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POSTHARVEST QUALITY ISSUES IN THE LOCAL MARKETING OF SEMI- PROCESSED MANGOES: A CASE STUDY OF THREE SUB-METROS IN GREATER ACCRA.

BY

EVELYN AMPOMAH- NKANSAH

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY (MPHIL. POSTHARVEST TECHNOLOGY) DEGREE

JUNE, 2015

DECLARATION

I hereby declare that, except for specific references which have been duly acknowledged, this project is the result of my own research and it has not been submitted either in part or whole for any other degree elsewhere.

Signature……..... .....……
EVELYN AMPOMAH- NKANSAH Date
(Student)

Signature…….. .....……
MR. PATRICK KUMAH Date
(Supervisor)

Signature…….. .....……
DR. FRANCIS APPIAH Date
(Head of Department)

DEDICATION

This project is dedicated to my husband, Mr. Anthony Augustus Mainoo; my sons, Nelson Osei Mainoo and Joseph Nyantakyi Mainoo; my daughters, Caroline Abena Korkor Mainoo and Adwoa Aniwaa Owusu-Boakye; my sister Philomina Ampomah-Nkansah and more especially my mother, Ms. Grace Ankomah for their inspiration, love, support and encouragement.

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ABSTRACTS

Fresh fruits promote good health but are highly perishable and affected by different microbial contaminates from production up to consumption. A study was conducted to investigate the postharvest quality issues in the local marketing of semi processed mangoes: A case study of the Accra Municipality. Field survey was conducted in three towns including La-Dadekotopon, Ledzokuku Krowor and Accra Metro. Interviews together with semi-structured questionnaires were used in data collection from consumers and processors of mango fruits who were randomly selected from each location. One hundred and fifty consumers; and Ninety processors were interviewed from the towns. Food quality assessment was also conducted to assess the quality of the fruit at the Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR), near Legon, Accra between May to September, 2014. Fresh cut mango fruits from different processor types were selected for the quality assessment study. The study showed that consumers purchased fruits from wayside/hawkers (51%) and from local fruit stores and supermarkets (49%). Quality traits consumers consider when purchasing fruits include softness, colour, aroma, sweetness, and type of mango fruits; with sweetness and softness (71.3%) being the most preferred traits consumers consider. Some of the barriers to the purchase of fresh cut mango fruits according to consumers include price (45.3%), difficulty in choosing a ripe mango fruit (11.4%), degree of blemish or defect (27.3%) and packaging and presentation (16.0%). Poor handling of fresh cut fruits (37.1%), bacteria (31.9%), fungi (17.6%) and the use of contaminated packaging material and knife (13.4%) were the cause of infections on fresh cut mango fruits. Keit (81.0%), Kent (18.0%), Palma and Jafna (1.0%) were the mango types processors from the three different locations processed. Keit was the most preferred mango for processing followed by Kent, Palma and Jafna. Keit was common and liked my consumers. It was revealed that processors are more likely to purchase fruits that are fully ripped for processing into fresh cuts. Some of the activities fresh mango fruits are taken through before processing included washing of

fruits with water (85.5%), washing of hands (46.7%), washing with salt water (7.8%) and the cleaning of the processing tools (31.1%). Processing procedure for fresh cut mangoes included washing of hands (53.3%), cleaning of tools (48.9%), peeling of fruits (55.6%), cutting peeled fruits into smaller sizes (56.7%) and packaging of the fresh cut fruits into containers (42.2%). Processors reported that decay/rot (27.8%), cracks (26.7%), sand burns (5.6%), and bruises (36.7%) as defects on fruits purchased for processing. Insect bites (26.7), moulds (0.0%), and spots (71.1%) also affect the quality of fruits purchased. Causes of fresh cut fruits wastage included high price of mango fruits (31.1%), poor storage conditions (51.1%), low selling rate (45.6%) and low quality of fruits (14.4%) from source of production. Some measures were, however, taken by processors to reduce wastage. Fresh cut mango fruits that were already processed but hawked (A), on demand cut (D) and restaurant processed (R) at two different sales periods i.e. immediate cut and after 6 hours taken from La-Dadekotopon , Ledzokuku Krowor and Accra Metro were used. The mean values for APC, Moulds, Yeast and *E. coli* at the different processors and sale periods were not significant ($P>0.05$). There was however, significant difference ($P<0.05$) in TCC with D ($7.455x10^2$cfu/g) being significantly higher than R ($2.085x10^2$cfu/g) and A ($4.375x10^2$cfu/g). There was no significant difference in TSS content, however, the change in TSS generally showed an ascending trend as the sale periods delayed, i.e., from 4.38^{o}Brix in the immediate cut to 5.11^{o}Brix in the after 6 hours of cut. Titratable acidity (% citric acid) levels in the fruits from the 3 processing types (P) were significantly different ($P<0.05$). Mango fruits from R had a higher mean acidity (0.562% citric acid) than fruits from the other processors. A had the least mean acidity (0.443%). Market conditions that favor contamination from poor hygiene of the venders, using microbial unsafe containers, poor handling practice and poor environmental conditions such as sanitarily unsafe marketing environment were identified.

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LIST OF ABBREVIATIONS

ANOVA	Analyusis of Variance
CA	Controlled Atmosphere
CMC	Carboxymethyl cellulose
CPIMS	Centre for the Promotion of Imports from Developing Country Markets
CRD	Complete Randomized Design
CSIR	Council for Scientific and Industrial Research
DHAA	Dehydro Ascorbic Acid
EU	European Union
FAGE	Federation of Association of Ghanaian Exporters
FAO	Food and Agriculture Organization
FDA	Food and Drugs Authority
FRI	Food Research Institute
GABA	Gama-Aminobutyric Acid
GEPC	Ghana Export Promotion Council
GFPED	Ghana Fresh Produce Exporters' Directory
GNA	Ghana News Agency
IR	Infra-red
MAP	Modified Atmosphere Packaging
MCP	1-methylcyclopropene
NGOs	Non Governmental Organisations
PCA	Plate Count Agar
PET	Polyethylene terephthalate
RAA	Reduced Ascorbic Acid

SADoH	South Africa Department of Health
SCF	Scientific Committeeon Food
MoH	Ministry of Health
SHG's	Self Help Groups
SPS	Sterile Salt Pepton Solution
SPSS	Statistical Package for the Social Scientist
TAA	Total Ascorbic Acid
TSA	Tryptone Soya Agar
UAE	United Arab Emirates
UK	United Kingdoms
UNSSCN	United Nation System Standing Committee on Nutrition
UV	Ultra violet
VRBA	Violet Red Bile Agar

CHAPTER ONE

1.0 INTRODUCTION

According to FAO (1980), the loss of foods in the postharvest system is not new since it has always been a problem for humankind. The recent rapid increasing populations in the poorest countries in which there is already food scarcity requires ways and means to conserve mankind's food supply in order to alleviate hunger and malnutrition (Saeed, 2012). Estimates of production losses in developing countries are hard to tell, but some put losses as high as 50 percent, or half of what is grown (FAO, 1980).

Mango is one of the most highly esteemed fruits of the tropics. After bananas, mangoes are the most important fruits grown in the tropical areas around the world (CPIMS, 2008; Eurostat, 2008). Over the last 10-15 years, there has been widespread interest in the cultivation of the crop not only by development agencies under various environmental protection and poverty reduction programmes, but also by private individuals and companies for export (GFPED, 2007). Mango is one of the country‘s largest fresh produce exported to the EU (GEPC, 2008). Despite this, Ghana‘s mango industry is still in an infant stage. Its productivity and exports are low. It contributed about 0.3% of total agricultural exports in 2009. The Centre for the Promotion of Imports from Developing Countries Market Survey (CPIMS, 2008) reported that the mango fruit is one of the most highly esteemed fruits of the tropics. The importance of mango to many Ghanaians is epitomized in the description for the crop as Golden tree, next cash crop, gold mine, Ghana‘s future, amongst others (Avah *et al*., 2008).

Much need to be studied to determine the best treatments for fresh-cut mangos to ensure maximum shelf life and a tasty product (Kader, 2008). Kareth *et.al.*,(2013) studied postharvest handling practices and knowledge of stakeholders involved in the fruit sub sector in Tanzania and reported that the handling practices were not good enough to prevent the losses. Ofor *et al*., (2009) and SCF (2002) noted that to keep the number of microorganisms as low as possible there is the need to keep clean environment together with washing fruits with potable water and cleaning of the fruits to reduce surface contamination. The longer time fruits take in the market, the higher change in texture, aroma, flavour, spoilage and softening (Yahia, 2006). In another study, Turan (2008) points out that improper harvest and postharvest practices result in losses due to spoiling of the product before reaching the market, as well as quality losses such as deterioration in appearance, taste and nutritional value.

The consumption of large quantities of fruits and vegetables in a diet protects against various health problems such as coronary heart disease (Rapley and Coulson, 2005), stroke (Bradley and Shinton, 1998) as well as some forms of cancer (Rapley and Coulson, 2005; Weisburger, 1991).The increasing public concerns about food safety issues and increasing awareness of environmental quality issues have led to an expanding demand for quality products (Rimal and Moon, 2005). As a result national Governments are concerned about diet and health, and there has been renewed recognition of the role of public policy in promoting healthy diets, thus to provide healthier, safer and more confident citizens (Pool and Martinez-Carrasco, 2007). In fact, nutrition transition towards

unhealthy diets, which is occurring at a faster rate in developing countries than was the case for developed countries, is a global problem (Fraser, 2005) which must be addressed.

The outcome of the study would benefit Government and NGOs in their policy making towards local processing of mango and consumption. In Ghana, the Ministry of Health (MoH) is advocating for consumption of more fruits but these products as already indicated could have health implications, due to the poor processing methods applied by street vendors.

The main objective of this work was, therefore, to evaluate the local marketing of fresh-cut mangoes and determine the postharvest quality issues associated with it.

The specific objectives of this study, therefore, were to determine the:

- state of marketing of value added mangoes on the fresh market;
- perception and level of knowledge of consumers on the postharvest quality issues;
- effect of mode of handling and processing on the quality of freshly cut mangoes; and
- level of microbial loads, chemical changes and level of contaminations in fresh cuts mangoes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 NUTRITIONAL IMPORTANCE, HEALTH BENEFITS AND DIFFERENT USES OF MANGO FRUITS

Mango fruit is rich in pre-biotic dietary fiber, vitamins, minerals, and poly-phenolic flavonoid antioxidant compounds (Van Camp *et al.*, 2009). According to new research study, mango fruit has been found to protect against colon, breast, leukemia and prostate cancers (Van Camp *et al.,* 2009). Several trial studies suggest that *polyphenolic anti-oxidant* compounds in mango are known to offer protection against breast and colon cancers (www.nutrition-and-you.com). Mangoes are extremely nutritious and contain carbohydrates, proteins, fats, minerals, vitamins: vitamin A (beta carotene), B1, B2, and vitamin C (ascorbic acid) (Bally, 2006).

Mango fruit is an excellent source of vitamin-A and flavonoids like *beta-carotene, alpha-carotene,* and *beta-cryptoxanthin*. 100 g of fresh fruit provides 765 IU or 25% of recommended daily levels of vitamin-A. Together; these compounds have been known to have antioxidant properties and are essential for vision (Van Camp *et al.*, 2009). Vitamin A is also required for maintaining healthy mucus membranes and skin (www.nutrition-and-you.com). Consumption of natural fruits rich in carotenes is known to protect the body from lung and oral cavity cancers (Bally, 2006). Fresh mango is a good source of potassium. 100 g fruit provides 156 mg of potassium and 2 mg of sodium. Potassium is an important component of cell and body fluids that helps controlling heart rate and blood pressure. These nutrients no doubt play a crucial role in human nutrition thus the

health of the individual. For instance, deficiency in vitamin A can lead to reversible night blindness and keratinization of normal mucous tissue of the eye, lungs skin and other ectodermic tissues. Lack of vitamin B1 can cause beriberi (oedema and heart hypertrophy) (www.nutrition-and-you.com).

Again deficiency in vitamin C which is a vitamin for humans and primates results in scurvy (Van Camp *et al.*, 2009). It is also a very good source of vitamin-B6 (pyridoxine), vitamin-C and vitamin-E. Consumption of foods rich in vitamin C helps the body develop resistance against infectious agents and scavenge harmful oxygen-free radicals. Vitamin B-6 or pyridoxine is required for GABA hormone production within the brain. It also controls homocystiene levels within the blood, which may otherwise be harmful to blood vessels resulting in CAD, and stroke. Mangoes also make important seasonal contributions to the diet of many countries in the tropics especially African countries that primarily have a starch (carbohydrates)-based diet.

Ripe mangoes fruits are rich sources of vitamin A and are used to treat vitamin A deficiencies such as night blindness. Drinks also made from the infusion of fresh mango leaves has been used to treat diabetes and dried mango seed ground into powder is used to treat diarrhea. Diarrhea and throat disorders are treated by bubbling the bark extracts mixed with water (Bally, 2006).

Further, it contains moderate amounts of copper. Copper is a co-factor for many vital enzymes, including *cytochrome c-oxidase* and *superoxide dismutase* (other minerals

function as co-factors for this enzyme are manganese and zinc). Copper is also required for the production of red blood cells (Martin *et al.*, 1998). Additionally, mango peel is also rich in phytonutrients, such as the pigment antioxidants like carotenoids and polyphenols. Some other uses of the mango includes its use in agro forestry and environmental practices such as livestock shelter, home gardens, fence post, wind breaks and animal foods (Martin *et al.*, 1998). Other uses include: flavorings in which its puree is used to give flavor to many foods such as drinks, ice cream, wines, teas etc., honey (from its nectar), making leaf vegetables from boiled young leaves and used for tannin/dye (Martin *et al.*, 1998).

Naturland (2001) reports the importance of mango that ripened fruits are eaten fresh everywhere, and used to make juice or marmalade, dried and made into candy. Also all leftovers from the fruits can be used as animal feed. For instance, the young leaves are very good as cattle feed, because they have a protein content of 8-9% and a high Ca content as well. The bark and leaves of mango trees can also be used as a dye for cloth. The wood from mango trees is highly suitable for making charcoal which is widely used in rural areas in Africa as a source of fuel (Naturland, 2001).

2.2 PRODUCTION AND MARKETING TRENDS OF MANGOES

The production of mango globally currently stands at about 25 million tons of fresh fruits and 290,000-processed mango pulp, puree and juice. Africa out of this produces only 2.5 million tons (about 10%) of fresh fruits and 11 percent of processed mango. The major mango producing countries includes India, Mexico,

Pakistan, Brazil, Indonesia, China, Haiti, the Philippines, Madagascar and Tanzania (GNA, 2008). Ghana's current production of mango has increased from about 1,200 tons in 2007 to about 2,000 in 2008 (Table 2.1). The varieties of mangoes that are grown in Ghana include Kent, Keitt, Palmer, Haden, Tommy Atkins, Irwin, Sensation, Julie, and the local variety (GEPC, 2005).

Table 2.1: Fresh mango exports from Ghana from 2004 -2008 (in tones)

2004	2005	2006	2007	2008
227	772	366	1,200	2000

Source: Ghana Export Promotion Council (GEPC) (2005)

2.2.1 Mango Production Scenario in the World

Mangoes account for approximately half of all tropical fruits produced worldwide. The aggregate production of the top 10 countries is responsible for roughly 80% of worldwide production. India tops the list of countries producing mango in terms of area and production and in terms of value (Sarada, 2013). But in terms of export by per unit value, India is far behind France, China, EU and other countries (Sarada, 2013). Major mango importing countries from India are UAE, Bangladesh, UK, South America, Kuwait, Qatar, Bahrain, Nepal, USA, Oman, Singapore etc. and the foreign exchange earned from such exports amounts to about Rs: 2005 millions in 2009-10. Large markets for fresh produce are the EU, North-America and Asia. Literature shows that India has more than 1000 to 6000 mango varieties growing, but productivity here is low when compared with countries like Brazil, Indonesia, Pakistan, Mexico, Bangladesh and China. The average world yield of mango is 25 t/ha (Sauco, 1993) when compared with India's average yield of 6 t/ha. The national

average productivity is as low as 5.5 t/ha while Uttar Pradesh which tops the list produces more than 12 t/ha in 2009 (Biswas and Kumar, 2011). There is a potential to increase mango exports to many countries, with strong demand for mango products in the Middle East and Europe.

2.2.2 Marketing System in the Supply of Mango

2.2.2.1 Traditional mango fruit marketing channel

The traditional mango fruit marketing channel is shown in Figure 2.1. The number of players in the marketing channel is more and the mango grower's share in consumer's cedis is less in Ghana. In the case of mango, because of its perishability and seasonality, mango growers do not want to take the risk of marketing and so contract marketing system is popular prevalent.

Figure 2.1: Traditional mango marketing channel; Source: Sarada, 2013.

2.2.2.2 Contract marketing system

"Contract farming can be defined as an agreement between farmers and processing and/or marketing firms for the production and supply of agricultural products under forward agreements, frequently at predetermined prices (Eaton and Sherpherd, 2011). The arrangement also invariably involves the purchaser in providing a degree of production support through, for example, the supply of inputs and the provision of technical advice. The basis of such arrangements is a commitment on the part of the farmer to provide a specific commodity in quantities and at quality standards determined by the purchaser and a commitment on the part of the company to support the farmer's production and to purchase the commodity" (Eaton and Sherpherd, 2011).

A contract is simply an institutional construct that outlines the mutually agreed upon rules (and expectations) of how the fundamental element, such as the allocation of value (or the distribution of gains from trade), the allocation of risk (when value is subject to uncertainty) and the allocation of decision rights, will be addressed in the transaction relationships among the contractor and contractees (Sykuta and Parcell, 2003; Heperen, 2009; Paulson *et al.*, 2010). Contractual arrangements are becoming increasingly important for improving the effectiveness and efficiencies of agricultural supply chains (Tsoulouhas and Vukina, 1999; Sykuta and Parcell, 2003; Vavra, 2009).

According to Hobbs (1996), three major contracts exist and these include;

- Market specification contract: Agreement between buyer and seller to provide a market for the product (output). The seller has influence on the product and marketing activities.
- Production-management contract: Characterized through more control by the buyer compared to the market specification contract. The buyer influences the production management by inspecting the production process and influencing the input use.
- Resource providing contract: Allows the buyer to provide a market outlet for the product, supervise the production and supply key inputs.

2.2.2.3 Cooperative marketing system

According to Ali and Kumar (2011), four cooperatives of fruits and vegetable growers existed. There are 385 fruit processing units in Tamil Nadu out of which 80% are small industries with an average capacity of 5.5 tonnes per day and the remaining units are medium scale with an average capacity of 80 tonnes per day (Ali and Kumar, 2011). Marketing channel for mango pulp through Co-operatives is shown in Figure 2.2.

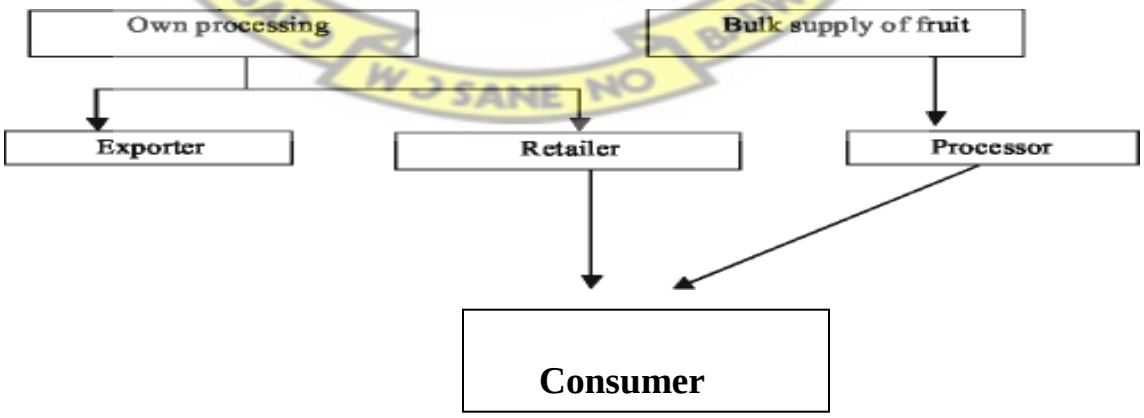

Figure 2.2: Marketing Channel for Mango pulp through Cooperatives- Source:

Muthuvelayutham and Paul (2009).

Aharam Traditional Crop Producers Company Limited is a farmers' owned organization. The 600 producers are organized in 40 Self Help Groups at village level. The SHG's are in direct contact with the Federation of Mango Farmers, which are organized at regional level. Company Aharam acts as umbrella organization. The vision is to increase and sustain rural incomes by empowering the members through the coordination of Community Based Organizations and offering services which increase the opportunity to add value along the chain (Aharam, 2009). There are however other marketing systems which include; Online Marketing, Farmer Owned Producer Company and Corporate Farming (Sarada, 2013).

2.2.3 Constraints in Marketing of Mangoes

2.2.3.1 Harvesting and postharvest practices

The method of harvesting in mango is by hand picking, harvesting by climbing on the tree, harvesting with a notched stick having a pouch. Accidental falling of fruits, results in bruising and cracking of fruits and losses are estimated to a maximum of 15% in mango (Sarada, 2013).

Numerous intermediaries in the marketing channel

- High level of wastage accounting for 20 to 40% (High cumulative wastages across the supply chain (i) Mango - 22% (ii) Banana - 30% (iii) Pineapple - 20 % (iv) Guava - 16 %
- Lack of transparency in prices, availability, demand and customer preferences etc.

- Poor infrastructure - storage, packaging, transportation, cold chain etc.
- Poor linkage in the marketing channel.

2.2.3.2 Suggestions

- At the farm level, value addition can be obtained through post-harvest handling, grading and packaging. These activities reduce the loss of the mango fruit and increase the quality of the product in the market.
- Grading the fruit is necessary for a better outlook and maintains the quality of the product. Mangoes can be graded by selecting superior quality, sorting by weight, size and removing fruits with defects.
- It is essential to follow the preventing measures at every level right from the farmers, private traders, operators, processors and marketers (Sarada, 2013).

2.3 QUALITY OF THE MANGO FRUIT

Villareal (1980) stated that an effective quality control system throughout the handling steps between harvest and retail display is essential to providing a consistently good-quality supply of fresh fruit to the consumer and to protecting the reputation of a given marketing label. The quality of fresh fruit has been described by Swiader *et al.,* (1992) as the combination of characteristics, attributes and properties that give a commodity value to humans for food. These important attributes which is associated with the quality of fruits (mango) vary according to the individual(s) defining the term.

Growers are interested in disease resistance, high yielding, uniform maturity, desirable size and ease of harvest; post-harvest characteristics have not been one of their main interests (Swiader *et al.,* 1992).

Consumers care about appearance, price, and table quality, including texture, flavour, colour, and nutritive value of mango (Swiader *et al.*, 1992). Shippers and handlers are concerned with shipping quality and market quality; firm fruit that can endure inexpensive handling and transport and still maintain high market quality is desirable (Moomin, 2010). Litz (2003) concluded that large numbers of mango varieties with variable attributes affect the quality and uniformity of the processed products. Similarly, lack of simple and reliable methods for determining the stage of fruit maturity also affect quality (Litz, 2003).

2.3.1 Chemical Composition of Mango Fruit

Research carried out by Doreyappa and Ramanjaneya (1994), stated that physio-chemical composition of mango is an important factor in the selection of suitable cultivars for processing, and that mangoes can be processed at both unripe (green mature) and ripe stages of maturity for conversion into a wide range of products. Green mangoes (firm fruit with developed stone but unripe) are processed into traditional products like brine stock, pickles, chutneys and dried powder. Instant mango pickles, drum-dried green mango powder and raw mango beverage base are the latest developments (Chau *et al.*, 1989). Chau *et al*. (1989) indicated also that unripe mango slices are preserved with salt for later conversion into pickles, chutney or as salt stock for export. It has been reported that when raw mango slices are dried in the sun or in a mechanical drier and powdered it is referred to as ³amchur´ in the trade and is used in culinary preparations for traditional Indian cooking (Anon., 1989). Studies have been conducted to improve the process by using slices of mangoes at an optimum stage of maturity (9–10 weeks after fruit set) and by

sulphite treatment of the slices to improve retention of colour and vitamin C (Chau *et al.*, 1989). Chau *et al*. (1989) stated that raw mango beverage is a traditional product prepared and consumed in most households in India. Baking green mangoes (firm mature fruit with developed stone but unripe) at 200^{o}C for 25 minutes is useful for extracting good quality pulp with higher yield and more retention of vitamin C; and that squash and nectar prepared from this pulp is acceptable.

Franklin (1991) reported that ripe mangoes (mature and post–climacteric ripe fruit with full flavour development) are processed into:

- frozen mango products e.g. slices in syrup, pulp and beverage base;
- canned products e.g. slices in syrup, pulp, juice and nectar;
- ready–to–serve beverages; and
- dehydrated products e.g. mango fruit bar, mango cereal flakes, mango powder, strained baby foods, mango toffees etc.

Canned mango slices in juice, mango concentrate, mango aroma concentrate, low viscosity and low pulp–containing mango beverage base, aseptic bulk packing of pulp and concentrate, structured mango products etc. are relatively new product developments (Franklin, 1991). Kurdiya and Roy (1986) found that mangoes are generally canned at the 'just ripe´ stage as slices, cheeks or dices. Mango jam and mango toffee are indicated to be sweet mango products produced and exported from India (Anon., 1985). Among Indian mangoes, 'Alphonso´ mango variety is reportedly most suitable because other varieties yield canned products with mild flavour and colour, and that addition of ascorbic acid to the canned mango slices in syrup at different levels (50–100mg/l) aids flavour retention (Kurdiya and Roy, 1986).

Alzamura *et al.* (1993) stated that dehydrated tropical fruits are becoming popular worldwide and that a number of products based on mango have been developed. These include dehydrated mango slices, intermediate moisture mango and high moisture mango slices and puree. According to Britnell (1991) structured mango products can be incorporated into yoghurt, ice cream and confectioneries such as mango fruit bar, mango cereal flakes, strained baby food and mango powder (Nandanasahapathi *et al.*, 1993). Litz (2003) mentioned mango concentrate, mango aroma concentrate and alcoholic beverages as other mango products and that demand for mango concentrate in export markets has been increasing.

Research by Ethiraj and Suresh (1992) reported that peels and stones are the main waste products of processing, and constitute 35–55% of unripe as well as ripe mangoes. Useful products can be recovered from these wastes and simultaneously avoid the disposal problem. These wastes can be treated with pectic enzymes, their juice compressed and used in the preparation of nectar, vinegar or concentrated and used as a colouring and flavouring agent (Ethiraj and Suresh, 1992).

Krishnanand (1994) reported that mango peel can also be used for biogas production by anaerobic digestion. The results of pilot plant studies have shown that mango peel, supplemented with essential nutrients, can yield biogas at a rate as high as 0.68m^3 per kilogram volatile solids added; the gas contains 52% methane (Krishnanand, 1994). Ethiraj and Suresh (1992) indicated that the mango seed kernel is a rich source of carbohydrates, protein, fat and tannins and that due to its blandness, plasticity and absence

of toxic substances, the kernel fat (average 12%) has potential use for preparing sweetmeats. No difference has been noticed in the texture, taste and flavour of toffees prepared from mango kernel oil and cocoa butter (Ethiraj and Suresh, 1992). It can also be used in soap manufacturing and as a substitute for cocoa butter. According to Ethiraj and Suresh (1992), mango seed kernels also contain 47-63% starch of which 19–22% is amylase and that the starch is recommended for food use. The mango fruit is mostly consumed in the fresh state. However, the fruit can be frozen, dried, pickled or canned for use. The fruit is also used in the preparation of salads and in some countries, for example, India the green mango is cooked in stews and soups (Moomin, 2010). Aside its food uses, mango also has some medicinal value because it is rich in astringents employed in the treatment of some diseases (Litz, 2003). The mango fruit contains amino acids, carbohydrates, fatty acids, minerals, organic acids, proteins and vitamins (Litz, 2003).

Research carried out by Krishnanand (1994) described that ripe mango is especially rich in carotenes which have antioxidant properties thought to lower the risk of heart disease and stroke and contains an enzyme with stomach soothing properties similar to papain found in papayas. These comforting enzymes act as a digestive aid (Krishnanand, 1994). During the ripening process, the fruits are reported to be initially acidic, astringent and rich in ascorbic acid (vitamin C). Ripe mangoes contain moderate levels of vitamin C but are fairly rich in provitamin A and vitamins B1 and B2 (Litz, 2003).

Fruit acidity is primarily due to the presence of malic and citric acids and that in addition, oxalic, malonic, succinic, pyruvic, adipic, galacturonic, glucuronic, tartaric, glycolic and

mucic acids are also present (Litz, 2003). According to Litz, (2003) acidity is cultivar–related; during ripening acidity decreases. Following fruit set, starch accumulates in the mesocarp. Free sugars including glucose, fructose and sucrose generally increase during ripening but the sucrose content increases three–to four fold due to the hydrolysis of starch as the fruits are climacteric in nature (Castrillo *et al.,* 1992). Nutritive value of 100g edible portion of raw mango fruit has been reported to be as follows: inedible waste (34%), energy (59kcal or 253kJ), protein (0.5g), fat (0. 0g), carbohydrate (as monosaccharide) (15.3g), water (83g), Ca (10mg), iron (0.5mg), Na (7mg), Vitamin A (retinol equivalent) (200g), Thiamine (0.3mg), Riboflavin (0.04mg), Niacin equivalent (0.4mg), and Vitamin C (30mg) (Anon., 1985).

2.3.2 Some of the Quality Components Considered when Dealing with Mango Fruits

Wills *et al.,* (1998) stated that important quality components for producers, exporters/distributors and consumers are appearance; including size, colour, shape, condition (such as freshness) and absence of defects; texture and firmness; flavour and nutritive value.

2.3.2.1 Appearance

A rapid visual assessment of the mango fruit appearance can be made on the basis of size, shape, colour, condition and or the presence of defects or blemishes and rot as indicated by Wills *et al.,* (1998). Atherton and Rudich (1986) stated that freshness, stage of senescence or ripeness, the extent of mechanical damage and pest or disease incidence detract from appearance and in most markets detract from price, even when the blemishes

reduce neither keeping quality nor eating quality. Evaluation of defects is only subjective since there are no objective ways of evaluation (Atherton and Rudich, 1986). Earlier work by Arthey (1975) had reported that colour measurements in fresh and processed fruits and vegetables and other foods are without doubt the most important single quality factor that affects grower-processor relationship and consumer acceptance of products.

Appearance therefore is a major determinant of quality, especially because it is often the only criterion available to the buyer of the commodity (Arthey, 1975).

2.3.2.2 Firmness

Research work done by Atherton and Rudich (1986) suggests that, firmness is closely related to stage of ripeness. The sensory evaluation of fruit textural quality involving finger feel, mouth feels and slicing characteristics are all related to firmness (Atherton and Rudich, 1986). Beattie *et al*., (1983) indicated earlier that firm fruits (tough skin and firm flesh) are less susceptible to physical and mechanical damage, and therefore store better and enhance transportation and distribution in the marketing system. Atherton and Rudich (1986) also stated that for successful mechanization of the fruit industry, the most important characteristic is a concentrated set of firm, tough fruits. Gormley and Eghan (1982) earlier on stated that to ensure reasonable shelf-life, mango fruits should have firmness value of at least 200g/5mm fruit compression. El-Sayed and Erickson (1966), however, stated that fruit firmness is under genetic control.

2.3.2.3 Flavour

Flavor is comprised of taste and aroma and that the aromas of many chemical constituents are responsible for the flavour of fruits when tasted (Kader *et al.,* 1985). According to Wills *et al.,* (1998) the taste of fruit and vegetables is usually a blend or balance of sweet and sour, often with overtones of bitterness due to tannins. The sweetness, sourness and overall flavour intensity in fruits according to De Bruyn *et al.,* (1977) are influenced by sugars, acids and their interactions; and Davies and Hobson (1981) testified that fructose and citric acid are more important to sweetness and sourness than glucose and malic acid respectively. High sugars and relatively high acids give best flavour. High acids and low sugars produce tart (unpleasant sharp taste) fruit while low acids and high sugars give bland (mild in flavour, not having interesting taste) taste. Low acids and low sugars give tasteless, insipid fruits (Grierson and Kader, 1986).

2.3.2.4 Total Soluble Solids (TSS) and titratable acidity (TA)

Some of the important characteristics that contribute to the quality of fresh-cut melon include its sweetness, flesh firmness, and taste. Results from Cantwell and Portela (1997) in a midseason trial of 17 western cantaloupe varieties, show that there was an average 5% decrease in TSS (range 0 to 11%) and an average 8% decrease in sugar (range 0 to 21%) when cubes were stored 12 days (in air) at 5 °C (41 °F). After 9 days at 10 °C (50 °F) or 15 days at 5 °C (41 °F), TSS in CA-stored melon pieces were higher than in air: 10.3 vs. 9.5% and 10.2 vs. 9.1% at 10 and 5 °C (50 and 41 °F), respectively (Cantwell and Portela 1997). Cantaloupe balls prepared from four eastern varieties stored 8 days at 0 °C (32 °F) had an average TSS decrease of 9.7% with a range of 2.3 to 13% (Lange, 1998).

TSS remained somewhat constant for 7 days storage at 4 °C (39 °F) in fresh-cut cantaloupe when harvest maturity was at least half-slip, and cubes prepared from fruit harvested at quarter-slip had significantly lower initial TSS, which rapidly declined after only 5 days storage (Beaulieu and Baldwin, 2002). It is well established in the food industry that sugar content (TSS) is generally positively correlated with desirable flavor quality. However, occasionally too much sugar is perceived negatively. The best sugar range for storage of fresh-cut cantaloupe was 10 to 13 °Brix. However, some judged the 13 °Brix fruit as too sweet (Anon., 2000b).

TA and TSS have also been used to assess quality via the TSS: TA ratio in some fresh-cut fruits. Changes in TA, pH, and TSS in apple slices from 12 cultivars that were stored at 2 °C (36 °F) for 12 days were small and varied by cultivar (Kim *et al.*, 1993). Likewise, there were changes in TSS in fresh-cut strawberries stored under various CA for 7 days at 5 °C (41 °F). However, pH increased over time (Wright and Kader, 1997b). Fresh-cut persimmons stored under various CA had increased TSS for 3 days, then decreased TSS by day 8; pH tended to increase through storage (except when stored under 2% O_2) (Wright and Kader, 1997b). In cantaloupe slices, a 17% loss in TSS and a 2-fold increase in TA occurred after only 2 days storage at 20 °C (68 °F), but the acidity change was attributed to lactic acid bacteria (Lamikanra *et al.*, 2000). TA in fresh-cut oranges stored 8 days at 4 °C (39 °F) decreased 36% (Rocha *et al.*, 1995).

2.3.3 Effect of Harvesting Time, Handling and Desapping on Quality of Mango

According to Joyce and Patterson (1994) the water potential of fruit at harvest can affect

susceptibility to handling, heat damage and product storage potential. In hot weather, advantage can be gained from harvesting in the coolest part of the day to reduce risks associated with fruit overheating and energy requirements for postharvest cooling, and minimizes worker discomfort (Joyce and Patterson, 1994). Harvesting during rain can also have deleterious effects on fruit quality (Joyce and Patterson, 1994). Rough handling at harvest can cause skin damage and internal fracturing or bruising. Using hooked sticks to detach fruit (from larger/higher trees), and then picking them off the ground leads to excessive internal fracturing (Ledger, 1991) and sap–burns. Mechanical damage during harvest can also lead to the appearance of soft, darkened areas and bruises on fruit following hot water treatment. Sap–burn is associated with certain cultivars, as such latex needs to be drained from the fruit (a process known as desapping or bleeding) in a manner which minimizes the incidence and severity of sap–burn (Moomin, 2010). Several systems of desapping have been assessed for reducing damage (O'Hare, 1994). Notable among these include desapping in a 1% solution of calcium hydroxide; washing fruit in 1% aluminium potassium sulphate; applying surface coatings to fruit prior to desapping; trimming and desapping at the pack–house followed by inversion on a stationary rack or a roller–conveyer running below water (or water/detergent) sprays for 20 minutes and inversion in the soil (usually in the shade beneath the trees) immediately after harvest for 30 minutes (O'Hare, 1994).

2.3.4 Physiological Disorders Effect on Mango Fruit Quality

The inherent postharvest physiological disorders of mango are more difficult to study because their occurrence is often intermittent and thus unpredictable; also, the

predisposing factor(s) responsible for these disorders presumably occur during the pre-harvest period (Brown *et al.,* 1981). According to Brown *et al.,* 1981, a good example is the spongy stem-end disorder of 'Kensington' mangoes. Several other internal disorders of mango have been described. These include 'soft nose' in Florida mangoes (Young, 1960); black-tip (Ram, 1989) and 'internal breakdown', 'spongy tissue' or 'soft tissue' (Subramanyan *et al.,* 1971) in Indian 'Alphonso' mangoes. Research work by Litz (2003) described mango fruits as being susceptible to several physiological disorders which become apparent during ripening and this influence fruit quality. Such disorders can be considered as either induced or inherent (Litz, 2003). According to Chaplin (1989), chilling injury after exposure to low temperature and impaired ripening of fruit after storage in atmospheres containing high levels of CO2 are some examples of induced disorders of mangoes.

2.4 FACTORS AFFECTING QUALITY OF FRESH-CUT MANGOES

According to Moomin (2010), quality of the intact mangoes depends upon the cultivar, pre-harvest cultural practices and climatic conditions, maturity at harvest, and harvesting method. Handling procedures, conditions, and time between harvest and preparation as a fresh-cut product also have major impacts on quality of intact fruits and vegetables and, consequently, quality of the fresh-cut products (Moomin, 2010). According to Moomin (2010), method of preparation (sharpness of the cutting tools, size and surface area of the cut pieces, washing, and removal of surface moisture) and subsequent handling conditions (packaging, speed of cooling, maintaining optimum ranges of temperature and relative humidity, expedited marketing, and proper sanitation procedures) are the notable additional factors that influence quality of fresh-cut mangos.

2.4.1 Maturity and Ripeness Stage Effects on Mango Quality

Mangoes in most production areas are noted to reach their best eating quality when allowed to ripen on the tree. Mangoes are usually picked mature-green so that they can withstand the postharvest handling system when shipped long-distance (Moomin, 2010). Research findings of Limbanyen *et al.,* (1998) described 'Tommy Atkins', 'Haden', and 'Palmer' mangoes with yellow flesh color (no green color remaining) as having optimum maturity for fresh-cut in terms of maintenance of acceptable appearance, texture, and taste. Riper fruit developed flesh breakdown and more browning. Post-cutting life of fresh-cut mango at 5C was 8 to 10 days and was limited by flesh browning and loss of firmness. Peeling to a depth of at least 2mm and trimming flesh near the stem was necessary to minimize browning (Limbanyen *et al.,* 1998). According to Limbanyen *et al.,* (1998), mangoes with slight to moderate anthracnose symptoms on their peel can be used for fresh-cut.

Most currently used maturity indices are based on a compromise between those indices that would ensure the best eating quality to the consumer and those that provide the needed flexibility in marketing (Moomin, 2010). Ripening is the composite of the processes that occur from the mature-green stage through the early stages of senescence and that result in the desirable color, textural, and flavor (taste and aroma) quality (Moomin, 2010). According to Moomin (2010), mangoes produce relatively small quantities of ethylene (0.1 to 2 microliters per kilogram per hour) in association with their ripening, and exposure to ethylene treatment (100ppm for 1-2 days at 20 - 25°C) will result in faster and more uniform ripening. Once fruits are ripened they require more careful handling to minimize bruising. Mangoes must be ripened, at least partially (almost ready-to-eat), before cutting to assure better flavor quality in the fresh-cut products.

Partially-ripe 'Kent' mango slices continued to ripen after cutting, but did not reach the same level of ripeness as whole mangoes did after 5 to 7 days at 13°C or 23°C (Tovar *et al.*, 2000). Allong *et al.*, (2000) found that fresh-cut slices made from half-ripe (12.5 to 14% soluble solids) and firm-ripe (14.5 to 17% soluble solids) 'Julie' and 'Graham' mangoes had a shelf-life of 8 days at 5C or 4 days at 10C. Half-ripe (13-16% soluble solids) mangoes are ideal for fresh-cut purposes in terms of maintenance of acceptable appearance, texture, and taste during post-cutting life at 5°C (Allong *et al.*, 2000). Rattanapanone *et al.*, (2001) recommended that 'Tommy Atkins' and 'Kent' mangoes should be 13 to 27 N firmness (penetration force with an 11mm probe) when cut to have an acceptable quality and reasonable shelf-life as a fresh-cut product. Marketability was limited by development of watery condition, slight darkening, and microbial growth on the cubes. DeSouza *et al.*, (2006) reported that fresh-cut 'Tommy Atkins' mango had a shelf-life of 10 days at 3°C. They also found that naturally-ripened mango presented the best flavor and consumer preference as compared with mature-green mangoes that were ripened with ethylene for 12 hours at 25-30°C before cutting.

Beaulieu and Lea (2003), compared volatile and quality changes in stored fresh-cut mango cubes prepared from firm-ripe (86-92 N flesh firmness as penetration force with 11-mm probe and 9-10% soluble solids) and soft-ripe (27-29 N flesh firmness and 12.5-14% soluble solids) 'Keitt' and 'Palmer' mangoes. They found that most soft-ripe cubes were unmarketable by day 7 at 4°C and that firm-ripe cubes were not ripe enough to deliver an optimum product to consumers, even though their storage-life was greater than soft-ripe cubes.

2.4.2 Effect of Washing Whole Mangoes before Cutting

Ngarmsak *et al.* (2005) reported that washing whole 'ChokAnun' mangoes in warm (50^{o}C) or cold (12^{o}C) chlorinated (100 ppm) water for 5 minutes significantly reduced total microbial populations on the skin and stem end of the mangoes. According to Moomin (2010), microbial populations on fresh-cut mango slices prepared from unwashed fruit were significantly higher than those prepared from washed fruit immediately following preparation and after 7 days at 5^{o}C.

2.4.3 Effect of Hot Water Quarantine Treatment

Hot water quarantine treatment (dip in 46^{o}C water for 65 to 110 minutes depending on cultivar and fruit size) of whole mangoes does not significantly affect the quality of fresh-cut 'Kent' mango slices stored at 5^{o}C (Dea *et al.*, 2008b). However, if the temperature and/or duration limits of hot water treatment are exceeded resulting in heat damage, the mangoes will not be useable for fresh-cut processing. According to Moomin (2010), cooling after heat treatments reduces the potential for heat damage.

2.4.4 Calcium Treatments Effects on Firmness Retention of Mango Fruits

According to research conducted by Moomin (2010), shelf life (post-cutting life based on reaching limit of marketability or visual quality score = 5) of fresh-cut mango cubes was limited by softening and browning. Banjongsinsiri *et al.* (2004) concluded that texture of 'Kent' mango is most likely moderated by changes in the solubility of large molecular weight insoluble pectin and non-pectin components, such as cellulose and hemicellulose, in the cell wall.

Chantanawarangoon (2000), concluded that at 5°C, shelf lives of mango cubes treated with distilled water (control), 0.5% CaCl2 and 1% CaCl2 were about 5, 7 and 9 days respectively. Mango cubes treated with 1% CaCl2 had higher flesh firmness and calcium content than those treated with 0.5% CaCl2 or water (control). Firmness of mango cubes in all treatments decreased during storage. Chantanawarangoon, (2000), however, confirmed that firmness of mango cubes treated with 1% CaCl2 was significantly higher than those treated with 0.5% CaCl2 or water (control). Firmness on day 9 of mango cubes treated with 1% CaCl2 decreased by about 25% of initial firmness (Chantanawarangoon, 2000).

Later research conducted by Trindade *et al.* (2003) concluded that the most suitable conditions for quality preservation of fresh-cut 'Tommy Atkins' mango were dipping in a solution of 3.5% (w/w) calcium chloride at 35^{o}C for 20 minute and packaging under active modified atmosphere (5% oxygen + 5% carbon dioxide). According to Trindade *et al.*, (2003), under these conditions, fresh-cut mango maintained good quality for 5 days at 5^{o}C.

2.4.5 Effects of Wounding (Peeling and Cutting) on Mango Fruits

Mango peels had the highest respiration and ethylene production rates followed by whole mangoes and mango cubes, respectively (Chantanawarangoon, 2000). Peeled whole mangoes had lower respiration and similar ethylene production rates compared to mango cubes. The $C_2H_4$and CO2 production rates of whole mangoes were about 1.5-2 times higher than peeled whole mangoes. According to the author, the results indicated that

mango peels are major contributors to C2H4 and CO2 production by mango fruits. The CO2 production rates of mango cubes was about 1.5 times higher than peeled whole mangoes, which indicated that cutting increased respiration rates of mangoes (Chantanawarangoon, 2000). However, the CO2 and C_2H_4 production rates of whole mangoes were about 1.5 times higher than those of mango cubes. This means that the preparation steps of fresh-cut mango cubes, including peeling and cutting, resulted in the reduction of the CO2 and C2H4 production rates. Wounding therefore was noted to have a minor effect on physiology of fresh-cut mangoes, which is helpful in extending post-cutting life (Chantanawarangoon, 2000).

According to Moomin (2010) wounding increases rates of water loss, softening, and browning. Using very sharp tools to peel mangoes and cut their flesh limits cellular damage and reduces leakage of cellular contents and enzymatic browning mediated by the enzymes polyphenol oxidase and phenol oxidase. According to the author, packaging in rigid containers is essential to reduce water loss and mechanical damage during distribution. Allong *et al.,* (2001) found that storage of fresh-cut 'Julie' and 'Graham' mangoes at lower temperatures (5^{o}C instead of 10^{o}C) reduced the negative effects of wounding, including the level of microbial contamination. Gil *et al.* (2006) recommended complete removal of the mango skin (peel) with a very sharp knife or peeler to avoid brown discoloration of the remaining peel tissues, which appears faster than flesh tissue browning of fresh-cut mango products. Mango fruit peeling and flesh cutting by hand can result in less damage than mechanical peeling and cutting if the sharpness of the cutting tools is similar, but the latter will likely be more consistent in the extent of wounding

(Moomin, 2010). When comparing hand versus mechanical peeling and cutting of mango fruits, these factors plus efficiency and relative cost should be considered as well.

2.4.6 Atmospheric Modification Effects on Mango Fruits

Chantanawarangon (2000) observed that the visual quality of 'Haden', 'Keitt', and 'Kent' mango cubes stored in 2% O_2 + 10% CO_2 atmosphere was much better maintained than of those stored in other atmospheres (2% O_2 or air + 10% CO_2) or in air (control) during storage at 5°C. Shelf life of mango cubes dipped in 1% $CaCl_2$ and stored in 2% O_2 + 10% CO_2 was about 12 days, compared to 9 days for those dipped in 1% $CaCl_2$ and stored in air. Firmness of mango cubes in all treatments declined during storage. However, rate of softening was slowest in mango cubes stored in 2% O_2+ 10% CO_2. Limbanyen *et al.* (1998) reported that a modified atmosphere of 10% oxygen + 10% carbon dioxide slowed browning and softening of fresh-cut mangoes as compared to air control. Martinez-Ferrer *et al.* (2002), working with 'Keitt' mangoes that were harvested at 7-8% soluble solids and kept at 13-15^{o}C until their soluble solids reached 11-12% before preparation of the cubes, found that packaging in a modified atmosphere of 4% oxygen + 10% carbon dioxide + 86% nitrogen resulted in the longest shelf-life (25 days at 5^{o}C) of the mango cubes in comparison with vacuum packaging, 100% oxygen, and air control. This treatment significantly inhibited the growth of spoilage microorganisms, particularly molds and yeasts.

Rattanapanone and Watada (2000) concluded that fresh-cut 'Tommy Atkins' mango cubes can be held in low oxygen atmospheres (0.5 to 4.0% oxygen, balance nitrogen) at

5°C. According to the authors, marketability was limited by the development of watery condition and slight darkening only in air and 4% oxygen atmosphere, respectively. Rattanapanone *et al.,* (2001) reported that the marketable period of fresh-cut 'Tommy Atkins' and 'Kent' mango cubes was 3 to 5 days at 10°C or 5 to 8 days at 5°C and was extended by 1 to 2 days when cubes were held in 4% oxygen + 10% carbon dioxide or 2% oxygen + 10% carbon dioxide (balance nitrogen) atmospheres. They concluded that while CA was beneficial in maintaining quality of the cubes, temperature was more effective than CA. Donadon and Durigan (2004) compared three types of polymeric films for packaging 'Tommy Atkins' mango slices and found that those packed in the polyethylene terephthalate (PET) clamshell trays had a shelf-life of 14 days at 3°C versus 11 days for the mango cubes in the other packages. Singh *et al.* (2007) concluded that the shelf-life of fresh-cut mangoes could be extended by packaging in PET containers. Chonhenchob *et al.* (2007) reported that extended shelf-life was observed in fresh-cut mangoes packed in PET due to reduced oxygen and elevated carbon dioxide concentrations.

The shelf-life of fresh-cut 'Carabao' mangoes, based on brown discoloration and water-soaked appearance, was 6 days at 5°C and 4 days at 13°C (Poubol and Izumi, 2005a). A 10% carbon dioxide-enriched atmosphere enhanced texture and retarded the development of water-soaked 'Carabao' cubes at 5°C and 13°C. The 10% carbon dioxide atmosphere also reduced bacterial count on mango cubes held at 13°C. According to Poubol and Izumi (2005b) 60% oxygen atmosphere reduced the respiration rate of fresh-cut 'Carabao' mango cubes kept at 5°C, but stimulated the rate after 2 days at 13°C.

Browning of 'Carabao' mango cubes was accelerated by 60% oxygen at 13°C. Thus, they

concluded that 60% oxygen is not a desirable atmosphere for mango cubes when held at 13^{o}C. A mango film provided a good oxygen barrier with sufficient mechanical properties to wrap whole and minimally-processed mangoes. When the latter were wrapped in a mango film and kept in cellophane bags, the shelf-life was extended to 6 days at 5^{o}C (Sothornvit and Rodsamran, 2008).

2.4.7 Storage Temperature and Relative Humidity Effects on Mango Quality

Chantanawarangoon (2000) found that the CO2 production rate of mango cubes stored at 5^{o}C was higher than those of mango cubes stored at 2^{o}C and 0^{o}C, respectively. However, the C2H4 production of mango cubes stored at 0^{o}C was about 2.5 times higher than those stores at 5^{o}C and 2^{o}C. Normally, based on temperature effects, produce kept at lower temperature should have lower CO2 and C_2H_4 production. However, at chilling temperatures many chilling sensitive fruits and vegetables show increased respiration and ethylene production rates. Therefore, the higher C2H4 production of mango cubes stored at 0^{o}C might be a sign of chilling injury. The symptom of chilling injury was obviously observed on day 13 as surface darkening (smoky color). None of the mango cubes stored at 0, 2 or 5°C had any juice leakage during 13 days of storage. The overall visual quality of mango cubes stored at 2°C was slightly better than those of mango cubes stored at 5°C or 0°C The results of this experiment indicate that 2°C to 5°C is the optimum storage temperature range for fresh-cut mango cubes since storage at 0°C for more than 10 days can cause chilling injury. However, for up to 10 days, 0°C can be used. According to

Moomin (2010), keeping intact and fresh-cut fruits within their optimum ranges of

temperature and relative humidity is the most important factor in maintaining their quality and minimizing postharvest losses. According to the author, above the minimum safe temperature for mango as a chilling-sensitive commodity, every 10°C increase in temperature accelerates deterioration and the rate of loss in nutritional quality by 2- to 3-fold. Delays between harvesting and cooling or processing can result in quantitative losses (due to water loss and decay) and qualitative losses (losses in flavor and nutritional quality). The extent of these losses depends upon the commodity's condition at harvest and its temperature, which can be several degrees higher than ambient temperatures, especially when exposed to the hot water treatment (Moomin, 2010).

Dea *et al.,* (2008a) found that shelf-life of fresh-cut 'Kent' mangoes was 3 to 4 days at 12°C versus 5 to 6 days at 5°C. It was unclear whether this storage period at 5°C caused chilling injury in fresh-cut mango slices since no visual chilling injury symptoms were noted. Dea *et al.,* (2008a), however, observed a reduced ascorbic acid content and increased softening at 5°C which suggested that the fresh-cut slices did experience chilling stress. Maciel *et al.,* (2004) observed that the sensory characteristics of minimally-processed 'Espada' mangoes were significantly changed during storage limiting storage time to 4 days at 7°C and 61% relative humidity. Izumi *et al.,* (2003) recommended 5°C as the best temperature for maintaining quality of fresh-cut 'Carabao' (partially-ripe with 50-60% yellow skin color) mango cubes; the shelf-life was 4-6 days and CA (1-2% oxygen, balance nitrogen) had an additional benefit.

2.4.8 Anti-browning Chemical Treatments Effects on Mango Quality

According to research work done by Chantanawarangoon (2000), during storage at 5°C,

mango cubes with no dipping treatment and those dipped in water had significantly lower visual quality scores than those treated with various chemical solutions. On day 12 of storage, mango cubes treated with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine, 1% CaCl2 + 1% citric acid + 0.5% N-acetylcysteine or 1% CaCl2 + 1% ascorbic acid had higher visual quality scores than those dipped in water. There was no significant difference in firmness of mango cubes treated with all the chemical solutions that had 1% CaCl2 as a component. Firmness of mango cubes with no dipping and those dipped in water was significantly lower than those treated with the various chemical solutions that included 1% CaCl2 as a component. These results showed that 1% CaCl2 is essential for maintaining firmness of fresh-cut mango cubes (Chantanawarangoon, 2000).

Based on firmness and appearance, it is clear that 1%CaCl2 is a key compound that should be applied for maintaining firmness and extending shelf life of fresh cut mango cubes regardless of the intended marketing periods. However, if the marketing period is longer than 6 days, additional chemicals, such as 1% ascorbic acid + 0.5% L-cysteine or 1% citric acid + 0.5% N - acetylcysteine, should be applied in addition to 1% CaCl2 in order to delay browning. Considering cost and availability of food grade chemicals, ascorbic acid is comparable to citric acid. However, L-cysteine is less expensive and more available than N-acetylcysteine. Therefore, the mixture of ascorbic acid and L-cysteine in addition to 1% CaCl2 might be a better choice for maintaining quality of fresh-cut mango cubes (Chantanawarangoon, 2000).

Chonhenchob *et al.*, (2007) concluded that the most effective chemical treatment to

reduce browning, softening, and decay of fresh-cut 'Namdokami' mangoes were 0.1 M ascorbic acid. Plotto *et al.*, (2004) compared the effects of edible coatings on quality maintenance of fresh-cut 'Tommy Atkins' mangoes kept at 5°C or 10°C. Mango pieces were dipped for 30 seconds in 5ppm chlorine dioxide, 2% calcium ascorbate and 0.5% N-acetyl-L-cysteine (antioxidants) or coated with 1% carboxymethyl cellulose (CMC) or CMC and 0.5% malto dextrin (CMM). Coated mango pieces and those treated with antioxidants maintained good visual quality for up to 21 days at 5°C or 14 days at 10°C. This study confirmed the necessity to treat fresh-cut mangoes with antioxidants to prevent color darkening in storage. Storage temperature of 5°C maintained visual quality of fresh-cut mangoes, but overall volatiles were decreased. Carboxy methyl cellulose alone or in combination with malto dextrin may improve fresh-cut mangoes. However, fruit quality at the time of cutting may affect storage capacity and quality more than additives on the fruit pieces. NatureSeal, Inc. (a subsidiary of Mantrose-Haeuser Co., Inc.) sells a NatureSeal formulation for fresh-cut mangoes that is promoted for extending their shelf-life to 10 to14 days at 2 to 5°C (http://www.natureseal.com/).

2.4.9 Effects of Ethylene Action Inhibitors on Fresh Mango Quality

Plotto *et al.* (2003) investigated the effects of treating whole 'Kent' mangoes with 1-methylcyclopropene (1-MCP, 25ppm), heat (38C and 98% relative humidity for 12 or 24 hours), or ethanol (5g/kg) on quality and shelf-life of fresh-cut pieces. The fresh-cut pieces were dipped in 2% calcium ascorbate and 1% citric acid to prevent browning. They found that the 1 -MCP and heat treatments decreased firmness while the ethanol treatment maintained firmness similar to the control. After 12 days at 7-8°C, cut pieces from

ethanol-treated mangoes maintained the best visual quality, but had off-flavor. These ripening inhibition treatments did not influence shelf-life of fresh-cut 'Tommy Atkins' mangoes but delayed spoilage of 'Kent' mangoes by 2 days.

Vilas-Boas and Kader (2007) found that softening and browning were delayed when 1 -MCP (0.5 or 1.0 ppm for 6 hours) was applied directly on fresh-cut 'Kent' and 'Keitt' mango slices. Respiration rate of mango slices was not affected by 1 -MCP whereas ethylene production rate was affected only towards the end of their shelf-life (9 days at 5^{o}C). Treating whole mangoes before cutting was less effective than treating the cut product. According to the authors, combination of 1 -MCP treatment with calcium treatment and/or modified atmosphere packaging results in synergistic effects on maintaining good appearance and textural quality. Since 1-MCP (Smartfresh) is now available in liquid formulation (AgroFresh, Inc.), its application to fresh-cut mangoes as a dip alone or in combination with other chemicals should be evaluated.

2.4.10 Combination Treatments Effects on Mango Quality

Gonzalez-Aguilar *et al.,* (2000) found that combinations of anti-browning agents and modified atmosphere packaging (MAP) reduced browning and deterioration of fresh-cut 'Kent' mangoes stored at 10^{o}C for up to 14 days. According to the authors, a combination of 4-hexylresorcinol (0.001M), potassium sorbate (0.05M) and D-isoascorbic acid (0.5M) was more effective than the individual chemicals in inhibiting browning, decay, and deterioration of fresh-cut mangoes. There were no significant differences in visual quality scores between mango cubes treated with 1% CaCl2 + 1%ascorbic acid + 0.5% L-cysteine and stored in air or in CA (2% O2 + 10% CO2). Visual quality scores of mango cubes in different treatments were not significantly different until day 10, when the visual quality

score of mango cubes in the control decreased to about the limit of marketability. Based on appearance, shelf lives of mango cubes treated with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine stored in air or in CA were up to 17 days, compared to 12 days for those treated with 1% CaCl2 and stored in CA and to 10 days for the control (Chantanawarangoon, 2000).

DeSouza *et al.* (2005) indicated that the symptoms limiting shelf-life of fresh-cut 'Kensington' mangoes were tissue darkening, development of a glassy appearance, surface desiccation, and loss of firmness. Low (2.5%) oxygen atmosphere was effective in controlling tissue darkening and the development of a glassy appearance, while calcium (3%) application was partly effective in controlling darkening. Calcium chloride however significantly slowed loss of tissue firmness. According to the authors, carbon dioxide (5-40%) and citric acid had little positive effect on shelf-life, with both treatments promoting tissue softening. A combination of 2.5% oxygen and 3% calcium allowed 'Kensington' mango slices to be held for at least 15 days at 3C.

Gonzalez-Aguillar *et al.* (2008) reported that combinations of calcium chloride, antioxidants (ascorbic acid, citric acid) and two commercial film coatings resulted in a reduction of browning and deterioration of fresh-cut 'Keitt', 'Kent', and 'Ataulfo' mangoes stored at 5C. Shelf-life of fresh-cut 'Ataulfo' mangoes was 21 days while that of fresh-cut 'Keitt' and 'Kent' mangoes were only 9 and 12 days, respectively. The authors related this difference to better response of 'Ataulfo' than 'Keitt' and 'Kent' mangoes to treatment with antioxidants.

2.4.11 Effect of Other Minimal Processing Methods

A short osmotic dehydration treatment (sucrose at 65 degree Brix at 30^{o}C) under vacuum (211 mbar) together with low temperature (5^{o}C) storage may be used to extend the shelf-life of minimally processed 'Kent' mango slices for 20 days (Tovar *et al*., 2001a and b). Boynton *et al.* (2000 and 2002) evaluated the effects of high pressure processing (300 and 600 MPa for one minute) on sensory quality and stability of mango cubes kept for up to 9 weeks at 3^{o}C. Fresh mango flavor declined and off-flavor increased during storage, but colour and other sensory attributes changed very little. They also found that high pressure prevented increases in microbial load that were noted in the control.

2.5 QUALITY ASSURANCE ON MANGOES

According to Litz (2003), the purpose of postharvest handling is timely delivery of a product that closely matches buyer specifications and complies with mandatory regulatory requirements. Satisfying customers underpins quality assurance which aims to produce a product of the desired standard, encouraging regular, larger and more frequent purchases and brand loyalty (Litz, 2003). Bunt and Piccone (1994) reiterated that as export markets become increasingly competitive, responsive quality assurance can be the vital strategy for maintaining and expanding market niche. Mitra (1997) maintains, however, that in general terms, quality infers some degree of excellence, giving the customer satisfaction. Thus, quality assurance is a management system for controlling quality through establishing operational procedures involving the integration of the processes, services and people concerned with the product (Mitra, 1997).

Litz (2003) reiterated that the key issues or attributes of pre-harvest management that affect or influence postharvest development of mangoes include fruit maturity, colour (internal and external), shape, size, sweetness, position–on–tree, vitality, incidence of pests and diseases or biotic/abiotic damage, weather conditions before or at harvest, frequency of irrigation and nutrient content. In any given tree/orchard/district/season, such attributes vary (Litz, 2003). According to Mitra (1997) the critical control points for quality are identified throughout the postharvest chain and procedures put in place to monitor and eliminate hazards. This may be seen in the context of a total quality management philosophy whereby the company is geared toward quality at all stages of the process; the end-result being that quality is built into the system, resulting in the final check of produce prior to distribution or storage being simply one part of the system rather than the catch-all at the end of a poorly controlled chain (Mitra, 1997).

2.6 NUTRIENT RETENTION IN FRESH-CUT MANGOES

Treatment of fresh-cut mangoes with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine for 2 min approximately doubled the reduced ascorbic acid (RAA) and total ascorbic acid (TAA) concentrations in mango cubes (Chantanawarangoon, 2000). According to the author, during 10 days of storage at 5°C, there were no significant changes in RAA, dehydroascorbic acid (DHAA), and TAA concentrations of mango cubes in control and those treated with 1% CaCl2 and stored in CA. In contrast, RAA and TAA contents of mango cubes treated with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine and kept in air or CA declined, while DHAA increased during storage. However, the decreases of RAA and TAA and the increase of DHAA were slower in those mango cubes stored in CA.

After 17 days at 5°C, the amounts of TAA of mango cubes treated with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine and stored in air decreased by about 29% of initial amount while TAA of the mango cubes treated with the same solution and stored in CA decreased by 18% of initial amounts. The results indicated that CA (2% O2 + 10% CO2) was effective in maintaining TAA by slowing the oxidation of RAA to DHAA. Therefore, the loss of RAA during storage due to the hydrolysis of DHAA to 2,3-diketogulonic acid after oxidation of RAA to DHAA were retarded under CA storage (Chantanawarangoon, 2000).

Gil *et al.*, (2006) reported that fresh-cut 'Ataulfo' mango cubes maintained good visual quality and there were no significant changes in soluble solids content, titratable acidity, and pH for up to 9 days at 5°C. The initial vitamin C content was 80 mg per 100 g fresh weight and there was a loss of about 10% during the 9 days at 5°C. No losses in total carotenoids content were noted until day 9 when the loss was about 25%. There was a slight decrease in total phenolics after 3 days at 5°C, but no subsequent losses were found between day 3 and day 9 at 5°C. In general, fresh-cut mangoes visually spoil before any significant nutrient losses occur (Gil *et al.*, 2006).

The major carotenoid in mango cubes is â-carotene with only trace quantities of á-carotene. During storage at 5°C for 17 days, there were no significant differences in â-carotene content of mango cubes at 5°C. However, mango cubes treated with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine and stored in air or CA for 17 days, whose visual quality scores were still above the limit of marketability, had lower â-carotene than those stored for 10 days (Chantanawarangoon, 2000). Robles-Sanchez *et al.*, (2007) concluded

that low temperature and controlled or modified atmospheres can preserve quality and antioxidant capacity of fresh-cut mangoes for up to 10 days.

Gonzalez-Aguilar *et al.,* (2007) reported that exposure to ultraviolet C (UV-C) irradiation for 10 minutes appears to be a good technique to improve the total antioxidant capacity by increasing phenolic and flavonoid contents of fresh-cut 'Tommy Atkins' mangoes stored for 15 days at 5C. However, this treatment reduced vitamin C and carotenoids contents.

2.7 MICROBIAL SAFETY OF FRESH-CUT MANGOES

Surface sterilization of mango fruits with 80% ethanol before peeling followed by storage in 1.5% O2 and 11% CO2 in sealed LDPE bags totally inhibited microbial spoilage of peeled mango pieces for 3 weeks at 5°C (Thambaramala, 1997). Chantanawarangoon (2000) found that after 4 days at 5°C, both the total microbial and yeast and mold counts of mango cubes in the control increased rapidly. Up to day 10, there were no significant differences in total microbial and yeast and mold counts of mango cubes among all treatments except the control, which had higher microbial counts than other treatments. After 10 days at 5°C, the microbial counts of mango cubes treated with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine and stored in air increased more rapidly than those in treatments that were stored in CA. It is clear that treatment with 1% CaCl2 + 1% ascorbic acid + 0.5% L-cysteine was effective in reducing microbial growth on fresh-cut mango cubes for up to 10 days in air and for up to 17 days in CA (2% O2 + 10% CO2) at 5°C. However, after 17 days at 5°C, microbial growth was observed only in the control mango cubes.

Narciso and Plotto (2005) pointed out that the method of whole fruit sanitation plays a role in determining the cleanliness of the cut fruit. Use of peroxyacetic acid (100ppm) to sanitize whole 'Keitt' mangoes followed by a 30-seconds dip of cut slices in peroxyacetic acid (50ppm) or acidified sodium hypochlorite (200ppm) effectively reduced microbial growth and kept microbial counts low on cut fruit surfaces for 21 days when compared to cut fruit slices from 200 ppm sodium hypochlorite-treated whole mangoes.

Plotto *et al.* (2006) concluded that, due to inconsistent results, ethanol (5g/kg) vapor applied for 20 hours to whole 'Kent' mangoes prior to processing for fresh-cut is not a practical approach to delay ripening. However, at lower doses (10 hours) it could be a safe microbial control in a fresh-cut production sanitation system. Ngarmsak (2007) found that treating fresh-cut mangoes with 80 mM vanillin solutions before packing and storage at 5^{o}C or 10^{o}C significantly delayed the growth of spoilage yeast and fungi in the fresh-cut mangoes. Although there was a noticeable faint vanilla odor immediately after processing, it was no longer evident after 7 days of storage.

Acidified sodium chlorite is a sanitizing agent recently approved by the FDA for dip or sprays treatment of food items, including fresh and fresh-cut fruits and vegetables, and has shown a strong ability to control pathogens. He *et al.* (2008) related the anti-browning action of sodium chlorite (3mM) to its inactivation of polyphenol oxidase directly and the oxidative degradation of phenolic substances. Thus, the potential effects of sodium chlorite on quality and safety of fresh-cut mangoes merit evaluation.

According to Moomin (2010), there is a positive correlation between longer shelf-life of

fresh-cut fruits and low aerobic plate count, low total plate count, and especially low yeast and mold counts. Thus, it is very important to avoid sources of microbial contamination and to wash the fruits with disinfected water before cutting.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 FIELD SURVEY

A preliminary survey was conducted with market women to identify important mango consuming and processors areas in the Greater Accra Metropolis. Information gathered from the Ministry of Food and Agriculture, Accra Regional and District offices together with the outcome of the preliminary survey were used in selecting appropriate areas (La-Dadekotopon, Ledzokuku Krowor and Accra Metro) covered in this work. On the basis of this, La-Dadekotopon-Dadekotopon, Ledzokuku Krowor and Accra Metro within Greater Accra were selected for the study. The survey was conducted between May to July, 2014.

3.1.1 Questionnaire Construction

Semi-structured questionnaires were used to assess the requisite information needed. The semi-structured questionnaires were of two types. The first questionnaire focused on the consumers of fresh cut mangoes to determine the perception and level of knowledge on the postharvest quality issues etc., whilst the second questionaire was for processors to determine variety, mode of handling, packaging etc. of fresh mango fruits. In addition to the above, data collection covered the following sections: bio-data of respondents, location, variety, purchase and sales; mango quality issues as well as infection and contamination issues. Secondary data was also sourced from the Ministries of Agriculture and Trade, NGOs and Associations such as FAGE (Federation of Association of Ghanaian Exporters) on information on trends and development of mango marketing. The data was used to draw a value chain map of value-added mangoes in Accra.

3.1.2 Sampling Area

Sampling was done in the three selected areas namely; La-Dadekotopon, Ledzokuku Krowor and Accra Metro, all in the Accra Metropolis. Areas among high mango consuming and processors were identified and used as sampling location.

3.1.3 Questionnaire Administration

Interviews using semi-structured questionnaires were administered to two different groups (processors and consumers) randomly in the selected areas randomly. Semi-structured questionnaires were administered to elicit information from 90 processors in *La-Dadekotopon, Ledzokuku Krowor* and *Accra Metro*, whilst a second set of semi-structured questionnaires were administered to elicit information from 150 consumers of fresh-cut fruits from the Accra metropolis for their perception and knowledge on quality issues of mango. The questionnaires explored attitudes, perception and purchasing behaviour of mangoes with particular emphasis on specific postharvest product quality attributes that consumers consider when buying mangoes and the determination of microbial and contaminations and effect of mode of handling and processing. For the processors, the questionaire focused on personal information, consumer preference on mango varieties, postharvest quality issues; source of purchase (farm gate, bulkers, wholesalers); stage of ripeness (full ripe, half ripe, half green, full green); handling (pre-processing treatment - finding out processes involved in preparing the fresh cuts- washing the fruits, washing with salt, cleaning of cutting materials, type of packaging materials); storage (room temperature, refrigeration); processing(peeling, cutting in smaller sizes); quantity bought ; quantity sold; how long it takes to sell after processing; environment

where sold; determination of knowledge level of the seller/ processor on bacteria and microbial infection of the fresh cut; barriers to purchase (price, difficulty in choosing a ripe mango, degree of blemish or defect); packaging and presentation (materials) and storage (before processing and selling and storage of unsold fresh cuts).

3.1.4 Statistical Analysis

Data collected from all sampling locations were analyzed using the Statistical Package for the Social Scientist (SPSS) version 16. Descriptive statistics were the statistical tools employed in the analysis. The data output were presented in tables and graphs (pie and bar charts).

3.2 LABORATORY EXPERIMENTS

The laboratory analyses were carried out at the Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR), near Legon, Accra between May to September, 2014.

3.2.1 Sources of Microbial Loads on Fresh Cut Mango Fruits

Fresh cut mango fruits from different processing types were selected for the study. These were those that were already processed and Hawked (A), those that were cut on demand, thus, on Demand cut (D) and those that were processed in Restaurant (R). These fruits were taken from three different localities in the Accra Metropolis, namely, *La-Dadekotopon*, *Ledzokuku Krowor* and *Accra Metro*. These different cut fruits from

different sources were however observed/analysed at different period of sales, i.e. immediate cut and after 6hours of cut.

3.2.2 Preparation of PCA (Plate Count Algar)

Ten (10g) grams of sample were added to 90ml of sterile salt peptone solution(SPS) containing 0.1% peptone and 0.8% Sodium Chloride(Nacl), with pH adjusted to 7.2 and homogenized in a stomacher (Lab blender, Model 4001, Seward Medical) for 30seconds at normal speed. From appropriate tenfold dilution 1ml aliquots of each dilution was directly inoculated into sterile petri dish. 15-20ml of molten PCA cooled at 45^{o}C±1^{o}C was poured into the inoculated plated and mixed by rotation and shaking and allowed to set while the plates were in a horizontal positions.

The plates were incubated at 30^{o}C for 72hours in accordance with the Nordic Committee at Food Analysis Method (NMKL No. 86 2006).

3.2.3 Amending of PCA

Amendment of PCA was carried out using a broad spectrum antibiotic, Ampicillin (250mg). Two capsule of Ampicillin was dissolved in 2ml of autoclaved distilled water and added to 500ml molten PCA. This was gently shaken to obtain a fine mixture before pouring was done. This done in accordance with [NMKL No. 71, 1999].

3.2.4 Isolation of Coliform Bacteria

10g of sample were weighed into sterile stomacher bag and 90ml of diluent (SPS) added. The sample then homogenised using stomacher machine for 30seconds from appropriate

ten-fold dilution, 1ml of aliquots was directly inoculated into sterile petri dish by means of sterile pipette. 5ml of tryptone soya agar (TSA), previously cooled to 45^{o}C±1^{o}C in water bath (No 047) was poured and mixed with the inoculum thoroughly and allowed to solidify. The plates were then pre-incubated at room temperature (20-25^{o}C) for 2 hours. 10-25ml of Violet Red Bile Agar (VRBA) (selective medium) was poured on the pre-incubated TSA and allowed for solidification. The ration between the top layer and bottom which was at least 2:1 plates were then incubated invertedly at 37^{o}C±1^{o}C for 24hours.

Plates with 10-100 colonies with purplish red and diameter of 0.5mm or greater, surrounded by reddish precipitation zone were selected.

3.2.5 Identification of Microbial Loads

Pure cultures of individual microbial isolates (14 day old) were critically examined and identified. Colony identification was based on colony characteristics such as colour and texture and type of pigmentation. Microscopic characteristics of microbes such as shape and colour were depended on in identifying the microbial isolates based on descriptions of Holliday (1995) and Mathur and Kongsdal (2003).

3.3 CONFIRMATION TEST

3.3.1 Experiment One: Identification *E. coli*

For *E. coli* the plates were incubated at 44±1^{o}C for 24hours±3hours. A single colone was sub-cultured into *E. Coli* broth and incubated at 44±1^{o}C. Production of gas in the Durham

tube, which was half filled, was suspected to be *E. coli*. A suspected tube was streak on tryptone soya agar and incubated at 44±1^{o}C for pure culture. A single colone of suspected culture, was then sub-cultured into 5ml tryptone water and incubated at 44±1^{o}C for 24hours 2-3 drops of Kovacs reagent added into each tube. The appearance of Red ring on the surface of the broth within 3seconds to 1minutes was an indication of positive test. This was done in accordance with [NMKL No. 71, 1999].

3.3.2 Experiment Two: Identification of Yeast and Moulds

Ten grams (10g) of sample were weighed into sterile stomacher bag and 90ml of SPS of pH 7.2±2 added to obtained 1:10, thus, 10^{-1} dilution. It is then homogenised using stomacher machine at normal speed for 30 seconds. By spread method, 0.1ml was inoculated onto Dichloran Rose-Bengel Chloramphenicol Agar plates, to which a supplement of Chloramphenicol (SR0078) added to inhibit bacterial growth and spreading moulds. With sterile spreader, the inoculum was carefully spread on the DRBC plate. The plate was then incubated at 25^{o}C for 3 – 5 days in accordance with (ISO 21527 – 1 2008).

3.4 EXPERIMENTAL DESIGN

A 3x2 Factorial Experiment in a Completely Randomized Design (CRD) was the experimental design used. Experiments were replicated three times. The different processor types served as factor one, thus, processed in Restaurant (R), already processed and Hawker (A), on-Demand processing (D) whilst the period of sale served as factor two, thus, Immediate (I), 6hrs Later (L). The different localities served as replicates. There were 3 replications R1 (La

Dadekotopon); R2, (Accra Metro); R3(Ledzokuku Krowor). In all, there were 18 samples of cut fruits (6 samples each replicated 3 times) were involved.

3.5 STATISTICAL ANALYSIS

Data collected was subjected to statistical analysis using Analysis of Variance (ANOVA). Statistical package used was Statistix version 9. Testing for differences between means was at 5% level (P = 0.05).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter presents the findings of the questionnaires elicited from the respondents who comprised of mango consumers and processors randomly selected from the three areas in the Accra Metropolis. It also contains findings from the laboratory experiments conducted on the microbial loads of freshly cut mango samples collected from the various locations.

4.1 FIELD SURVEY

4.1.1 Gender of Consumers

Generally, the data on the sex of the respondent in the three localities showed that males dominated in the consuming of fresh cut mangoes in all the three towns with an average percentage of 58.1% and the females forming 41.9% (Figure 4.1). The study therefore, showed that majority (58.1%) were male while 41.9% were females.

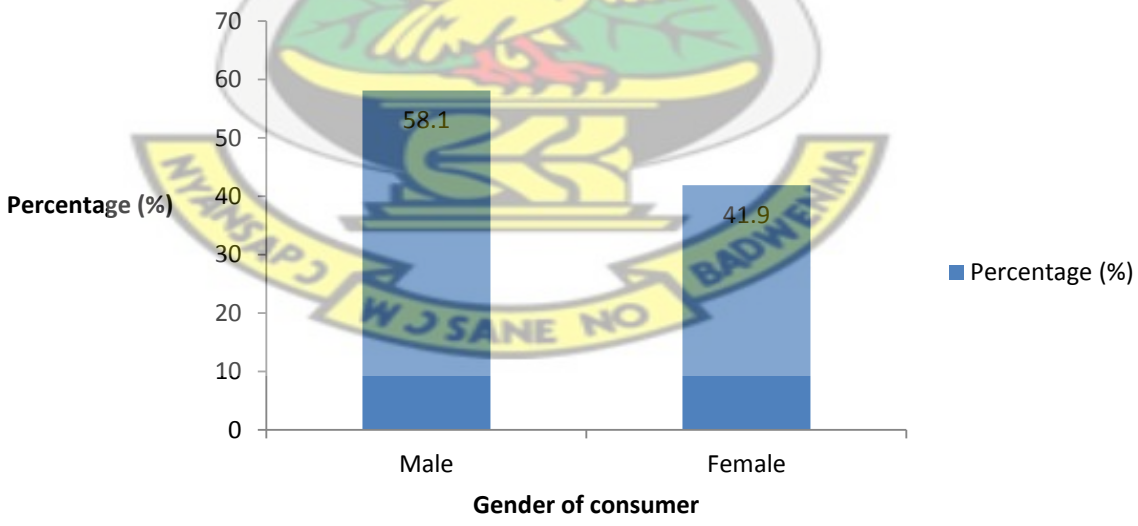

Figure 4.1: Gender of consumers

4.1.2 Age Distribution

Data on age distribution of the consumers are summarized in Table 4.1. Most of the respondents were in the age range of 19-24 years (27.3%), 25-30 years (19.3%), 13-18 years (18.7%), 31-36 years (11.3%) while 1.3% were in the range of above 60 years (Table 4.1). Deducing from Table 4.1 below, about 80% of the respondents were below 40 years whilst less than 20% of the respondents were 40 years and above.

Table 4.1: Age Distribution of Consumers

Age Range (years)	Frequency	Percentage (%)
Below 13	4	2.7
13-18	28	18.7
19-24	41	27.3
25-30	29	19.3
31-36	17	11.3
37-42	8	5.3
43-48	11	7.3
49-54	6	4.0
55-60	4	2.7
Above 60	2	1.3
Total	**150**	**100.0**

4.1.3 Level of Education

On the level of education, majority (47.3%) of the consumers interviewed had SHS education, 18.0% had Diploma, 14.0% had basic education while 12.0% had tertiary education (Table 4.2).

Table 4.2: Level of Education of Consumers

Educational level	Frequency	Percentage
Basic	21	14.0
SHS	71	47.3
Diploma	27	18.0
1st or 2nd Degree	18	12.0
Professional	13	8.7
Total	**150**	**100.0**

4.1.4 Perception and Level of Knowledge of Consumers on Postharvest Quality Parameters, Microbial Loads and Contaminations.

4.1.4.1 Softness

From Figure 4.2, 77.33% of the consumers interviewed were able to determine ripeness of the fruits based on its softness while 22.67% could not determine their ripeness. Majority (78%) preferred buying fruits that are ready to eat on that same day, 12% preferred fruits that could be eaten within a day or two whilst 10% preferred fruits that could be consumed within 3 or more days.

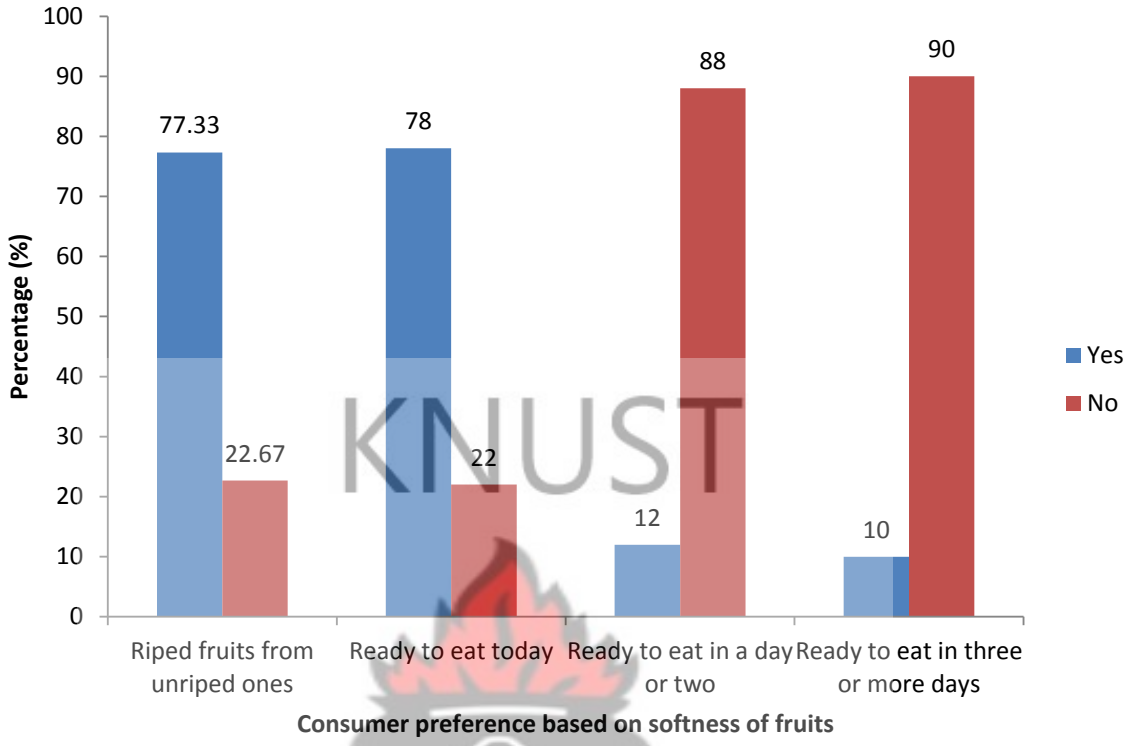

Figure 4.2: How consumers' preference for fresh mango fruits is affected by their ability to distinguish between ripe mango fruits by its softness

4.1.4.2 Smell

Figure 4.3 showed that most (78%) preferred buying fruits that are ready to eat on that same day, 12% preferred fruits that could be eaten within a day or two whilst 10% preferred fruits that could be consumed within 3 or more days. Few of the consumers interviewed were able to know that the fruits are riped based on its smell while 87.33% of the consumers could not determine that the fruits were ripped based on its smell.

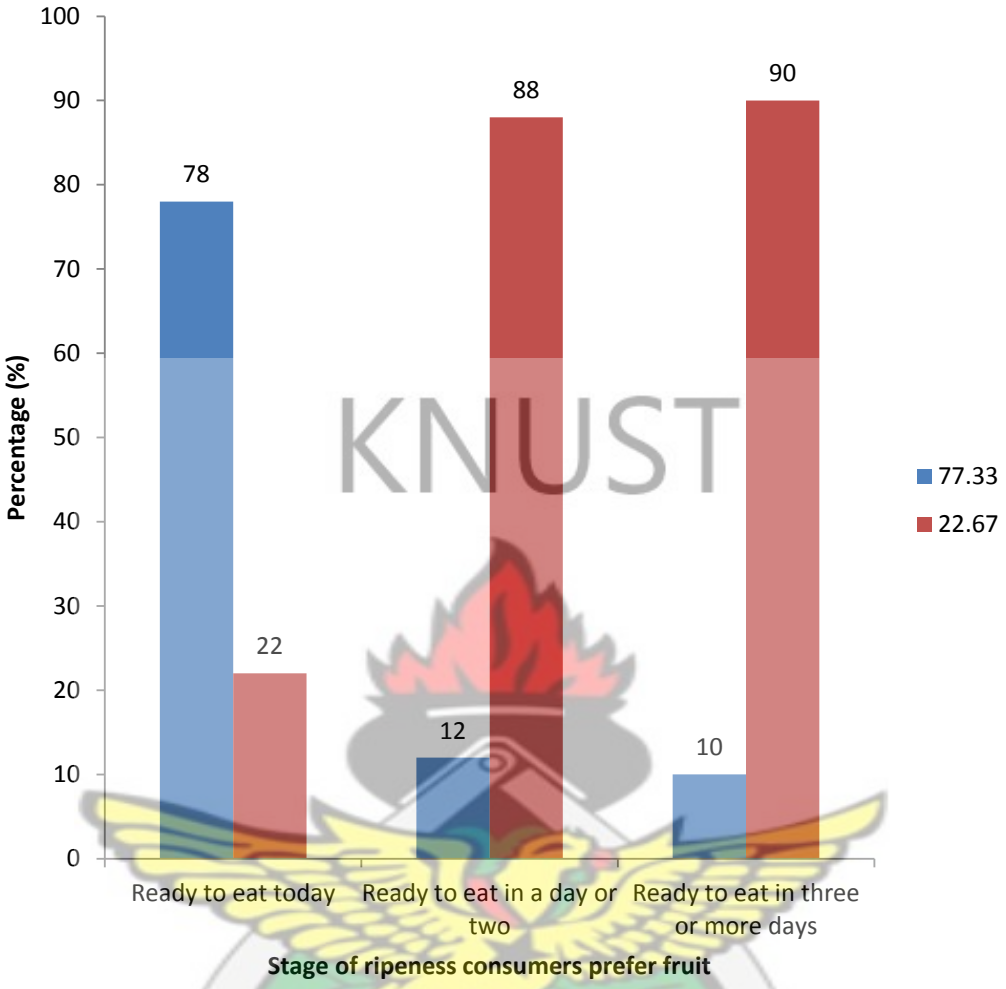

Figure 4.3: How consumers' preference for fresh mango fruits is affected by their ability to distinguish between ripe mango fruits by its smell

4.1.4.3 Skin color

From Figure 4.4, 36% of the consumers interviewed were able to know that the fruits are ripped based on the colour of the skin while the majority (64%) of the consumers could not determine that the fruits were riped based on its skin colour. Most (78%) of the consumers preferred buying fruits that are ready to eat on that same day, 12% preferred fruits that could be eaten within a day or two while 10% preferred fruits that could be consumed within 3 or more days.

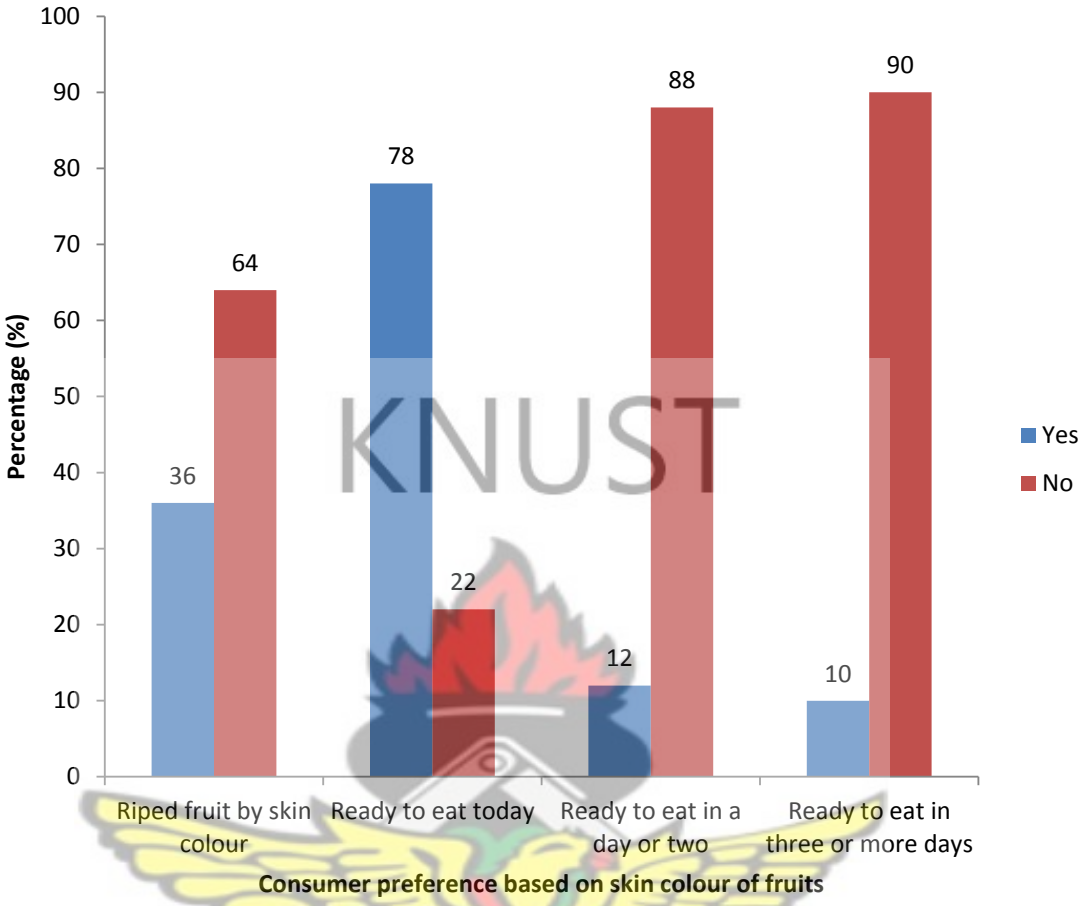

Figure 4.4: How consumers' preference for fresh mango fruits is affected by their ability to distinguish between ripe mango fruits by colour of the skin

4.1.4.4 Riped and unriped fruits

From Figure 4.5, 2.67% of the consumers interviewed could not ascertain as to whether a mango fruit is ripped or not. The majority 97.33% of the consumers could determine that the fruits were ripped or not. Most (78%) consumers preferred buying fruits that are ready to eat on that same day, 12% preferred fruits that could be eaten within a day or two while 10% preferred fruits that could be consumed within 3 or more days.

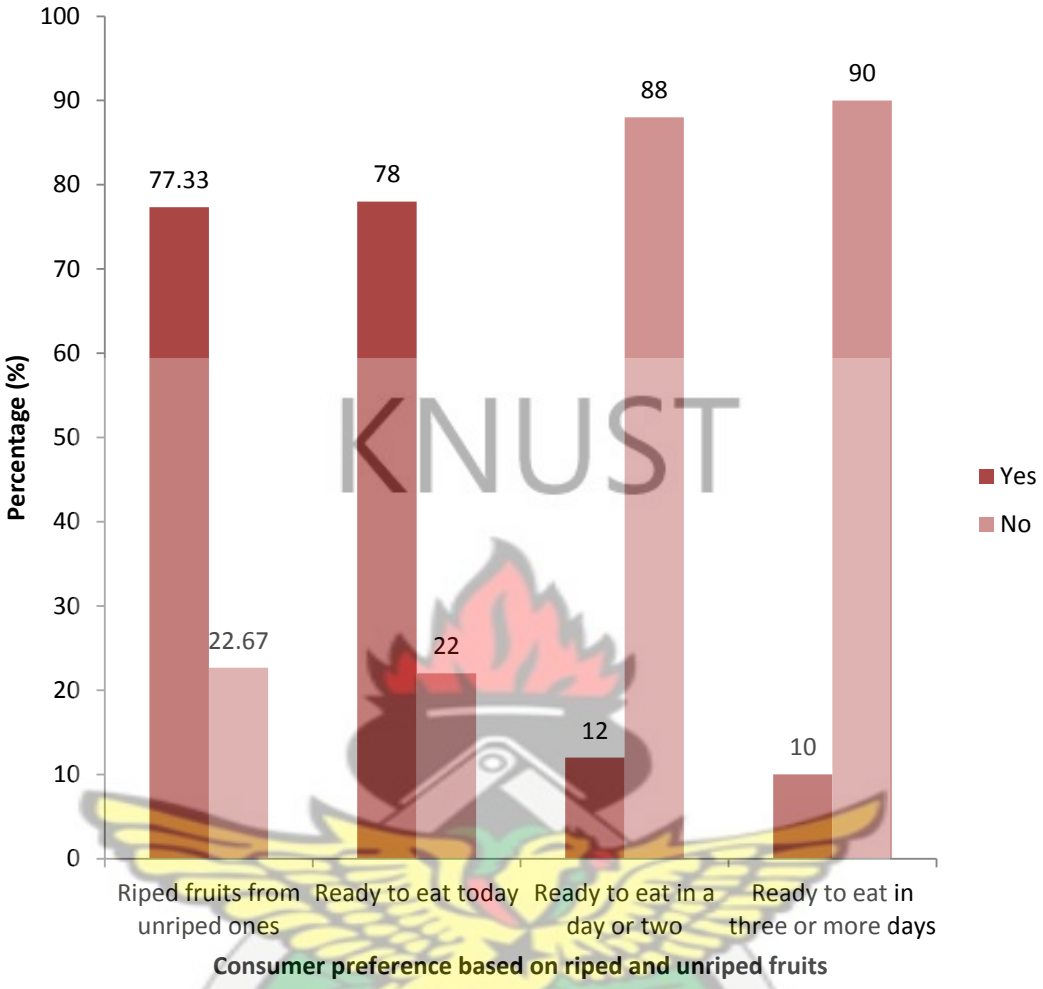

Figure 4.5: How consumers' preference for fresh mango fruits is affected by not knowing whether fruits are ripped or not.

4.1.5 Source of Fresh Cut Mango Fruits.

Table 4.3: Source/ Purchasing point of fresh cut mango

Source of fresh cut mango fruits	**Frequency**	**Percentage**
Supermarket	9	6.0
Local fruit store	65	43.3
Wayside/Hawkers	76	50.7
Total	**150**	**100.0**

From the survey, it was realized that most (50.7%) consumers purchased their fresh cut fruits from wayside/hawkers, 43.3% bought their fresh cut fruits from local stores while 6% of the consumers purchased their fresh cut fruits from supermarkets (Table 4.3).

4.1.6 Quality Traits Consumers Consider When Buying Fresh Cut Fruits

Consumers were also questioned on the specific traits they consider when buying fresh cut mango fruits.

It was realised that consumers consider traits like the softness of the fruits (32%), the colour (16.7%), aroma (4%), sweetness (39.3) and the type of fruits they buy (8%) (Table 4.4).

Table 4.4: Qualities consumers consider when purchasing fresh cut mango fruits

Quality traits	Frequency	Percentage
Softness	48	32.0
Colour	25	16.7
Aroma	6	4.0
Sweetness	59	39.3
Type	12	8.0
Total	**150**	**100.0**

4.1.7 Consumers Preference on Mango Varieties

Consumers' knowledge was also sought on the varieties of fresh cut mango fruits they preferred to buy. It was realized 67.1% of consumers preferred to buy Keit, 18.9% preferred Kent 11.9% preferred Palma whilst 2.1% preferred the Jafna type of mango (Figure 4.6).

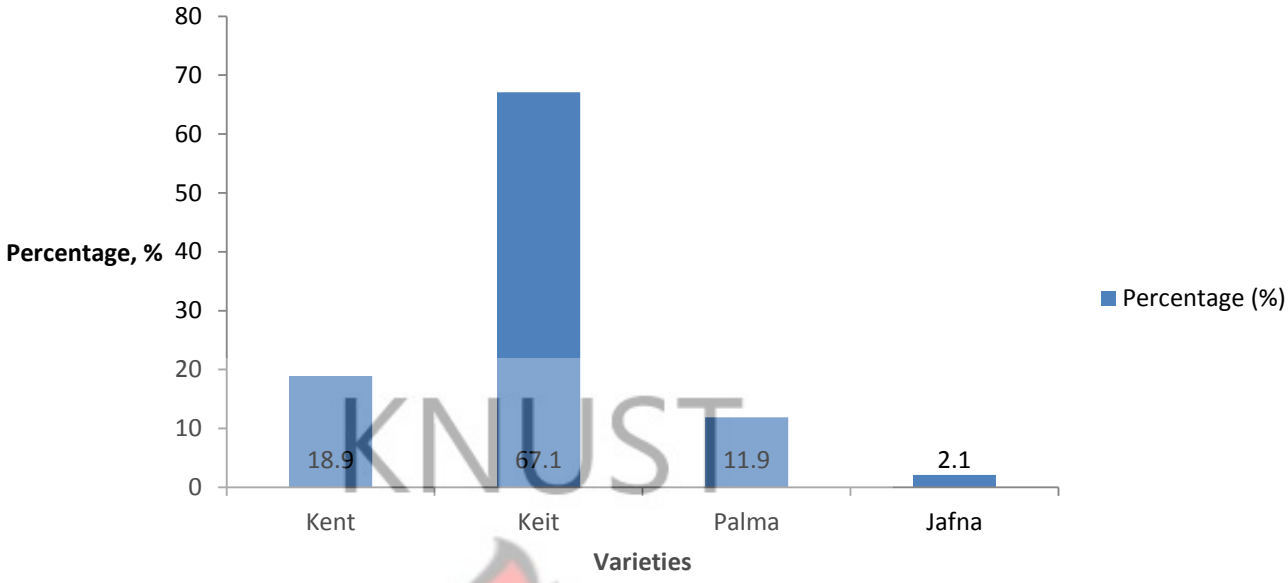

Figure 4.6: Varieties preferred by consumers

4.1.8 Consumer satisfaction

Consumers were asked how satisfied they were with the fresh cut mango fruits they purchased. Majority (88.7%) were satisfied with its quality whilst 11.3% said they were not satisfied with the quality of the fruits they buy (Table 4.5).

Table 4.5: Consumer satisfaction with quality of the fresh mango fruits purchased

Satisfied or not	Frequency	Percentage
Yes	133	88.7
No	17	11.3
Total	**150**	**100.0**

4.1.9 Barriers to the Purchase of Fresh Cut Mango

From Table 4.6, barriers that affected consumers that purchase fresh cut mango fruits were the price of the cut fruits (45.3%), degree of blemish or defect formed (27.3%),

quality of packaging and presentation of the cut fruits (16%) whilst difficulty in choosing a ripe mango had 11.4%.

Table 4.6: Some barriers to the purchase of fresh cut mango fruits by consumers

Some barriers	Frequency	Percentage
Price	68	45.3
Difficulty of choosing a ripe mango	17	11.4
Degree of blemish or Defect	41	27.3
Packaging and presentation	24	16.0
Total	**150**	**100.0**

4.1.10 Consumer Preference Characteristic

Higher proportion of the respondent forming 40% prefer to buy fresh cut fruits using the natural taste/flavor, 36.6% consider the freshness of the fruits whilst 20% consider the fact that no additives/ preservatives are added. Few (3.4%) of the respondents buy fresh cut fruits considering the fact that they have better appearance/colour.

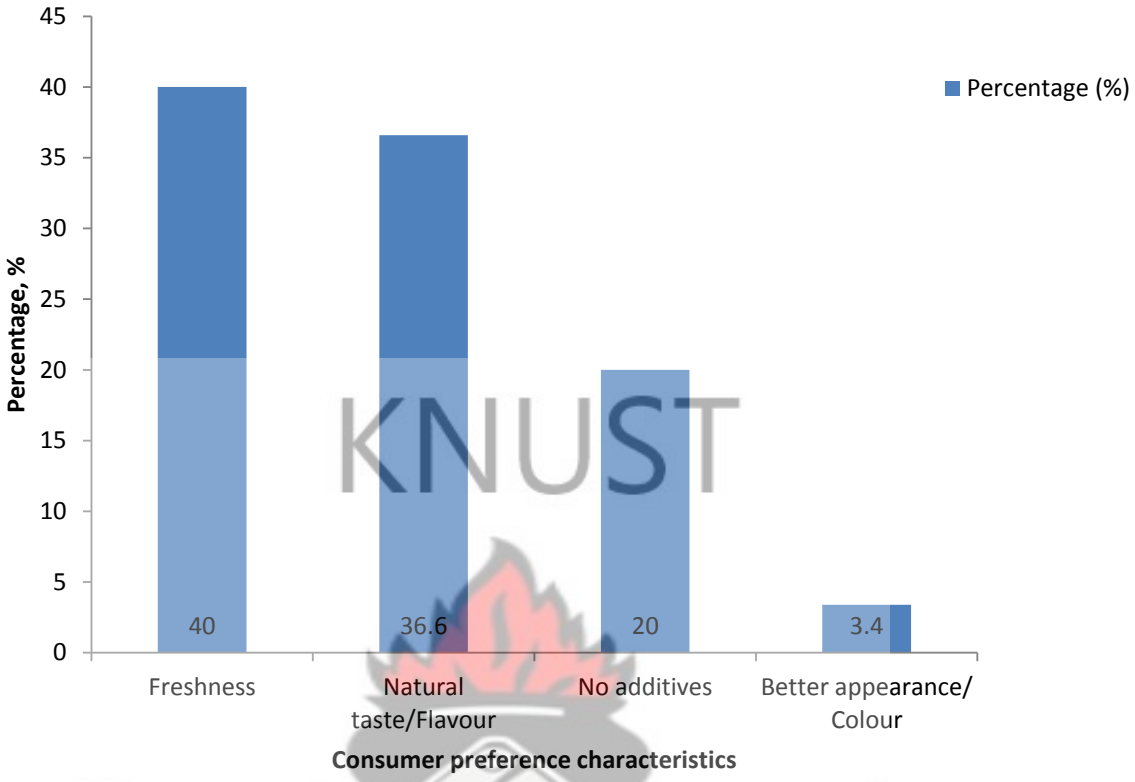

Figure 4.7: Percentage distribution of consumer preference characteristics

4.1.11 Determination of Knowledge Level of the Consumer on Bacteria and Microbial Infection of the Fruits that are purchased

Majority (70.7%) were aware of the infections on fresh cut mango fruits while 29.3% did not know fresh cut mango fruits can get contaminated (Table 4.7).

Table 4.7: Consumers awareness of the infections on fresh cut mango fruits

Infections awareness	**Frequency**	**Percentage**
Yes	106	70.7
No	44	29.3
Total	**150**	**100.0**

Figure 4.8 showed the percentage distribution of some of the possible causes of contamination on fresh cut mango fruits. Sources of most contaminations were from poor

handling of fresh cut fruits (37.1%), bacteria causing infections (31.9%) whist fungi causing infections had 17.6%. The use of contaminated packaging material represented 8.4% and the use of contaminated knife recorded 5%.

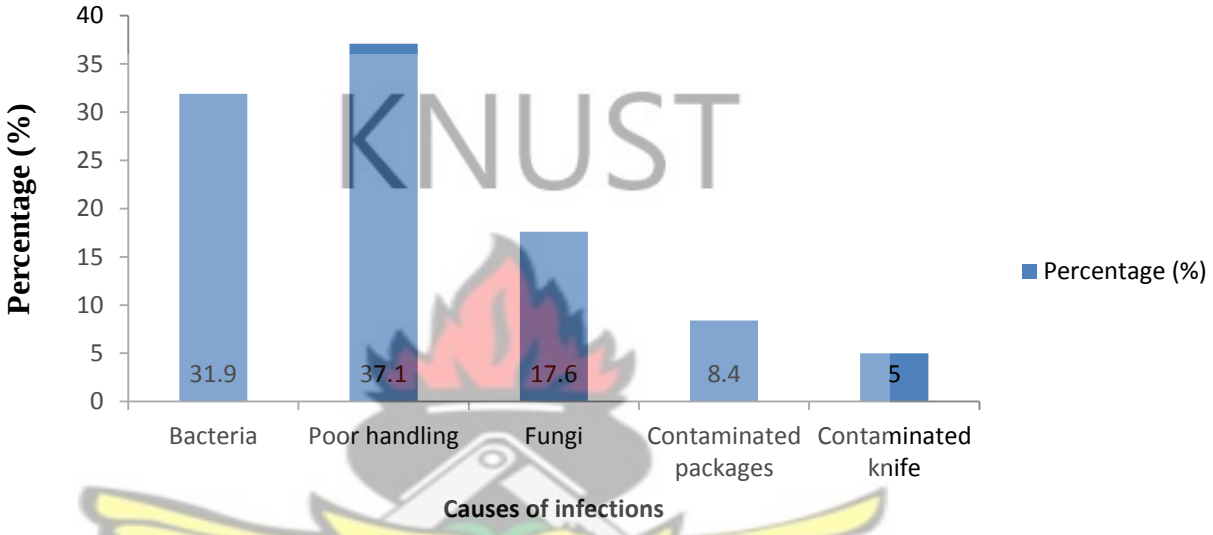

Figure 4.8: Percentage distribution on causes of infections to fresh cut mango fruits

Majority (67.1%) of the consumers eat their fruits immediately after purchase while 32.9% of them do not usually eat them as soon as purchased (Figure 4.9).

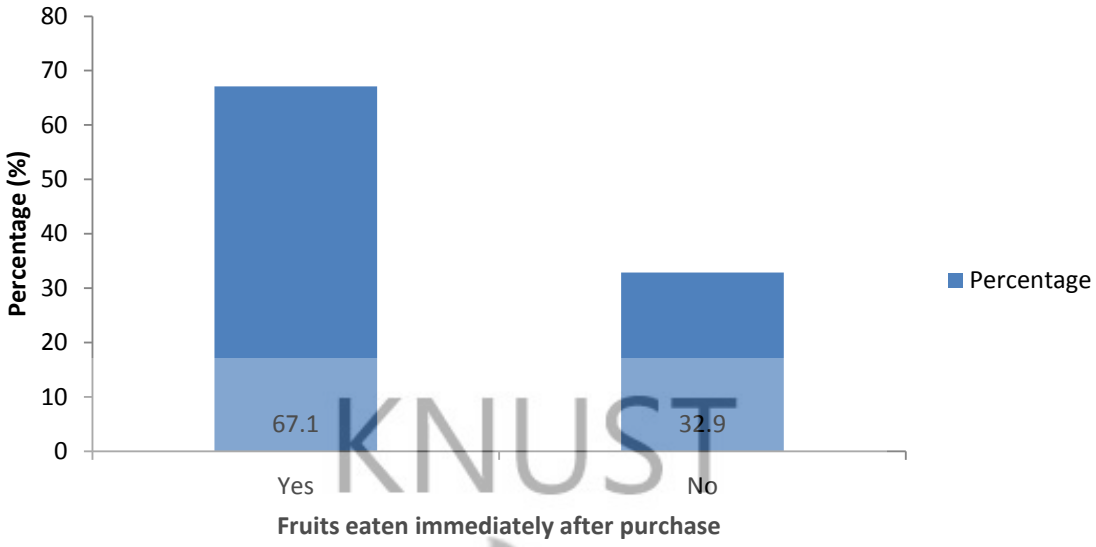

Figure 4.9: Percentage distribution on whether consumers eat fresh cut mango fruits immediately after purchase or not

4.1.12 Storage of Fresh-Cut Mango Fruits

Majority (67.1%) of the consumers kept their fruits in the fridges, 24.2% kept theirs at room temperatures while 8.7% of the consumers kept their fresh cut mango fruits in cool and dark places (Figure 4.10).

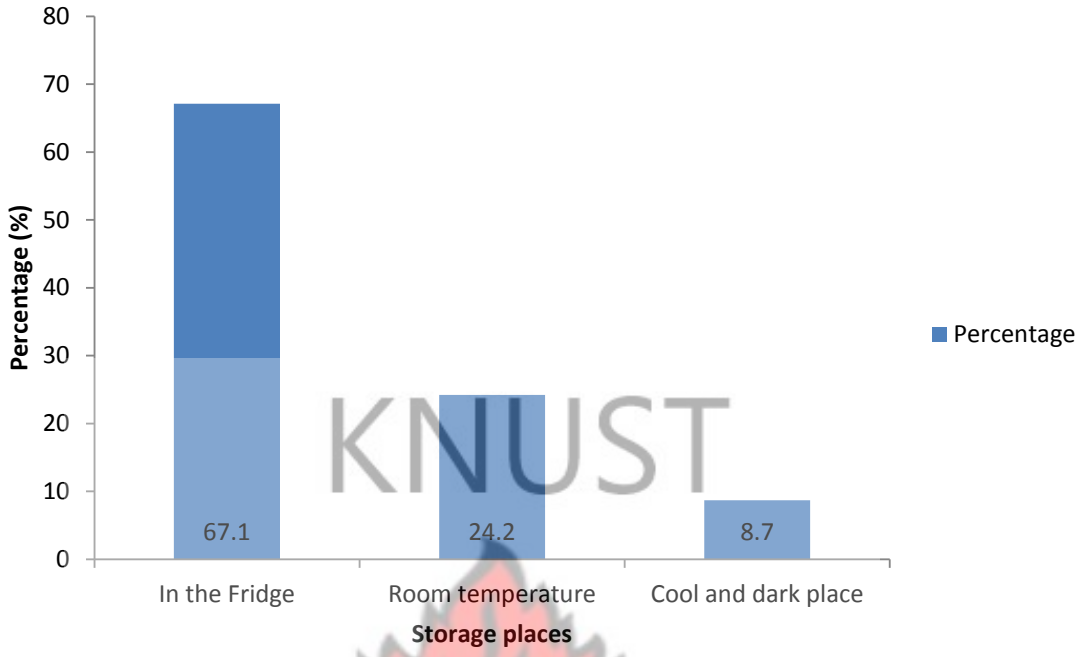

Figure 4.10: Percentage distribution for storage of fresh cut mango fruits at home by consumers

4.1.12.1 Storage time of fresh-cut mango fruits

It was realised that most of the consumers constituting about 78% consume their fresh cut mango fruits within an hour of purchase, 18.67% consume their fruits within 6 hours of purchase while 3.33% were found to consume their fruits after 6 hours (Table 4.8).

Table 4.8: Time period consumers normally consume fresh cut fruits after purchase

Time period	Frequency	Percentage
Within 1 hour	117	78.00
Within 6 hours	28	18.67
After 6 hours	5	3.33
Total	**150**	**100.0**

4.1.12.2 Storage of leftover fresh-cut mango fruits

From Figure 4.11, most (91.8%) of the consumers stored their leftover fresh cut mango fruits in refrigerators whilst 8.2% were stored theirs at room temperatures.

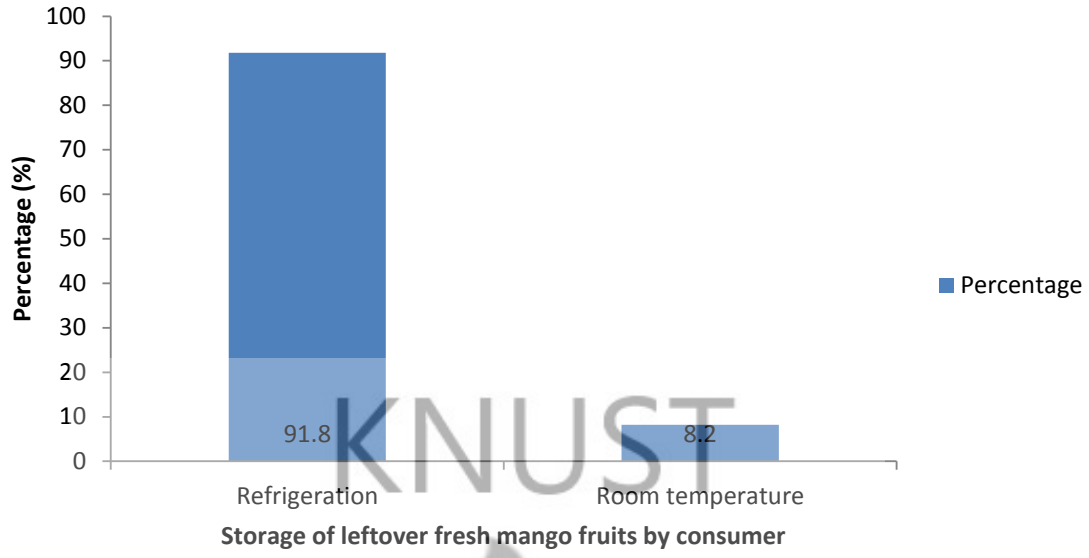

Figure 4.11: Percentage distribution on storage of left over fresh mango fruits by consumers

4.2 PROCESSORS/SELLERS

4.2.1 Gender

Data on the sex of the respondent in the three localities showed that females dominated in the value addition (processing) to fresh cut mangoes in all the three towns with an average percentage of 90.0% and the males forming 10.0% (Table 4.9).

Table 4.9: Gender of the Processors

Location	Gender		Total percentage
	Male	Female	
Accra Metro	3.33	96.67	100
La-Dadekotopon	0.00	100.00	100
Ledzokuku Krowor	26.67	73.33	100
Percentage mean	**10.00**	**90.00**	**100.00**

4.2.2 Age Distribution

Data on age distribution of the processors from the three different localities are summarized in Figure 4.12. Most (22.22%) of the processors were in the age range of 25-30 years, 18.89% were in the age range of 36-40 years, 31-35 years had 15.56%, 18-24 years had 14.44%, 41-45 years had 13.34%, 46-50 years had 8.89% while 51-55 years and 56-60 years each occurred with the same percentages of 3.33% (Figure 4.12). Deducing from Figure 4.12, about 71.1% of the respondents were 40 years and below whilst less than 28.9% of the respondents were above 40 years.

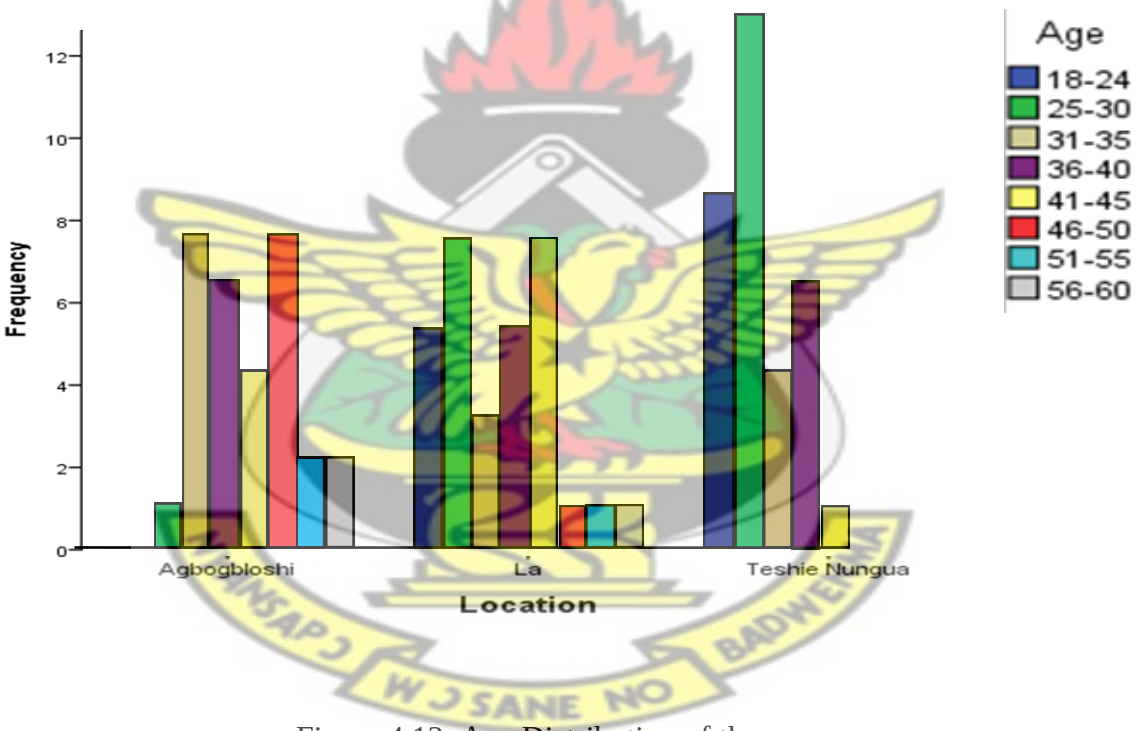

Figure 4.12: Age Distribution of the processors.

4.2.3 Educational Level

On the level of education, majority (82.22%) of the processors interviewed had basic education, 15.56% had been into SHS/Vocational while 2.22% of the processors from Ledzokuku Krowor have had post-

secondary qualifications (Figure 4.12). From Figure 4.12 below, none of the respondents from Accra Metro has any other qualification aside basic ones.

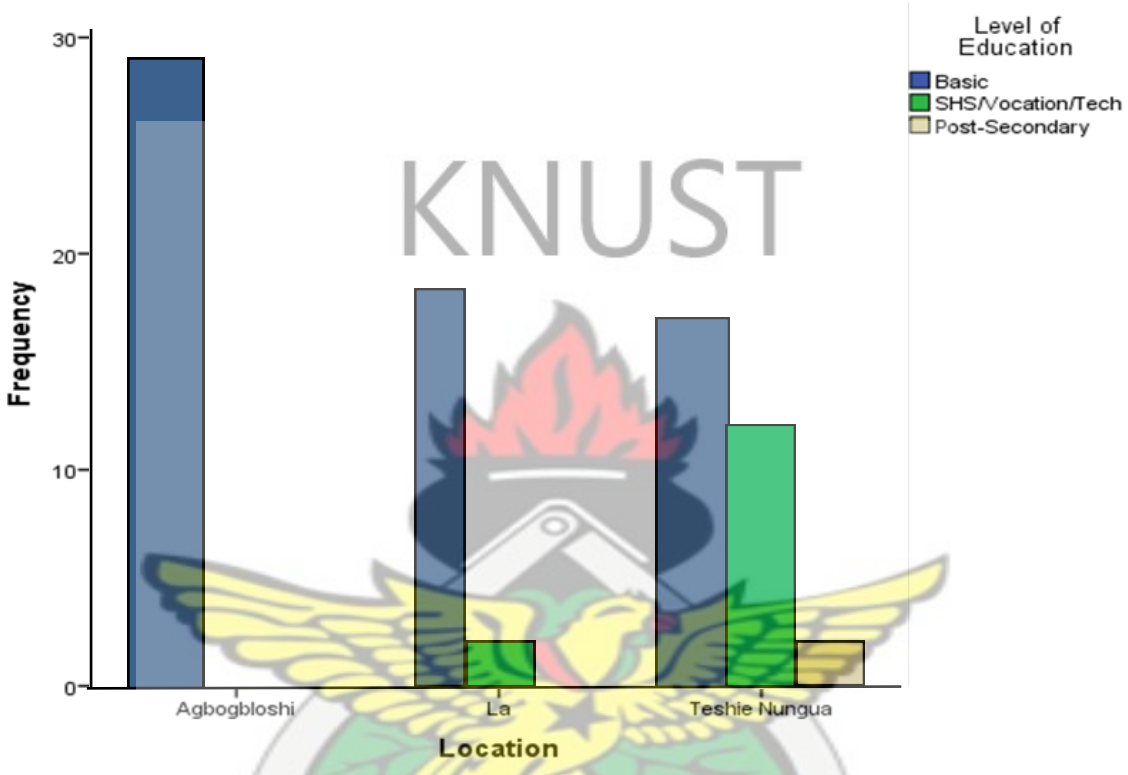

Figure 4.13: Educational level of processors

4.2.4 Perception and Level of Knowledge of Processors on Postharvest Quality Parameter, Microbial and Contaminations.

4.2.4.1 Processors preference on mango varieties

None of the processors from the three areas was in the sales of Jafna (Table 4.10a). Customers prefer Keit the most (81%), followed by Kent, Palma and Jafna respectively.

Table 4.10a: Variety of mango processors' customers prefer to buy

Mango varieties	Preference	Location (%)			Totals (%)
		Accra Metro	La-Dadekotopon	Ledzokuku Krowor	
Kent	Yes	16.67	3.33	66.67	28.89
	No	83.33	96.67	33.33	71.11
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Keit	Yes	73.33	100.0	96.67	90.0
	No	26.67	0.0	3.33	10.0
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Palma	Yes	6.67	0.0	0.0	2.22
	No	93.33	100.0	100.0	97.78
	Total	**100.0**	**100**	**100**	**100.0**
Jafna	Yes	0.0	0.0	0.0	0.0
	No	100.0	100.0	100.0	100
	Total	**100.0**	**100.0**	**100.0**	**100.0**

Keit and Kent varieties of mango were the ones processors were interested in, with 81% of the processors interested in Keit while the remaining 17.78% were interested in the Kent with 1% interested in others varieties such as Jafna (Table 4.10b).

Table 4.10b: Varieties of mango processors prefer to buy and process

Location	Mango varieties (%)			Total (%)
	Kent	Keit	Others	
Accra Metro	6.6	90.00	3.33	100.0
La-Dadekotopon	3.33	96.67	0.00	100.0
Ledzokuku Krowor	43.33	56.67	0.00	100.0
Total	**17.78**	**81.11**	**1.11**	**100.0**

4.2.5 Sources of Fresh Fruits by Processor/Sell

According to Figure 4.14, markets and farm gates are the common places where processors sourced their fruits. Processors from Accra Metro sourced/purchased their fresh fruits from farm gates (22.2%) whilst processors from La-Dadekotopon and Ledzokuku Krowor sourced/purchased their fruits from markets (22.2% and 18.9% respectively).

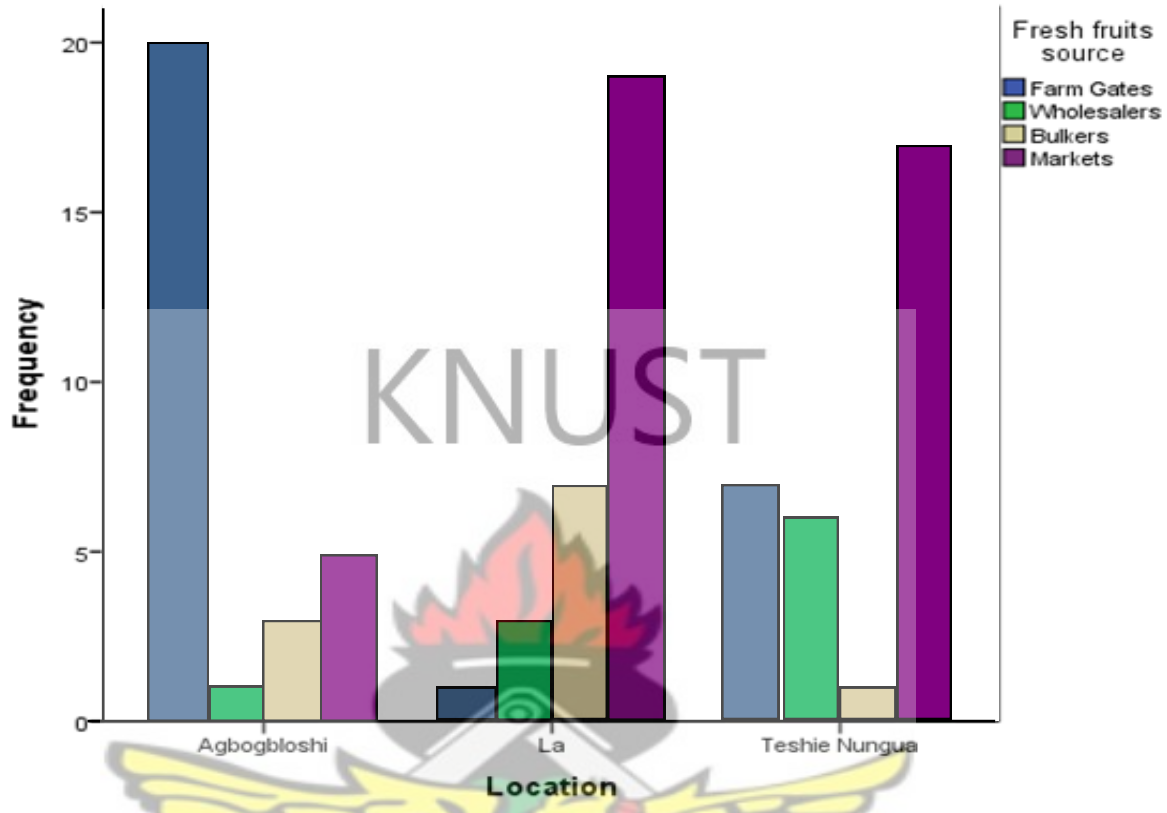

Figure 4.14: Sources of fresh mango fruits by processors.

4.2.6 Stage of Ripeness Processors Purchase Mango Fruits

Different processors prefer their fruits at different ripe stage. Some prefer their fruits at full ripe, half ripe, full green and half green stages of ripeness (Figure 4.15).

From Figure 4.15 above, processors from Accra Metro and La-Dadekotopon prefer their fresh fruits at the full green stage (26.6 and 14.4% respectively) while those from Ledzokuku Krowor like their fruits at half green stage (22.2%).

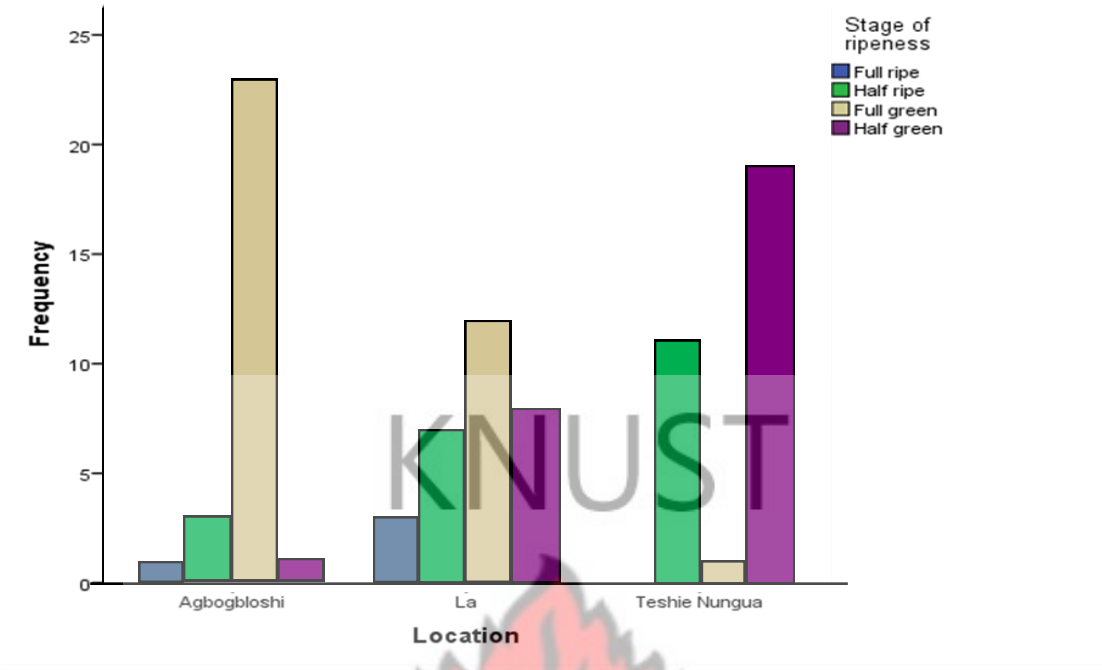

Figure 4.15: Stage of ripeness processors purchase their fruits.

4.2.7 Quantities of Mango Fruits Purchased and Sold by Processors

Table 4.11a showed the quantities of fresh mango fruits processors are able to purchase at a time for processing. Some processors (32.22%) are able to purchase 51-100%, 11.11% purchase 20-50% whilst others too are able to buy less than 20 fruits (6.67%), (Table 4.11a).

From Table 4.11a that out of the 30 people that were interviewed from from Accra Metro, about 73% of them are more likely to sell more than 100 fruits while about 47% and 30% from La-Dadekotopon and Ledzokuku Krowor s Nungua respectively are more likely to sell above 100 fruits.

Table 4.11a: Quantity of fresh mango fruits processors purchase at a time

Location	Quantity purchased at a time (%)				Total (%)
	Less than 20	20–50	51–100	Above 100	
Accra Metro	3.33	3.33	20.00	73.34	100.0
La-Dadekotopon	16.67	10.00	26.67	46.67	100.0
Ledzokuku Krowor Nungua	0.00	20.00	50.00	30.00	100.0
Total	**6.67**	**11.11**	**32.22**	**50.00**	**100.0**

4.2.7.1 Sells of purchased fruits by consumers

Most of the processors from the three locations are more likely to sell the fresh purchased mango fruits within 7 days (46.67%) followed by those who sell them within 6 days (14.44%), 3 days (11.11%), 4 days (8.89%), 5 days (7.78%), 2 days (6.67%) and within a day (4.44%) (Table 4.11b).

Table 4.11b: Period taken to sell purchased fresh mango fruits

Period of sale	Location (%)			Total (%)
	Accra Metro	La-Dadekotopon	Ledzokuku Krowor	
Within a day	3.33	10.00	0.00	4.44
2 Days	6.67	13.33	0.00	6.67
3 Days	3.33	26.67	3.33	11.11
4 Days	10.00	3.33	13.33	8.89
5 Days	3.33	6.67	13.33	7.78
6 Days	10.00	0.00	33.33	14.44
7 Days	63.33	40.00	36.67	46.67
Total	**100.0**	**100.0**	**100.0**	**100.0**

Processor are able to sell less than 50% (53%) in a day, followed by those who can sell between 51-70% (20%) of their fruits in a day whlist about 17% are able to sell between 71-100% of their fruits (Table 4.11c).

Table 4.11c: Proportion of fresh fruits processors sell in a day

Location	Proportion sold/day				Total
	Less than 50%	51-70%	71-100%	Other	
Accra Metro	15	7	3	5	30
La-Dadekotopon	18	5	6	1	30
Ledzokuku Krowor Nungua	20	8	2	0	30
Total (%)	**53**	**20**	**11**	**6**	**90**

4.2.8 Fresh Mango Processing Activities

Table 4.12 showed the activities processors take mangoes through when processing them into fresh cuts for consumers/customers to buy. The main processes that processors take fresh mangoes through when preparing them into fresh cuts included: washing of fruits with water (85.5%), washing of hands (46.7%), washing with salt water and cleaning of tools (7.8 and 31.1% respectively) (Table 4.12).

Table 4.12: Activities fresh mangoes are taken through before processing

Processes	Preference	Location			Totals
		Accra Metro	La-Dadekotopon	Ledzokuku Krowor Nungua	
Washing of fruits with water	Yes	90.0	83.3	83.3	85.5
	No	10.0	16.7	16.7	14.5
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Washing of hands	Yes	6.7	50.0	83.3	46.7
	No	93.3	50.0	16.7	53.3
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Washing with salt water	Yes	6.7	16.7)	0.0)	7.8
	No	93.3	83.3)	100.0	92.2
	Total	**100.0**	**100.0)**	**100.0**	**100.0**
Cleaning of tools	Yes	13.3	50.0	30.0	31.1
	No	86.7	50.0	70.0	68.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**

4.2.9 Processes for Preparing Fresh Cut Mangoes

Fresh mangoes are taken through these processes before taken to consumers/customers. The processes include : washing of hands (53.3%), cleaning of tools (48.9), peeling of fruits (55.6%), cutting peeled fruits into smaller sizes (56.7), packaging into containers as well as other processes (42.2 and 5.6% respectively) (Table 4.13).

Table 4.13: Fresh cut mangoes preparation processes

Processes	**Preference**	**Location (%)**			**Totals (%)**
		Accra Metro	**La-Dadekotopon**	**Ledzokuku Krowor Nungua**	
Washing of hands	Yes	20.0	53.3	86.7	53.3
	No	80.0	46.7	13.3	46.7
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Cleaning of tools	Yes	26.7	56.7	63.3	48.9
	No	73.3	43.3	36.7	51.1
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Peeling	Yes	36.7	73.3	56.7	55.6
	No	63.3	26.7	43.3	44.4
	Total	**100.0**	**100**	**100**	**100.0**
Cutting into smaller sizes	Yes	56.7	83.3	30.0	56.7
	No	43.3	16.7	70.0	43.3
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Packaging into containers	Yes	33.3	50.0	43.3	42.2
	No	66.7	50.0	56.7	57.8
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Others	Yes	16.7	0.0	0.0	5.6
	No	83.3	100.0	100.0	94.4
	Total	**100.0**	**100.0**	**100.0**	**100.0**

4.2.10 Determination of Knowledge Level of the Seller/Processor on Bacteria and Microbial Infection of the Fresh Cut.

Some of the processors admitted that fresh cut fruits are likely to be infected with bacterial (41.1% from the three locations) and fungi (15.5% from the three location)

whilst about 45.6% know that the fruits get infected but could not tell the kind of infection it might be, i.e. whether bacterial, fungi etc. (Table 4.14).

Table 4.14: Knowledge about infections and contamination sources processors face

Knowledge on infection	Preference	Location			Totals
		Accra Metro	La-Dadekotopon	Ledzokuku Krowor	
Infection awareness	Yes	6.7	26.7	93.3	42.2
	No	93.3	73.3	6.7	57.8
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*Bacterial	Yes	6.7	36.7	80.0	41.1
	No	93.3	63.3	20.0	58.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*Fungi	Yes	3.3	20.0	23.3	15.5
	No	96.7	80.0	76.7	84.5
	Total	**100.0**	**100**	**100**	**100.0**
*Others (have no idea)	Yes	93.3	43.3	0.0	45.6
	No	6.7	56.7	100.0	54.4
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Contaminations	Yes	93.3	96.7	100.0	96.7
	No	6.7	3.3	0.0	3.3
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*Dust,stones & metal particles	Yes	0.0	6.7	56.7	21.1
	No	100.0	93.3	43.3	78.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*Use of packaging materials	Yes	0.0	6.7	53.3	20.0
	No	100.0	93.3	46.7	80.0
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*Use of rusted knife	Yes	0.0	6.7	3.3	3.3
	No	100.0	93.3	96.7	96.7
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*House flies	Yes	6.7	6.7	100.0	37.8
	No	93.3	93.3	0.0	62.2
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*Worms	Yes	90.0	90.0	0.0)	60.0
	No	10.0	0.0	100.0	40.0
	Total	**100.0**	**100.0**	**100.0**	**100.0**

The possible contaminations on the fresh cut fruits observed by the processors from the three areas include; dust,stones & metal particles (21.1%), use of packaging materials (20.0%), use of rusted knife (3.3%), house flies (37.8) and worms (60%) (Table 4.14).

4.2.11 Determination of Knowledge Level of the Seller/Processor on Some Defects on Fresh Mango Fruits

Table 4.15: Defects on fresh cut mangoes and processors' knowledge on them

Knowledge on defects	Preference	Location (%)			Totals (%)
		Accra Metro	La-Dadekotopon	Ledzokuku Krowor	
Defects on fruits at purchase	Yes	13.3	73.3	90.0	58.9
	No	86.7	26.7	10.0	41.1
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*Rot (decay)	Yes	0.0	60.0	23.3	27.8
	No	100.0	40.0	76.7	72.2
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*Cracks	Yes	0.0	63.3	16.7	26.7
	No	100.0	36.7	83.3	73.3
	Total	**100.0**	**100**	**100**	**100.0**
*Sand burns	Yes	3.3	13.3	0.0	5.6
	No	96.7	86.7	100.0	94.4
	Total	**100.0**	**100.0**	**100.0**	**100.0**
*Bruises	Yes	3.3	10.0	96.7	36.7
	No	96.7	90.0)	3.3	63.3
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Insect bites	Yes	6.7	53.3	20.0	26.7
	No	93.3	46.7	80.0	73.3
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Moulds	Yes	0.0)	0.0	0.0	0.0
	No	100.0)	100.0	100.0	100.0
	Total	**100.0)**	**100.0**	**100.0**	**100.0**
Spots	Yes	90.0	86.7	36.7	71.1
	No	10.0	13.3	63.3	28.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**

The possible defects observed on the mango fruits by processors included rot (decay) (27.8%), cracks (26.7%), sun burns (5.6%), bruises (36.7%), insect bites (26.7%), moulds (0.0%) and spots (71.1%) (Table 4.15).

4.2.12 Mango Fruits Wastage and Postharvest Activities Undertaken to Prevent Wastage

Some factors contributed to fresh cut fruits wasted. These factors according to the survey (2014) included high price of mango fruits (31.1%), poor storage conditions (51.1%), low selling rate (45.6) as well as low quality from source of production (14.4) (Table 4.16a). Higher prices couple with unfavourable conditions contributed to deteriotion of fresh cut mango fruits. However, processors undertake some measures to overcome/reduce these condition in order to get better returns from their purchased fruits. Some of the postharvest activities undertaken by processors to minimize wastage of fresh cut fruits included; precooling/shading of fruits (45.6%), grading (thus to separate fruits in bad shapes from those in good conditions) (28.9%), washing of fruits (18.9%), refrigeration (21.1%), waxing (0.0%) as well as cooling (4.4%) (Table 4.16a).

There were some reduction meassures taken by processors to minimize the quantities of fruits that go wastage. In order to minimize the quantities of fruits that go waste, processors avoid purchasing infected fruits from source (43.3%). Some of them graded/sorted their fruits according to level of ripeness (51.1%) whilst others too give attractive prices to their customers (23.3%) to ensure that they sell their purchased fruits early (Table 4.16b).

Table 4.16a: Causes of fresh cut wastage and postharvest activities taken to prevent wastage

Cause of wastage	Preference	Location (%)			Totals (%)
		Accra Metro	La-Dadekotopon	Ledzokuku Krowor	
High price of mango	Yes	10.0	30.0	53.3	31.1
	No	90.0	70.0	46.7	68.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Poor storage conditions	Yes	53.3	66.7	33.3	51.1
	No	46.7	33.3	66.7	48.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Low selling rate	Yes	33.3	53.3	50.0	45.6
	No	66.7	46.7	50.0	54.4
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Low quality from source of production	Yes	6.7	26.7	10.0	14.4
	No	93.3	73.3	90.0	85.6
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Postharvest measures undertaken to prevent wastage					
Precooling / Shading	Yes	10.0	30.0	96.7	45.6
	No	90.0	70.0	3.3	54.4
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Grading	Yes	20.0	63.3	3.3	28.9
	No	80.0	36.7	96.7	71.1
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Washing	Yes	13.3	23.3	20.0	18.9
	No	86.7	76.7	80.0	81.1
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Refrigeration	Yes	13.3	26.7	23.3	21.1
	No	86.7	73.3	76.7	78.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Waxing	Yes	0.0	0.0	0.0	0.0
	No	100.0	100.0	100.0	100.0
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Cooling	Yes	10.0	3.3	0.0	4.4
	No	90.0	96.7	100.0	95.6
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Others	Yes	76.7	16.7	0.0	31.1
	No	23.3	83.3	100.0	68.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**

Some also give their fruits good ventilation (11.1%) whilst other store them in fridges (13.3) (Table 4.16b). All these are done by processors from the different areas to minimize spoilage.

Table 4.16b: Reduction in quantities of fruits that go wastage

Reduction measures	Preference	Location (%)			Totals (%)
		Accra Metro	La-Dadekotopon	Ledzokuku Krowor	
Avoid purchasing infected fruits from source	Yes	16.7	63.3	50.0	43.3
	No	83.3	36.7	50.0	56.7
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Sorting/Grading according to level of ripeness	Yes	60.0	56.7	36.7	51.1
	No	40.0	43.3	63.3	48.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Attractive prices to customers	Yes	3.3	20.0	46.7	23.3
	No	96.7	80.0	53.3	76.7
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Good ventilation	Yes	6.7	13.3	13.3	11.1
	No	93.3	86.7	86.7	88.9
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Refrigeration	Yes	26.7	13.3	0.0	13.3
	No	73.3	86.7	100.0	86.7
	Total	**100.0**	**100.0**	**100.0**	**100.0**

4.2.13 Effects of Mode of Handling and Processing

Table 4.17 below shows the packaging materials processors use for their fruits.

Take away packs (38.9%), plastic bowls (20.0%) and plastic films (48.9%) are the main packaging materials that were used by processors from the different towns that were investigated (Table 4.17).

Table 4.17: Packaging materials processors use for their fresh cut fruits

Packaging materials	Preference	Location (%)			Totals (%)
		Accra Metro	La-Dadekotopon	Ledzokuku Krowor	
Take away pack	Yes	30.0	3.3	83.3	38.9
	No	70.0	96.7	16.7	61.1
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Plastic bowls	Yes	16.7	26.7	16.7	20.0
	No	83.3	73.3	83.3	80.0
	Total	**100.0**	**100.0**	**100.0**	**100.0**
Plastic films	Yes	56.7)	70.0	20.0	48.9
	No	43.3)	30.0	80.0	51.1
	Total	**100.0)**	**100**	**100**	**100.0**
Others	Yes	20.0	3.3	6.7	10.0
	No	80.0	96.7	93.3	90.0
	Total	**100.0**	**100.0**	**100.0**	**100.0**

4.2.14 Storage (Before Processing and Selling; and Storage of Unsold Fresh Cut Fruits).

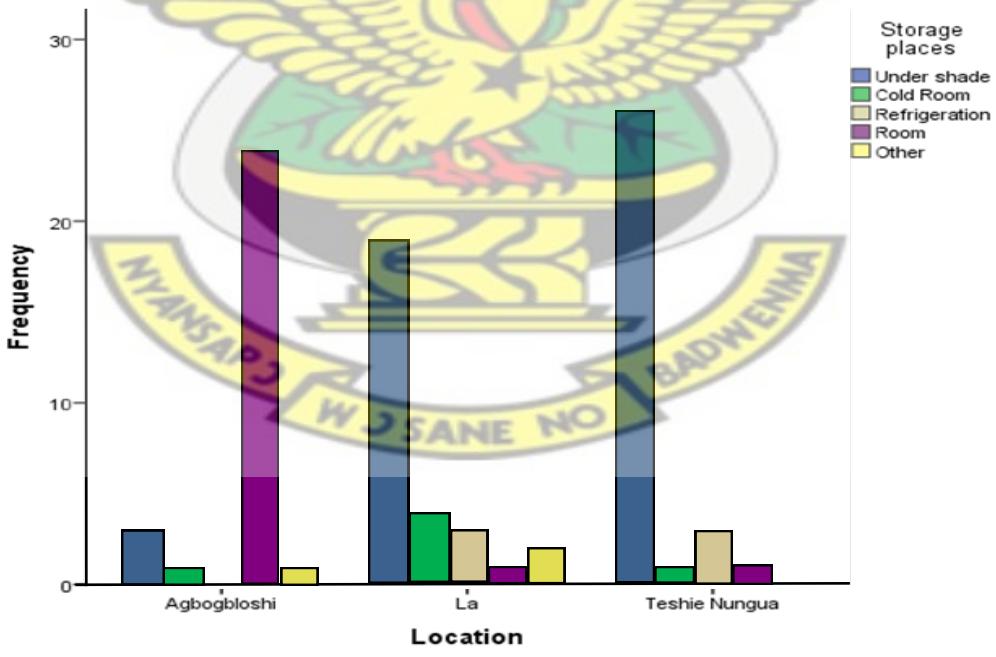

Figure 4.16: Storage places processors store fresh cut mango fruits

Figure 4.16 showed the storage places for fresh cut mango fruits, thus, before processing

and selling as well places for storing unsold/left over fresh cut fruits. It was observed from the survey that processors a cross the investigated towns stored their fresh fruits/fresh cut fruits under shade (56.6%), cold room (10.0%), refrigeration (8.8%) as well as in room temperatures (32.2%).

4.3 MICROBIAL LOADS AND SOME CHEMICAL PROPERTIES (TA AND TSS) ON THE FRESH CUT MANGO FRUITS FROM THE THREE PROCESSOR TYPES.

Table 4.18 presents a summary of the data on the microbial load and some chemical properties on the fresh cut mangoes from the three different processor types at different sale periods from La-Dadekotopon, Ledzokuku Krowor and Accra Metro.

The three different processor types (P), thus, Already processed and Hawked (A), Demand-cut processed (D) and processed in Restaurant (R) had mean values of 22543.0, 17855.0 and 1188.0 respectively for Aerobic plate count, APC. These values were similar (P>0.05). The different sales period (S), thus, immediate and after 6 hours recorded mean values of 74.0 and 27650.0 respectively for APC (Table 4.18a). The values were not significantly different (P>0.05) from each other. The interactions between P and S, thus P*S for APC also recorded mean values that were not different (P>0.05) from each other (Table 4.18a).

Table 4.18a: Aerobic Plate Count (cfu/mL) on the fresh cut mangoes from the three different processor types at different sale periods of the different localities (La-Dadekotopon, Ledzokuku Krowor and Accra Metro)

	Aerobic Plate Count (cfu/mL)			
	Processor type			
Period of sales	**A**	**D**	**R**	**Mean**
Immediate	120	43	60	74.0
After 6 hours	44967	35667	2317	27650.0
Mean	**22543.0**	**17855.0**	**1188.0**	
Lsd	Period of sale = 51355.2 Processor type = 62897			
	Period of sales*Processor type=88949.9			

[abc] means with the same superscript are not significantly different (P>0.05) from each other whilst means with different superscripts are different (P<0.05); NS= not significant (P>0.05); * means significant at 5% (P<0.05). **A**= Hawker- already processed; **D**= Hawker -on-demand processing; **R**=Restaurant- Already processed; P*S is the interaction between processor type and period of sales.

From Table 4.18, the mean values of A (668.0), D (338.0) and R (888.0) were similar (P>0.05) for mould. The values recorded for mould at the different sale period; immediate (10.0) and after 6 hours (1253.0) were also not different (P>0.05). The interactions between P and S values were not significantly different (P>0.05) from one another (Table 4.18).

Table 4.18b: Mould (cfu/mL) on the fresh cut mangoes from the three different processor types at different sale periods of the different localities (La-Dadekotopon, Ledzokuku Krowor and Accra Metro)

	Mould (cfu/mL)			
	Processor type			
Period of sales	**A**	**D**	**R**	**Mean**
Immediate	10	10	10	10.0
After 6 hours	1325	667	1767	1253.0
Mean	**668.0**	**338.0**	**888.0**	
Lsd	Period of sale = 1337.8 Processor type = 1638.5			
	Period of sales*Processor type=2317.2			

[abc] means with the same superscript are not significantly different (P>0.05) from each other whilst means with different superscripts are different (P<0.05); NS= not significant (P>0.05); * means significant at 5% (P<0.05). **A**= Hawker- already processed; **D**= Hawker -on-demand processing; **R**=Restaurant- Already processed; P*S is the interaction between processor type and period of sales.

H, D and R had mean values of 93.0, 247.0 and 373.0 respectively for Yeast. These values were however similar (P>0.05) for one another. The period of sale (S), i.e. immediate and after 6 hours recorded mean values of 10.0 and 466.0 respectively for Yeast. The values were not significantly different (P>0.05) from each other (Table 4.18c). The interactions between P and S, thus P*S for Yeast also recorded mean values that were not different (P>0.05) from each other (Table 4.18c).

Table 4.18c: Yeast (cfu/mL) on the fresh cut mangoes from the three different processor types at different sale periods of the different localities (La-Dadekotopon, Ledzokuku Krowor and Accra Metro)

	Yeast (cfu/mL)			
	Processor type			
Period of sales	**A**	**D**	**R**	**Mean**
Immediate	10	10	10	10.0
After 6 hours	177	483	737	466.0
Mean	**93.0**	**247.0**	**373.0**	
Lsd	Period of sale = 477.0 Processor type = 584.2 Period of sales*Processor type=826.1			

[abc] means with the same superscript are not significantly different (P>0.05) from each other whilst means with different superscripts are different (P<0.05); NS= not significant (P>0.05); * means significant at 5% (P<0.05). **A**= Hawker- already processed; **D**= Hawker -on-demand processing; **R**=Restaurant- Already processed; P*S is the interaction between processor type and period of sales.

The mean values of A (38.3), D (10.0) and R (10.0) were similar (P>0.05) for the *E. coli*. The values recorded for *E. coli* at the different sale period; immediate (11.1) and after 6 hours (27.8) were also not different (P>0.05). The interactions between P and S values were not significantly different (P>0.05) from one another (Table 4.18d).

Table 4.18d: E. coli (cfu/mL) on the fresh cut mangoes from the three different processor types at different sale periods of the different localities (La-Dadekotopon, Ledzokuku Krowor and Accra Metro)

	***E. coli* (cfu/mL)**			
	Processor type			
Period of sales	**A**	**D**	**R**	**Mean**
Immediate	13.3	10	10	11.1
After 6 hours	63.3	10	10	27.8
Mean	**38.3**	**10.0**	**10.0**	
Lsd	Period of sale = 38.43 Processor type = 47.07 Period of sales*Processor type=66.57			

[abc] means with the same superscript are not significantly different (P>0.05) from each other whilst means with different superscripts are different (P<0.05); NS= not significant (P>0.05); * means significant at 5% (P<0.05). **A**= Hawker- already processed; **D**= Hawker -on-demand processing; **R**=Restaurant- Already processed; P*S is the interaction between processor type and period of sales.

There was however significant difference (P<0.05) between the TCC values. The three different processor types (P), thus, A, D and R had mean values of 437.5, 745.5 and 208.5 respectively for TCC. These values were significantly different from each other (P<0.05) with D being significantly higher than A and R. The period of sale (S), i.e. immediate and after 6 hours recorded mean values of 85.3 and 842.3 respectively for TCC (Table 4.18e). The values were significantly different (P<0.05) from each other with After 6 hours period being significantly higher than the immediate. The interactions between P and S, thus P*S for TCC also recorded mean values that were different (P<0.05) from each other (Table 4.18e).

Table 4.18e: Total coliform count (TCC) (cfu/mL) on the fresh cut mangoes from the three different processor types at different sale periods of the different localities (La-Dadekotopon, Ledzokuku Krowor and Accra Metro)

	Total coliform count (TCC) (cfu/mL)			
	Processor type			
Period of sales	**A**	**D**	**R**	**Mean**
Immediate	108^{a}	91^{b}	57^{c}	85.3^{b}
After 6 hours	767^{b}	1400^{a}	360^{b}	842.3^{a}
Mean	**437.5^{b}**	**745.5^{a}**	**208.5^{b}**	
Lsd	Period of sale = 243.9 Processor type = 298.7 Period of sales*Processor type=422.4			

^{abc} means with the same superscript are not significantly different (P>0.05) from each other whilst means with different superscripts are different (P<0.05); NS= not significant (P>0.05); * means significant at 5% (P<0.05). **A**= Hawker- already processed; **D**= Hawker -on-demand processing; **R**=Restaurant- Already processed; P*S is the interaction between processor type and period of sales.

The three different processor types (P), thus, A, D and R had mean values of 0.443, 0.572 and 0.562 respectively for TA. These values were not similar (P<0.05). The period of sale, (S), i.e., immediate and after 6 hours recorded mean values of 0.556 and 0.496 respectively for TA. The values were not significantly different (P>0.05) from each other. The interactions between P and S, thus P*S for TA also recorded mean values that were not different (P>0.05) from each other (Table 4.18f). Titratable acidity (% citric acid) levels in the fruit from the three processing types (P) were significantly different. Fruits of R had a higher mean acidity (0.562% citric acid) than fruits of the other processors while A had the lowest mean acidity (0.443% citric acid) (Table 4.18f). There were no significant differences in TA content among fruits of D and R. TA of A was significantly lower than D and R (Table 4.18f).

Table 4.18f: Titratable acidity, (TA) (% acitric acid) on the fresh cut mangoes from the three different processor types at different sale periods of the different localities (La-Dadekotopon, Ledzokuku Krowor and Accra Metro)

	Titratable acidity, (TA) (% acitric acid)			
	Processor type			
Period of sales	**A**	**D**	**R**	**Mean**
Immediate	0.503	0.560	0.603	0.556
After 6 hours	0.383	0.583	0.520	0.496
Mean	**0.443[a]**	**0.572[b]**	**0.562[b]**	
Lsd	Period of sale =0.22 Processor type = 0.014 Period of sales*Processor type= 0.42			

[abc] means with the same superscript are not significantly different (P>0.05) from each other whilst means with different superscripts are different (P<0.05); NS= not significant (P>0.05); * means significant at 5% (P<0.05). **A**= Hawker- already processed; **D**= Hawker -on-demand processing; **R**=Restaurant- Already processed; P*S is the interaction between processor type and period of sales.

Table 4.18g shows changes in TSS (^{o}Brix) from the different processors (P) of mango fruits at the different sale periods (S). The changes in TSS (^{o}Brix) from A, D and R of the mango fruits were similar (P>0.05). Content of TSS from the two sale periods were not significantly different (P>0.05). There were no significant differences in TSS content among the interactions between P*S. The lowest TSS content (4.12^{o}Brix) was recorded for D while A had the highest TSS content (5.27^{o}Brix). The change in TSS generally showed an ascending trend as the sales period delayed, i.e., from 4.38^{o}Brix in the immediate cut to 5.11^{o}Brix in after 6 hours of sales (Table 4.18g).

Table 4.18g: Total Soluble Solids, (TSS) (^{o}Brix) on the fresh cut mangoes from the three different processor types at different sale periods of the different localities (La-Dadekotopon, Ledzokuku Krowor and Accra Metro)

	Total Soluble Solids, (TSS) (^{o}Brix)			
	Processor type			
Period of sales	A	D	R	Mean
Immediate	4.18	3.89	5.08	4.38
After 6 hours	6.36	4.35	4.62	5.11
Mean	**5.27**	**4.12**	**4.85**	
Lsd	Period of sale = 1.22 Processor type = 1.81			
	Period of sales*Processor type=2.05			

[abc] means with the same superscript are not significantly different (P>0.05) from each other whilst means with different superscripts are different (P<0.05); NS= not significant (P>0.05); * means significant at 5% (P<0.05). **A**= Hawker- already processed; **D**= Hawker -on-demand processing; **R**=Restaurant- Already processed; P*S is the interaction between processor type and period of sales.

CHAPTER FIVE

5.0 DISCUSSION

5.1 FIELD SURVEY

Quality traits consumers considered when buying fresh cut fruits included softness of the fruits, the colour, aroma, sweetness and fruit type (Table 4.4). The quality of fresh fruit has been described by Swiader *et al.*, (1992) as the combination of characteristics, attributes and properties that give a commodity value to humans for food. These important attributes which are associated with the quality of fruits (mango) vary according to the individual(s) defining the term.

Growers were interested in disease resistance, high yielding, uniform maturity, desirable size and ease of harvest; postharvest characteristics have not been one of their main interests (Swiader *et al.*, 1992). Consumers care about appearance, price, and table quality, including texture, flavour, colour, and nutritive value of mango (Swiader *et al.*, 1992). Freshness, natural taste/flavor, no additive/preservatives added and better appearance or colour of fruits are some characteristics consumers consider when buying fresh cut mango fruits (Table 4.7).

Appearance is a major determinant of quality, especially because it is often the only criterion available to the buyer of the commodity (Arthey, 1975). Litz (2003) concluded that large numbers of mango varieties with variable attributes affect the quality and uniformity of the processed products. Similarly, lack of simple and reliable methods for

determining the stage of fruit maturity also affect quality (Litz, 2003).

Some barriers to the purchase of fresh cut mango fruits included price, difficulty of choosing a ripe fruit, degree of blemish/defect, as well as packaging and presentation (Table 4.6). From the results of the survey work, it was observed that some causes of contaminations of fresh cut mango fruits included bacteria, poor handling, fungi, the use of contaminated packaging materials and the use of contaminated knife (Table 4.8). Johnson *et al.* (1995) reported that, mango fruits are susceptible to wound and damage during postharvest handling (lenticels spotting, sap burn), temperature injury (heat and chilling injury) and mechanical damage which may occur during transportation, and in pack houses (brushing, abrasion, pressure and impact damage).

Storage places for fresh cut mango fruits according to the field survey included fridge, room temperature as well as cool and dark place (Table 4.10). Dea *et al.* (2008a) found that shelf-life of fresh-cut 'Kent' mangoes was 3 to 4 days at 1 2^{o}C versus 5 to 6 days at 5^{o}C. It was unclear whether this storage period at 5^{o}C caused chilling injury in fresh-cut mango slices since no visual chilling injury symptoms were noted. Dea *et al.* (2008a), however, observed a reduced ascorbic acid content and increased softening at 5^{o}C which suggested that the fresh-cut slices did experience chilling stress.

Processors preference on mango varieties included Keit, Kent and Palma. The varieties of mangoes that are grown in Ghana include Kent, Keitt, Palmer, Haden, Tommy Atkins, Irwin, Sensation, Julie, and the local variety (GEPC, 2005). Processors preferred their fruits at different ripe stage which included full ripe, half ripe, full green

and half green stages of ripeness (Figure 4.15). Ripe mango fruits are rich sources of vitamin A and are used to treat vitamin A deficiencies such as night blindness (Bally, 2006). Research carried out by Krishnanand (1994) described that ripe mango is especially rich in carotenes which have antioxidant properties thought to lower the risk of heart disease and stroke and contains an enzyme with stomach soothing properties similar to papain found in papayas. These comforting enzymes act as a digestive aid (Krishnanand, 1994).

Some activities fresh mango fruits are taken through before processing according to the field survey included washing of fruits, washing of hands, washing of fruits with salt water and cleaning of tools (Table 4.12). According to Moomin (2010), method of preparation (sharpness of the cutting tools, size and surface area of the cut pieces, washing, and removal of surface moisture) and subsequent handling conditions (packaging, speed of cooling, maintaining optimum ranges of temperature and relative humidity, expedited marketing, and proper sanitation procedures) are the notable additional factors that influence quality of fresh-cut mangos. Fresh mangoes are taken through some processes before taken to customers/consumers and some of these processes included washing of hands, cleaning of tools, peeling of fruits, cutting peeled fruits into smaller sizes and packaging into containers (Table 4.13). Ngarmsak *et al.* (2005) reported that washing whole 'ChokAnun' mangoes in warm (50^{o}C) or cold (12^{o}C) chlorinated (100 ppm) water for 5 minutes significantly reduced total microbial populations on the skin and stem end of the mangoes.

According to Moomin (2010), microbial populations on fresh-cut mango slices prepared from unwashed fruit were significantly higher than those prepared from washed fruit immediately following preparation and after 7 days at 5^{o}C. Research by Ethiraj and Suresh (1992) reported that peels and stones are the main waste products of processing, and constitute 35–55% of unripe as well as ripe mangoes. Useful products can be recovered from these wastes and simultaneously avoid the disposal problem. Infections on cut mango fruits included bacterial and fungi infections.

Contaminations on cut mango fruits included dust and stone particles; use of packaging materials; use of rusted knife; houseflies and worms (Table 4.14). Ngarmsak (2007) found that treating fresh-cut mangoes with 80 mM vanillin solutions before packing and storage at 5^{o}C or 10^{o}C significantly delayed the growth of spoilage yeast and fungi in the fresh-cut mangoes. Peels and stones are the main waste products of processing, and constitute 35–55% of unripe as well as ripe mangoes (Ethiraj and Suresh, 1992). The possible defects observed on the mango fruits by processors included rot/decay, cracks, sand burns, bruises, insect bites, moulds and spots (Tables 4.15). The method of harvesting in mango is by hand picking, harvesting by climbing on the tree and harvesting with a notched stick having a pouch. Accidental falling of fruits, results in bruising and cracking of fruits and losses are estimated to a maximum of 15% in mango (Sarada, 2013).

Some causes of fresh cut fruit wastages (Table 4.16a) included high price of mango, poor storage conditions, low selling rate and low quality of fruits from source of production.

According to Sarada (2013), some of the reasons why fresh fruits go waste included; lack of transparency in prices, availability, demand and customer preferences; poor infrastructure - storage, packaging, transportation, cold chain etc. and poor linkage in the marketing channel. Some postharvest measures undertaken to prevent fresh cut fruit wastages included precooling/shading, grading, washing, refrigeration, waxing and cooling (Table 4.16a).

Grading the fruit is necessary for a better outlook and maintains the quality of the product. Mangoes can be graded by selecting superior quality, sorting by weight, size and removing fruits with defects (Sarada, 2013). Some of the measures to reduce quantity of fruits that go waste included avoid purchasing infected fruits from source, sorting/grading according to level of ripeness, attractive prices to customers, good ventilation and refrigeration.

5.2 LABORATORY STUDIES

5.2.1 Microbial Loads on the Fresh Cut Mangoes from the Three Different Processor Types at Different Sale Periods of the Different Localities (La-Dadekotopon, Ledzokuku Krowor and Accra Metro).

The mean aerobic plate count (APC) changed from $7.4x10^{1}$ cfu/mL in the immediate cut sale period to $2.765x10^{4}$ cfu/ml in the after 6 hours sale period among the different processors (Table 4.18).

The result indicated that all fruits surfaces contain some amount of microbial load. This microbial load might be contributed from different sources such as from preharvest, harvesting and poor handling practice at the processing activities. The assessment on the

management of fruit in these processing areas at different sale periods indicated that there were different conditions such as poor handling of fruits as well as the sanitary problem of some processing areas. These conditions might have their own contribution on the microbial load for that area. The areas were crowded by vehicles that emit dust particles; there were sheep, goats, pigs and cattle feces which may be the source of different contaminant. Moreover, the fruit handlers put fruits on the ground without using covering material and used the measuring balance for different commodities such as onion, tomato, different vegetables and cereal crops. These factors could increase the microbial load of the fresh cut fruits.

From statistical analysis, there was no statistical significance difference between the mean APC of the three processing areas at the two different sales period ($p=0.371>0.05$). That is, the processing areas in which the mango fruits were processed had no significant impact on the value of APC of fruits samples. This may be due to the fact that the different variables such as the handling practice of fruits and sanitary condition of the area were similar.

Total coliforms count (TCC) changed from $8.53x10^{1}$ cfu/mL in the immediate cut to $8.423x10^{2}$ cfu/mL in the after 6 hours of sales among the different processors from the different locations. *E. coli* level changed from $1.11x10^{1}$ cfu/mL in immediate cut to $2.78x10^{1}$ cfu/mL in the after 6 hours of cut. The presence of coliform bacteria especially *E. coli* indicated fecal contamination of fruits which may be contributed from different sources such as the water used during preharvest and postharvest activities, exposure

during transport facility, improper storage conditions and poor handling practices at any stage (NACMF, 1999).

From statistical analysis ($p=0.008<0.05$), there was significance difference about total coliform count among the three different processor/ processing areas. This shows that the processing area had impact on the total coliform count. This may be attributed to different variables such as the sanitary condition of the market area and handling practice differences in different areas/localities. Similar observation was made by Sahile and Asmaru (2013) when they looked into the microbial spectrum of fruit in Gondar town markets. Based on the sale period, ($p=<.001<0.05$), there was significant ($P<0.05$) differences between fruits that contained total coliforms, which means where a fruit is sold also affects TCC. The mean mould moved from $1.0x10^1$ cfu/ml in the immediate cut to $1.253x10^3$ cfu/ml in the after 6 hours of sale among the different processors.

Yeast level changed from $1.0x10^1$ in immediate cut to $4.66x10^2$ cfu/ml in after 6 hours of sale (Table 4.18). South Africa has proposed a standard guideline for raw fruits and vegetables on the microbiological safety.

According to the guideline, the yeast and mold count greater than $1x\ 10^5$ cfu/g in any raw fruits and vegetables has no acceptance (SADoH, 1997). The average mold and yeast count from the study area was less than 10^5. The average mold and yeast count observed fall within this range and recorded no significant ($P>0.05$) difference between the different processors at different sale periods.

5.2.2 Some Chemical Changes (TA and TSS) on the Fresh Cut Mangoes from the Three Different Processor Types at Different Sale Periods of the Different Localities (La-Dadekotopon, Ledzokuku Krowor and Accra Metro).

There was no significant difference in total soluble solids, TSS, content. TSS however, generally showed an ascending trend as the sales period delayed. Thus TSS value changed from 4.38^{o}Brix in the immediate cut to 5.11^{o}Brix in the after 6 hours of sales among the three different processors (Table 4.18g).

Titratable acidity (% citric acid) levels in the fruits from the three processing types (P) were significantly different ($P<0.05$). Fruits of the Restaurant processed type (R) had a higher mean acidity (0.562%citric acid) than fruits of the other processors, while already processed and hawked type (A) had the lowest mean acidity (0.443% citric acid) (Table 4.18f). Doreyappa and Ramanjaneya (1994), however, reported a higher level of TSS (18.9^{o}Brix) and an acidity of 0.22% in mango fruits, indicating that different growing conditions affect the physico-chemical attributes of the fruit. Similar changes were also observed by Kliewer (1965) in grapes.

The variability of TSS of different processors at different sales periods might be attributed to the alteration occurring in cell wall structure during maturation processes. Moreover various hydrolytic enzymes also affect complex carbohydrates changing them into smaller compounds (Kays, 1991; Kittur *et al.,* 2001) thus reflecting the conversion of starch into sugars. At advanced maturity, organic acids form salts which contribute to the increase of TSS (Kliewer, 1971).

The TSS content of fruit is important both from the stand point of product consistency and processing, as well as the quality of the fresh produce (Gould, 1983). Opena (1983)

indicated that high value of TSS is desirable because it relates to the yield of processed products. For most fruits, a higher TSS/acidity ratio indicates better eating quality (Singleton and Gortner, 1965). The pattern of chemical changes was strikingly similar in all the processing types at the different sale periods.

The increase in TSS (from 4.38^{o}Brix in the immediate cut to 5.11 ^{o}Brix) and the decreasing trend in TA (from 0.556% citric acidity in immediate cut to 0.496% citric acidity) could be used as another easily estimable criterion for processing mango fruits.

CHAPTER SIX

6.0 CONCLUSION

The study indicated that both consumers and processors prefer Keit variety. This is because according to S, Asante-Mensah -ADRA 2014 (personal communication), Keit is the commonest variety grown on large scale in Ghana. Additionally, processors (81.11%) prefer the Keit variety because of its large sizes.

Majority of the consumers (78%) consume their fresh cut mango fruits within an hour of purchase, hence 78% of consumers preferred buying fruits that are ready to eat on that same day.

The study indicated that processors preferred mangoes with different ripening stages

Majority of consumers (88.7%) were satisfied with fresh cut mango they purchased

Thou there were the precence of contaminants and microbes in the fresh cut mangoes, the level of the microbial loads on the fresh cut mangoes were within acceptable levels.

From the studying, it can be said that the local fresh cut mango industry is promising but there are a number of postharvest handling and processing issues that need to be address urgently so as not put consumers off.

6.1 RECOMMENDATION

It is recommended that a similar study be carried out in different towns at different sales periods to identify other organisms that are common in fresh cut mangoes. This will help develop a more comprehensive control programme.

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APPENDICES

APPENDIX A: Anaysis of variance (ANOVA) tables

Appendix A1: Anaysis of variance (ANOVA) for Aerobic plate count

Source of variation	Df	s.s	m.s	v.r	F pr
Reps stratum	2	2.319E+09	1.159E+09	1.69	
Processor type	2	1.512E+09	7.558E+08	1.10	0.370
Period of sale	1	3.422E+09	3.422E+09	4.98	0.050
Processor type*Period of sale	2	1.506E+09	7.531E+08	1.10	0.371
Residual	10	6.869E+09	6.869E+08		
Total	17	1.563E+10			

Appendix A2: Anaysis of variance (ANOVA) for Mould

Source of variation	Df	s.s	m.s	v.r	F pr
Reps stratum	2	11061536	5530768	3.41	
Processor type	2	919236	459618	0.28	0.759
Period of sale	1	6950235	6950235	4.28	0.065
Processor type*Period of sale	2	919236.	459618	0.28	0.759
Residual	10	16223247.	1622325		
Total	17	36073490			

Appendix A3: Anaysis of variance (ANOVA) for Yeast

Source of variation	Df	s.s	m.s	v.r	F pr
Reps stratum	2	472578	236289	1.15	

Processor type	2	235911	117956	0.57	0.582
Period of sale	1	933889	933889	4.53	0.059
Processor type*Period of sale	2	235911	117956	0.57	0.582
Residual	10	2062022	206202		
Total	17	3940311			

Appendix A4: Anaysis of variance (ANOVA) for *E.coli*

Source of variation	**Df**	**s.s**	**m.s**	**v.r**	**F pr**
Reps stratum	2	2678	1339	0.93	
Processor type	2	3211	1606	1.11	0.367
Period of sale	1	1250	1250	0.86	0.374
Processor type*Period of sale	2	2500	1250	0.86	0.450
Residual	10	14456	1446		
Total	17	24094			

Appendix A5: Anaysis of variance (ANOVA) for Total coliforms count, TCC

Source of variation	**Df**	**s.s**	**m.s**	**v.r**	**F pr**
Reps stratum	2	203916	101958	1.91	
Processor type	2	870327	435164	8.16	0.008
Period of sale	1	2577964	2577964	48.35	<.001
Processor type*Period of sale	2	781740	390870	7.33	0.011
Residual	10	533220	53322		
Total	17	4967167			

Appendix A6: Anaysis of variance (ANOVA) for TSS

Source of variation	Df	s.s	m.s	v.r	F pr
Reps stratum	2	2.442	1.221	0.65	
Processor type	2	4.041	2.020	1.07	0.379
Period of sale	1	2.391	2.391	1.27	0.286
Processor type*Period of sale	2	5.346	2.673	1.42	0.287

Residual	10	18.858	1.886	
Total	17	33.077		

Appendix A7: Anaysis of variance (ANOVA) for titratable acidity, TA

Source of variation	Df	s.s	m.s	v.r	F pr
Reps stratum	2	0.0245	0.0123	2.63	
Processor type	2	0.0611	0.0306	6.54	0.015
Period of sale	1	0.0162	0.0162	3.47	0.092
Processor type*Period of sale	2	0.0166	0.0083	1.78	0.218
Residual	10	0.0467	0.0047		
Total	17	0.1652			

APPENDIX B: SAMPLE QUESTIONNAIRE ADMINISTERED TO CONSUMERS AND PROCESSORS

Appendix B1: Questionnaire for Consumers

The purpose of this questionnaire is to gather data for a study on post-harvest quality issues in the local marketing of mangoes: A case study of the Accra municipality
Data collected would be used solely for academic purpose and respondents are assured of the confidentiality of information provided.

Name of Respondents……

A. PERSONAL INFORMATION

1. Gender: ☐ Male ☐ Female

2. ☐ Below 13 ☐ 13-18 ☐ 19-24 ☐ 25-30 ☐ 31-36 ☐ 37-42 ☐ 43-48 ☐ 49-54 ☐ 55-60 ☐ Above 60

3. Level of Education:
   ☐ Basic ☐ SHS ☐ Diploma ☐ 1st and or 2nd degree
   ☐ Professional ☐ Others, specify…….

4. How Confident are you in choosing a ripe mango?

   ☐ Very confident ☐ Somewhat confident
   ☐ Not very confident ☐ I don't know how to

5. How ripe do you prefer your mangoes to be when you buy them to eat?

☐

☐ Ready to eat today ☐ Ready to eat in one to two days Ready to eat in three or more days

6. How do you know a mango is ripe to eat?
(you can tick more than one response)
I don't know ☐ By smelling
☐ By softness ☐ By colour of the skin

7. How soft do you want your mango when you want to eat it instantly?
Very soft ☐ Soft
☐ Very hard ☐ Hard ☐ Others, specify

8. How often do you consume mangoes?
☐ Once a day ☐ Twice a day
☐ ☐ Once a week Twice a wee☐
Others, specify

9. Approximately how many times did you purchase a mango to eat in the last three months?
☐ More than once a week ☐ Once a week
☐ 2 -3 times a month ☐ Around once a month
☐ Less than once a month

10. When was the last time you purchased a mango to eat?
☐ In the past seven days ☐ In the past two weeks
☐ ☐ In the past month In the past three months

11. Where do you usually buy mangoes to eat?
☐ Supermarket ☐ Local fruit store
☐ Restaurant ☐ Wayside/Hawkers ☐ Others, specify

12. What influence your frequency of consumption?
☐ Seasonal availability ☐ Nutritional quality and Mango
☐ Size ☐ Price ☐ Others, specify

13. When buying a mango to eat, who do you usually buy mangoes for?
☐ Myself ☐ Friends/Visitors
☐ Family members ☐ Someone Else, Specify

14. Which of the following qualities of mango do you consider when purchasing a mango?

☐ Softness ☐ Colour ☐ Aroma
☐ Sweetness ☐ Type ☐ Others, specify

15. Which type of mango do you buy?

☐ Kent ☐ Keit
☐ Palma ☐ Jafna ☐ Others, specify

16. What barriers to purchase do you face?

☐ Price ☐ Difficulty of choosing a ripe mango
☐ Degree of blemish or Defect ☐ Packaging and presentation
☐ Others, specify

17. How do you store your mangoes at home?

☐ In the fridge ☐ Room Temperature
☐ Cool and Dark Place ☐ Others, specify

18. Are you satisfied with the quality of the fresh cut you purchase?

☐ Yes ☐ No ☐ No if No skip to

19. Which of the following do you like about fresh cut

☐ Freshness ☐ Natural taste/Flavour
☐ No additives/Preservatives added ☐ Others, specify
☐ Better appearance/Colour

20. Are you aware of any infections on fresh cut mangoes?

☐ Yes
☐ No

21. What do you think cause the infection?

☐ Bacteria ☐ Poor Handling
☐ Fungi ☐ The use of contaminated packaging materials
☐ The use of contaminated knife

22. Do you eat the fresh cut immediately after purchasing?

■ Yes ■ No

23. If No, when do you normally eat it?

■ Within 1hour ■ With in 6hours ■ After 6 hours
■ Others, specify

In the case where you are not able to consume all the fresh-cut immediately, how do you store it?

Refrigeration Room temperature Others, specify

Appendix B2: Questionnaire for Processors

The purpose of this questionnaire is to gather data for a study on post-harvest quality issues in the local marketing of mangoes: A case study of the Accra municipality
Data collected would be used solely for academic purpose and respondents are assured of the confidentiality of information provided.

B. PERSONAL INFORMATION

1. Location: ☐ Accra Metro ☐ La ☐ Ledzokuku Krowor

2. Gender: ☐ Male ☐ Female

3. Age: ☐ > 18 ☐ 18-24 ☐ 25-30 ☐ 31-35 ☐ 36-40
☐ 41-45 ☐ 46-50 ☐ 51-55 ☐ 56-60 ☐ Above 60

4. Level of Education:
☐ Basic ☐ SHS/Vocation/Tech ☐ Post-Secondary

C. VARIETY, PURCHASE AND SALES

5. Where do you get your mangoes from?
☐ Farm Gates ☐ Wholesalers ☐ Others, specify……
☐ Bulkers ☐ Markets

6. Why are you in this business?

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7. Do you do anything in addition to this?

☐ No ☐ Yes

8. If yes, what do you do?

……

9. Why do you prefer mangoes from this source?

☐ Easy Access ☐ Cheap price of mangoes
☐ Easy means of transport ☐ Others, specify……

10. Why do you prefer mangoes from this source?

☐ Easy Access ☐ Cheap price of mangoes
☐ Easy means of transport ☐ Others, specify……

11. What of 10 mangoes how many go waste?

---

12. How long does it take to sell the processed mango?

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13. Which variety of mangoes are popular ?

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14. What quantity of whole mangoes are you able to buy at a time?

☐ Less than 20 ☐ 51 – 100
☐ 20 – 50 ☐ Above 100

15. How long does it take to sell the quantity bought?

☐ Within a day ☐ 2 Days ☐ 3 Days ☐ 4 Days
☐ 5 Days ☐ 6 Days ☐ 7 Days

16. What proportion are you able to sell in a day?

☐ Less than 50% ☐ 71% - 100%
☐ 51% - 70% ☐ Others, specify……

D. MANGO QUALITY ISSUES

17. Which varieties of mango do you sell?

☐ Kent ☐ Palma ☐ Others, specify
☐ ☐

Kaitt Jafna

18. What stage of ripeness do you buy the mangoes?
☐ Full ripe ☐ Full green
☐ Half ripe ☐ Half green

19. Which varieties of mango do your customers like?
☐ Kent ☐ Keitt
☐ Palma ☐ Jafna
☐ Other; specify……

20. Can you mention the processes you go through to prepare the fresh cut mangoes?
☐ Washing with water ☐ Washing of hands
☐ Washing with salt water ☐ Cleaning of tools

22. Do you store the mangoes between the time of purchase and processing?
☐ Yes
☐ No

21. Where do you store the mangoes?
☐ Under shade ☐ Cold Room
☐ Refrigeration ☐ Room ☐ Others, specify

E. INFECTIONS AND CONTAMINATIONS

22. Do you normally see any defects on the mangoes at the time of purchase?
☐ Yes
☐ No

23. Mention some of the defects you normally see on the mangoes?
☐ Rot (decay) ☐ Cracks ☐ Sand burns
☐ Bruises ☐ Insect bites ☐ moulds
☐ Sports ☐ Others; specify…….

24. Do some of the mangoes you normally purchase have some of the defects?
☐ Yes
☐ No

25. What proportion of the mangoes you normally purchase show the defect?
☐ Less than 1% ☐ 6% - 10% ☐ 2% – 5%
☐ ☐ ☐

Above 10% None Others, specify……

26. What proportion of the mangoes show the defect at the time of processing

☐ Less than 1% ☐ 6% - 10% ☐ 2% – 5%
☐ Above 10% ☐ None ☐ Others, specify……

27. What percentage of the mangoes goes waste in the course of sale?

☐ Less than 1% ☐ 6% - 10%
☐ 1% - 5% ☐ Above 10%

28. What do you think causes the waste?

☐ High price of mango to the consumer ☐ Poor storage condition
☐ Low selling rate ☐ Others; specify……..….
☐ Low quality from source of production

29. Do you take any actions to prevent the mangoes from going waste?

☐ Yes
☐ No

30. Which of the following post-harvest activities do you undertake to prevent the mangoes from going waste?

☐ Precooling/Shading ☐ Grading ☐ Washing
☐ Refrigeration ☐ Waxing ☐ Cooling
☐ Others specify…….

31. How can you reduce/prevent the quantity of the fruits that go waste?

☐ Avoid purchasing infected fruits from source
☐ Sorting/Grading according to level of ripeness
☐ Give attractive prices to customers
☐ Good ventilation
☐ Refrigeration

32. Which of the following fresh cut processing activities do you go through to make the mangoes?

☐ Washing of hands ☐ Cleaning of tools ☐ Peeling
☐ Cutting into smaller sizes ☐ Packaging in containers ☐ Others, specify….

33. Which of the following packaging materials do you use?

☐ Take away pack ☐ Plastic Bowls

☐ Plastic Film ☐ Others, specify…

34. How long does it take to sell the fresh cut mangoes after processing?

☐ Within an hour ☐ After 6 hours

☐ Within 6 hours ☐ Others, specify…….

35. What quantity of fresh cut are you able to sell aday?

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36. How do you store the fresh cut mangoes that are not sold?

☐ Refrigeration ☐ Others; specify……

☐ Room temperature

37. Are you aware of any infection that can affect the fresh cut mangoes?

☐ Yes

☐ No

38. Which type of infection can affect the fresh cut mangoes?

☐ Bacteria ☐ Others, specify…….

☐ Fungi

39. Can there be any contaminations on the fresh cut mangoes?

☐ Yes

☐ No

40. What are the sources of contamination on the fresh cut mangoes?

☐ Dust, stone and metal particles ☐ The use of packaging material

☐ The use of rusted knife ☐ House flies

☐ Worms ☐ Others, specify……