of iron and zinc in cashew gum were also found to be in the range of 258 to 398 mg/kg and 6.25 to 35.5 mg/kg respectively (Figs. 4.11-412). Zinc which forms an essential element in our diet (Branca and Ferrari, 2002, Grantham-McGregor and Ani, 1999) showed no significant differences between the gums from cashew trees of different ages and also from the different locations. Iron, which is also an essential component of proteins involved in oxygen transport in humans (Andrews, 1999, Ramakrishnan *et al.*, 1999) showed some significant differences ($p < 0.05$) in gums from cashew trees from the different locations and different age groups. The variations in the locations may be due to the soil composition of the areas whereas that in the ages may be due to the fact that mature trees relatively store more soil nutrients than young trees.

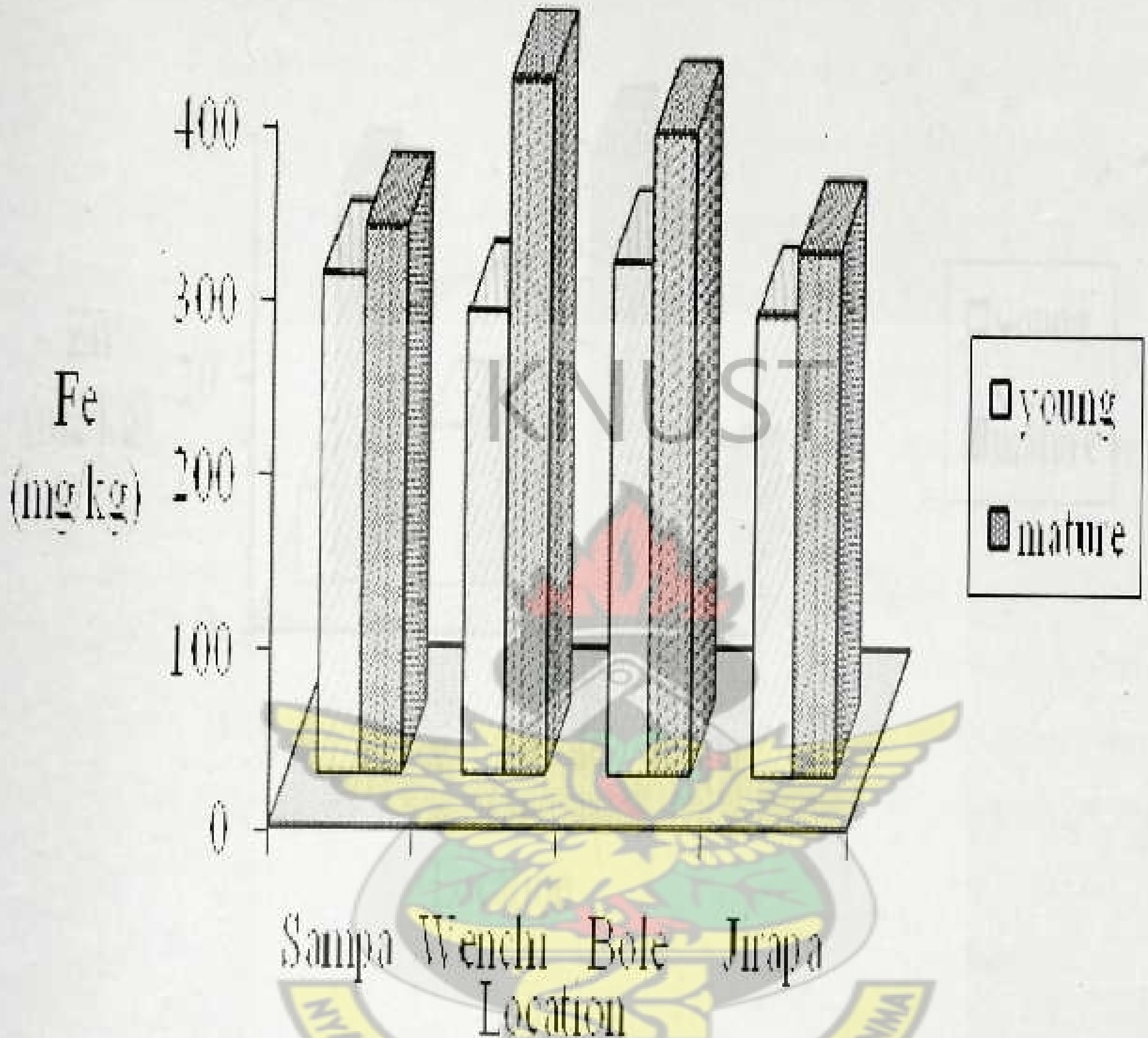

Fig 4.11: Effect of cashew tree maturity on iron content of gum

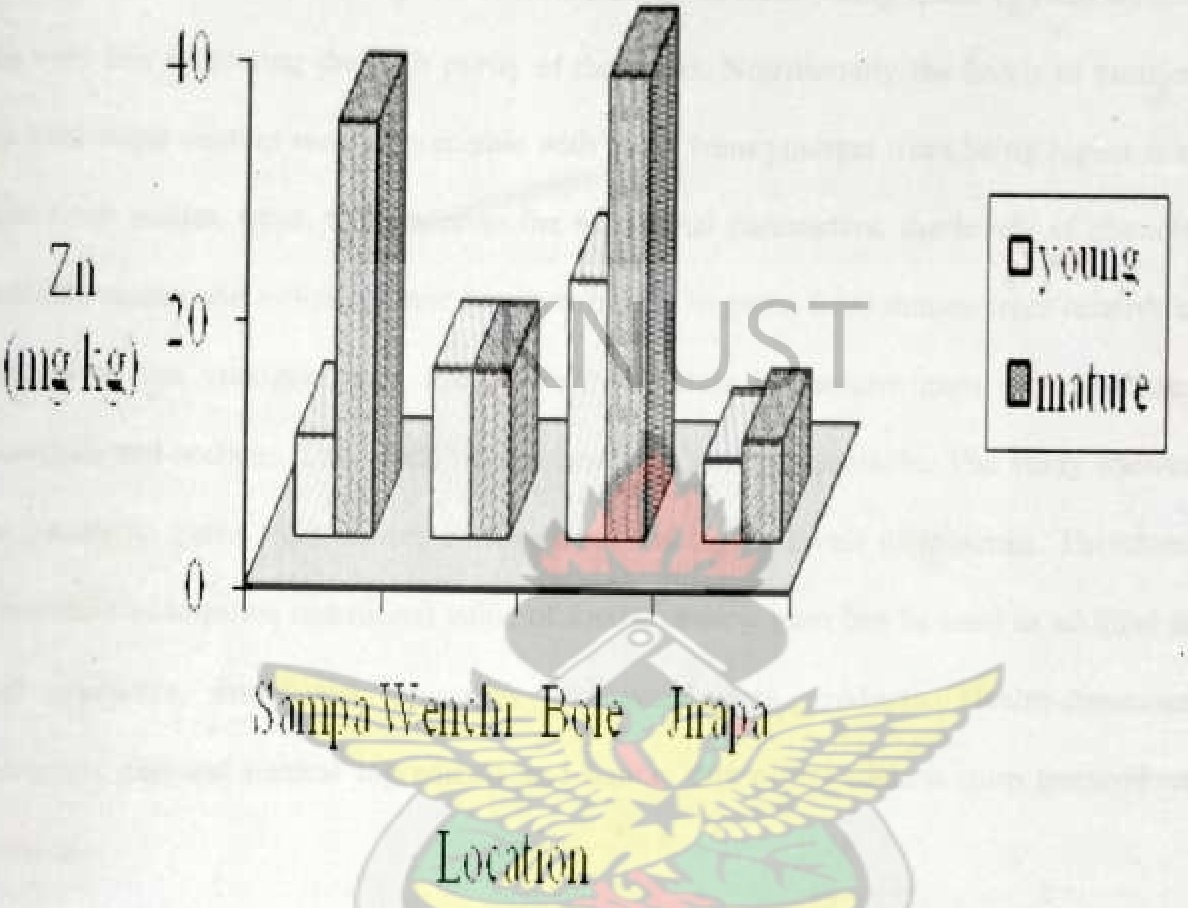

Fig 4.12: Effect of cashew tree maturity on zinc content of gum

4.5 CONCLUSION

The findings of this study indicate that cashew gum possesses good physico-chemial properties and high levels of minerals. Cashew gum was found to be acidic with gums from mature cashew trees being more acidic than those from young trees. The ash content was very low indicating the high purity of the gums. Nutritionally the levels of proteins and total sugar content were appreciable with gums from younger trees being higher than those from mature trees. Compared to the nutritional parameters, the levels of phenols, insoluble matter and moisture were however higher in gums from mature trees relative to those from the younger ones. Predominant minerals in cashew gum were calcium, potassium and sodium. The levels of iron and zinc were appreciable. The study showed that generally, gums from mature cashew trees had higher levels of minerals. Therefore, to maintain or improve nutritional value of foods, cashew gum can be used as additive in meal replacers, nutritional beverages and weight-loss products. Health-conscious consumers demand natural ingredients and hence, this offers cashew gum tremendous potential.

CHAPTER 5

RHEOLOGICAL PROPERTIES OF CASHEW GUM

5.1 ABSTRACT

The rheological properties (gel and flow properties) of cashew gum collected from four cashew growing districts (Sampa, Wenchi, Bole and Jirapa) in Ghana were studied to help promote the utilization of cashew gum in the food industry. The gum was collected from trees of two age groups, those that are 10 years and below and those above 10 years. Gelation properties of cashew gum showed that the gum gelled at a high concentration of 80% and rapidly dissolved at 80°C. Viscosities of aqueous gum solutions at concentrations of 1.0, 2.5, 5.0 and 10% were studied with measurements adopted at 25 and 70 °C. Viscosity increased with increased while an increase in temperature reduced the viscosity. The gum from mature cashew trees (above 10 years) was found to be more viscous than that from young trees (10 years and below). However, cashew tree gums from different cashew growing districts did not differ significantly in their vicosities. Gum produced during the rainy season was less viscous than that produced in the dry season. The observed data showed that viscosities of gum reduced slightly after 6 and 12 months storage. The study showed that location, maturity and storage had no significant effects on the viscosity of cashew gum even though the observed data showed slight reduction in viscosity on storage.

5.2 INTRODUCTION

There are two rheological properties of particular importance to hydrocolloids and these are their gel and flow properties. Hydrocolloids are used to thicken and/or gel aqueous solutions and otherwise modify and/or control the flow properties of liquid food and beverage products and the deformation properties of semi-solid foods (Diego and Navaza, 2003). They are generally used in food products at concentrations of 0.25 to 0.50%, indicating their great ability to produce viscosity and to form gels (BeMiller and Whistler, 1993). Many hydrocolloids, which include natural gums, are capable of forming gels of various strengths depending on their structure and concentration and environmental factors such as ionic strength, pH and temperature.

Cashew gum is similar to gum Arabic in rheological properties (Owusu *et al.*, 2005). However, its gelation properties and viscosities of gums from different sources have not been studied. Some application based on cashew gum has been proposed in the last few years, such as superabsorbent hydrogel as soil conditioner and polyelectrolyte complex with chitosan for drug delivery. The polysaccharide has also been modified by carboxymethylation with monochloroacetic acid as the etherifying agent (De Paula *et al.*, 1998).

Due to the limited supply and increasing cost of traditional hydrocolloids, the search for alternative and cheaper, naturally occurring gums with stabilising potential like the cashew gum is timely. This study was carried out to evaluate the rheological properties of cashew gum from four major producing areas.

5.3 MATERIALS AND METHODS

Crude cashew gum samples collected as natural gum exudates from the four cashew growing districts (Sampa, Wenchi, Bole and Jirapa) were dried in an oven at 30° C and milled for rheological analyses.

5.3.1 Determination of gelation properties

This was done using the method of Coffman and Garcia (1977). Samples of gum (2, 4, 6, 8, 10, 20, 30, 40 and 50 g) were mixed with 50 ml distilled water in test tubes and blended with a whirl mixer for 5 minutes. The test tubes were then heated for 30 minutes at 80° C in a water bath followed by rapid cooling under running tap water. The samples were further cooled at 4° C for 2 hours. The lowest gelation concentration was determined as that concentration when the sample did not fall down or slip from the inverted test tube.

5.3.2 Effect of concentration and temperature on viscosity

The viscosity measurements of aqueous gum solutions were performed using a cone/plate viscometer (Brookfield Eng Labs Inc., Ma 02072 USA) at 25° C at the shear rate of 100rpm. Further tests were done at 70° C by holding the cashew samples in a hot water bath. The concentrations of gum solutions used were 1.0, 2.5, 5.0 and 10.0%. Viscosity measurements were also conducted on cashew gum collected during the rainy season and the results were compared to those collected in the dry season. The effect of storage time (0, 6 and 12 months) was studied on viscosity of cashew gum samples by storing samples in polyethylene bags at room temperature (25° C). The data were analyzed using Statgraphics Plus programme for analysis of variance (ANOVA).

5.4 RESULTS AND DISCUSSION

5.4.1 Gelation properties of cashew gum

The results indicated that cashew gum samples gelled at a concentration of 80% and higher. It was observed that gum solutions were liquid at concentrations of 4 to 12%, viscous at 16 to 40% and the solutions gelled at 80% and higher. However, the gel produced rapidly dissolved when heated in the hot water bath at 80° C. The result revealed that increasing the concentration facilitated gelation and this shows that enhanced interactions occurred among binding forces as the concentration increased as reported by BeMiller and Whistler (1993). Viscosity, which is the measure of thickness of gums, is used in the determination of the quality of gums (Glicksman, 1969), the higher the viscosity the better the quality of gum. The average viscosity of 1% cashew gum solution at 25° C was 10.03 cPs and the viscosity of gum arabic as reported by TIC Gum (2001) is less than 5 cPs at 1% solution. Thus, making cashew gum a better thickening or stabilizing agent.

5.4.2 Effect of concentration and temperature on viscosity

The viscosities of gums from the different locations increased with concentration and this agrees with the results of Mothé and Rao (2000) (Figures 5.1 and 5.2). The differences in the concentrations were statistically significant ($p<0.05$). This may be due to increase in internal friction as observed in the determination of the gelation potential. However, an increase in temperature reduced the viscosity of samples from the different locations (Figures 5.1 and 5.2). Diego and Navaza (2003) reported that the main effect produced by temperature on hydrocolloids is a decrease in viscosity. The average viscosities of cashew gum were 15.48 and 10.41 cPs at 25° C and 70° C respectively for Sampa whilst those for Bole were 15.50 and 10.45 cPs at 25° C and 70° C respectively. Those for Wenchi are 15.90 and 10.54 and for Jirapa, 14.18 and 10.18 cPs at 25° C and 70° C respectively (Table 5.1). The change in viscosity with temperature was statistically significant ($p<0.05$) indicating the possible thermal decomposition of cashew gum during heating. However, the mechanism of thermal decomposition of gums is unknown (Cunha *et al.*, 2007). Therefore, high operational temperatures are normally not used in the processes that involve hydrocolloids such as cashew gum since that could produce undesirable effects on their structural characteristics (Diego and Navaza, 2003).

5.4.3 Effect of maturity on viscosity of cashew gum

It was observed that viscosities of gums produced by mature trees in the different locations were less than that produced by young trees (Figures 5.3 and 5.4) at lower concentrations and vice versa for higher concentrations. This may be due to differences in the molecular structure and the pH of the different gums as reported by BeMiller and Whistler (1993) that the viscosity of gums is influenced by their molecular structure and pH. In the previous chapter, the pHs of gums from mature trees were found to be lower than those from young trees and this may have contributed to the observed change in viscosity. The differences between the viscosities of gums from both young and mature trees were statistically significant ($p<0.05$) but that between the locations were not significant (Table 5.1).

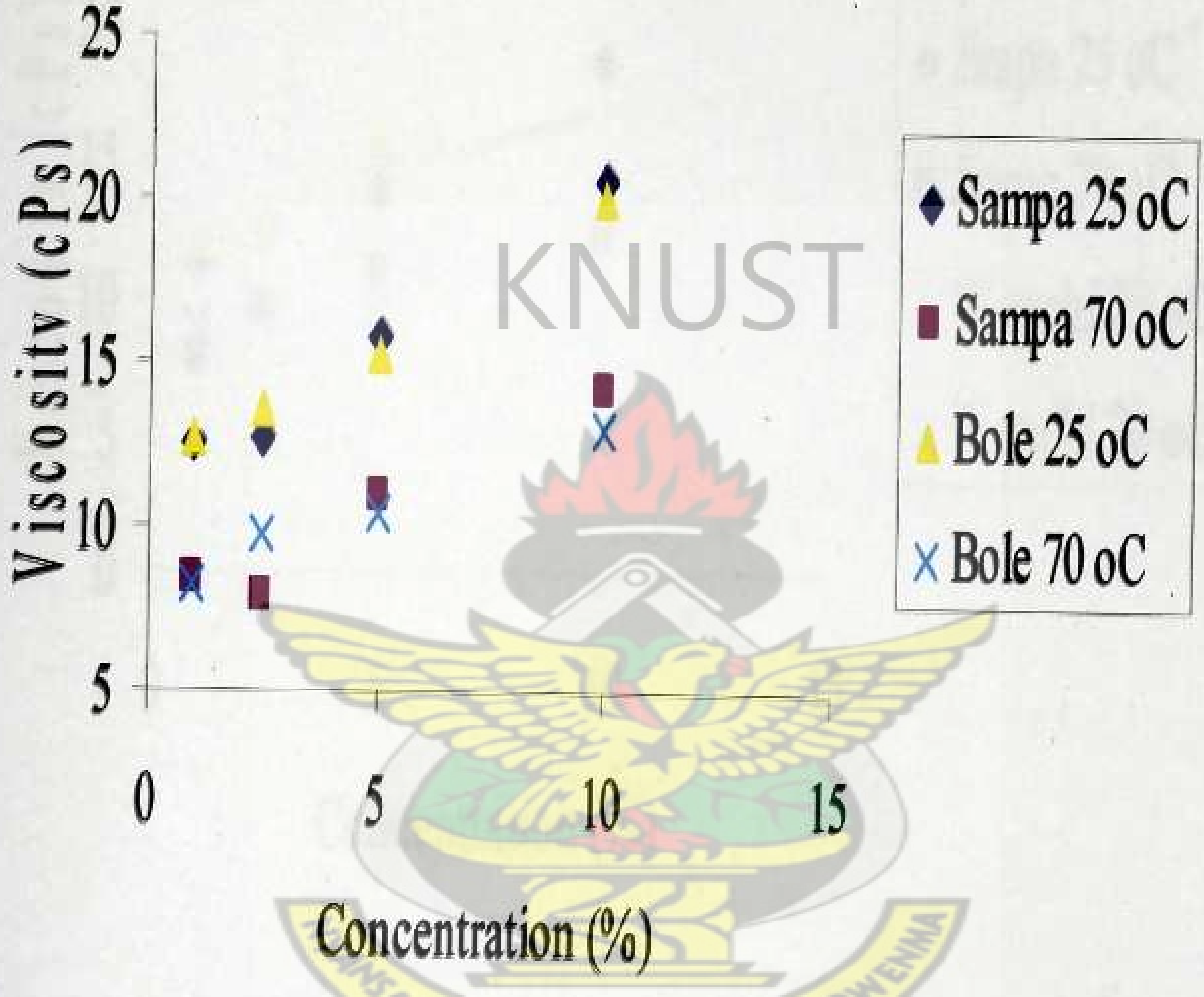

Fig 5.1: Effect of temperature and concentration on viscosity of cashew gums from Sampa and Bole

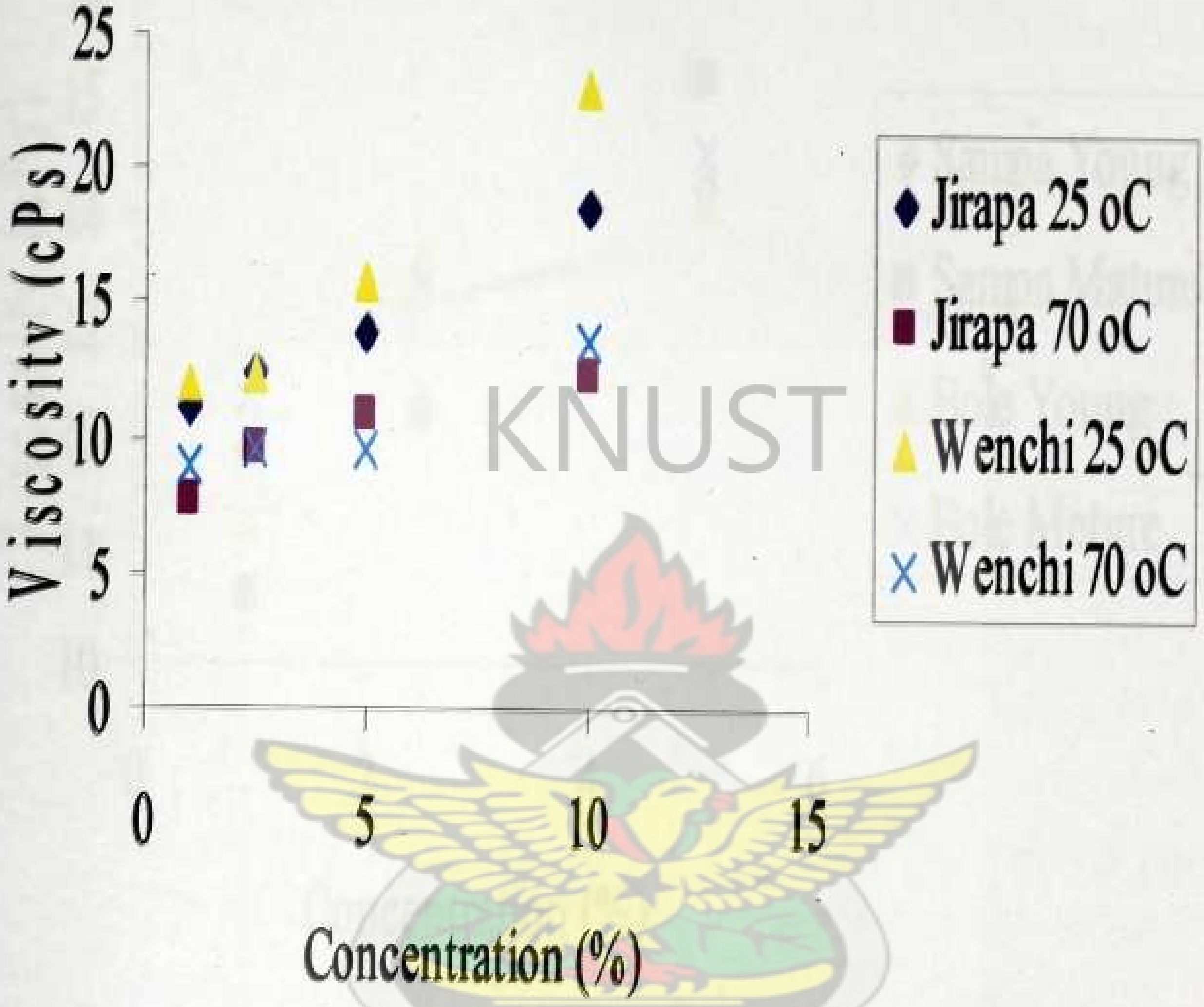

Fig 5.2: Effect of temperature and concentration on viscosity of cashew gums from Jirapa and Wenchi

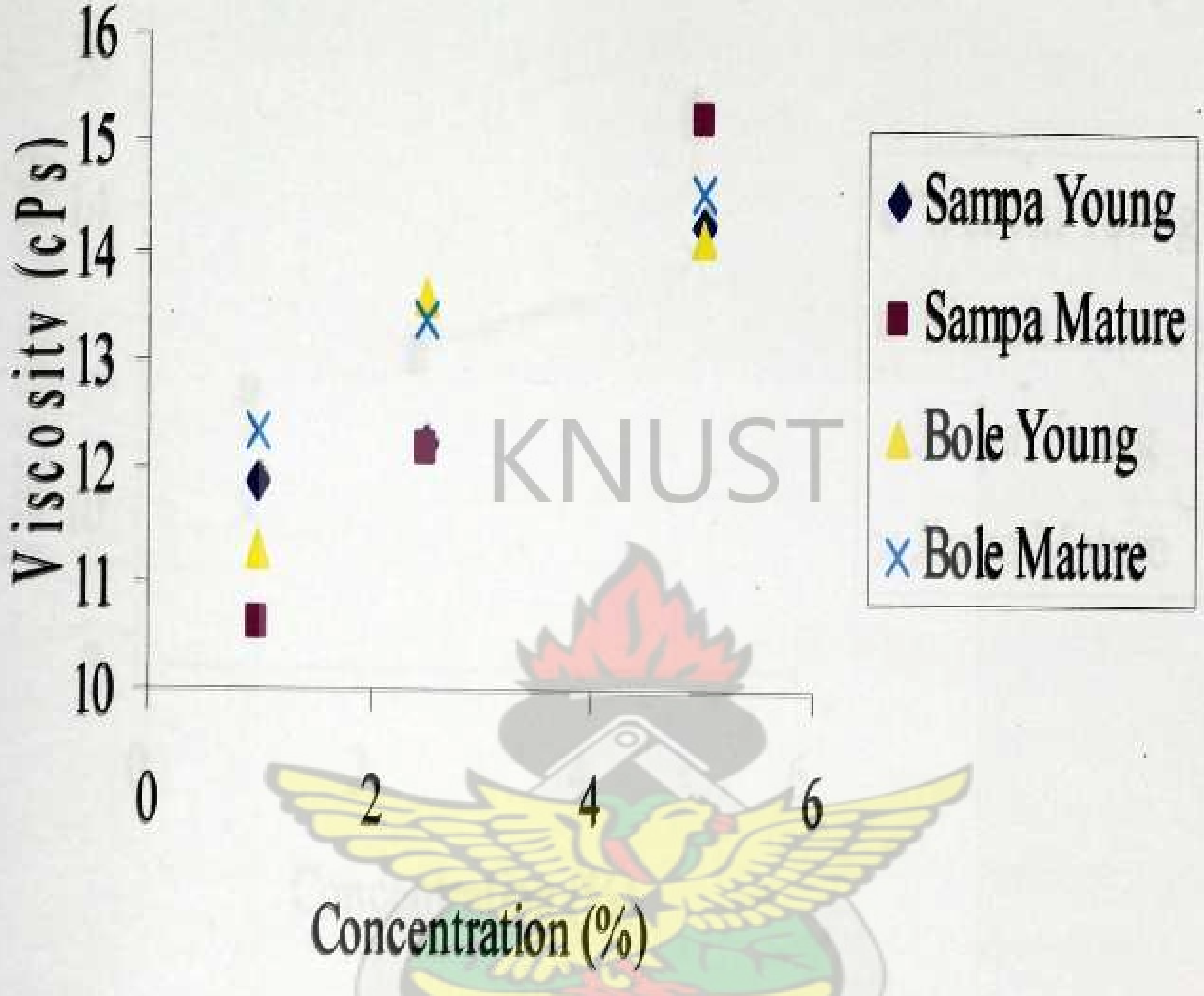

Fig 5.3: Effect of cashew tree maturity and concentration on viscosity of gums from Sampa and Bole

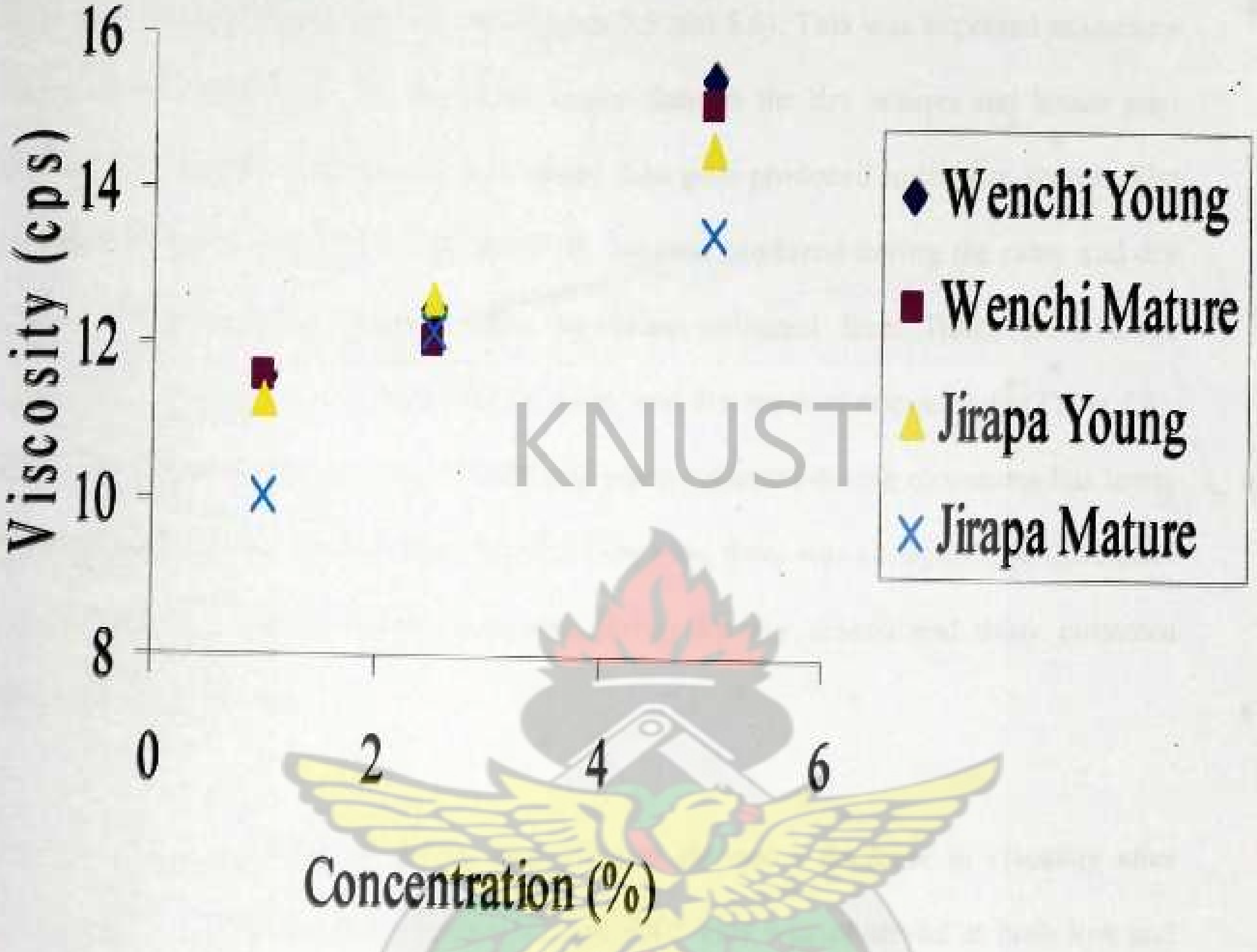

Fig 5.4: Effect of cashew tree maturity and concentration on viscosity of gums from Jirapa and Wenchi

5.4.4 *Effect of production time on viscosity*

The viscosities of cashew gum samples produced during the rainy season were lower than those produced during the dry season (Figures 5.5 and 5.6). This was expected as cashew plants take up more water in the rainy season than in the dry season and hence gum produced in the rainy season was more dilute than gum produced in the dry season. The average viscosities were 13.13 and 16.37 cPs for gum produced during the rainy and dry seasons respectively in Sampa, while for those collected from Bole, the average viscosities were 14.1 and 16.5 cPs for the rainy and dry seasons respectively (Table 5.1). This confirms the report by Fitwi (2000) that gums collected during monsoons has lower viscosity than that collected during summer. However, there was no significant difference between the viscosities of gums collected during the dry season and those collected during the rainy season.

Cashew gum collected from all the four districts showed a decrease in viscosity after storing for 6 and 12 months (Figures 5.7 and 5.8). This was observed at both low and high concentrations of the gums. BeMiller and Whistler (1993) reported that gums show a decrease in viscosity after 6 months of storage. However, statistical analysis of the data obtained showed that there was no significant difference between the viscosities of the gums before and after storage and at the different locations. The mean viscosity values and standard error for storage are shown in Table 5.2.

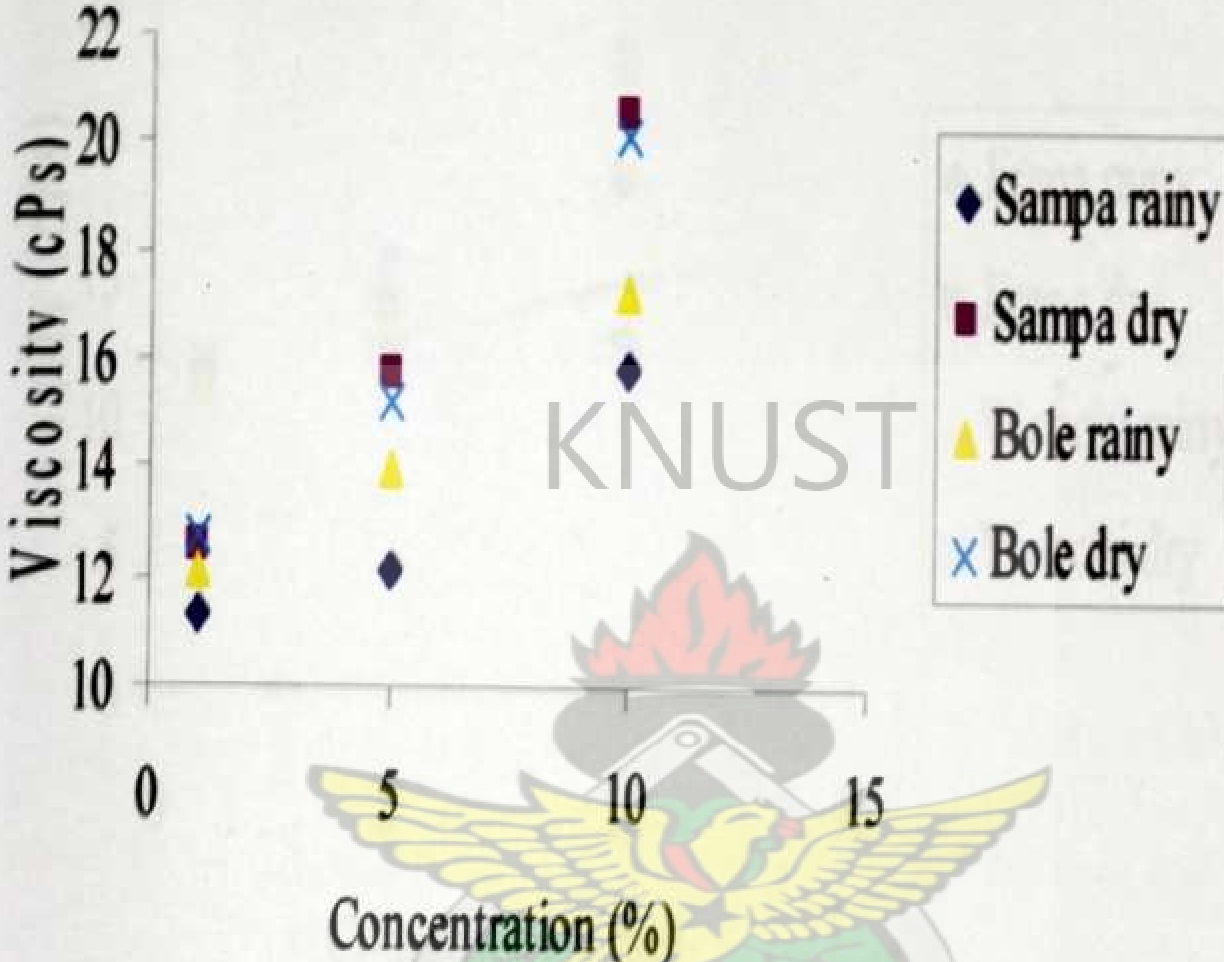

Fig 5.5: Effect of production time on viscosity of cashew gums from Sampa and Bole

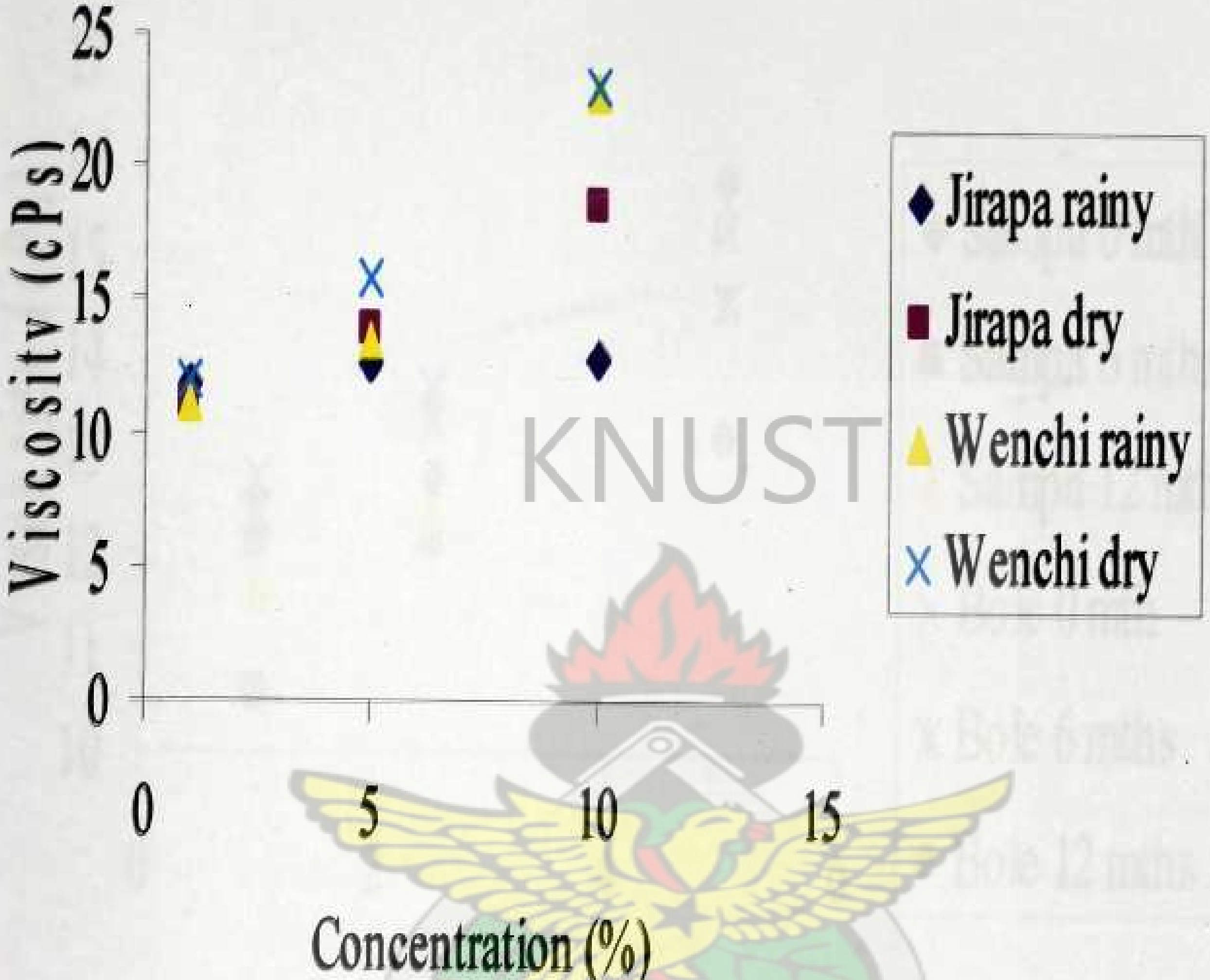

Fig 5.6: Effect of production time on viscosity of cashew gums from Jirapa and Wenchi

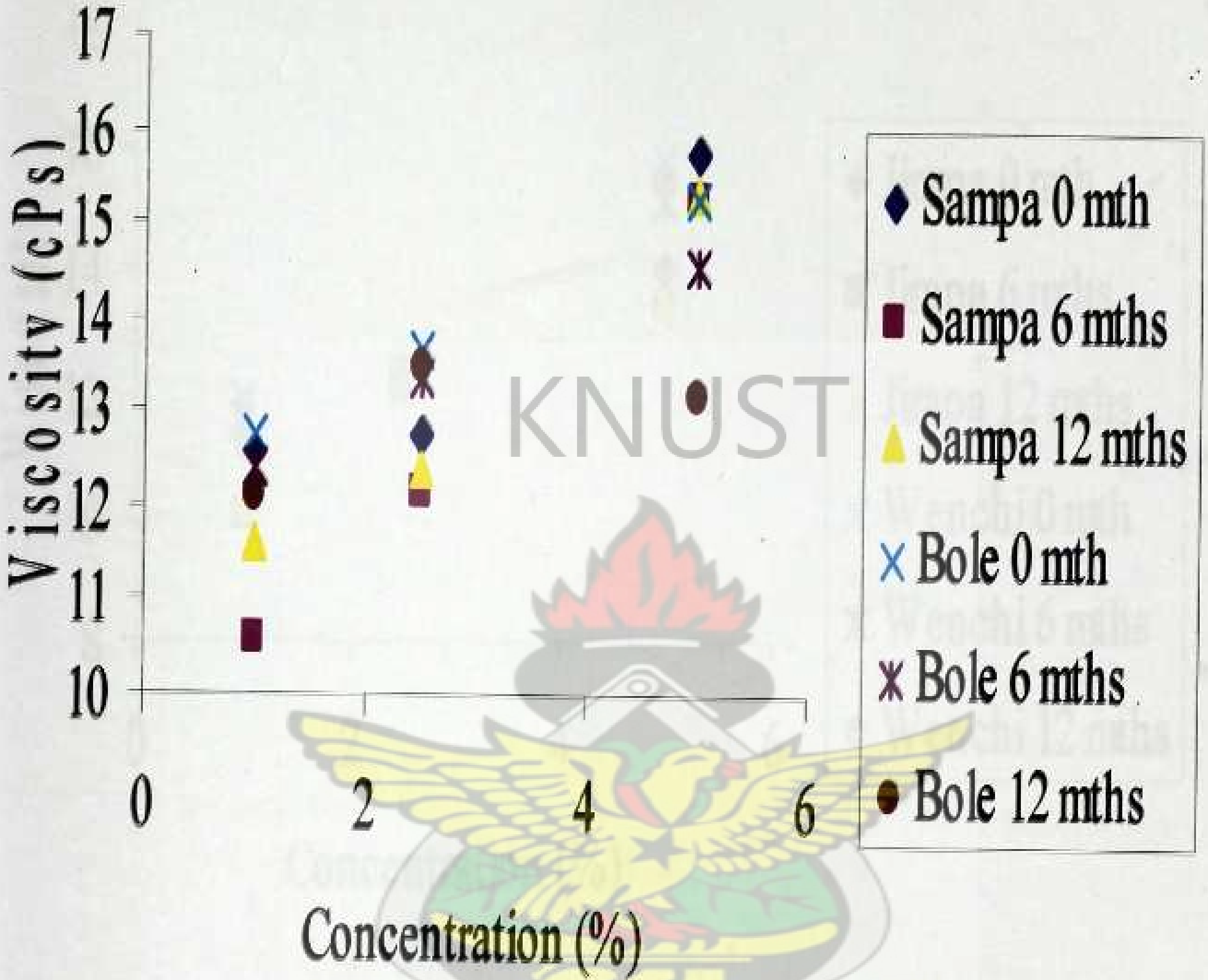

Fig 5.7: Effect of storage on viscosity of cashew gums from Sampa and Bole

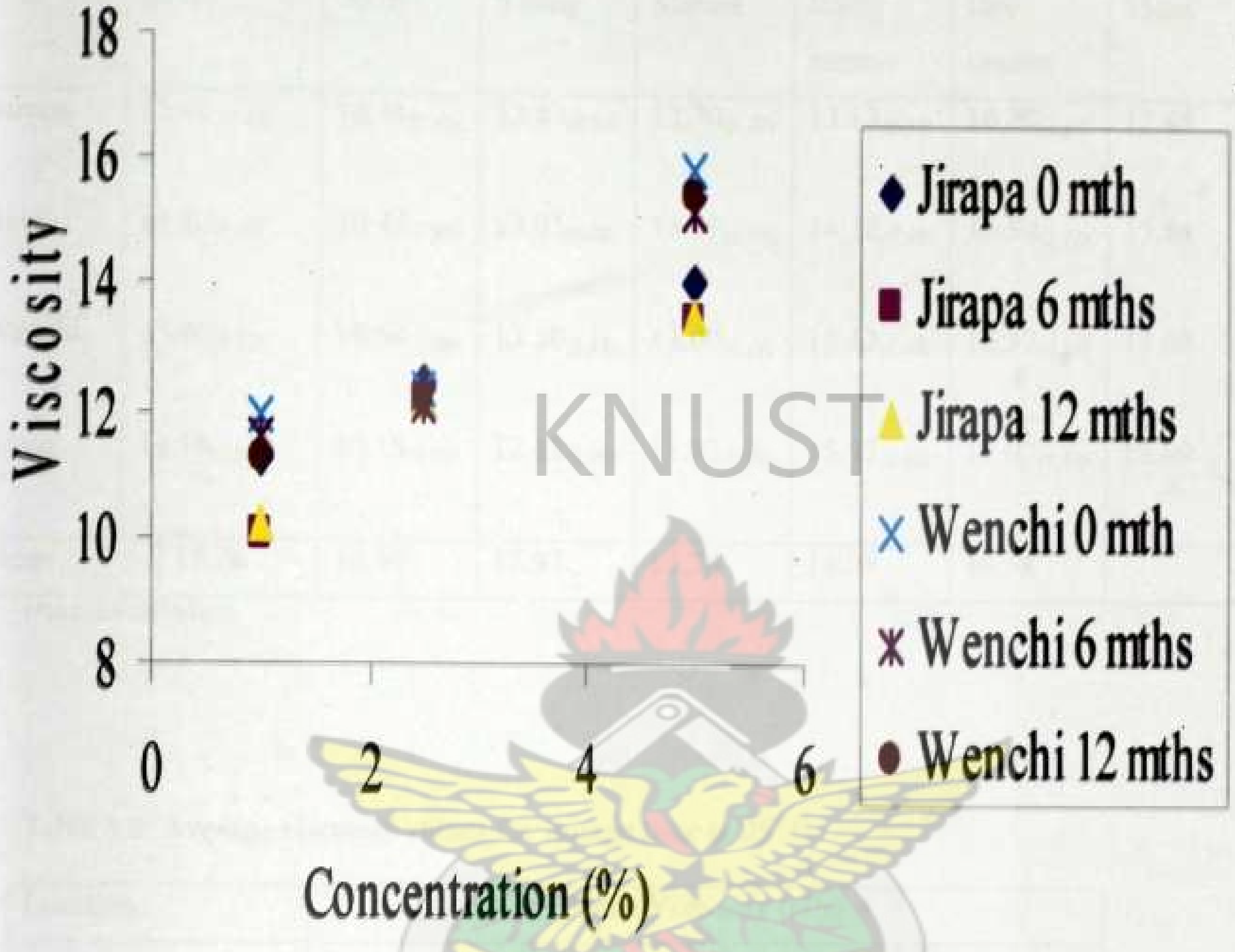

Fig 5.8: Effect of storage on viscosity of cashew gums from Jirapa and Wenchi

Table 5.1: Average viscosity values for temperature, age and period of production

Location	Mean Viscosity (cPs)						
	25° C	70° C	Young	Mature	Rainy season	Dry season	Mean
Sampa	15.46 *(1.89)*	10.41 *(1.46)*	12.83 *(0.74)*	12.70 *(1.37)*	13.13 *(0.34)*	16.37 *(2.19)*	13.48
Bole	15.50 *(1.63)*	10.45 *(1.82)*	13.03 *(0.88)*	13.47 *(0.64)*	14.10 *(1.49)*	16.50 *(2.17)*	13.84
Wenchi	15.90 *(2.62)*	10.54 *(1.06)*	13.20 *(1.18)*	13.00 *(1.13)*	13.13 *(1.41)*	16.37 *(2.36)*	13.69
Jirapa	14.18 *(1.64)*	10.18 *(1.00)*	12.83 *(0.96)*	11.93 *(0.99)*	15.97 *(3.62)*	17.07 *(3.31)*	13.69
Mean	15.26	10.40	12.97	12.76	14.08	16.58	

(*Std dev in italics)

Table 5.2: Average viscosity values for storage time at 25° C

Location	Mean Viscosity (cPs)			
	0 mth	6 mths	12 mths	Mean
Sampa	13.73 *(1.03)*	12.70 *(1.38)*	13.13 *(1.16)*	13.19
Bole	13.93 *(0.23)*	13.47 *(0.64)*	12.93 *[illegible]*	13.44
Wenchi	13.43 *(1.24)*	12.97 *(1.13)*	13.00 *(1.28)*	13.13
Jirapa	14.18 *(1.64)*	11.93 *(0.99)*	12.00 *(0.99)*	12.70
Mean	13,82	12.77	12.77	

(*Std dev in italics)

5.5 CONCLUSION

In conclusion, increasing the concentration of aqueous cashew gum solution enhanced the interactions among the binding forces of the gum causing the gum to gel at 80% concentration and above. Increasing the temperature also caused thermal degradation of cashew gum, thus reducing viscosity and dissolution of the gelled gum. Concentration and temperature significantly affected on the viscosities of the gums. Gums produced by mature cashew trees had lower viscosities than those produced by young trees at lower concentrations. However, at higher concentrations, gums from mature trees had higher viscosities. Age of the gums had a significant effect on the viscosities of gums; however locations showed no significant effect. Time of production of the gums and storage periods lowered the viscosities of the gums. The study indicated that viscosity of cashew gum is high because at concentration of 1% cashew gum solution at 25° C, viscosity was found to be 10.03 cPs. Therefore, its utilization in food products should be encouraged.

CHAPTER 6

TOXICOLOGICAL EVALUATION OF CASHEW GUM

6.1 ABSTRACT

For any substance especially food substance to be approved for use or marketing, it must undergo toxicological evaluation. This is to ensure that all substances are safe before usage. Therefore, there is the need to assess cashew gum toxicologically before promoting its use in the food industry. Acute toxicity test was conducted by administering six doses of cashew gum orally to six groups of rats for 14 days. Results of the test did not reveal any abnormal changes attributable to ingestion of cashew gum. The median lethal dose, LD_{50}, for cashew gum was more than 30 g/kg b.w. Determination of the microbial status of gums from both young and mature cashew trees showed that the total microbial load were <3.0 x 10^3 and <3.4 x 10^3 cfu/ml for gums from young and mature trees respectively. Yeasts and moulds were also found to be 660 and 270 cfu/ml for young and mature tree gums respectively. They both contained no coliforms indicating that the gum posed no hazard in terms of disease-causing bacteria. Therefore, cashew gum was found to be safe for consumption according to WHO Acute Hazard Rankings.

6.2 INTRODUCTION

Food safety continues to be a matter of great concern to the consumer. A processor does not want to buy something that will have to be disposed off because of safety concerns (IFT, 1992). Issues of food safety include hazards, risks and safety. A hazard is source of danger such as microbial food poisoning and allergic reactions, whereas a risk is a measure of the probability and severity of harm to human health. Safety is the judgement of the acceptability of risk (IFT, 1992). A substance in food can therefore be considered safe if its risks are judged to be acceptable. The risk of exposure to a substance can be determind by identifying a hazard and determining the dose or amount of the substance at which there is the likelihood of the hazard occurring and finally determining the quantity of the substance to which humans are or could be exposed (Hotchkiss, 1989).

All substances must be safe for use before marketing and thus must undergo risk of exposure or toxicity assessment. Therefore, to introduce cashew gum as a food additive to the food industry in Ghana, it must be assessed for toxicity by determining its microbial status and the amount to which humans and animals could ingest. Toxicity studies provide an insight on how the substance can induce toxicity in one or more organs of humans or animals. It can be acute, sub-chronic or chronic (Gorrod, 1981). Studies of toxicity in animals have become a basic requirement prior to the introduction of a new drug or food additive (Timbrell, 1982).

Acute toxicity involves harmful effects in an organism through a single or short term exposure. Data from acute toxicity tests can be used to screen for toxicity (determine if the compound is toxic), rank toxicity to identify the best ingredients to continue investigating for use in a product and assess the potential for effects in the environment. WHO/FAO Joint Expert Committee on Food additives (JECFA) worked in 1969, 1982 and 1989 and produced specifications and toxicological evaluations for gums such as gum Arabic, tragancath and karaya gums (Walker, 2005). This has led to the screening of cashew gum for toxicity.

6.3 MATERIALS AND METHODS

6.3.1 Determination of microbial status

i. Enumeration of total microbial growth

This was determined by adding 90 ml Ringer's solution to 10 g of milled cashew gum samples. The mixture was then heated in a hot water bath at 40° C for 15 min. 1 ml of the mixture was pipetted into a petri dish and a highly rich nutrient agar poured on it. A second dilution of 1 in 100 was also prepared and plated as above. The plates were incubated at 35° C for 48 hours and the colonies formed counted.

ii. Enumeration of yeasts and moulds

Serial dilutions of samples were prepared as in section (i) and pour-plated with malt extract agar. The plates were incubated at 27° C for 48 hours and the colonies formedcounted.

iii. Enumeration of Coliforms (*Escherichia coli*)

Serial dilutions of samples were prepared as in section (i). 1 ml of each dilution was pippetted into a test tube containing 9 ml of lauryl sulphate and inverted tubes. Some malt extract agar was also added. They were then incubated at 35° C for 24 hours and the colonies formed counted. The absence of air bubbles in the inverted tubes indicates the absence of *Escherichia coli*.

6.3.2 Acute toxicity

Thirty mature male rats divided into groups of five were used for the toxicity test. They were weighed and fed with food and hygienic water and their initial weights measured. Six doses of cashew gum per kg body weight (b.w.) were selected and administered to the different groups of rats orally. The doses were prepared by dissolving gum samples in water. A control group was given water. The doses were administered as follows: 3, 5, 10, 15, 20 and 30 g/kg b.w. The rats were then observed continuously for 14 days for changes in movement, appetite, water intake, salivation, diarrhoea, and urination.

6.4 RESULTS AND DISCUSSION

6.4.1 Determination of microbial status

The results of the microbial determination of cashew gum showed that the gum contained an average of 3.2×10^3 cfu/ml of total microorganisms and 465 cfu/ml of yeasts and moulds (Table 6.1) which can easily be destroyed by heating. Cashew gum was also found to be free from coliforms, which is an indicator of the presence of disease-causing bacteria, such as those that cause typhoid, dysentery, hepatitis A, and cholera. This indicates that cashew gum has no potential of being a health hazard to humans or animals in terms of its microbial status. Statistical analysis of data from the microbial determination of the gum showed no significant difference between gum from mature cashew tree and that from young tree. This confirms the Walker (2005) report which says that from the toxicological point of view, differences between gums from different tree species are not significant.

Table 6.1: Microbial status of cashew gum from young and mature cashew trees

	Gum from young tree	Gum from mature tree
TPC	$<3.0 \times 10^3$ cfu/ml	$<3.4 \times 10^3$ cfu/ml
Y/M	660 cfu/ml	270 cfu/ml
Coliforms	Negative	Negative

6.4.2 Acute toxicity

Acute toxicity studies showed that the median lethal dose (LD_{50}) for cashew gum was more than 30 g/kg b.w. Cashew gum had no allergic or adverse effect on the rats (Table 6.2) by showing no changes in movement, appetite, water intake, salivation and urination. Diarrhoea was also absent. This indicates that the gum is not acutely toxic according to World Health Organization (WHO) Acute Hazard Rankings (WHO, 2001) (Table 6.3) and also confirms that cashew gum presents no hazard when exposed to it for a short period. FAO (1995) report on the acute toxicity of gum Arabic stated that groups of rats fed with gum Arabic in their diet for 6 days showed normal weight gain and food efficiency. A similar observation was made in the study of cashew gum. The LD_{50} of gum Arabic was in the range 8 – 18 g/kg b.w. as a bolus dose (Walker, 2005). These observations suggest that natural polysaccharides such as cashew gum and gum Arabic are better than synthetic polymers.

Table 6.2: Visual observation of rats

	Movement	Appetite	Water intake	Salivation	Diarrhoea	Urination
Control rat	Normal	Normal	Normal	Normal	Absent	Normal
Rat fed with CG	Normal	Normal	Normal	Normal	Absent	Normal

Table 6.3: WHO Acute Hazard Rankings (WHO, 2001)

WHO Toxicity classification		Rat LD_{50} (mg of chemical per kg body weight	
Class	Description	Solids (oral)	Liquids (oral)
Ia	Extremely hazardous	<5	<20
Ib	Highly hazardous	5-50	20-200
II	Moderately hazardous	50-500	200-2000
III	Slightly hazardous	>500	>2000
IV	Not acutely toxic	>2000	>3000

6.5 CONCLUSION

Cashew gum when subjected to acute toxicological evaluation showed no adverse effects on rats even at high doses. It was also found to be free from disease-causing bacteria. The LD_{50} of cashew gum was found to be more than 30 g/kg b.w. and this compared well with that of gum Arabic which is 8 – 18 g/kg b.w. From the microbiological point of view, gum from mature cashew tree was not significantly different from that from young trees.

CHAPTER 7

UTILIZATION OF CASHEW GUM IN THE PRODUCTION OF CHOCOLATE PEBBLES AS A QUICK COATING AGENT

7.1 ABSTRACT

Owing to the limited supply and high cost of gum Arabic, cashew gum was assessed as a quick coating agent in the production of chocolate pebbles, using gum from both young and mature cashew trees. Pebbles produced with cashew gum samples were compared with those produced with gum Arabic. The ash contents of the three products ranged from 2.37 to 2.63% and the moisture content from 2.33 to 2.76% whilst the sugar concentration ranged from 26.05 to 29.66%. The microbial status of the three products conformed to specifications of the Cocoa Processing Company Limited, Tema (CPC Ltd). Some chemical parameters determined showed significant differences among the three products ($p < 0.05$). Sensory analysis showed no significant difference among products in terms of flavour, hardness and smoothness. The overall acceptability of the products were similar and the mean scores were 7.4, 6.8 and 7.1 for pebbles produced with gum Arabic, that produced with cashew gum from young and mature trees respectively. On a 9-point hedonic scale, this range varies from "like slightly" to "like moderately". Pebbles produced with cashew gum compared favourably with that produced with gum Arabic.

7.2 INTRODUCTION

Plant exudates are gums from various plant species obtained as a result of tree bark injury. They are normally collected as air-dried droplets (Fitwi, 2000). They have been found to have many lucrative possibilities for industrialization. They have both food and non-food applications. Their non-food applications include pharmaceutical, cosmetic, lithographic and offset preparations (FAO, 2002). They are used extensively as adhesives and as sizing and finishing materials in the textile industry. In the food industry they are used in confectionery, dairy products, snack foods and bakery products. However, cashew gum has not been used extensively in the food industry like other gums therefore there is the need to study its utilization in food products and promote its consumption.

Chocolate products are a world wide passion. Ghana as a cocoa producing country produces chocolate products such as chocolate bars and chocolate pebbles. The production of pebbles utilizes gums specifically gum Arabic. However, due to the high cost and limitation in supply of gum Arabic there is the need for alternative gum sources such as cashew gum. Large plantations of cashew have been cultivated in various parts of Ghana, which could be a potential source of cashew gum. This study was thus carried out to assess the suitability of cashew gum as a substitute of gum Arabic in the production of chocolate pebbles.

7.3 MATERIALS AND METHODS

7.3.1 Production of chocolate pebbles

This study was carried out at the CPC factory in Tema, Ghana. Production of chocolate pebbles was done by adopting the method of panned goods of Fabry (1992), which is also used by the CPC Ltd. This method involved three steps.

i. Preparation of beeswax, sugar syrup, starch and gum solutions

Preparation of beeswax (Ghana), sugar syrup, starch and gum solutions was based on the formulations of Cocoa Processing Company (CPC) for pebble production. An aqueous solution of gum Arabic (FORIG, Kumasi), which is the conventional gum used for pebbles production (TIC Gums, 2001) in a water:gum ratio of 50:50 w/v (100%) was also prepared. Sugar (Brazil) syrup was prepared to 72% (w/v) sugar solids. Starch solution was made by mixing cornstarch (Ghana) with sugar syrup. Powder starch was also produced by mixing cornstarch and icing sugar in the proportion of 1:3 (w/w). Titanium dioxide was added to the starch solution to give it a white colour. Beeswax was then melted in frytol oil (UNILEVER, Ghana) in the proportion of 1kg beeswax in 4 L frytol oil. Gums from both mature and young cashew trees were sterilized in a Gallenkamp autoclave (UK) at 121° C for 15 minutes and used in the preparation of aqueous gum solutions in a water:gum ratio of 60:40 w/v (66.7%). The concentration of cashew gum solution was reduced because of its high viscosity.

ii. Preparation and pre-coating of centres

Selected amounts of peanuts, which ~~are the~~ centres of the pebbles were cleaned and calibrated into even sizes. The centres were then fried with cocoa butter (CPC Ltd, Tema) and put into a mechanically operated elliptical pan, which rotates on an inclined shaft at an angle of 40° to the horizontal (Plate 7.1). The pan has a fan attached which blows cold air for drying attached to it. The centres were then pre-coated with the gum solution by applying the gum solution in a small quantity at a time and rotating the pan for the solution to coat the centres. Sugar syrup was also applied in the same manner and then air-dried.

iii. Chocolate coating

This involved the application of chocolate liquid (CPC Ltd, Tema) to the centres and dusting with chocolate powder. They were then air-dried. Dusting with chocolate powder (CPC Ltd, Tema) ensures proper drying. This was repeated five times to build up the chocolate layer. They were then left overnight for drying. The application of the chocolate layer was repeated about 8-10 times to obtain a desired number of layers or about half of the total weight of the final product. They were again left overnight for drying.

iv. Starch coating

A second gum coating was applied and dried to protect the chocolate layer. The starch solution was applied and dusted with starch powder and air-dried. This was also repeated five times. They were then coloured with a colour solution (colour and sugar syrup) and then polished with the beeswax.

Plate 7.1: Mechanically operated elliptical pan with fan

7.3.2 Determination of microbial status of pebbles

i. Enumeration of total microbial growth

This was determined by adding 90 ml Ringer's solution to 10 g of pebbles (1 in 10 dilutions). The mixture was then heated in a hot water bath at 40° C for 15 min. 1 ml of the mixture was pipetted into a petri dish and a highly rich nutrient agar poured on it. A second dilution of 1 in 100 was also prepared and plated as above. The plates were incubated at 35° C for 48 hours and the colonies formed counted.

ii. Enumeration of yeasts and moulds

Serial dilutions of samples were prepared as in section (i) and pour-plated with malt extract agar. The plates were incubated at 27° C for 48 hours and the colonies formed counted.

iii. Enumeration of Coliforms (*Escherichia coli*)

Serial dilutions of samples were prepared as in section (i). 1 ml of each dilution was pippetted into a test tube containing 9 ml of lauryl sulphate and inverted tubes. Some malt extract agar was also added. They were then incubated at 35° C for 24 hours and the colonies formed counted. The absence of air bubbles in the inverted tubes indicates the absence of *Escherichia coli*. The results were then compared to internal specification of CPC, which also conforms to international specification for chocolate products.

7.3.3 Determination of some chemical composition of pebbles

i. Sugar content

The total sugar concentration was determined using the phenol-sulphuric acid method (Dubois *et al.*, 1956). An aqueous solution of 1 g of each sample in 10 ml water and was clarified with equal volumes of 0.3N $Ba(OH)_2$ and 5% $ZnSO_4$ solutions and filtered. The filtrate was deionised with Amberlite cation-anion exchange resins and filtered. 0.1 ml of the deionised solution was diluted with 0.9 ml distilled water to give a final dilution of 1 in 100. Aliquots were then used for the colorimetric analysis after adding 1 ml of 10% phenol followed by 5 ml conc. Sulphuric acid.The absorbance was read at 490 nm and glucose was used as a standard for calibration curve.

ii. Ash content

The ash content was determined by weighing 2 g of each sample into porcelain crucibles and incinerating in a muffle furnace at 600° C for 1 hour until carbon-free ash was obtained. The weight of the ash was expressed as a percentage of the weight of milled gum. Data obtained were compared to international specification for chocolate products.

iii. Moisture content

Moisture content was determined by weighing 2 g of each sample into porcelain crucibles and drying to a constant weight in an oven at 105° C for 18 hours. The moisture loss on drying was expressed as percentage of the weight of milled gum. Data obtained were analyzed using ANOVA.

7.3.4 Sensory Analysis

This was done using the triangle test where 20 judges (staff of the Cocoa Research Institute of Ghana, CRIG) were presented with sets of 3 coded samples of pebbles, two of which were the same. Judges were asked to identify the odd sample in terms of flavour, hardness and smoothness (Stone and Sidel, 1995). Data obtained was analyzed using Binomial distribution. Acceptability test was also conducted by asking the panelists to determine their overall acceptability using a 9 - point hedonic scale with 1-3 = dislike extremely, 4-6 = neither likenor dislike and 7-9 = like extremely (Stone and Sidel, 1995). Data obtained were analyzed using the Statgraphic Plus programme for ANOVA.

7.4 RESULTS AND DISCUSSION

7.4.1 Pebbles production

At a concentration of 80% and higher cashew gum forms a gel (Gyedu-Akoto *et al.*, 2007) and this could not be used in coating the centres of the pebbles since it caused the sticking of centres to each other resulting in uneven surface of products. This led to the use of 66.7% (w/v) cashew gum solutions in the production of pebbles instead of 100% (w/v) used for gum Arabic. This confirms cashew gum as a better thickening agent than gum Arabic. Physico-chemical analysis conducted on the three products gave significant differences between the products ($p < 0.05$). Multiple comparison tests showed that pebbles produced with gum from both young and mature cashew trees differed significantly from that produced with gum Arabic. The results are presented in table 7.1. The moisture and sugar contents of the three products fell within the acceptable levels for chocolate pebbles (Fabry, 1992) which are 1-3% and 20-30% for moisture and sugar contents respectively. The microbial status of the three products conformed to the internal specification of CPC for chocolate products (Table 7.2). However, the total microorganisms were relatively lower for cashew gum based pebbles compared to the control (gum Arabic based pebbles).

Table 7.1: Some chemical analysis of pebbles produced from gum Arabic, gums from young and mature cashew trees

Parameter	Gum Arabic	Gum from young tree	Gum from mature tree
Ash (%)	2.46 *(0.02)*	2.63 *(0.008)*	2.37 *(0.005)*
MC (%)	2.33 *(0.01)*	2.38 *(0.09)*	2.76 *(0.11)*
Sugar (%)	26.05 *(0.03)*	29.66 *(0.70)*	27.55 *(0.80)*

(*Std dev. in italics)

Table 7.2: Microbial status of pebbles produced from the 3 different gums

	Gum Arabic	Young tree gum	Mature tree gum	Specifications of CPC
TML[1]	3.9×10^2 cfu/ml	3.0×10^2 cfu/ml	3.0×10^2 cfu/ml	5.0×10^3 cfu/ml
Y/M[2]	0	0	0	<5 cfu/ml
Coliforms	Negative	Negative	Negative	Negative

1 – Total microbial load 2 – Yeasts and moulds

7.4.2 Sensory analysis

Sensory analysis showed no significant difference between the three products in terms of flavour, hardness and smoothness (Table 7.3). Overall acceptability of the products was similar. The results confirm the similarity of cashew gum and gum Arabic reported by Smith and Montgomery (1959). Mean scores observed for overall acceptability of the pebbles were 7.4, 6.8 and 7.1 for gum arabic, gum from young cashew trees and mature trees, respectively. On the hedonic scale, this range varies from "like slightly" to "like moderately" (Mothé and Correia, 2004). The deserved frequency percentage of hedonic scale scores of overall acceptability, obtained for products is presented in Figure 7.2. The frequency of responses are more concentrated between the scores of 7 and 9, meaning that pebbles produced with cashew gum compared favourably with that produced with gum Arabic.

Table 7.3: Binomial distribution on sensory test

Sensory attribute	Groups	N	Observed prob	Test prob	Sig.(2-tailed)
Hardness	1	25	0.63	0.50	0.155
	2	15	0.38		
	Total	40	1.00		
Flavour	1	19	0.48	0.50	0.874
	2	21	0.53		
	Total	40	1.00		
Smoothness	1	20	0.50	0.50	1.000
	2	20	0.50		
	Total	40	1.00		

7.5 CONCLUSION

Concentration of aqueous cashew gum solution for the production of pebbles was 66.7% as compared to the 100% solution for gum Arabic. The ash contents of pebbles made from gum Arabic, gums from young and mature cashew trees ranged from 2.37 to 2.63% and the moisture content from 2.33 to 2.76% whilst the sugar concentration ranged from 26.05 to 29.66%. The microbial status of the three products also conformed to internal specifications of CPC. Although there were significant differences in the physico-chemical parameters determined on the products, sensory analysis showed no difference. This is indicative of consumers' acceptance to pebbles produced with cashew gum. Therefore, cashew gum can be used as a substitute for gum Arabic in the production of chocolate pebbles.

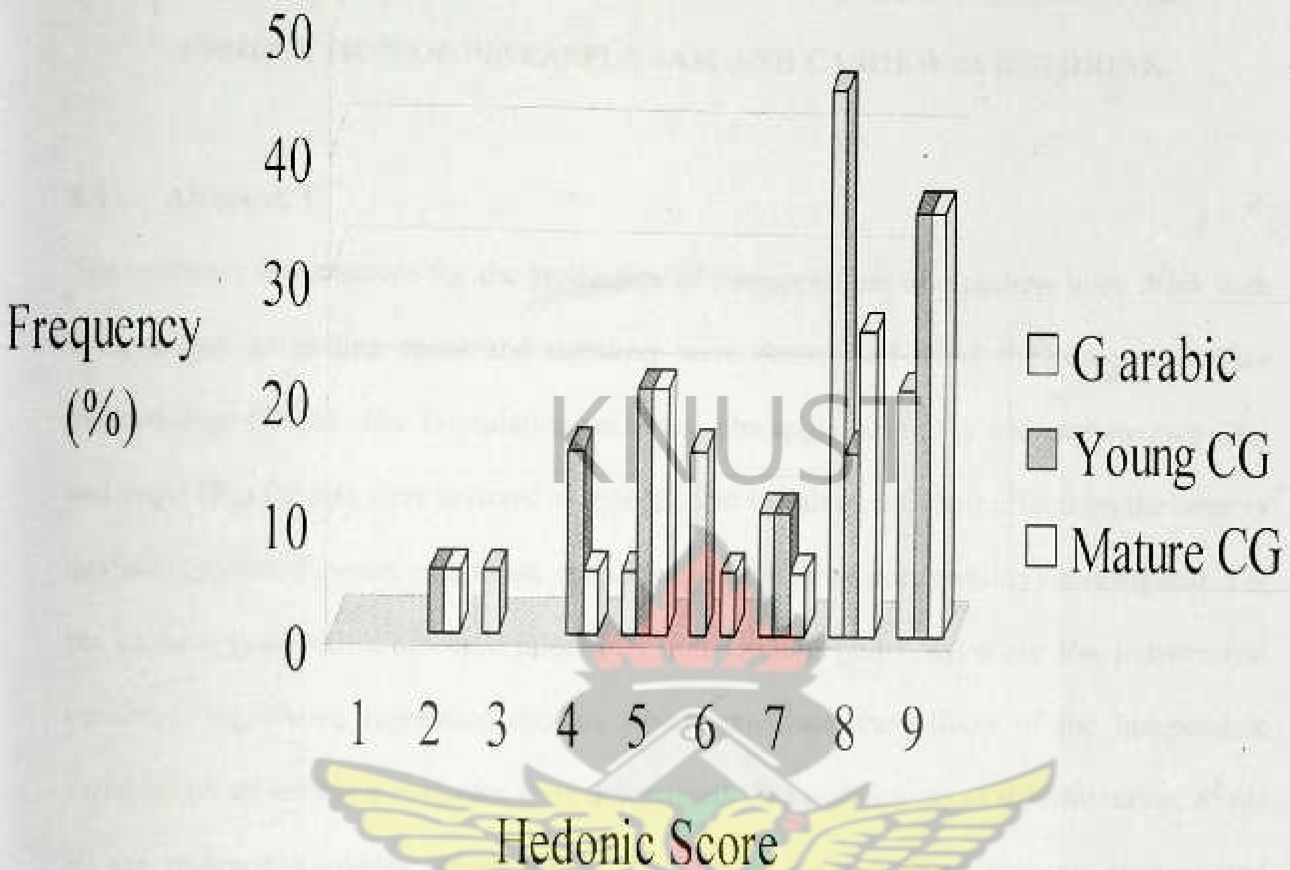

Fig 7.1: Frequency of hedonic scale scores of pebbles produced with gum arabic, cashew gum from both young and mature trees for overall acceptability (1 = dislike extremely; 9 = like extremely)

CHAPTER 8

OPTIMIZATION OF THE UTILIZATION OF CASHEW GUM IN THE PRODUCTION OF PINEAPPLE JAM AND CASHEW JUICE DRINK

8.1 ABSRACT

The optimum formulations for the production of pineapple jam and cashew juice drink with cashew gum as gelling agent and stabilizer were determined using the response surface methodology (RSM). The formulation variables, pineapple pulp (X_1) and cashew gum (X_2) and sugar (X_3) for jam were selected as independent variables and their effects on the sensory qualities (colour, flavour, sweetness, consistency and overall acceptability) investigated. For the cashew juice drink, cas hew juice (X_1) and cashew gum (X_2) w ere the independent variables. Significant regression models which explained the effects of the independent variables on all response variables were determined. The coefficients of determination, R^2 for all the response variables which were 0.7 or higher were used to generate contour and response surface plots. Based on the results, the possible combinations of ingredients for the production of jam with the desired sensory qualities were to be in the range 0.5-0.7, 0.05-0.10 and 0.3-0.5 for pineapple pulp, cashew gum and sugar respectively. Cashew gum was found to be suitable as a clarifying agent rather than a stabilizer in cashew juice production.

8.2 INTRODUCTION

The addition of value to raw agricultural products has been of immense importance to both producers and consumers over the past decades. The demand for stable, convenient foods such as fruit juice and preserves has increased markedly especially exotic products (FAO, 1999). Cashew apple which is a by-product of the cashew nut can be processed to generate extra income for the producers and also provide low cost vitamin C to the consumer (Barros *et al., 2001*). Therefore, there is the need to develop a product such as a stable cashew juice drink which will be appealing to consumers using cashew gum as a stabilizer. Pectin which is very important in jam making is very expensive in Ghana. It is used in the setting of jams (Teagasc, 2005). Its high cost has led to the search for other suitable gelling agents. Cashew gum appears to be a good candidate among other products which are capable of performing the functions as substitutes for pectin in jam making.

Traditionally food formulations are developed by changing one variable at a time. This method is time consuming and difficult to evolve an ideal formulation since the combined effects of the independent variables are not considered (Cochran and Cox, 1992) . It is therefore important to understand the complexity of the formulations by using established statistical tools such as the classic mixture and factorial designs.

This investigation was thus aimed at optimizing the process of formulating pineapple jam and cashew juice by using cashew gum as both a gelling agent and juice stabilizer.

8.3 MATERIALS AND METHODS

8.3.1 Formulation of pineapple jam using cashew gum as gelling agent

a. Experimental design

A three-component constrained simplex lattice design was used (Cornell, 1983). Design mixtures consisted of coordinates of the vertices and uniformly spaced distribution of points on the face and sides of the constrained region of the simplex factor space. Pineapple pulp (X_1), cashew gum (X_2) and sugar (X_3) were the ingredients (variables) for jam formulation. The sum of the component proportions was one. The proportions of X_1 and X_2 were limited to the range of 0.20-0.70 and 0-0.10, respectively, based on preliminary studies. To support a second or higher-order polynomial equation that represents response behaviour over the restricted simplex region (Cornell, 1983) 12 blends (Table .1) were identified. The location of each blend in the simplex coordinate system was plotted (Fig. 8.1).

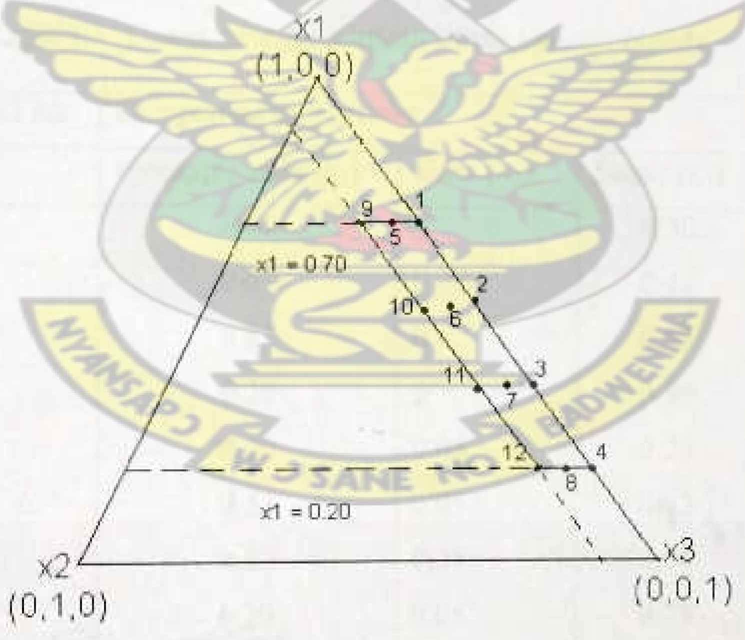

Figure 8.1: Constrained region in the simplex coordinate system defined by the restrictions $0.20 < X_1 < 0.70$ and $0 < X_2 < 0.10$

b. Sample calculation

a. Since the sum of component proportions was one, then

$$X_1 + X_2 + X_3 = 1$$

i. If X_1 and X_2 are 0.70 and 0 respectively, then

$$X_3 = 0.30$$

ii. If X_1 and X_2 are 0.20 and 0 respectively, then

$$X_3 = 0.80$$

b. Since the points are uniformly distributed on the face and sides of the constrained region, then for X_1 and X_3, the difference between each point will be 0.17 while that of X_2 will be 0.05

Table 8.1: Component proportions of the various blends

Blend no.	Component proportions		
	Pineapple pulp (x_1)	Gum (x_2)	Sugar (x_3)
1	0.70	0	0.30
2	0.53	0	0.47
3	0.37	0	0.63
4	0.20	0	0.80
5	0.70	0.05	0.25
6	0.53	0.05	0.42
7	0.37	0.05	0.58
8	0.20	0.05	0.75
9	0.70	0.10	0.20
10	0.53	0.10	0.37
11	0.37	0.10	0.53
12	0.20	0.10	0.70

8.3.2 *Production of pineapple jam*

Pineapple pulp was mixed with sugar and cashew gum in different proportions (Table 8.1) and boiled to set. Sodium metabisulphite was added as a preservative to the concentration at 0.01%. Then the set jam was filled into jars, which were pre-sterilized in hot water. Total ash content and pH were measured on each experimental product.

8.3.3 *Some chemical analysis of pineapple jam*

i. Ash content

The ash content was determined by weighing 2 g of each sample into porcelain crucibles and incinerating in a muffle furnace at 600° C for 1 hour until carbon-free ash was obtained. The weight of the ash was expressed as a percentage of the weight of milled gum.

ii. pH

Aqueous solution of each product was made by dissolving 2 g of each sample in 50 ml water and the pH measured with a glass electrode fitted to a Jenway 3020 pH meter (UK).

8.3.4 *Formulation of cashew juice drinks using cashew gum as suspension agent*

Experimental design

The central composite design (CCD) was used in the formulation. The formulation ingredients (variables) used were cashew juice (X_1) and cashew gum (X_2), with X_1 being 9.0 > x_1 < 10.0 and X_2 being 0.0 > x_2 < 0.25. Five levels of each of the parameters were used with values of -1.414, 0 and +1.414 assigned to the lowest, middle and highest levels respectively (Table 8.2). The Altogether 9 combinations were chosen (Table 8.3) (Cochran and Cox, 1992).

Table 8.2: Range of levels of parameters

CCD code	-1.414	-1	0	+1	+1.414
Cashew juice (X_1)	8.75	8.95	9.00	9.05	10.0
Cashew gum (X_2)	0.00	0.05	0.10	0.15	0.20

Table 8.3: Combinations of ingredients of the various blends

Blend no.	Cashew juice (x_1)		Gum (x_2)	
	Code	Uncode	Code	Uncode
1	1	9.05	-1	0.05
2	-1	8.95	-1	0.05
3	1	9.05	1	0.15
4	-1	8.95	1	0.15
5	+1.414	10.0	0	0.10
6	-1.414	8.75	0	0.10
7	0	9.00	-1.414	0.00
8	0	9.00	1.414	0.20
9	0	9.00	0	0.10

8.3.5 Production of cashew juice

Cashew gum was mixed with cashew apple juice in the various proportions and boiled till a brown colour was obtained. Sodium metabisulphite was added to the concentration at 0.01%. The boiled juice was then filled into polyethylene bottles, which were pre-sterilized in hot water.

8.3.6 Some chemical analysis of cashew juice

i. Turbidity

Turbidity of the products was determined by measuring the absorbance of each product at 490 nm using Shimadzu UV-20-02 Spectrophotometer (Shimadzu, Japan).

ii. pH

The pH of each product was measured with a glass electrode fitted to a Jenway 3020 pH meter (UK).

8.3.7 Determination of preference for products

This was done by presenting 33 panelists (staff of CRIG) with sets of coded samples of pineapple jam and cashew juice to assess and rank in order of preference for colour, sweetness, flavour, astringency and consistency (Ballot sheet, Appendix). They were then asked to determine their overall acceptability using a 9 - point hedonic scale with 1 = dislike extremely and 9 = like extremely (Ballot sheet, Appendix).

8.3.8 Statistical analysis

Data obtained for each product was analyzed using Statgraphics Plus (Windows version 3.0) program package for analysis of variance and regression. Regression analysis was used to fit a relation to the data of all dependent sensory and physical variables evaluated (Cochran and Cox, 1992). Correlation was also used to find the effect of colour, consistency, astringency, sweetness, flavour and the physical variables on overall acceptability.

8.4 RESULTS AND DISCUSSION

8.4.1 Pineapple jam production

Results on the chemical analyses showed an increase in pH with a decrease in the proportion of pineapple pulp whereas the ash content decreased with a decrease in the proportion of pineapple pulp (Table 8.4). The lowest pH was with blend 9 and the highest with blend 4. For ash, blend 1 gave the highest level while blend 4 gave the lowest. The p-values and the regression coefficients (R^7) of the dependent variables are presented in Table 8.5. The closer the R^2 is to unity the better the empirical model fits the actual values. Analysis of the data indicated that muliple regressions gave very high and significant coefficients for acceptability (R^2 = 0.70), sweetness (R^2 = 0.69), pH (R^2 = 0.71) and ash (R^2 = 0.53). Regression of the second order polynomial also gave very high and significant coefficients for acceptability (R^2 = 0.89), sweetness (R^2 = 0.69), pH (R^2 = 0.90) and flavour (R^2 = 0.62). From these results, it implies that pH is the most important factor influencing product quality. Consumer acceptaility of the product is also highly dependent on the sweetness of the product (Table 8.5).

Table 8.4: Effect of pineapple pulp, cashew gum and sugar combinations on dependent variables

Blend no.	Sweetness	Flavour	Consistency	Colour	Acceptability	pH	Ash(%)
1	6.9	8.3	5.7	6.0	5.6	3.56	0.41
2	8.3	9.6	6.3	7.5	4.9	3.51	0.38
3	7.2	6.6	6.0	8.2	4.5	3.56	0.36
4	12.4	7.4	11.0	5.0	2.6	3.82	0.04
5	7.5	7.4	10.6	9.5	6.7	3.52	0.22
6	8.4	11.2	8.2	10.5	7.0	3.53	0.21
7	8.9	9.8	9.2	10.5	6.5	3.55	0.18
8	11.8	5.2	11.3	4.1	2.9	3.75	0.16
9	8.2	7.6	10.6	8.3	6.5	3.47	0.17
10	9.8	9.8	9.8	7.9	5.9	3.57	0.10
11	10.6	7.5	11.8	6.5	5.2	3.62	0.18
12	10.2	7.2	10.0	6.6	3.5	3.70	0.14

Table 8.5: Regression coefficients and p-values for dependent variables

Variable	R^{2*}	P-value	R^{2**}	P-value
Sensory				
Colour	0.25	0.27	0.46	0.06
Consistency	0.54	0.03	0.06	0.76
Flavour	0.16	0.46	0.62	0.01
Acceptability	0.70	0.004	0.89	0.0001
Sweetness	0.69	0.01	0.69	0.01
Physical				
Ash	0.53	0.03	0.07	0.71
pH	0.71	0.004	0.90	0.00

*Multiple linear regression **Polynomial regression (2nd order)

Correlation analysis of the data showed that colour and pH highly correlated positvely with acceptability, giving correlation coefficients (R) of 0.85 and 0.88 respectively (Table 8.6). Flavour and sweetness also showed some degree of correlation with coefficients of 0.65 and 0.66 respectively. A similar trend was observed between colour and flavour (R = 0.67). Irrespective of these strong positve correlations, ash showed a strong but negative correlation with sweetness (R = -0.86) and cosistency (R = -0.86) (R = -0.84). A similar trend was made between color and pH (R = -0.75). These findings indicate that sensory indicators and these two chemical parameters play a significant role in the quality of pineapple jam.

Response surface plots are used to explain the effects of independent variables on the dependent variables (Box *et al.*, 1978). Response surface plots were generated for acceptability, sweetness and flavour. These responses were used because of their significant impact on the quality of the product and also because the consumer is the ultimate judge. The distribution of the response surface for acceptability showed that increase in pineapple pulp proportion increased acceptability (Figure 8.2a) and that for sweetness showed that reducing pineapple pulp proportion

Table 8.6: Correlation coefficients (R) of dependent variables

	Acceptability	Ash	Colour	Consistency	Flavour	pH	Sweetness
Acceptability		0.24	0.85	-0.18	0.65	0.88	0.66
Ash	0.24		0.14	-0.86	0.09	-0.54	-0.84
Colour	0.85	0.14		-0.22	0.67	-0.75	-0.54
Consistency	-0.18	-0.86	-0.22		-0.34	0.45	0.74
Flavour	0.65	0.09	0.67	-0.34		-0.51	-0.31
pH	0.88	-0.54	-0.75	0.45	-0.51		0.82
Sweetness	0.66	-0.84	-0.54	0.74	-0.31	0.82	

also increased sweetness (Figure 8.3a). This is because when pineapple pulp content is reduced, sugar content was increased. The distribution of response surface for flavour also showed that increasing pineapple pulp proportion also increased the fruity flavour of the jam (Figure 8.4a).

In order to predict optimum levels of pineapple pulp, cashew gum and sugar, contour plots were drawn at the constant levels of cashew gum X_2 (0, 0.05, and 0.10). At 0 level of cashew gum acceptance was high for products with pineapple pulp proportion of 0.65-0.85 (Figure 8.2b) while at 0.05 level it was high for products with pineapple pulp proportion of 0.53-0.95 (Figure 8.3b). At 0.10 level, acceptance was high for products of 0.53-0.85 pineapple pulp proportions (Figure 8.4b). Although acceptance was high at all three levels for high pineapple pulp products it was highest at the 0.05 level of cashew gum inclusion indicating that the optimum level of cashew gum for jam was 0.05 and that for pineapple pulp and sugar were 0.53-0.70 and 0.25-0.42 respectively.

8.4.2 *Cashew juice production*

Results on cashew juice are shown in Table 8.7. Visual observation of the products showed that sediments formed in the juice after heat treatment could not remain suspended indefinitely indicating that cashew gum could not have any stabilizing effect on the juice. However, turbidity of the juices showed that the addition of cashew gum caused more sedimentation at all levels (Table 8.7). Thus the products were rather clarified by cashew gum and this may be due to the galacturonic acid component in its structure. It has been reported by Baker (1976) that the addition of base-solubilized polygalacturonic acid to fruit juices yielded immediate and relatively complete clarification.

Table 8.7: Effect of cashew gum on cashew juice quality

Blend no.	Sweetness	Flavour	Astringency	Colour	Acceptability	pH	Turbidity
1	9.1	8.3	7.5	10.5	5.7	5.48	2.64
2	6.5	6.6	7.4	4.0	5.1	5.40	2.02
3	7.6	7.6	5.7	7.7	5.8	5.44	2.16
4	7.9	7.6	7.3	5.7	5.2	5.41	2.30
5	6.6	6.8	6.5	8.3	4.7	5.36	2.25
6	6.9	7.3	6.3	7.2	5.5	5.39	2.33
7	5.8	7.8	8.0	1.8	5.2	5.39	1.17
8	7.3	7.5	5.5	7.3	5.4	5.36	1.01
9	6.6	8.7	7.0	6.2	5.8	5.37	2.24

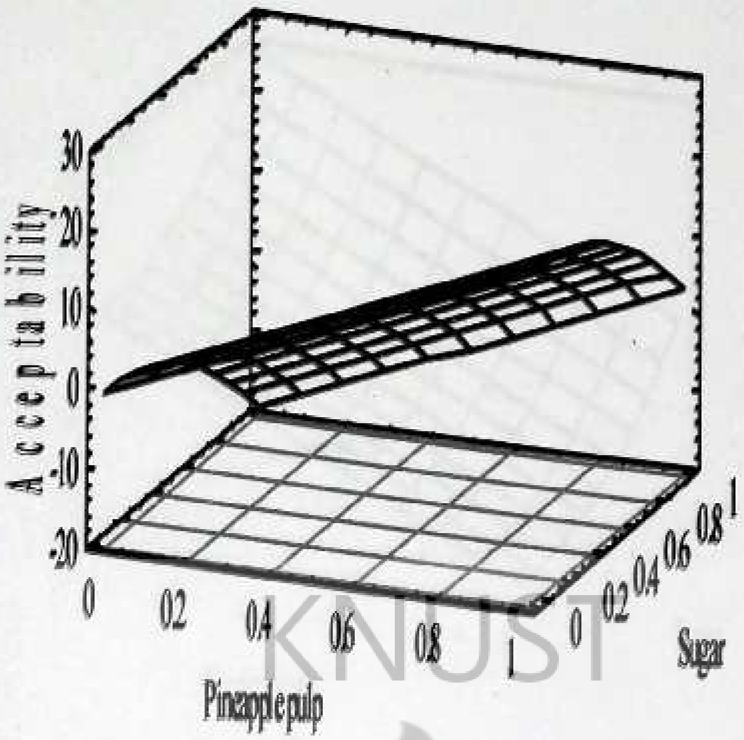

Figure 8.2a: Distribution of the response surface for acceptability of pineapple jam

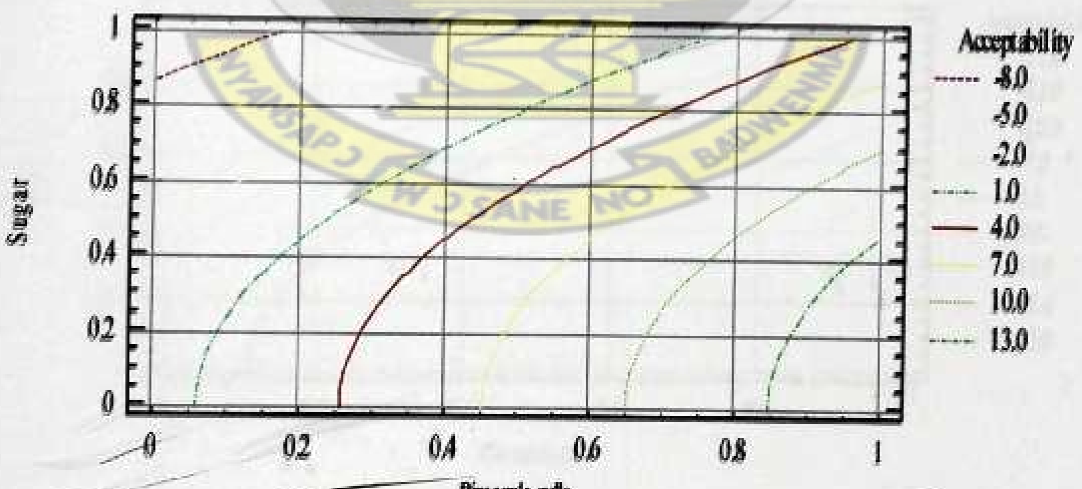

Figure 8.2b: Contour plot at 0 level of cashew gum

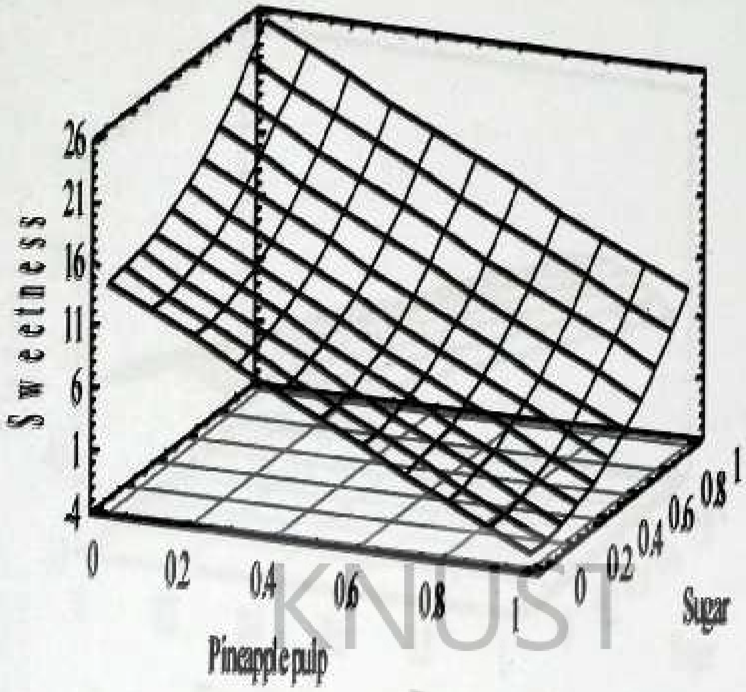

Figure 8.3a: Distribution of the response surface for sweetness of pineapple jam

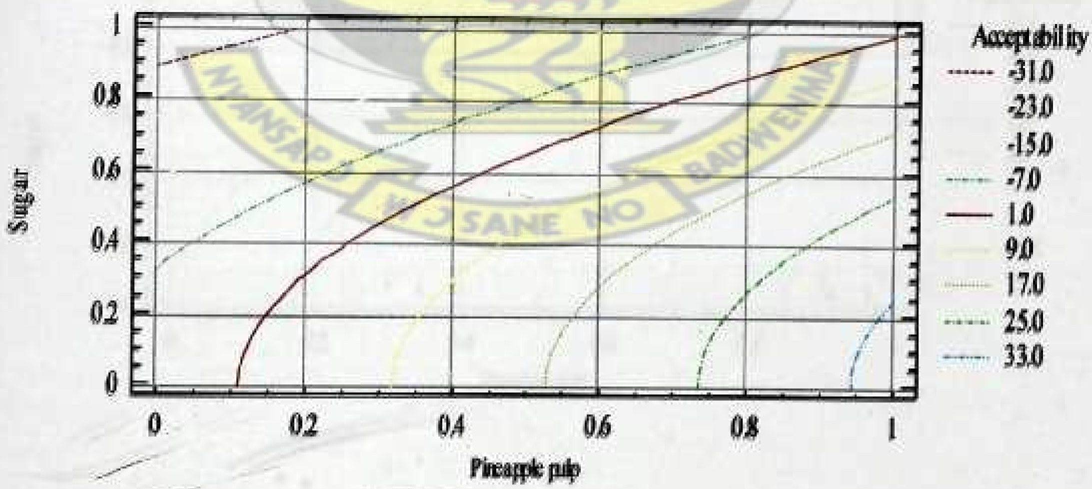

Figure 8.3b: Contour plot at 0.05 level of cashew gum

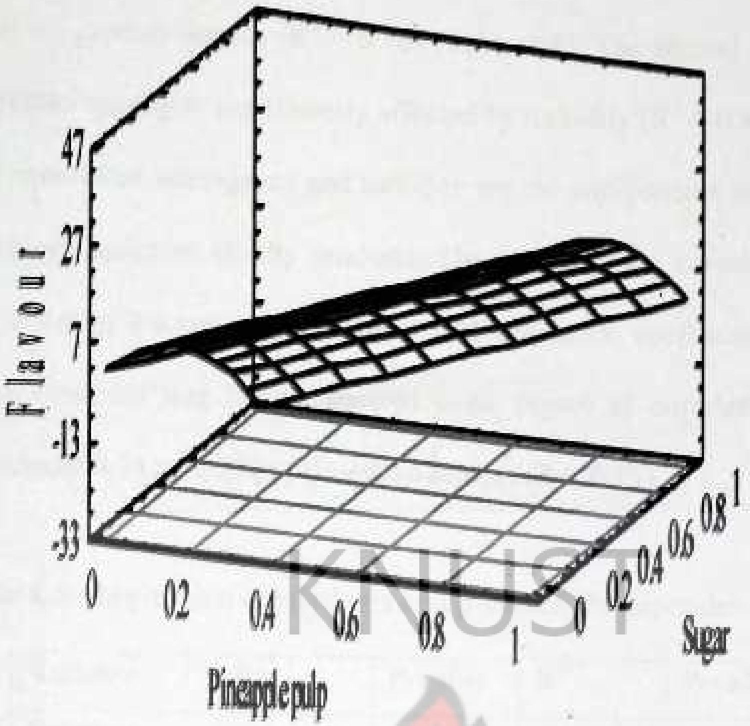

Figure 8.4a: Distribution of the response surface for flavour of pineapple jam

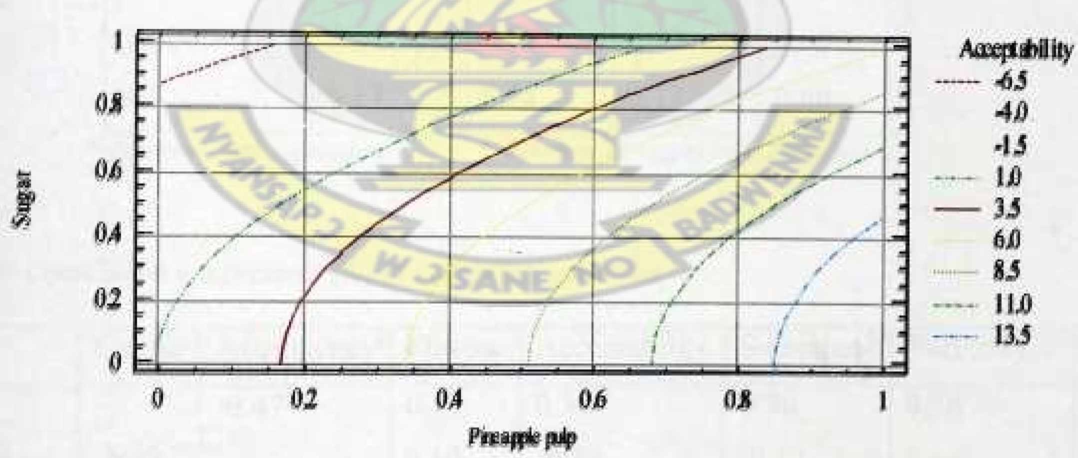

Figure 8.4b: Contour plot at 0.1 level of cashew gum

The results indicated that for both multiple and polynomial regressions, astringency had a significant effect on product quality ($R^2 = 0.70$) (Table 8.8). The second order polynomial also indicated that product quality is significantly affected by turbidity ($R^2 = 0.81$ and 0.82). Thus, for all the variables monitored astringency and turbidity are the components to observe and work on if one has to achieve optimum quality products. The results of the correlation analysis showed that colour had a strong linkage with sweetness with corelation coefficients (R) of 0.76 (Table 8.9). It was also observed that flavour showed some degree of correlation with acceptability having a coefficient of 0.74 as well as pH with sweetness (R = 0.75).

Table 8.8: Regression coefficients and p-values for dependent variables

Variable	R^{2*}	P-value	R^{2**}	P-value
Sensory				
Colour	0.22	0.48	0.30	0.34
Astringency	0.70	0.03	0.70	0.03
Flavour	0.11	0.70	0.33	0.31
Acceptability	0.40	0.21	0.55	0.09
Sweetness	0.09	0.75	0.25	0.48
Physical				
Turbidity	0.81	0.07	0.82	0.005
pH	0.17	0.58	0.13	0.66

*Multiple linear regression **Polynomial regression (2nd order)

Table 8.9: Correlation coefficients (R) of dependent variables

	Colour	Astringency	Flavour	Acceptability	Sweetness	Turbidity	pH
Colour		-0.47	0.17	0.30	0.76	0.56	0.38
Astringency	-0.47		0.19	-0.20	-0.12	0.14	0.25
Flavour	0.17	0.19		0.74	0.32	0.11	0.29
Acceptability	0.30	-0.20	0.74		0.43	0.19	0.48
Sweetness	0.76	-0.12	0.32	0.43		0.51	0.75
Turbidity	0.56	0.14	0.11	0.19	0.51		0.51
pH	0.38	0.25	0.29	0.48	0.75	0.51	

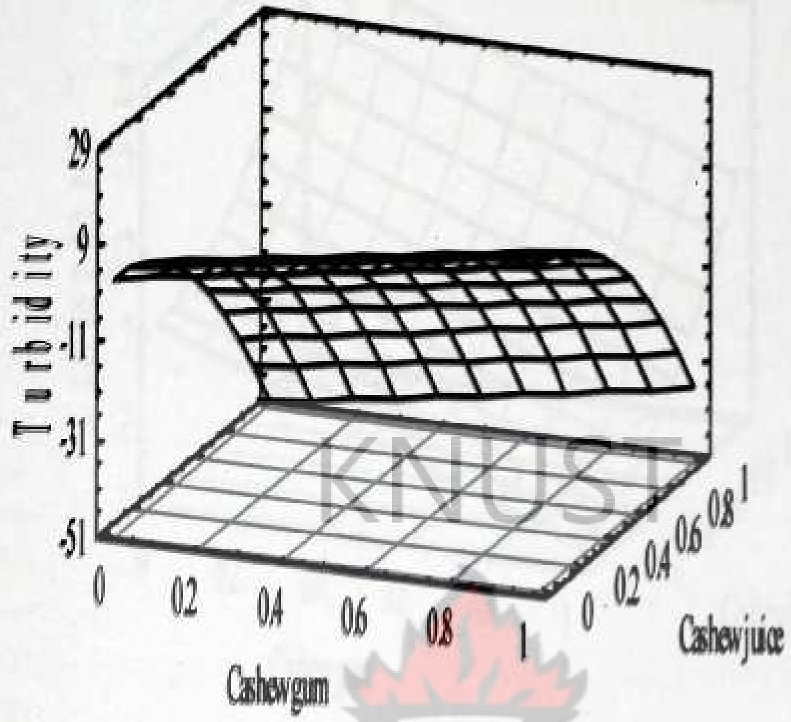

Figure 8.5a: Distribution of the response surface for turbidity of cashew juice

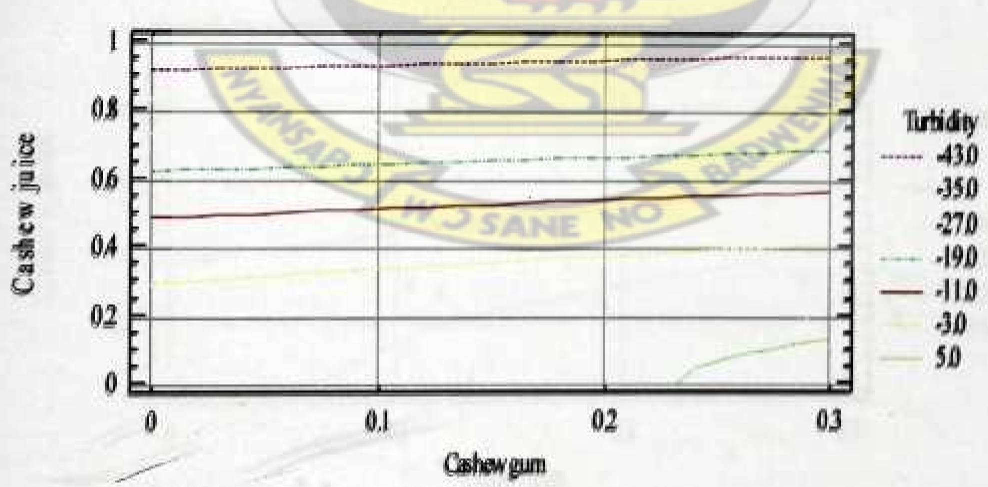

Figure 8.5b: Effect of cashew gum on turbidity

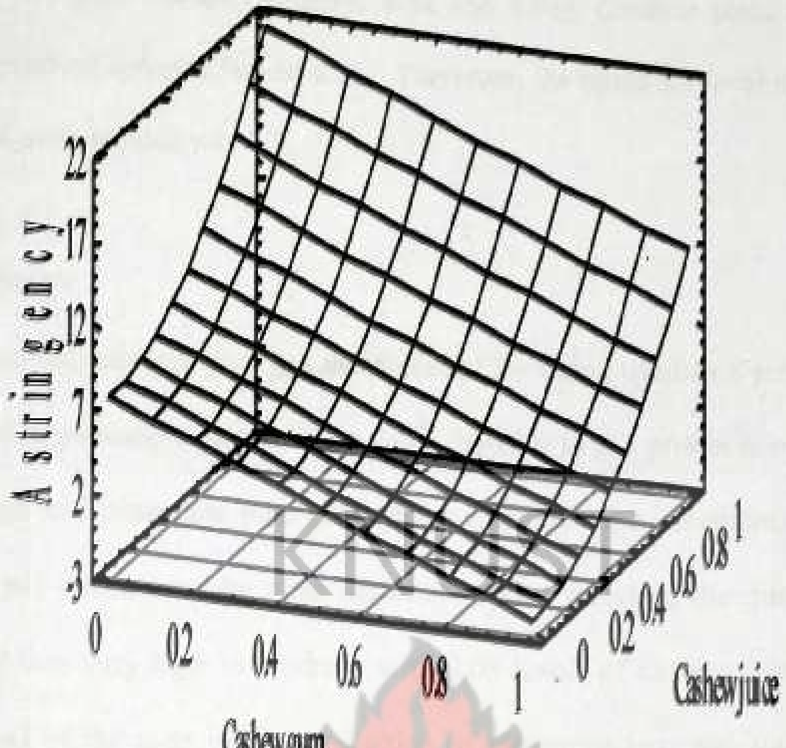

Figure 8.6a: Distribution of the response surface for astringency of cashew juice

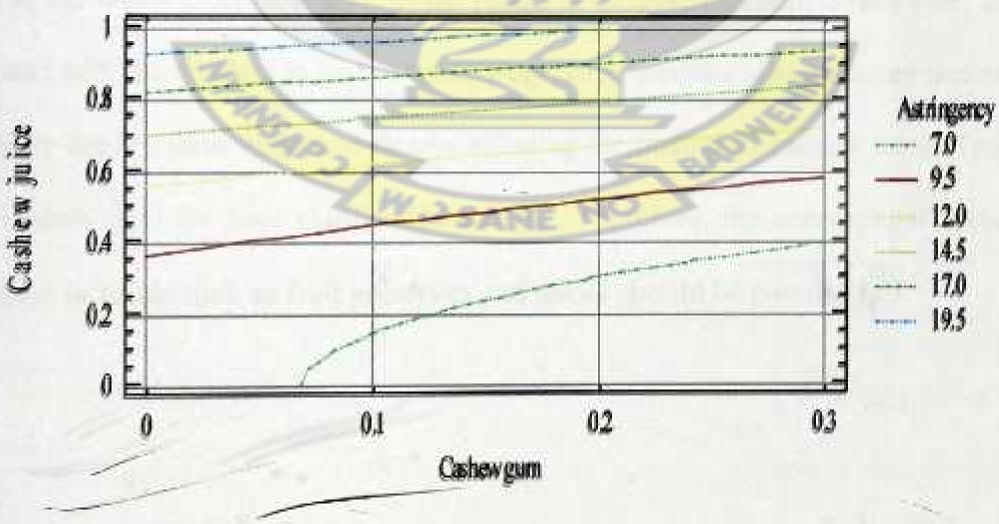

Figure 8.5b: Effect of cashew gum on astringency

The distribution of response surface showed that increasing cashew gum levels reduced astringency and increased turbidity (Figures 8.5a and 8.6a). Contour plots of both attributes showed similar trends (Figures 8.5b and 8.6b). Therefore, the optimum level of cashew gum for the clarificaton of cashew juice was 0.3.

8.5 CONCLUSION

The study showed that cashew gum has the potential for being used as a substitute for pectin in the production of pineapple jam and as a juice clarifier in the production of cashew juice. High cashew gum and pineapple pulp proportions increased the acceptance of the products but reduced the pH which was the most important factor affecting the quality of pineapple jam. Acceptabity was very high in products with 0.05 levels of cashew gum, indicating that the optimum level of the gum in the production of pineapple jam was 0.05. The optimum levels for the other ingredients were found to range from 0.53-0.7 and 0.25-0.42 for pineapple pulp and sugar respectively. Second order polynomials were found to be adequate to predict the responses of flavour, acceptability and pH. Addition of cashew gum to cashew juice caused sedimentation of the juice. Thus, clarifying the juice rather than stabilizing its cloudiness. Increase in the levels of cashew gum in the products increased turbidity. However, astringency was reduced with the increase in cashew gum. Regression analysis also indicated that astringency and turbidity are the most important factors affecting the quality of cashew juice. The optimum level of cashew gum for juice clarification was 0.3. Therefore, the commercial application of cashew gum in foods such as fruit preserves and juices should be encouraged.

CHAPTER 9

UTILIZATION OF CASHEW GUM AS A FAT REPLACER IN BAKED DOUGHNUTS

9.1 ABSTRACT

Awareness of adverse effects of excessive dietary fat intake is virtually universal. Consequently, health conscious individuals are modifying their dietary habits and eating less fat. Cashew gum, a high-molecular-weight polysaccharide produced by the cashew tree has elicited industrial interest in recent years as a high-viscosity gum. This study reports on the utilization of cashew gum as a fat replacer in baked dough nuts. The gum was used at five different levels in the preparation of the products. The levels are 0, 20, 40, 60 and 80% of fat used. The fat content of each product was determined and sensory analysis conducted on the products.in the literature. The fat contents were 16.72, 14.68, 8.10, 8.24 and 5.82% for products with 0, 20, 40, 60 and 80% cashew gum respectively. Results of the sensory analysis showed that decreasing the fat content reduced the flavour, moistness and consumer acceptance of the products. Regression analysis indicated that fat content, flavour and moistness influenced the quality of the dough nuts. However, there was no significant difference between the products. The mean scores for acceptability for products with 0 and 20% cashew gum were 7.4 and 6.5 respectively. On a 9-point hedonic scale, this range varies from "like slightly" to "like moderately". Therefore, it is suggested that cashew gum can replace fat in baked dough nuts up to 20%.

9.2 INTRODUCTION

Dietary fat is a nutrient needed for a healthy life style. However, high fat intake is associated with increased risk for obesity, cancer, high blood cholesterol and coronary heart diseases (AHA, 1996). Dietary fats contribute key sensory and physiological benefits such as flavour, creaminess, palatability, appearance, texture, and increases satiety during meals (Akoh and Swanson, 1994). Much awareness of the adverse effects of excessive fat intake has been created world wide and this has led to the modification of dietary habits by health conscious people by eating less fat (Miller and Groziak, 1996).

According to the Continuing Survey of Food Intakes of Individuals in the United States of America, the average intake of total fat of individuals ranges from about 32 to 34% of total calories (USDA and USDHHS, 1995). The main contributors include butter, margarine, vegetable oils, egg yolks, nuts and baked products. To help consumers moderate their dietary fat intake, advances in food science have allowed for the development of a wide variety of reduced-fat meat, dairy, and packaged food products. Fat replacers are developed to duplicate the taste and texture of fats and these fall into three categories, carbohydrate, protein or fat-based replacers (Bruhn *et al.*, 1992). Each type of fat replacer ingredient provides some or all of the taste and functions of fats such as moistness in baked goods. The ingredients that are used to replace fats depend on how the food product will be eaten or prepared. For example, not all fat replacer ingredients are heat stable. As such, the type of fat replacer used in a fat-free salad dressing may not work well for a muffin mix.

The most important sensory attribute of foods is taste and as much as consumers now want foods with little or no fat, they also want foods with good taste. Foods formulated with fat replacers do not compare favourably in flavour with full-fat containing foods and this makes it difficult for some people to reduce their fat intake primarily (CCC, 1992). It is therefore important to search for an ideal fat replacer that tastes and functions like conventional fat without any adverse health effects. The attempt to maximize the use of cashew gum has necessitated its utilization as a fat replacer in baked doughnuts.

9.3 MATERIALS AND METHODS

9.3.1 Formulation of doughnuts using cashew gum as a fat replacer

a. Experimental design

Cashew gum (x_1) was used to replace part of the fat (x_2) used in baked dough nuts. Five different levels of cashew gum were used (Table 9.1). The sum of the component proportions was 100%. The proportions of x_1 and x_2 were limited to the range of 0-80% and 20-100%, respectively, based on preliminary studies.

9.3.2 Preparation of dough nuts

The recipe used for the formulation is the Alice's doughnut recipe (CDKitchen, 2008) (Table 9.2). The egg was beaten in a large bowl until foamy; sugar was then added gradually with a constant beating. The milk and vanilla were then stirred in the egg slurry. Flour, baking powder, nutmeg and the gum were sifted together and added to the liquid mixture and mixed well. The dough was then rolled out on a slightly floured board to a half inch thickness and cut into small squares. They were then placed on greased baking sheets and baked in a pre-heated oven at 180° C until they were golden brown (CDKitchen, 2008).

9.3.3 *Determination of preference for products*

This was done by presenting 20 panelists with sets of coded samples of doughnuts asking them to rank the samples in order of preference for moistness, hardness, flavour and crispiness. They were then asked to determine their overall acceptability using a 9 - point hedonic scale with 1 = dislike extremely, 5 = neither like nor dislike and 9 = like extremely.

Table 9.1: Alice's doughnut recipe

Ingredient	Proportion
Flour	120 g
Margarine	40 g
Sugar	50 g
Egg	1
Baking powder	1 tsp
Vanilla	1tsp
Nutmeg	1tsp
Milk	2 table spoons

Table 9.2: Levels of cashew gum used in recipe

Product	Fat		Cashew gum	
	(g)	(%)	(g)	(%)
1	40	100	0	0
2	32	80	8	20
3	24	60	16	40
4	16	40	24	60
5	8	20	32	80

9.3.4 Determination of fat content

This was determined Soxhlet extraction method. 2.0 g samples were weighed into thimbles and plugged with cotton wool. These were placed in extraction tubes. Clean, dried soxhlet flasks were weighed and filled over half their volumes with petroleum ether (60°). The extractors were assembled and refluxed for 6 hours. The flasks were then removed into rotary vapourizer for evaporation of the ether, cooled and weighed. The weight of the extracted fat was determined and expressed as a percentage of the weight of the samples.

9.3.5 Statistical analysis

Data obtained for each product was analyzed using Statgraphics Plus program package for analysis of variance and regression.

9.4 RESULTS AND DISCUSSION

Results of the sensory analysis revealed that as fat content decreased, flavour, moistness and acceptability reduced (Table 9.3) confirming the report by Akoh and Swanson (1994) that fats enhance sensory attributes such as flavour, palatability, texture and creaminess. However, increasing cashew gum increased hardness and crispiness of products. This may be due to the absorption of water by carbohydrate-based fat replacers from baked products (IFT, 1998). There was no significant difference between products from one level of cashew gum to the other. Regression analysis of the data showed that both linear and polynomial regressions gave very high coefficients for acceptability, flavour, moistness, hardness and fat content (Table 9.4). They all had a regression coefficient (R^2) above 0.70 indicating that the quality of baked dough nuts depends on flavour, moistness, hardness and fat content.

Table 9.3: Effects of fat content on sensory variables

Product	Fat (%)	Moistness	Hardness	Flavour	Crispiness	Acceptability
1	16.72	7.5	5.7	7.5	6.8	7.4
2	14.68	7.2	5.7	7.2	5.7	6.5
3	8.10	6.7	8.7	6.4	7.2	5.4
4	8.24	5.8	10.7	6.2	8.5	3.9
5	5.82	6.3	10.3	6.5	8.0	4.7

Table 9.4: Regression and correlation coefficients of sensory variables

Variable	R^{2*}	P-value	R^{2**}	P-value
Acceptability	0.82	0.03	0.90	0.10
Crispiness	0.57	0.14	0.60	0.40
Flavour	0.72	0.04	0.90	0.10
Hardness	0.86	0.02	0.87	0.12
Moistness	0.78	0.05	0.83	0.17
%Fat	0.90	0.01	0.93	0.01

*Linear regression **Polynomial regression (2nd order)

Correlation analysis also showed that moistness, flavour and fat content highly correlated positively with acceptability with correlation coefficients (R) of 0.99, 0.96 and 0.89 respectively (Table 9.5). However, crispiness and hardness negatively correlated with acceptability R values of -0.82 and -0.96 respectively. There was a strong and positive correlation between the fat content of the products and moistness (R = 0.85) as well as flavour (R = 0.93) but correlated negatively with crispiness (R = -0.76) and hardness (R = -0.94). Similar trends were observed for the other variables.

Distribution of response surface showed that increasing the level of cashew gum in the product reduced both acceptability and flavour (Figs. 9.1a and 9.2a). A similar trend was observed in the contour plots of both attributes. Since the observed mean scores for overall acceptability of products with 0 and 20% cashew gum were 7.4 and 6.5

respectively, it is therefore suggested that fat may be replaced by cashew gum in baked dough nuts up to 20%.

Table 9.5: Correlation coefficients (R) of dependent variables

	Acceptability	Moistness	Crispiness	Flavour	%Fat	Hardness
Acceptability		0.99	-0.82	0.96	0.89	-0.96
Moistness	0.99		-0.86	0.93	0.85	-0.96
Crispiness	-0.82	-0.86		-0.77	-0.76	0.92
Hardness	-0.96	-0.96	0.92	-0.94	-0.94	
Flavour	0.96	0.93	-0.77		0.93	-0.94
%Fat	0.89	0.85	-0.76	0.93		-0.94

9.5 CONCLUSION

Addition of cashew gum to baked dough nuts reduced acceptability, moistness and flavour of the products but increased hardness and crispiness. The most important factors influencing product quality were found to be fat content, flavour, moistness and hardness. Both linear and second order polynomial regressions were found to be adequate to predict the responses of flavour, acceptability, moistness and hardness. However, the products were not significantly different from each other and it is suggested that fat of baked dough nuts may be replaced with up to 20% cashew gum.

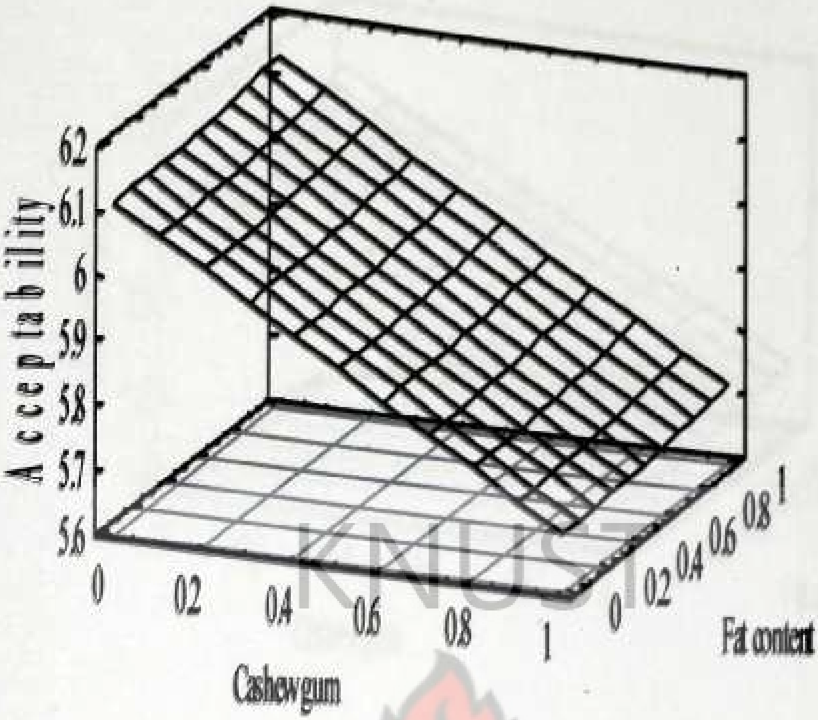

Figure 9.1a: Distribution of the response surface for acceptability of doughnuts

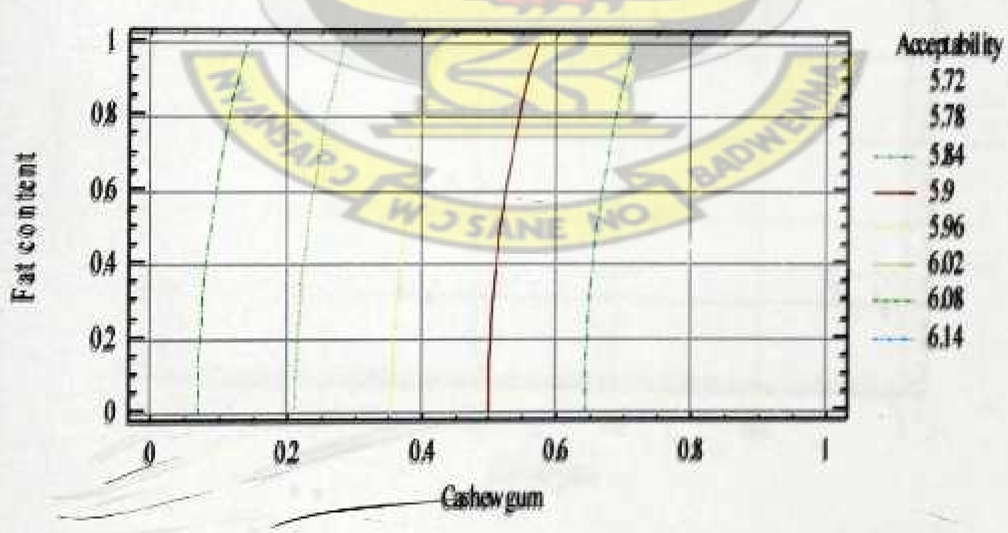

Figure 9.2b: Effect of cashew gum on acceptability of doughnuts

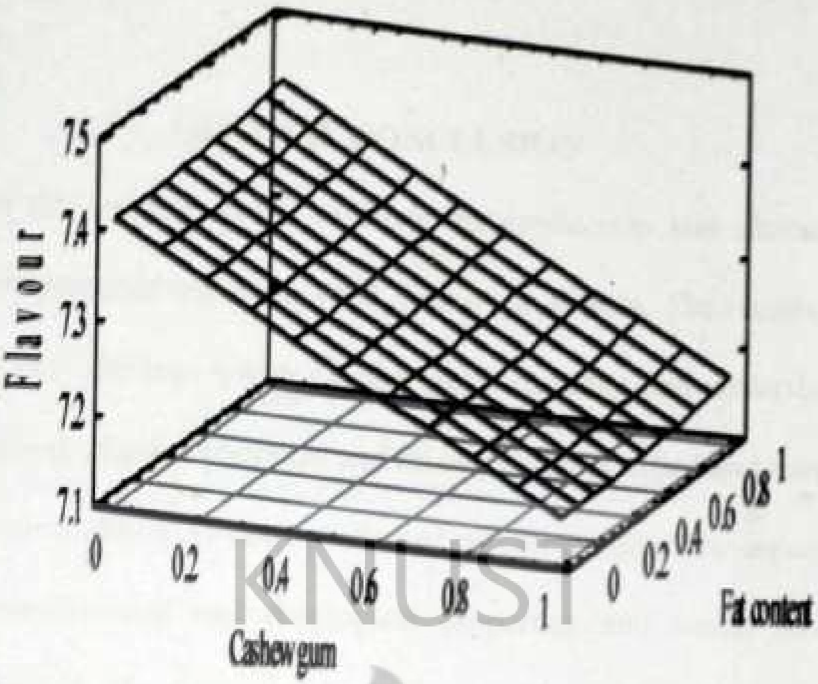

Figure 9.2a: Distribution of the response surface for flavour of doughnuts

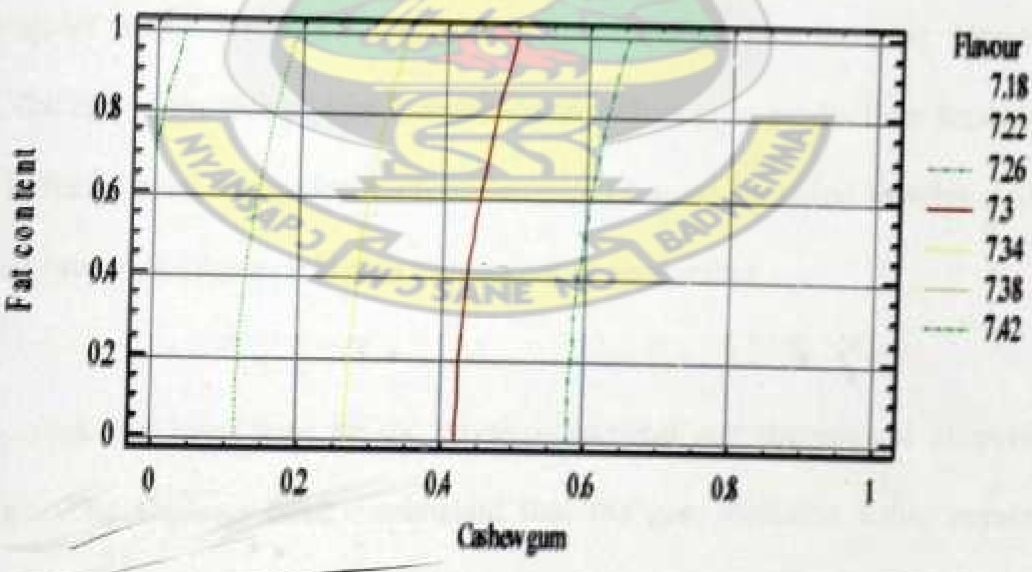

Figure 9.2b: Effect of cashew gum on flavour of doughnuts

CHAPTER 10

GENERAL CONCLUSION

The major aim of this project was to evaluate the production and characterization of cashew gum and its potential use in the food industry in Ghana. The results presented in this thesis contain new findings which expand our knowledge and understanding of the agricultural production, physico-chemical and rheological properties and usage of cashew gum. Although some studies have been conducted on cashew gum, the aspects relating to production, physico-chemical and rheological properties and usage have not been extensively investigated. The results of the study provide useful information to cashew farmers, food scientists, food processors, nutritionists and consumers as a whole.

Although it is known that the cashew tree produces an appreciable amount of gum, the findings of this study has shown that much of it is produced during the dry season when the tree is under stress. Trees as young as four years can produce the gum. However in this study, the age of the tree and its location do not affect gum production. Cashew gum conforms to the general organoleptic characteristics of gums by being tasteless, whitish, yellowish or brown in colour. It is also translucent in appearance.

Very little work has been done on the physico-chemical and rheological properties of cashew gum. The findings have established that the gum contains some appreciable amount of proteins and high quantities of calcium, potassium, sodium, iron and zinc, making it nutritious and a rich source of minerals. Therefore, it can be used in promoting good health by incorporating it into diets. Cashew gum has high viscosity compared to gum Arabic and gels at a very high concentration. However, the viscosity reduces when heated. Storage also reduces its quality by an average of 5.5% with respect to viscosity.

Due to the limited supply and consequent sharp increase in cost of traditional hydrocolloids, cheaper alternatives such as naturally occurring gums like the cashew tree gum has become very important. It has been shown from this work that cashew gum can be used as a substitute to gum Arabic in the production of chocolate pebbles as a film-former. It can also be used as a substitute to pectin in the production of pineapple jams, clarifying agent in the production of cashew juice and as a fat replacer in baked dough nuts. The information on gum production is important to farmers and producers of the gum and the information generated on the characterization and end uses of the cashew gum will help food scientists and technologists on the behaviour and potential areas of application of the cashew gum.

These findings are consistent with results from previous studies on other gums. Fitwi (2000) reported that drought; a condition which puts trees under stress stimulates gum production in acacia trees. Best quality gums have been reported by Robbins (1988) to be generally tasteless, whitish, yellowish or pale brown in colour and transparent or translucent in appearance. Results from a study on rheological properties of cashew gum and gum Arabic by Mothe and Rao (1999) revealed that viscosities of gum increased with concentration. However, an increase in temperature reduces the viscosity of food hydrocolloids (Diego and Navaza 2003). Whistler and BeMiller (1993) also observed that gums will show a decrease in viscosity after 6 months storage. A study on the acute toxicity of gum Arabic revealed that groups of rats fed with gum Arabic in their diet for 6 days showed normal weight gain and food efficiency (FAO, 1995).

Recommendations for further investigation

It is being recommended that because the production and utilization of cashew gum has a higher potential as an industry, more studies be carried out on the impact of agronomic practices on the increase in yield of gum production and also to investigate the expanded uses of the gum in other food products.

Publications

Portions of this work have been published in refereed journals. These are listed below:

1. Gyedu-Akoto E., Oduro I., Amoah F.M., Oldham J.H., Ellis W.O. and Opoku-Ameyaw K. (2007). Rheological properties of aqueous cashew tree gum solutions, *Scientific Research and Essay*, vol. 2(10), pp.458-461.
2. Gyedu-Akoto E., Oduro I., Amoah F.M., Oldham J.H., Ellis W.O., Opoku-Ameyaw K. and Hakeem B. R., (2007). Locational and maturity effects on cashew tree gum production in Ghana, *Scientific Research and Essay*, vol. 2(11), pp.499-501.
3. Gyedu-Akoto E., Oduro I., Amoah F.M., Oldham J.H., Ellis W.O., Opoku-Ameyaw K., F. Asante and S. Bediako, (2008). Quality estimation of cashew gum and Its utilization in the production of chocolate pebbles, *African Journal of Food Science*, vol. 6, pp.016-020.

4. Gyedu-Akoto E., Oduro I., Amoah F.M., Oldham J.H., Ellis W.O., Opoku-Ameyaw K. and Hakeem B. R., (2008). Physico-chemical properties of cashew gum, *African Journal of Food Science*. vol. 2(5), pp.060-064

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APPENDIX

Appendix 1

Appendix 1.1: Rainfall pattern for Wenchi and Bole from January – December 2006

Month	Rainfall (mm)		
	Wenchi	Bole	Wa
January	9.4	3.9	35.9
February	42.0	15.4	13.8
March	86.1	23.5	78.0
April	139.5	170.7	50.3
May	174.1	156.2	41.0
June	119.7	121.3	143.3
July	50.7	178.9	100.9
August	47.7	176.8	304.7
September	170.5	134.6	219.7
October	299.7	134.9	33.4
November	-	1.1	-
December	-	-	-

Appendix 1.2: Mineral content of cashew gum

Mineral (mg/kg)	Sampa		Wenchi		Bole		Jirapa	
	Young	Mature	Young	Mature	Young	Mature	Young	Mature
Ca	1152	1755	1012	1358	1269	1471	1405	1750
K	139	386	295	386	275	554	908	1397
Na	114	152	160	180	186	301	255	293
Fe	258	313	264	398	294	368	263	301
Zn	7.8	31.5	12.8	12.8	19.8	35.5	6.3	7.8

Appendix 1.3: Mean values of physico-chemical parameters of cashew gum

Parameter	Sampa		Wenchi		Bole		Jirapa	
	Young	Mature	Young	Mature	Young	Mature	Young	Mature
Phenol(%)	0.21 *0.002*	0.50 *0.008*	0.29 *0.001*	0.51 *0.04*	0.35 *0.001*	1.35 *0.03*	0.34 *0.01*	2.26 *0.02*
MC (%)	11.8 *0.29*	12.0 *0.00*	11.2 *0.27*	13.2 *0.29*	9.8 *0.76*	11.3 *0.29*	11.5 *0.02*	12.5 *0.00*
IM (%)	3.1 *0.56*	1.9 *0.42*	2.8 *0.57*	3.8 *0.20*	2.0 *0.28*	4.8 *0.28*	2.4 *0.42*	2.2 *0.28*
Sug(mg/g)	2.10 *0.30*	0.89 *0.29*	1.20 *0.37*	1.37 *0.27*	0.96 *0.30*	0.85 *0.30*	1.64 *0.10*	1.36 *0.16*
pH	4.1 *0.00*	3.9 *0.01*	4.2 *0.00*	3.8 *0.01*	4.1 *0.01*	3.8 *0.01*	4.0 *0.01*	3.8 *0.00*
Ash (%)	1.0 *0.00*	1.0 *0.00*	1.0 *0.00*	0.5 *0.00*	1.0 *0.00*	0.8 *0.29*	1.0 *0.00*	1.2 *0.29*
Protein(%)	1.56 *0.10*	1.35 *0.00*	1.40 *0.04*	1.41 *0.01*	1.80 *0.28*	1.27 *0.01*	1.58 *0.20*	1.38 *0.39*

*Std dev. in italics

Appendix 2: ANOVA tables for physico-chemical parameters

Variate: pH

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
age	1	0.3844000	0.3844000	1337.04	<.001
district	3	0.1753250	0.0584417	203.28	<.001
age.district	3	0.5059500	0.1686500	586.61	<.001
Residual	8	0.0023000	0.0002875		
Total	15	1.0679750			

Variate: Insoluble matter

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
age	1	0.6400	0.6400	1.86	0.210
district	3	2.3500	0.7833	2.27	0.157
age.district	3	10.6400	3.5467	10.28	0.004
Residual	8	2.7600	0.3450		
Total	15	16.3900			

Variate: Phenolics

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
age	1	0.2668	0.2668	0.93	0.364
district	3	0.6119	0.2040	0.71	0.574
age.district	3	1.5992	0.5331	1.85	0.216
Residual	8	2.3042	0.2880		
Total	15	4.7821			

Variate: Sugar

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
age	1	0.2668	0.2668	0.93	0.364
district	3	0.6119	0.2040	0.71	0.574
age.district	3	1.5992	0.5331	1.85	0.216
Residual	8	2.3042	0.2880		
Total	15	4.7821			

Variate: Moisture content

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
age	1	15.0417	15.0417	46.58	<.001
district	3	11.9167	3.9722	12.30	<.001
age.district	3	0.2083	0.0694	0.22	0.885
Residual	16	5.1667	0.3229		
Total	23	32.3333			

Variate: Ash content

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
age	1	0.16667	0.16667	5.33	0.035
district	3	0.54167	0.18056	5.78	0.007
age.district	3	0.25000	0.08333	2.67	0.083
Residual	16	0.50000	0.03125		
Total	23	1.45833			

Variate: Protein content

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
age	1	0.91260	0.91260	12.82	0.003
district	3	0.33240	0.11080	1.56	0.239
age.district	3	0.24033	0.08011	1.13	0.368
Residual	16	1.13900	0.07119		
Total	23	2.62433			

Appendix 3

Appendix 3.1: Viscosity measurements for temperature and concentration

Conc. (%)	Viscosity (cPs)		Conc. (%)	Viscosity (cPs)	
	Sampa			Bole	
	25° C	70° C		25° C	70° C
1.0	12.6	8.44	1.0	12.8	8.2
2.5	12.8	7.91	2.5	13.7	9.9
5.0	15.8	11.0	5.0	15.3	10.6
10	20.7	14.3	10	20.2	13.1
Mean	15.48	10.41	Mean	15.50	10.45
Std error	1.89	1.46	Std error	1.65	1.02

Conc. (%)	Viscosity (cPs)		Conc. (%)	Viscosity (cPs)	
	Jirapa			Wenchi	
	25° C	70° C		25° C	70° C
1.0	11.3	7.73	1.0	12.0	9.04
2.5	12.5	9.6	2.5	12.4	9.68
5.0	14.1	11.0	5.0	15.9	9.75
10	18.8	12.4	10	23.3	13.7
Mean	14.18	10.18	Mean	15.90	10.54
Std error	1.64	1.00	Std error	2.62	1.06

Appendix 3.2: Viscosity measurements for maturity and concentration

Conc. (%)	Viscosity (cPs)		Conc. (%)	Viscosity (cPs)	
	Sampa			Jirapa	
	Young	Mature		Young	Mature
1.0	11.9	10.6	1.0	11.3	10.1
2.5	12.3	12.2	2.5	12.6	12.2
5.0	14.3	15.3	5.0	14.6	13.5
Mean	12.83	12.70	Mean	12.83	11.93
Std error	0.74	1.37	Std error	0.96	0.99

Conc. (%)	Viscosity (cPs)		Conc. (%)	Viscosity (cPs)	
	Bole			Wenchi	
	Young	Mature		Young	Mature
1.0	11.3	12.4	1.0	11.6	11.6
2.5	13.6	13.4	2.5	12.5	12.1
5.0	14.2	14.6	5.0	15.5	15.2
Mean	13.03	13.47	Mean	13.20	13.00
Std error	0.88	0.64	Std error	1.18	1.13

Appendix 3.3: Viscosity measurements for storage time and concentration

Conc. (%)	Viscosity (cPs)			Conc. (%)	Viscosity (cPs)		
	Sampa				Jirapa		
	0 mth	6 mths	12 mths		0 mth	6 mths	12 mths
1.0	12.6	10.6	11.6	1.0	11.3	10.1	10.2
2.5	12.8	12.2	12.4	2.5	12.5	12.2	12.2
5.0	15.8	15.3	15.4	5.0	14.1	13.5	13.6
Mean	13.73	12.7	13.13	Mean	12.63	11.93	12.00
Std error	1.03	1.38	1.16	Std error	0.81	0.99	0.99

Conc. (%)	Viscosity (cPs)			Conc. (%)	Viscosity (cPs)		
	Wenchi				Bole		
	0 mth	6 mths	12 mths		0 mth	6 mths	12 mths
1.0	12.0	11.6	11.3	1.0	12.8	12.4	12.1
2.5	12.4	12.1	12.2	2.5	13.7	13.4	13.5
5.0	15.9	15.2	15.5	5.0	15.3	14.6	13.2
Mean	13.43	12.97	13.00	Mean	13.93	13.47	12.93
Std error	1.24	1.13	1.28	Std error	0.73	0.64	0.43

Appendix 3.4: Viscosity measurements for period of production and concentration

Conc. (%)	Viscosity (cPs)		Conc. (%)	Viscosity (cPs)	
Wenchi				Bole	
	Rainy season	Dry Season		Rainy season	Dry Season
1.0	11.3	12.0	1.0	12.2	12.8
5.0	13.5	15.9	5.0	14.0	15.3
10.0	23.1	23.3	10.0	17.3	20.2
Mean	13.13	16.37	Mean	14.1	16.5
Std error	1.41	2.36	Std error	1.49	2.17

Conc. (%)	Viscosity (cPs)		Conc. (%)	Viscosity (cPs)	
	Sampa			Jirapa	
	Rainy season	Dry Season		Rainy season	Dry Season
1.0	11.3	12.6	1.0	11.9	11.3
5.0	12.2	15.8	5.0	12.8	14.1
10.0	15.9	20.7	10.0	13.0	18.8
Mean	12.57	14.73	Mean	15.97	17.07
Std error	0.34	2.19	Std error	3.62	3.31

Appendix 4: ANOVA tables for viscosity measurements

Variate: Viscosity (age and location)

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
age	1	20.8507	20.8507	29.33	<.001
dist	3	1.7939	0.5980	0.84	0.491
age.dist	3	0.9349	0.3116	0.44	0.729
Residual	16	11.3756	0.7110		
Total	23	34.9551			

Variate: Viscosity (Period of production)

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
period	1	0.907	0.907	0.30	0.593
Residual	10	29.782	2.978		
Total	11	30.689			

Variate: Viscosity (Storage)

Source of var.	d.f.	s.s.	m.s.	v.r.	F pr.
storage time	2	1.412	0.706	0.22	0.809
Residual	9	29.277	3.253		
Total	11	30.689			

Appendix 5

DIFFERENCE TEST FOR CHOCOLATE PEBBLES

NAME.. DATE.......................

Two of each group of samples presented to you, are identical. The third is different. Look at the samples, then taste and identify the odd sample based on each of the sensory attribute given.

Set	Hardness	Flavour	Smoothness
A	....	....	....
B	....	....	....
C	....	....	....

ACCEPTABILITY TEST

Code	Like extremely			Like/dislike			Dislike		
....	9	8	7	6	5	4	3	2	1
....	9	8	7	6	5	4	3	2	1
....	9	8	7	6	5	4	3	2	1

RANKING TEST FOR PINEAAPLE JAM AND CASHEW JUICE

NAME.. **DATE**.......................

Please evaluate the coded samples from left to right. Identify the attributes below and rank their intensity in order of preference on each line at the appropriate position.

COLOUR Light--Dark
0 15

SWEETNESS Absent--Strong
0 15

FLAVOUR Absent--Strong
0 15

CONSISTENCY Thin--Gummy
0 15

ASTRINGENCY Absent--Strong

RANKING TEST FOR BAKED DOUGHNUTS

NAME.. DATE.........................

Please evaluate the coded samples from left to right. Identify the attributes below and rank their intensity in order of preference on each line at the appropriate position.

MOISTNESS Dry---Oily
1 15

HARDNESS Soft---Hard
1 15

FLAVOUR Absent---Strong
1 15

CRISPINESS Battery---Brittle
0 15

ACCEPTABILITY TEST

Code	Like extremely			Like/dislike			Dislike		
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1
……….	9	8	7	6	5	4	3	2	1

Appendix 6

Plate 1: Gum collected from a pruned cashew tree

Plate 2: Afarmer harvesting cashew gum

Plate 3: Gum oozing from a branch of a cashew tree

Plate 4: Gum oozing fron a crack on a cashew tree