UNIVERSITY OF GHANA - LEGON

INTEGRI PROCEDAMUS

DEFINING THE QUALITY OF COMMERCIAL GHANAIAN-PRODUCED STIRRED YOGHURT

BY

ELMA KONTOR- MANU

10343596

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY (MPHIL) DEGREE IN FOOD SCIENCE

JULY, 2017

DECLARATION

I declare that this work presented as a dissertation to the Nutrition and Food Science Department, University of Ghana, Legon, was carried out entirely by me under the supervision and guidance of Dr. Maame Yaakwaah Adjei and Prof. F.K. Saalia. With the exception of references to cited works and textbooks which have been duly acknowledged, this dissertation has not been presented either in part or whole elsewhere for any other degree.

Elma Kontor- Manu
(10343596)

------------------------- **Signature** ------------------------- **Date**

Certified by Supervisors:

Dr. Maame Yaakwaah Adjei ------------------------- **Signature** ------------------------- **Date**

Prof. F.K. Saalia ------------------------- **Signature** ------------------------- **Date**

DEDICATION

This dissertation is dedicated to my parents, Mr Joe Kontor- Manu and Mrs Augustina Kontor-Manu and my only sister, Doreen Kontor- Manu, for their support, encouragement and prayers throughout this Master's program.

ACKNOWLEDGEMENT

I am grateful and thankful to the Lord God Almighty for bringing me thus far in my journey. I am grateful that He has been my source of hope through these two years and has pushed me on all my way even when I thought I could not pull through.

My appreciation goes out to my supervisors, Dr. Maame Yaakwaah Adjei and Prof. F.K. Saalia for their guidance and support throughout the course of this dissertation. I am grateful to them for giving me encouragement to conduct this study and taking time off their schedule to see this dissertation through.

My profound gratitude also goes to UG-CBAS Dairy Technology Centre Project for funding this project. This study will not have been successful if not for the cooperation of the Dairy Farmers and Processors Association of Ghana- DFPAG. I am forever grateful to them for their patience and time given to this study.

I express my sincerest appreciation to Bezalel Adainoo, Thomas Obeng, Kwame Dzardeh, Priscilla Ahadzi, Sylvia Baah- Tuahene, Richard Yaw Otwey and Mrs. Farida Adams for their immense help.

I also wish to thank the supervisor and team of the Nutrition& Food Science Sensory Evaluation Lab for the use of their facility as well as support in conducting this study. Many thanks to all my sensory panelists for their dedication to the project.

Many thanks also go to Senam Klomegah, Dr. Angela Parry- Hanson Kunadu, Marian Britwum and Doreen Kontor- Manu for being my pillars of support through the writing of this dissertation.

ABSTRACT

The dairy product industry is steadily growing on the Ghanaian market with increase in consumption and demand from consumers. Stirred yoghurt is a popular and highly consumed dairy product found on the market and there are different types available, with variability in flavouring, viscosity, colour and taste. To maximize market share, it is important to identify key quality criteria for yoghurt that will satisfy consumers.

This study was conducted to identify and define sensory characteristics of commercial stirred yoghurt on the Ghanaian market and determine key attributes that drive consumer acceptance. Fourteen stirred yoghurt samples were selected and assessed by 8 trained sensory panelists to develop a lexicon that describes the yoghurt samples. Acceptance testing was conducted with 61 consumers followed by preference mapping to identify key drivers of liking. Sensory, physicochemical and microbiological quality indices were monitored over time to determine quality of selected stirred yoghurt samples on the market.

The yoghurt samples were differentiated by twenty-one descriptive attributes ($p \leq 0.05$). Hierarchical clustering of the preference data identified three homogenous consumer clusters for yoghurt. Results from preference mapping showed that glossy appearance, yoghurt-like aroma, sour flavor and afterfeel, and an astringent afterfeel were the key drivers of consumer liking for commercial stirred yoghurt. There were significant differences ($p \leq 0.05$) in pH, % lactic acid, colour, and microbiological indicators of the yoghurt samples. Quality indices monitored over a period of 7 weeks showed inconsistency in the quality of the yoghurt samples evaluated.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

1.0 INTRODUCTION

1.1 Background Information

Yoghurt is a fermented dairy product made by culturing milk with lactic acid-producing bacteria, specifically *Streptococcus thermophiles* and *Lactobacillus delbrueckii* ssp. *bulgaricus* (Chipurura *et al.*, 2014). It is one of the most widely consumed dairy products. Yoghurt comes in different forms; stirred, set, Greek-style, and different flavours; vanilla, strawberry, plain and many others (Weerathilake *et al.*, 2014). Yoghurt is consumed widely because of its perceived health benefits. It is a good source of protein, minerals and vitamins. It is also a good alternative to fresh milk for lactose intolerant people. There are other additional health benefits associated with the consumption of probiotic bacteria used in some yoghurt products (Sanders, 2003).

Globally, yoghurt consumption has increased significantly. A global survey showed that more than 53% of consumers reported an increase in yoghurt consumption in the year 2015 than in the year 2012. The same study also showed that in 2014, the global spending on yoghurt amounted to €65.2 billion (DSM, 2015). The market is however still growing and numerous innovations are being developed for business to maintain a competitive edge in the industry.

In Ghana, yoghurt is ranked as the second most consumed dairy product after evaporated tinned milk (Aidoo *et al.*, 2009). The most popular Ghanaian-produced yoghurt brand is FanYogo. It is one of the most well established yoghurt brands on the market and very famous among consumers. However in recent years there have been an influx of other imported yoghurt brands on the market which have also gained popularity among consumers. With the increase in yoghurt products on the market and thus its continual exposure to consumers, as well as increased urbanization and other associated factors, demand for yoghurt has increased steadily (Agritrade, 2011). With increasing demand, quality differentiation is what will keep products on the market.

Food quality can be defined from various backgrounds. For instance, from a nutritional viewpoint, quality is defined as the required levels of nutrients in a diet, bioavailability of the nutrients and importance of non- nutrient substances naturally found in food (USLegal Inc., 2017). Microbiological definition of quality is the presence of a type or group of microorganisms or microbial toxins in a food meeting stated limits or the absence of these microorganisms (National Research Council (US) Subcommittee on Microbiological Criteria, 1985). However since the consumer is the final judge of a product's quality, as such the sensory or organoleptic quality is also important (Singham *et al.*, 2015) and may be defined as satisfying and meeting the demands of the consumer (Peri, 2006).

Yoghurt quality standards are difficult to achieve because of the various forms and flavourings, milk source as well as varying consumer preference to the product (Husain *et al.*, 2009). However, organizations such as World Health Organization/ Food and Agriculture Organization (Codex Alimentarius Commisison) propose objective standards to cover the nutritional composition, microbiological content, additives, contaminants, hygienic procedures and labelling; for yoghurt evaluation is documented in CODEX STAN 243-2003. In Ghana, the Ghana Standards Authority (GSA) is responsible for setting and enforcing product standards. Similar to other countries, GSA standards for yoghurt is based on the CODEX standards and documented in GS 1121:2016 (Ghana Standards, 2016, Milk and milk products- Specification for yoghurts and products heat treated after fermentation).

Like all other objective criteria for standards setting, the consumer appeal as determined by the products sensory quality is not covered although it is as important to ensure a products continued acceptance by consumers and its success on the market (Singham *et al.*, 2015). Sensory quality determination involves combinations of various tests. Costell (2002) outlines methods that can be used for sensory quality control. These include descriptive techniques, acceptance tests, difference tests as well as quality grading. All these methods are important for evaluations but are used depending on some factors such as the objective of the quality test, its practicality and appropriateness.

1.2 Study Rationale

With the increase in consumption of yoghurt amongst Ghanaian consumers, there is potential for the yoghurt market in the country to expand and become more competitive. In order to increase market share and guarantee consumer re-purchase of products, it is important for developers to know and satisfy consumer expectations while meeting expected standards set for yoghurt. This will limit the influx of imported yoghurts on the market and lead to high quality yoghurt products on the domestic market with potential for export.

The current standards available for determining the quality of yoghurt on the Ghanaian market are based only on the nutritional and microbiological quality of yoghurt. Although these are important quality parameters to assure the safety of yoghurt products on the market, they do not cover sensory properties of the product which is an important parameter to define market success through consumer acceptance. Defining the quality standards for yoghurt from a consumer viewpoint and ensuring that producers consistently meet product quality standards from all aspects including the sensory quality will help local yoghurt processors to remain competitive on the market leading to a more vibrant yoghurt industry in Ghana.

1.3 Main Objective

The main aim of the study was to define the sensory quality of Ghanaian- produced flavoured stirred yoghurt from a consumer viewpoint.

1.4 Specific Objectives

The specific objectives of the study were to:

i. establish the sensory profile for a representative sample of Ghanaian-made vanilla flavoured stirred yoghurt on the market
ii. ascertain the key attributes that drive liking of Ghanaian-made vanilla flavoured stirred yoghurt
iii. determine consistency of a representative sample of locally produced yoghurt on the market over time as a mark of product quality.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 History of Yoghurt

The history of yoghurt can be traced back to 6000 BC (Rahman *et al.*, 2016); where accounts show that yoghurt originated among the people from the Middle East (Fisberg & Machado, 2015). Historical accounts show that the herdsmen from this region stored milk in animal bags and these bags made from animal gut. It was found that enzymes from the gut acted on the milk and caused it to curdle (Fisberg & Machado, 2015). The curdled milk was found to keep longer than raw milk; and it is believed that the people liked the taste of the "new" product and therefore kept on with it (Rahman *et al.*, 2016). Yoghurt has since been commercialized on a very large scale and has seen increasing global trends. There have been different innovative products made with yoghurt and many more yet to be revealed. The word "yoghurt" is coined from the Turkish word "yoğurmak", translated as "to thicken, curdle or coagulate" (McGee, 2004). The word "yoghurt" was first written in the 11th century in a Turkish dictionary, *Diwan Lughat al- Turk* (Fisberg & Machado, 2015).

2.2 Nutritional and Health Benefits of Yoghurt

Yoghurt is a dairy product and contains high amounts of protein. Depending on the variety, it could have a protein content ranging between 3.1g to 5.7g per 100g of the product (Weerathilake *et al.*, 2014). It therefore serves as a great protein source for all individuals. It also contains nutrients such as calcium, magnesium, zinc, phosphorus, potassium, conjugated linolenic acids and the B-vitamins (riboflavin, niacin, B_6 and B_{12}) (Cano-Sancho *et al.*, 2015; El-Abbadi *et al.*, 2014; Fernandez & Marette, 2017). Yoghurt has a higher concentration of those minerals than fresh pasteurized milk (Cano-Sancho *et al.*, 2015). Yoghurt has been found to be a good dairy substitute for lactose intolerant people. Even though the lactose content present in yoghurt and milk are relatively the same, yoghurt is easily digested than milk (Savaiano, 2014). Observational studies have shown that yoghurt could play a key role in addressing the nutritional needs of the elderly especially in improving their bone health (El-Abbadi *et al.*, 2014). Some studies have also shown evidence of other health benefits related to yoghurt consumption. Some of these health benefits include weight management, improved cardiovascular and gastrointestinal health (Glanville *et al.*, 2015), protection against some cancers as well as improved immunology (Weerathilake *et al.*, 2014).

2.3 Types of Yoghurt

There are different types of yoghurt due to variations made at various points during its processing. The different types may be classified based on the composition of milk used, the type of starter culture used, the processing method used, or the type of flavouring, and additions such as fruit and nuts.

2.3.1 Types of yoghurt based on composition of milk used

These yoghurts are usually based on the fat content of the milk being used. There are three main types under this category. They are, regular yoghurt which contains not less than 3.25% milk fat and 8.25% solid non- fat; low-fat yoghurt, made from semi or partially skimmed milk with 0.5-2.0% milk fat and non-fat yoghurt made from skimmed milk with milk fat less than 0.5% (Weerathilake *et al.*, 2014).

The Ghana Standard Authority use similar categorizations to describe standards for yoghurt on the Ghanaian market. According to GS 1121:2016, regular yoghurt has the same standards for whole milk yoghurt based on the fat content. Most local processors however do not label their products according to this categorization hence consumers are unaware of the fat composition of the yoghurt they consume.

2.3.2 Types of yoghurt based on starter culture

These are categorized into two groups, standard and probiotic yoghurt. Standard yoghurts are made from the main yoghurt starter cultures, *Lactobacillus delbrueckii* sub-sp. *bulgaricus* and *Streptococcus thermophilus* (Weerathilake *et al*., 2014). These organisms can be found in the gastrointestinal tract on ingestion (Mater *et al*., 2005) and do not cause any detrimental effects in the body. In Ghana, this type of yoghurt is the most common in this category.

Probiotic yoghurt are made from culturing the yoghurt mix with probiotic strains of *Bifidobacteria* and *Lactobacillus acidophilus.* These strains when ingested in sufficient quantities is claimed to have some health benefits in the body (Nagpal *et al*., 2012). Some of these health benefits include decrease in serum cholesterol levels, improved intestinal and immune response as well as prevention of some cancers (Kechagia *et al*., 2013).

2.3.3 Types of yoghurt based on the processing method

There are three types of yoghurt under this category. These are:

1. Set yoghurt:

This yogurt is firm or jelly-like in nature and this is as a result of the process used prior to incubation of the yoghurt mix. This yoghurt type is usually incubated in the final package and thus after the fermentation process, it is cooled and stored without any further tempering of the yoghurt (Lee & Lucey, 2010) This yoghurt solid and has a more viscous consistency.

2. Stirred yoghurt

For this type, the yoghurt mix is incubated in tanks or vessels and after the fermentation process is stirred to break the coagulum before being packaged (Weerathilake *et al*., 2014). This makes the yoghurt less viscous than set yoghurt. It can be described as being semi- solid in nature.

Stirred yoghurt is the most commonly consumed type of yoghurt in Ghana. It is available in various corner shops, convenience shops and supermarkets all over the country (Adubofuor *et al.*, 2014). It is popularly referred to as "fresh yoghurt" by local consumers. This is to differentiate it from a popular Ghanaian- produced frozen yoghurt brand.

In most countries, stabilizers are added to improve the textural properties of this yoghurt type. This prevents defects such as whey separation and hence can be stored for longer periods without changing (Aswal *et al.*, 2012). In Ghana, the situation is quite different, most producers do not add stabilizers and thus Ghanaian-produced stirred yoghurt products on the market are usually stored for shorter periods so as to prevent this defect from occurring.

3. Drinking yoghurt

This is similar to stirred yoghurt, however its consistency is lighter as a result of the method used in breaking the coagulum. When the yoghurt is stirred after fermentation, a further process of whipping is done hence the product comes out being more liquid in nature (Watson, 2017). Drinking yoghurt is not very commonly produced in Ghana although many producers and consumers call stirred yoghurt, drinking yoghurt as they are often packaged in PET bottles and is often drank.

2.3.4 Types of yoghurt based on flavouring

In the selection of food or drinks by consumers, flavor is an important index for product purchase (Sharma, 2014). In yoghurt production, flavours which include fruits, vegetables or cereals are added to contribute to its appeal. The production of flavoured yoghurt in developing regions in the world is seen to likely increase market growth of yoghurt (Future Market Insights, 2014). Worldwide, vanilla and strawberry-flavoured yoghurts are most popular. For instance, Tribby (2009) reported that the most popular yoghurt flavor is vanilla however Sharma (2014) reported in a recent study, that strawberry flavour is the leading flavor in the world. The trend is no different in Ghana with the most popular flavours being vanilla and strawberry. Recently however, some small scale processors have experimented with other exotic flavours such as banana, mango, pineapple, apple and nutmeg. Plain or natural yoghurts, which have no added flavours or sweeteners, are also common generally, although not popular with consumers in Ghana. There are however some niche plain yoghurt processors with products on the shelf.

2.3.5 Other yoghurt types

There are other yoghurt types on the market. These are:

Greek yoghurt which is made from straining set yoghurt after draining the whey, also termed as strained yoghurt (Gyawali & Ibrahim, 2016). It has a higher protein content than other types of yogurt due to its manufacturing process. In the US, trends show that Greek yoghurt has contributed to increased yoghurt consumption (Ortinau *et al.*, 2013). Fruit yoghurt which is made by adding fruits and/or fruit related products such as drinks, syrups, concentrates, etc. to yoghurt (Jayasinghe *et al.*, 2015). It also known as fruit stirred yoghurt since the fruits are usually added to stirred- type yoghurt (Nazni & Komathi, 2014). Frozen yoghurt is simply described as the combination of ice cream and yoghurt; with the product adapting the physical properties of ice cream and the nutritional as well as sensorial characteristics of yoghurt (Ahmadi *et al.*, 2014). The product is made by adding stabilizers or emulsifiers as well as sugar to plain stirred yoghurt and freezing in an ice cream freezer (Mahrous & Abd-El-Salam, 2014). There are a lot more types of yoghurt available on the international market; some of which are Herbal yoghurt, Balkan- style, Dried yoghurt, French-style, UHT yoghurt, and others (Weerathilake *et al.*, 2014).

On the Ghanaian market, a new yoghurt type has become popular among consumers, which is the "grain yoghurt". This is made by adding grains, more specifically millet to yoghurt. This product was coined from a popular local fermented milk product, "Burkina". This product which is made from spontaneously fermented milk and parboiled millet has made such raves that some yoghurt processors have adapted this into making a new yoghurt type.

2.4 Food Quality

Quality is a complex concept that does not have a universally accepted definition. As a term, it has different meanings from different schools of thought (Wandel & Bugge, 1996). In food production or processing, food quality is a broad index and its definition as well as measurability varies widely.

2.4.1 Definitions of food quality

Wandel and Bugge (1996) describe four main groups who usually define food quality. These are the producers; their major indicator for quality being the products' technical use, marketers; focus more on the products' visual appeal as well as shelf-life, government organizations; define quality based on products adherence to some set regulations which are usually health- related and consumers; food quality is dependent on different factors such as its safety, visual appeal, taste, nutrition and others.

Grunert (2005) also suggests that food quality can be categorized into two; objective and subjective quality. Objective quality is usually defined by food engineers and technologists who relate quality to the products physical characteristics. Subjective quality, on the other hand is consumer- oriented. From a consumer viewpoint, quality can be further grouped into two; quality being perceived when a product meets its desired properties such as taste, appeal, etc. and the other form of quality is generally not considered as common consumer language for defining quality but contributes to consumer choices such as convenience. Peri (2006) defines quality *"as the requirements necessary to satisfy the needs and expectations of the consumer."* He further breaks consumer requirements as stated in his definition into two major groups; first, when the product is considered as a food and second, as an object of trade.

As a food product, quality is based on these consumer requirements; safety, conformity to standards (these two mentioned gives assurance to consumers as indicator of authenticity), nutrition, sensory, production context (these include origin and tradition of product, type of agricultural practices employed, etc.) and ethical considerations (defense of the ecosystem, animal lives, etc. during production).

When the product is considered as an object of trade, the following requirements define quality; guarantee (certification and traceability), packaging, product information, convenience, availability and price (Peri, 2006). All these different definitions and more show the different dimensions in which quality can be defined. As summarized by Grunert (2005), quality can be generally placed under two big branches, objective and subjective quality. These two can have different subgroups depending on individual or institutional preference for defining quality.

2.5 Objective Quality Assessment of Yoghurt

In defining quality of yoghurt, some major objective indicators that could be used for assessment include physicochemical and nutritional properties, as well as microbial assessment.

2.5.1 Physicochemical quality of yoghurt

The physicochemical properties of yoghurt is a key element in its quality description. Texture and flavor are two very important indices of yoghurt; there have been several studies done in relation to yoghurt textures, flavours and other physicochemical properties with more innovative methods being used in analyzing, determining and describing these properties (De Brabandere & De Baerdemaeker, 1999; García-Pérez *et al.*, 2005; Jayasinghe *et al.*, 2015; Nazni & Komathi, 2014; Olorunnisomo *et al.*, 2014; Routray & Mishra, 2011; Sfakianakis & Tzia, 2014).

Yoghurt has a unique flavor attributed to it as compared to other food products. This unique flavor is usually an index for quality, especially for consumers when purchasing the product. Flavours derived from yoghurt are obtained as a result of the production of lactic acid during fermentation, volatiles existing in the milk source and other volatiles generated during its production (Cheng, 2010). There are over 90 volatiles present in yoghurt and these can be grouped into four main categories; non-volatile acids (lactic, oxalic, pyruvic acids), volatile acids (acetic, propionic), carbonyl compounds (acetaldehydes, diacetyl, acetoin) and other compounds (certain amino acids) (Cheng, 2010). The carbonyl group is believed to have a stronger influence on the final yoghurt flavor as a result of higher amounts produced (Routray & Mishra, 2011).

Viscosity of yoghurt is also known to be a key property for yoghurt quality. Studies by some researchers has shown that yoghurt viscosity is related to consumer liking. The thickness as well as creaminess of yoghurt is associated with its acceptability; with thicker and creamier consistencies being more favoured by consumers as desired textural properties (Bayarri *et al.*, 2011; Pohjanheimo & Sandell, 2009). There are no laid down standards governing texture attributes such as consistency, flow index, etc. or flavor production in yoghurt since these are based on brand or company internal specifications for yoghurt products. However, there are standards for acidity and pH levels in yoghurt products. This is because fundamentally, pH and acidity (lactic acid, acetic acid, etc.) are the major contributors to characteristic flavor and textural attributes of yoghurt (Sfakianakis & Tzia, 2014). According to Codex regulations, titrable acidity of yoghurt expressed as % lactic acid (%m/m) should be at least 0.6% (WHO/ FAO of the United States, 2011). Weerathilake *et al*. (2014) also write that in the US and Australia/ New Zealand standards, the requirements for titrable acidity (%) and pH are ≥0.9 and ≤4.5 respectively. In Ghana, there is no legal documentation of this for determining quality of yoghurt hence Codex standards are applied.

2.5.2 Nutritional quality

Yoghurt has the same nutritional profile as its milk source, differences will be seen when other components such as fruits, cereals, nuts, vegetables are added to it (McKinley, 2005). Most yoghurt products are usually made from cow milk and hence the nutritional composition tends to be the same as that of cow milk, providing the same amount of nutrients. In Table 2.1, the composition of different yoghurt types are listed.

Table 2.1: Nutritional composition of different yoghurt varieties (per 100g)

Component	Whole milk yoghurt	Low fat yoghurt	Non-fat yoghurt
Energy (kJ)	330.54	234.30	225.94
Protein(g)	5.7	4.8	5.4
Carbohydrate (g)	7.8	7.4	8.2
Fat (g)	3	1	0.2
Thiamin (mg)	0.12	0.04	0.12
Riboflavin (mg)	0.27	0.22	0.29
Niacin (mg)	0.2	0.1	0.1
Vitamin B6 (mg)	0.1	0.01	0.07
Vitamin B12 (mg)	0.2	0.3	0.2
Folate (µg)	18	18	8
Carotene (µg)	21	Trace	Trace
Vitamin D	0	0.1	Trace
Potassium (mg)	280	228	247
Calcium (mg)	200	162	160
Phosphorus (mg)	170	143	151

Source: The Dairy Council (2013)

Apart from the general nutritional composition, there are standards for some specific nutritional components of yoghurt products. The Codex standards (CODEX STAN 243- 2003) states that for milk protein (%m/m) and milk fat ((%m/m), levels should be at a minimum of 2.7% and less than 15% respectively. This general criteria has been adapted by several countries with some variations made. Table 2.2 shows the required nutritional composition for different yoghurt types in some countries.

Table 2.2: Fat and solids non-fat content for various categories of yoghurt

Country	Regular yoghurt (%m/m)			Low-fat yoghurt (%m/m			Non-fat yoghurt(%m/m)		
	MaMF	MiMF	MMSF	MaMF	MiMF	MMSF	MaMF	MiMF	MMSF
Ghana	-	3	8.2	< 3	> 0.5	8.2	0.5	-	8.2
USA	-	3.25	8.25	2	0.5	8.25	0.5	-	8.25
Australia	-	3.25	8.25	2	0.5	8.25	0.5	-	8.25

Source: Ghana Standards Authority, GS 1121:2016 and (Weerathilake *et al*., 2014)
Abbreviations: MaMF- Max milk fat; MiMF- Min milk fat; MMSF- Min milk solids non-fat

2.5.3 Microbial quality assessment

2.5.3.1 Evaluation methods in determining microbial quality

In yoghurt production, starter cultures containing microorganism are used, therefore microbial assessment as a quality parameter is important to ensure the safety of the product for human consumption. To ensure overall safety of the yoghurt product, it is important that apart from the yoghurt culture bacteria or probiotic bacteria, other microorganisms' especially pathogenic bacteria are not present.

According to El-Malt *et al.* (2013), the microorganisms of interest when assessing the quality of yoghurt are usually psychotrophs, *Enterococci*, coliforms, *Escherichia coli*, *Staphylococcus aureus*, as well as yeasts and moulds. This is because any of these organisms have the potential of contaminating the product at any point on its production chain and thus can serve as indicators of microbial quality of the product. Indicator organisms such as Enterobacteriaceae and *Escherichia coli* are organisms usually tested for microbiological quality of yoghurt. These organisms are usually a reflection of poor hygiene and handling practices, and improper heat treatment of the milk thus are key when determining the quality of a yoghurt product (Food Authority, 2009). However, the most documented spoilage organisms of yoghurt are yeasts and moulds (Fernandes, 2009).

Yeasts and moulds tend to decrease the shelf-life of the yoghurt products, hence serve as an index for yoghurt spoilage. The presence of these organisms in a yoghurt product indicates low quality due to high incidence of spoilage. There are acid- tolerant fermentative yeasts such as *Candida spp.*, *Saccharomyces spp.*, *Rhodotorula spp*., etc. that can grow in yoghurt and produce CO_2 which then blows up the product. Yoghurt products with added sugars (in any form) are at higher risk of being contaminated by yeasts because most of these organisms are able to ferment sucrose (Fernandes, 2009). Acid tolerant moulds also contaminate yoghurt and usually do so during packaging, storage or transporting of the products. Species such as *Aspergillus*, *Rhizopus*, *Alternaria* and *Penicillium* are well known to contaminate yoghurt leading to its spoilage (Fernandes, 2009).

Generally, pathogenic organisms are usually considered to be limited in fermented milks as a result of the low pH and the high acidic environment created with its production. However, different factors such as attained pH, starter culture used, hygiene and handling practices as well as the organisms' adaptation abilities can lead to its survival and further potential risk (Fernandes, 2009). Therefore detecting the presence of pathogenic organisms are also used as quality assessment of yoghurt products. Some of these include *Listeria monocytogenes*, *E. coli* O157, Coagulase-positive *Staphylococcus aureus*, *Bacillus cereus*, *Yersinia spp*. and others depending on the country or organizational requirements (Fernandes, 2009; Food Authority, 2009; Gilbert *et al*., 2000).

For example, it is generally thought that *Listeria monocytogenes* is unlikely to be present in fermented milks because of the heat treatment prior to fermentation which if done at required time-temperature levels will kill the organism. However, it is possible for this microorganism to survive in the final product. Presence of *Listeria monocytogenes* in some yoghurt products has been traced to contaminated starter cultures with added influence of temperature used at fermentation as well as acidic levels reached. The combination of these factors (if favourable) may lead to survival of the organism (Fernandes, 2009).

2.5.3.2 Microbiological criteria for yoghurt

The Codex Alimentarius (CODEX STAN 243- 2003) as well as food standard organizations in different countries have documented standards governing the microbial load in yoghurt. These are set to ensure the safety of consumers and also to determine quality of yoghurt products. The table below gives some countries and their limits for microorganisms in yoghurt.

Table 2.3: Acceptable microbial load in yoghurt by different bodies (countries)

Microorganism	cfu/g			
	Codex	UK	Australia	Hong Kong
Total microorganisms(as starter culture)	min 10^7	-	-	-
Enterobacteriaceae	-	100-10^4	10^2-<10^4	10^2-<10^4
Total *E. coli*	-	20-<100	2-100	20-<100
Total *Listeria* spp	-	20-<100	-	-
Salmonella (in 25g)	-	n.d	n.d	n.d
E coli O157 (in 25g)	-	n.d	n.d	n.d
Listeria monocytogenes (in 25g)		n.d	-	n.d
Staphylococcus aureus		20-<100	10^2-<10^3	20-<104

n.d= not detected

Source: Centre for Food Safety (2014); Food Authority (2009); Gilbert et al. (2000); World Health Organization and Food and Agriculture Organization of the United States, (2011) In Ghana, the documented standards state that no cells of coliforms, *Escherichia coli* or *Salmonella* should be detected in yoghurt products (Ghana Standards, GS 337- 2003). A recent study conducted by Adubofuor et al., (2014) on commercial vanilla-flavoured stirred yoghurt in the Kumasi Metropolis, a city in Ghana, however showed that this set standard was not observed among yoghurt products analyzed. The study recorded a coliform count as high as 9.3×10 cfu/ml. Similar results have also been shown in other studies in different countries, with yoghurt products not meeting stated country and international standards (De *et al.*, 2014; El-Malt *et al*., 2013; Gulzar *et al.*, 2013; Okpalugo *et al.*, 2008; Onuorah & Obika, 2016; Varga, 2007). The high incidence of these microorganism was attributed to use of poor quality milk, improper heat treatment and improper sanitary practices.

2.6 Subjective Quality Assessment of Yoghurt

This aspect of quality is usually consumer-oriented and thus considered as subjective. However with the right principles, conditions and method in place, repeatable measurements can be obtained from the consumers (who become instruments). In this case, results are no longer subjective but objective since data is measurable and repeatable (Lawless & Heymann, 2010). Sensory characteristics of a product is important for consumer acceptance (Bayarri *et al.*, 2011; Bruzzone *et al.*, 2013; Pohjanheimo & Sandell, 2009). The product must satisfy and meet the consumer requirements, and this can be achieved if consumers' opinions are known and included from onset of product development through to its final release (Bayarri *et al*., 2011). Processors need to know attributes of a product that drives its liking by consumers when developing, improving or optimizing products. This knowledge also helps with setting up effective and efficient quality control programs (Bayarri *et al.*, 2011).

Yoghurt is a product that relies heavily on its sensory quality for its consumer appeal (Pohjanheimo & Sandell, 2009). Even with different novel yoghurt products being made, consumer expectations are still the same; thus they expect irrespective of the type of yoghurt, it still has that familiar and unique properties ascribed to it (Bølling Johansen *et al.*, 2009). Various studies have been conducted on different types of yoghurt so as to determine level of liking or to simply describe the product. Coggins *et al.* (2007) developed a list of descriptors that could be used to analyze commercially-produced conventional plain milk yoghurts on the US market. Bayarri *et al*. (2011); Bouteille *et al.* (2013); Bruzzone *et al.* (2013), have all done some work on plain yoghurts and have being able to identify attributes that could be used in describing these types of yoghurts. Other studies have also been done on consumer acceptance of yoghurt brands, novel yoghurts and yoghurt types (Adubofuor *et al*., 2014; Bayarri *et al.*, 2011; Bølling Johansen *et al.*, 2009; Bruzzone *et al.*, 2013; García-Pérez *et al.*, 2005; Jayasinghe *et al.*, 2015; Olorunnisomo *et al*., 2014; Silaula & Dlamini, 2009). Results from all these studies have shown the importance and contribution of sensory quality on overall yoghurt quality.

Even though consumer perception of a product may differ due to individuality, there are some general sensory attributes of yoghurt that are considered as defects and thus reduce its quality. The table below (Table 2.4) gives a list of such identified attributes.

Table 2.4: General yoghurt sensory defects

TERM	DEFINITION
BODY AND TEXTURE	
Free whey	Translucent, greenish-yellow liquid on surface, and around sides of the cup of yoghurt
Gel-like/ too firm	Appearance of formed gelatin in cup (or plate), and a very firm set
Weak	Appears “runny” or too- liquid-like
Shrunken	Yoghurt pulling away from side of cup and leaving a gap
Grainy	Small particles on tongue- surface
Ropy	Trailing stream (stringiness) between spoon edge and product container

COLOUR AND APPEARANCE	
Atypical	Colour of yoghurt does not represent flavor of named or labeled yoghurt
Colour leachimg	Ring or halo effect around pieces of fruit or berry
Lumpy	Appears rough, uneven and non-homogenous
FLAVOUR	
High acetaldehyde	Similar to green-apple hard candy (if too high)
Bitter	Offensive aftertaste
Cooked	Like caramelized sugar, or butterscotch, an eggy-like flavor sensation
Atypical (colour)	An out-of-place aroma and/or an off-taste
Lacks freshness	Stale-off flavor, storage off- flavor
Old ingredient	Dirty sock or dish rag flavor
Oxidized	Cardboardy or burnt hair/ burn feathers odour and off- flavor
Rancid	Off smell that resembles feta cheese
Unnatural flavouring	Not the listed flavor
Unclean	"dirty- sock" flavor and mouth does not "clean- up"
High acid	Too sharp, harsh and/or offensive
Sweetness	Too much or too little in a sweetened product
Low acid	Lacks an "acid" profile
Metallic	Metallic "off-flavours"
Flavouring	Too much or too little of listed flavour

Source: Tribby (2009)

In Ghana, studies have also been done by various researchers on consumer acceptance of various types of yoghurt, however, there is limited information on descriptors of yoghurts on the market and attributes that drive liking of the products. Yoghurt is a product that requires assessment in every aspect and sensory quality is a key focus in yoghurt quality tests. Hence, yoghurts on the Ghanaian market need to be analyzed to determine their sensorial quality to help with consistency, marketability and consumer satisfaction.

2.7 Effect of Processing on Yoghurt Quality

Depending on the brand or type of yoghurt, the process of production may differ. However, there is a general procedure used in making yoghurt. In yoghurt production the key steps include: milk standardization, homogenization, pasteurization of milk, inoculation and incubation, fermentation period, cooling of yoghurt and storage (Lee & Lucey, 2010). Figure 1 shows the main processing steps in yoghurt production. The quality of yoghurt can be affected depending on the techniques employed during processing. Each procedure used has an effect on the final yoghurt product and is therefore important to ensure that processing is efficient in order to obtain good quality yoghurt.

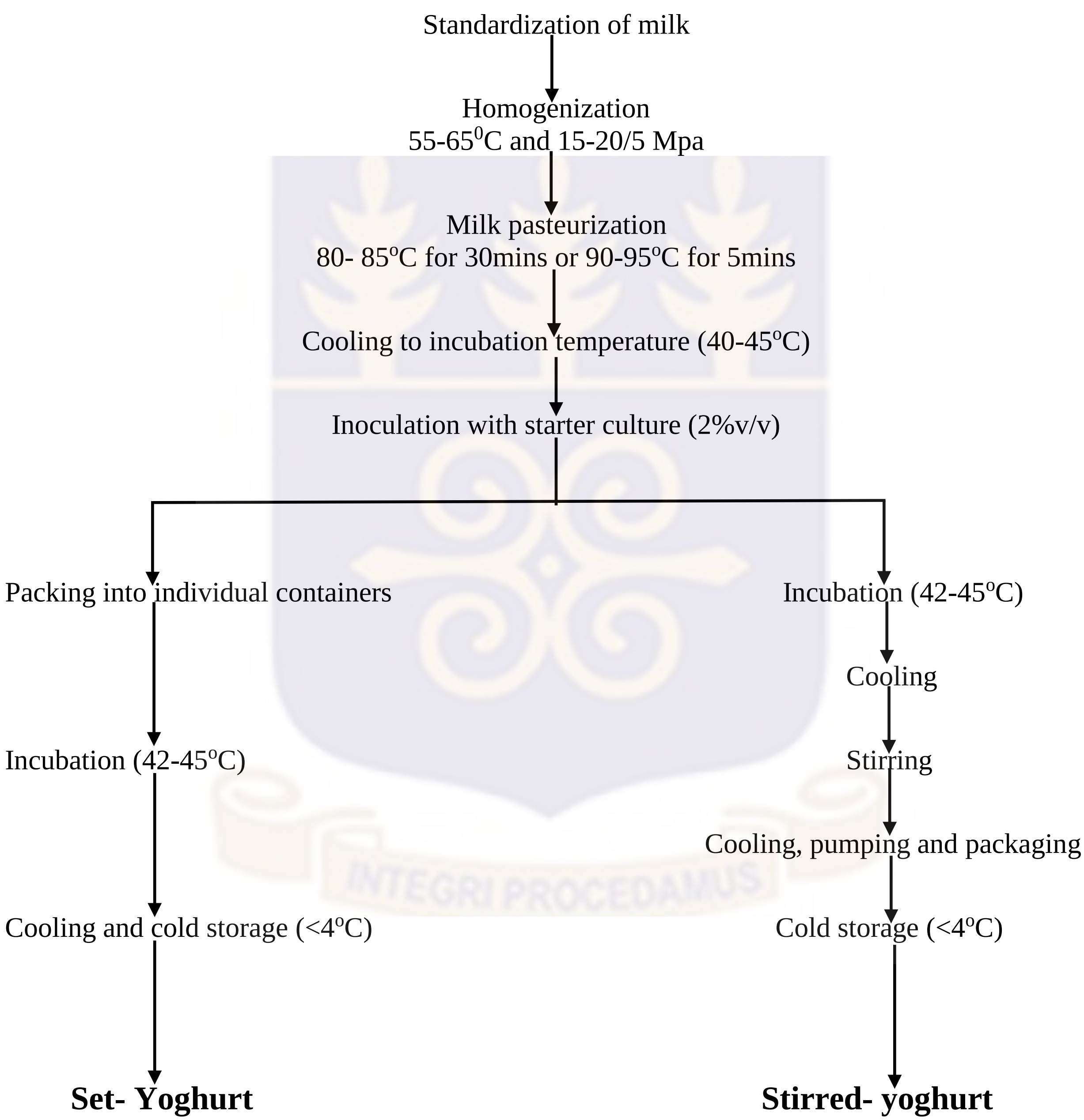


Figure 2.1: General manufacturing process for set and stirred- yoghurt (Adapted from Lee & Lucey, 2010)

The effects of processing on yoghurt quality are outlined below:

Milk standardization: Milk fat content is adjusted to standard levels and that is by reducing fat content and increasing total solids content (Watson, 2017). This is achieved by concentrating the milk through evaporation, ultrafiltration, other concentration processes or by the addition of concentrated milk or milk powder (Lee & Lucey, 2010; Weerathilake *et al.*, 2014). The total solids content is increased so as to ensure increased viscosity and prevent whey separation which are quality indices of yoghurt. A personal conversation with some small-scale yoghurt processors in Ghana showed different techniques are used to achieve a similar effect, due to a lack of appropriate equipment. Some processors who use cow milk for yoghurt freeze the fresh milk, leave it out to thaw and discard fats that floats on the surface. Milk standardization is then re-continued during pasteurization. Other processors add powdered milk to the fresh milk whereas others use only a powdered milk (whole or skimmed) to produce yoghurt. These variances can affect certain quality indices of the yoghurt.

Homogenization using homogenizers or viscolizers reduces the size of fat globules in the milk allowing uniform distribution thus increasing surface area for active fermentation during the course of processing (Olorunnisomo *et al.*, 2014). Some processors in Ghana totally ignore this step because they do not have the equipment or do not know about the effect of this on the product. The absence of this process can affect firmness, water holding capacity, sensorial properties such as its whiteness, taste as well as flavor and the stability of the milk emulsion thus leading to fat separation or creaming (Olorunnisomo *et al.*, 2014; Sfakianakis & Tzia, 2014; Weerathilake *et al.*, 2014)

Pasteurization: Heat treatment helps to ensure that all unwanted microorganisms are killed and also aids in achieving most physicochemical properties such as firmness and viscosity of yoghurt during fermentation (Watson, 2017; Weerathilake *et al.*, 2014). In Ghana, some small scale processors continue milk standardization with the heat treatment. Fat is intermittently removed from the surface using ladles during the few minutes of pasteurization. This is the most effective improvised way these processors use to achieve both milk standardization and pasteurization. These processors usually do not have pasteurizers and hence improvise by heating the milk in boiling water basins till the milk reaches a temperature of about 85-90^{o}C. It is then reduced to low heat and kept for about 15 minutes. They also do not necessarily use thermometers so the temperatures may be arbitrary.

Though this ensures heat treating of the milk, if proper sanitary measures are not taken this step may lead to further contamination of the milk emulsion, further reducing its quality.

Inoculation, incubation and fermentation: Most of the sensorial and physicochemical properties of yoghurt are developed here. Depending on the type of inoculum and duration of fermentation, unique desirable attributes are conferred unto the yoghurt. Inoculation and incubation temperatures of the milk emulsion is kept at 43- 46^{o}C or 42-44^{o}C to ensure effective fermentation (Wang, 2017). The unique yoghurt aroma and flavor are generated during fermentation (Baglio, 2014).

Personal conversations with small-scale processors showed different improvised techniques to ensure required temperatures for fermentation. The most common technique used by most was the use of steamed ice chest as an “incubator”. This is then kept in a warm and dark place to ensure seemingly warm atmospheres for continual fermentation. Fermentation for these processors are usually prolonged and uncontrolled and thus can affect the quality of the yoghurt such as its pH and acidity levels (Gulzar *et al.*, 2013), which in turn affects sensorial qualities such as sourness and other yoghurt flavours (Routray & Mishra, 2011).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Sample Selection

A list of commercial yoghurt brands available on the market was drafted by visiting 5 supermarkets namely: Accra Mall (Shoprite and Game), A&C Shopping Mall (Max Mart), 37 Max Mart Shopping Mall and All Needs Supermarket in the Accra Metropolis. Another list of registered yoghurt producers was also obtained from the Ghana Food and Drugs Authority. From the list generated, it was identified that the most common type of yoghurt on the market was vanilla-flavoured stirred yoghurt and majority of the registered yoghurts in Ghana are found in the Accra Metropolis. A survey of the supermarkets mentioned above showed most of the registered yoghurts could be found in at least one of those shops. This gave confidence that a selection from this list combined with the market survey will give a good representation of stirred yoghurts on the local Ghanaian market. In addition to this list, yoghurts produced by the Dairy Farmers and Processors Association of Ghana, a recognized dairy farmer group in Ghana, was included in this list

In total 52 commercial yoghurt brands were identified, and 14 brands (Appendix 1.0) were selected for the study based on the following criteria:

a. Type (vanilla-flavoured and stirred)
b. Locally-produced
c. Availability (consistent supply) of the products.
d. Convenience (in Accra metropolis)
e. Within expiry date by at least a week

3.2 Study Design

The study was conducted under three quality perspectives; sensory, physicochemical and microbiological. Sensory analysis was conducted using Quantitative Descriptive Analysis (QDA) to generate descriptors from 14 vanilla-flavoured stirred yoghurt brands and through preference mapping sensory quality indices were identified. A hybrid of QDA/ Sensory Spectrum was used to monitor consistency of these quality indices in the yoghurt products at 3 different times.

For physicochemical tests, the 14 brands were sampled 3 different times to check variability in pH, %lactic acid and colour. To monitor microbial quality and consistency, the 14 yoghurt brands were sampled at 3 different times and analysed for total mesophilic count, coliform, lactic acid bacteria, *Staphylococci, Listeria, Salmonella* and *E. coli*.

3.3 Sample Purchase and Transportation

The products were purchased either from supermarkets or directly from local producers at farm gate. All the products were obtained in the Greater Accra Region of Ghana. Samples intended for microbiological analysis were collected in separate containers from those intended for sensory and physicochemical tests. Samples on being obtained were transported in an ice chest which had an internal temperature of about $10^{o}C$. Average transit time from point of purchase to the lab was approximately 4 hours.

With the exception of Product D which was always frozen at time of purchase, all other samples were purchased at chilled temperatures of about $8\pm2^{o}C$. The samples were in their original packaging as would be presented to consumer at point of retail. Products A to G were sampled four times over a 7-week period, and products H to N were sampled three times over a 3 week period. Table 3.5 gives a description of the sampling plan for the yoghurt products.

Table 3.5: Yoghurt sampling plan for sensory analysis

Product	Sampling Period	Purpose
A	Weeks 1-3 and 7	Initial profile; Preference mapping; Routine checks
B	Weeks 1-3 and 7	Initial profile; Preference mapping; Routine checks
C	Weeks 1-3	Initial profile; Preference mapping; Routine checks
D	Weeks 1-3 and 7	Initial profile; Preference mapping; Routine checks
E	Weeks 1-3 and 7	Initial profile; Preference mapping; Routine checks
F	Weeks 1-3 and 7	Initial profile; Preference mapping; Routine checks
G	Weeks 1-3 and 7	Initial profile; Preference mapping; Routine checks
H	Weeks 4-6	Descriptor validation; Quality test
I	Weeks 4-5	Descriptor validation; Quality test
J	Weeks 4-6	Descriptor validation; Quality test
K	Weeks 4-6	Descriptor validation; Quality test
L	Weeks 5-6	Descriptor validation; Quality test
M	Weeks 4-5	Descriptor validation; Quality test
N	Weeks 6	Descriptor validation; Quality test

On arrival at the laboratory, samples were quickly transferred into a refrigerator (Digital Inverter Technology, RB39FERCDSA) with temperature of about 5±2^{o}C. Samples were stored for less than 24 hours before evaluations were done.

For consumer test, samples obtained for evaluation lasted 2 days after collection to allow for a 2- day test session. Samples were stored in the fridge throughout the test period.

3.4 Sensory Analysis

3.4.1 Descriptive Analysis

3.4.1.1 Hybrid Quantitative Descriptive Analysis- Spectrum

A hybrid of Quantitative Descriptive Analysis and Sensory Spectrum was adapted for this study. A merger of the techniques and principles of both tools was better suited in achieving the objective of the study.

PART I: Developing Yoghurt Lexicons

Seven (7) yoghurt samples, Products A-G, were randomly selected out of the fourteen (14) chosen products. This was because these same products were to be given to consumers for testing and to help reduce sensory fatigue as a result of the nature of the product the entire sample pool was not used at the initial stage. Trained panelists individually derived descriptors and definitions for the yoghurt samples. With the directives of the panel leader all terms generated were accumulated and on consensus those that were perceived to strongly describe the samples were selected and used for subsequent checks

Detailed definitions were also given to describe the generated attributes; references were provided and linked to the stated descriptor. The panelists were trained on the use of the line scale for evaluation with appropriate anchors placed on the scale. Panelists were then provided with 3 randomly coded samples to rate using the generated descriptors so as to test for concept alignment among the group. The assessors were made to re-evaluate all the 7 samples and this was performed in triplicates.

PART II: Validation of Lexicons

To validate the descriptor list obtained, the other seven (7) yoghurt samples (Product H-N) were used for evaluation. The panelists were given these samples to determine if the initial list captured all descriptors related to stirred yoghurt before individual evaluations. Any new descriptor generated was added to the initial list with its respective definition and reference (where applicable). Panelists then assessed these samples with the generated list; all evaluations were performed in triplicates.

3.4.1.2 Assessors (Trained panelists)

Eight panelists who had had about 6 weeks training in Quantitative Descriptive Analysis on dairy products prior to the study were recruited. They comprised of three (3) males and five (5) females. The panelists met for 2.5 to 3 hours per day, 3 times in a week for this study. A total of 21 sessions were attended by the panelists for the entire study.

Figure 3.2: Assessors having a group discussion on descriptors for yoghurt samples (**left**); individual assessment of samples in booths **(right**)

3.4.1.3 Sample Preparation and Serving

Before serving samples to panelists, the yoghurt samples were brought out of the fridge and allowed to thaw to a temperature of about 16 ± 2^{0}C. Each yoghurt sample was transferred into 1L jars and stirred 4 times with a wooden spatula before being poured into 80cc plastic transparent disposable cups and covered with plastic lids for serving. Each panelist was served with about 60ml of each yoghurt sample. All samples were coded with random three-digit numbers to minimize biases. Each panelist was given water (ambient temperature) and crackers as palate cleansers between tasting samples. The samples were presented to the panelists in a randomized balanced order using William's design in Compusense 5 Saas (Compusense5, Cloud, Compusense, Guelph, Ontario, Canada).

3.4.1.4 Environmental Controls

The sensory sessions were conducted in the Nutrition & Food Science Sensory Laboratory which is equipped with separate tasting booths for panelists with white lighting and a well-ventilated atmosphere.

3.4.1.5 Assessment Protocol

All evaluations were done on an anchored intensity line scale; and all evaluations were conducted in triplicates. A computerized system was used to capture the data (Compusense5, Cloud, Compusense, Guelph, Ontario, Canada).

3.4.2 Consumer Test (Untrained panelists)

3.4.2.1 Recruitment and Session

A total of seventy (70) consumers were recruited based on the following criteria: no allergies or yoghurt intolerances, drinks yoghurt at least once a month, availability and proximity to test centre and lowest educational level being a Junior High School graduate. However only sixty-one (61) consumers (28 males, 33 females) were able to complete the test. The test was conducted over 2 days with 4 different sessions per day. Each session lasted about 30 minutes, consumers completed the test only once. The participants were briefed about the test and signed informed consent form before commencement of the test.

3.4.2.2 General Design and Assessment Protocol

Acceptance test was used to determine sample liking on a 9-point hedonic scale for overall liking attribute; where 1= dislike extremely and 9= like extremely. Responses were recorded individually on paper ballots (Appendix 3.0c).

3.4.2.3 Sample Preparation and Serving

Products A to G which were obtained in the first week were used for the consumer test. The samples were served at temperatures of about 4±2^{o}C. Each panelist was served with about 25ml of each yoghurt sample in the same clear 25cc disposable plastic cups. All samples were coded with random three-digit numbers to ensure minimal biases. Panelists were instructed to drink water and use plain crackers to cleanse their palates between each tasting. The samples were presented to the panelists in a randomized balanced order using the William's presentation order generated from Compusense Cloud. Samples were served in two sets of 4 and 3 with a 5 minute forced break between serving sessions and 1 minute break between samples.

3.4.2.4 Environmental Control

The same environment as that provided for the trained panelists in the descriptive test was used for the consumer test.

3.5 Monitoring Quality Indices

Quality of the samples were monitored over a period using sensory, microbiological and physicochemical indices.

3.5.1 Sensory Analysis

A hybrid of Quantitative Descriptive Analysis and Sensory Spectrum was adapted for routine checks of yoghurt samples.

3.5.1.2 Assessment Protocol

Trained panelists rated intensities of identified sensory quality indices on a line scale with appropriate references placed as anchors. A computerized system was used to capture the data (CompusenseCloud, Compusense, Guelph, Ontario, Canada). All evaluations were conducted in triplicates.

3.5.2 Microbiological Analysis

This analysis was performed to check the microbiological quality of the products. Microbial analysis performed were to determine levels of some selected microorganisms in the yoghurt samples at different times during the course of the study.

3.5.2.1 Sample Preparation

For each yoghurt brand, microbiological analysis was performed at least thrice at different times during the study. Samples collected for analysis were received from producers in separate packaged bottles and transported in the same manner as other samples being used for the other tests.

Samples were worked on within 24 hours of being brought from place of collection. Frozen sample (Product D) was thawed at a max temperature of about 6^{o}C within 18 hours before analysis was done. The other test samples were thawed at room temperature for a maximum of 30 mins before analysis. All the packaged yoghurt bottles were sanitized with 70% alcohol and cleaned with sterile tissue before being opened for use. For each yoghurt brand, about 350ml of sample was collected.

3.5.2.2 Laboratory Microbiological Analysis

Samples were analyzed for total count of aerobic mesophiles, coliforms, *Staphylococci*, yeast and moulds, and lactic acid bacteria. The yoghurt samples were also analyzed for the presence of *Salmonella spp.*, *Escherichia coli*, and *Listeria monocytogenes.*

3.5.2.3 Preparation of Serial dilutions

For analysis of aerobic plate count, *Staphylococci*, coliforms, yeasts and moulds, 10ml of each sample was aseptically measured into sterilized bottles with 90ml of peptone water being added. After the addition of the diluent, the sample was carefully mixed by gently inverting the bottle ten times. In detection of *Salmonella* and *Listeria sp*., 25 ml of each sample was aseptically measured into stomacher bags with 225ml of buffered peptone water and Fraeser respectively, added and homogenized in a stomacher blender. Serial dilutions for all the microbial counts mentioned were carried out.

3.5.2.4 Aerobic Plate Count

The yoghurt samples were serially diluted and 0.1ml of two decimal dilutions was pipetted into sterile disposable petri-dishes. Each decimal dilution was done in duplicates. Twenty millilitres of Plate Count Agar (PCA) (Oxoid, CM0325) was poured on the inoculum using the pour- plate technique. The set dishes were incubated inverted at 37^{o}C for 3 days with checks every 24 hours (NMKL, 2013). After incubation, dilutions with 25- 250 discrete colonies were enumerated. All counts were reported as logarithm to base 10 of colony forming units per milliliter (log cfu/ ml)

3.5.2.5 Coagulase Positive Staphylococci

Two serial decimal dilutions of yoghurt samples were transferred onto the surfaces of well-dried Baird- Parker agar (Oxoid, CM0275) supplemented with egg yolk tellurite (Oxoid, SR0054C) using the spread plate technique. The agar plates were allowed to dry for about 15 minutes at room temperature. The inverted plates were incubated at 37°C for 24 hours following which typical colonies (black or grey, shining and convex, usually surrounded by a clear zone) were marked. The plates were re-incubated to a total of 48 hours with new colonies being marked and counted. Up to 5 suspicious colonies were picked and subcultured by streaking on well-dried nutrient agar (Oxoid, CM0003). Gram staining, catalase and coagulase test were performed. Typical *staphylococci* were catalase and coagulase positive, gram positive stacked cocci (NMKL, 2009).

3.5.2.6 Coliform Bacteria

Yoghurt samples were serially diluted and 0.1ml of two decimal dilutions was transferred into sterile disposable petri-dishes for each sample. Using the pour-plate technique, Violet Red Bile Agar (VRBA) (Oxoid, CM0107B) was added to the inoculum and mixed. Another VRBA layer was poured over the set medium and incubated in two different sets for each sample. The first set was incubated at 30°C and the second at 44°C for 24 hours.

Plates incubated at 30°C with 10-100 typical colonies (purple-pink colonies surrounded by a red precipitation zone) were reported as total presumptive coliform count and typical colonies on plates incubated at 44°C as total coliform counts (NMKL, 2004).

3.5.2.7 Escherichia coli detection

Purple- pink colonies with halos on VRBA (Oxoid, CM0107B) plates incubated at 30°C for 24 hours were selected and streaked on Levine Eosin Methylene Blue (EMB) agar (Oxoid, CM0069). This was incubated at 30°C for 24 hours. A minimum of 5 discreet purple coloured colonies with dry green metallic sheen on the EMB agar were selected.

Pink colonies identified, were selected and streaked on nutrient agar plate (Oxoid, CM0003). Pure isolates were tested for Triple Sugar Iron (TSI) reaction, Sulphur-Indole-Motility (SIM) tand Indole, Methyl red, Voges-Proskauer, Citrate (IMViC). *Escherichia coli* colonies were indole positive, H_2S negative, gas positive, ferments glucose and sucrose, and citrate negative .

Presumptively identified *Escherichia coli* colonies were confirmed with Malditoff.

3.5.2.7 *Yeasts and Moulds*

The serial decimal dilutions of yoghurt samples were pipetted into petri dishes and about 20ml of Malt Extract Agar (MEA) (Oxoid, CM0059) adjusted to a pH of 3.5 with 10% lactic acid added by pour –plating. The agar was mixed with the inoculum and incubated inverted at 25^{o}C. Cream-coloured colonies were enumerated as yeast and mould count per ml.

3.5.2.8 Listeria monocytogenes

Twenty- five millilitres of each yoghurt sample was diluted in 225ml Half-Fraeser broth (Oxoid, CM0895), homogenized and incubated at 30^{o}C for 24 hours. After incubation, 0.1ml of the broth was sub cultured into 10ml Fraeser broth and incubated for 26±2 hours.

A loopful of the enriched culture was streaked unto Chromagenic Listeria Agar (CLA) (Oxoid, 1017) and incubated at 37^{o}C for 24 hours or until satisfactory growth was observed. Suspect *Listeria* colonies appeared as blue-green colonies surrounded with an opaque halo.

Selected colonies on the CLA plates were streaked on blood agar (Oxoid, CM0055) for purification. Presumptive *Listeria monocytogenes* appeared whitish on blood agar and displayed β- haemolytic activity. Presumptive *Listeria* colonies were selected and purified on nutrient agar; and tested for motility on SIM, catalase activity and gram stain reaction (IS0 11290-1; ISO 11290-

2). Presumptive positive *Listeria* were catalase positive, gram positive short rods and displayed umbrella motility in SIM agar.

3.5.2.9 Detection of Salmonella spp.

Twenty- five millilitres of each yoghurt sample was diluted in 225ml buffered peptone water (Oxoid, CM0509), homogenized and incubated at 37^{o}C for 24 hours. After the incubation period, 0.1ml of the buffered peptone water was transferred into 10ml pre warmed (to 37^{o}C) Rappaport Vassiliadis broth (Oxoid, CM0669) and incubated in a water bath at 42^{o}C for 24- 48 hours. A loopful of the enriched culture was streaked unto well dried XLD agar and Salmonella-Shigella agar (Oxoid, CM0099), and incubated at 37^{o}C for 24 hours.

Presumptive positive *Salmonella* colonies were surrounded with a slightly transparent pink-red zone on XLD; and on Salmonella-Shigella agar appeared as straw- coloured with black centres. Suspect *Salmonella* colonies were selected and streaked on nutrient agar for well isolated pure cultures, this was incubated at 37^{o}C for 24 hours. The pure colonies were tested on TSI agar slants (Oxoid, CM0277). Presumptive positive *Salmonella* gave a yellow butt, produced gas and had a blackened butt as a result of H_2S produced (NMKL, 1999; IS0 6785). Presumptive identified *Salmonella* were confirmed with API 24E kit.

3.5.2.10 Lactic acid bacteria (LAB) count

0.1ml of appropriate serial decimal dilutions were plated on MRS agar (Oxoid, CM0361) using the pour-plate overlay technique. Plates were incubated at 30°C for 18-48 hours. Colony counts were reported as presumptive count of lactic acid bacteria per millilitre or gram (ISO 15214).

3.5.3 Physicochemical Analysis

Some physicochemical indices were selected and monitored during the period of the study. For each yoghurt brand these analysis were performed at least thrice at different times during the study. Samples were analyzed within 24 hours of being brought from place of collection. All samples were thawed to about 18±2^{o}C before test analysis were run.

3.5.3.1 pH Analysis

The pH of each yoghurt sample was measured using a pH meter (pH 2700, Oakton Instruments, Vernon Hills, IL, USA). All samples were measured in triplicates (AOAC, 2005).

3.5.3.2 Titrable Acidity

The titratable acidity values of each yogurt sample were determined by titrating 10ml of yoghurt (added 10ml of distilled water) with 0.1 N NaOH and using 0.5% phenolphthalein as an indicator to an end point of faint pink color (AOAC, 2005). The percentage lactic acid was determined thus:

$$\frac{titre\ value \times 0.009 \times 100}{volume\ of\ milk\ used}$$

All samples were measured in triplicates.

3.5.3.3 Colour Evaluation

The colour of each sample was evaluated using a colorimeter (Chroma meter CR-410, Konica Minolta, INC, Japan) which was calibrated with a white calibration plate (L=100). The measured L*-, a*- and b*- were determined as indicators of lightness, greenness and yellowness of the yoghurt samples respectively. This procedure was followed as stated in Tarakci *et al.* (2013). All measurements were done in triplicates.

3.6 Statistical Analysis

Univariate and multivariate statistical methods were used to evaluate all data obtained. Two-way analysis of variance with means of separation and Principal Component Analysis were used to analyze sensory descriptive data (XLSTAT, Addinsoft, New York, USA). A Tukey's honesty significance difference (HSD) post hoc test was carried out to determine sensory descriptors which were significantly different for yoghurt samples.

Frequencies and percentages were used to evaluate consumer demographic data. To classify consumers, Agglomerative Hierarchical Clusters (AHC) with squared Euclidian distance and Ward's methods were carried out on consumer scores; and preference mapping was performed to identify drivers of liking of yoghurt. Physicochemical and microbiological data were analyzed using analysis of variance with least square methods.

3.7 Limitation

Although efforts were made to ensure that a good representation of all yoghurts in Ghana were obtained to monitor consistency in processing, there is a possibility that the sampling method used would not allow a true reflection of the processing quality of the yoghurts particularly from a microbiological point of view. Ideally, samples should have always been collected from the processor or on specific dates from the shop to minimize storage and handling bias during sampling for microbiological studies. Given the objective of defining quality from the consumer view point however, shop samples were used as a reflection of what consumers would normally be faced with. Findings from this study should not be overgeneralized particularly from the microbiological view point. Yoghurt samples obtained for physicochemical and microbiological tests in this study may not be representative of all vanilla-flavoured stirred yoghurt samples on the market.

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 Validated Sensory Profile of Yoghurt

The samples used for the study (Appendix 1.0) were used to determine the overall sensory profile of yoghurt on the market. A total of twenty- six (26) attributes were identified by the sensory panel to describe commercial Ghanaian- produced vanilla-flavoured stirred yoghurt; with seven (7) yoghurt appearance attributes, four (4) aroma attributes, six (6) flavor attributes, five (5) texture attributes and four (4) aftereffect yoghurt attributes (Table 4.6). The initial descriptors generated by the panel were twenty-one (21) in number but during validation stage, five new descriptors were included. These terms were yellow colour, cheddar-cheese aroma, soybean flavor, salty and lumpy.

Most of the terms generated were similar to those indicated in Bayarri *et al*. (2011); Coggins *et al*. (2007); Tomic *et al*., (2017); with new terms such as FL-Soybean and AR-PlainVan being identified by the panel. The term PlainVan as identified by panelists was coined from plain yoghurt and vanilla aroma. The panelists insisted on using this term since they could perceive a different note from the combined effect of these two attributes. A term that was not identified by the group but was seen to significantly differentiate between yoghurt samples in studies conducted by Bayarri *et al.* (2011) and Coggins *et al.*, 2007) was cooked milk note. According to Tribby (2009), a cooked note in yoghurt may or may not be desirable depending on its intensity; and this attribute is usually as a result of pasteurization of the milk. Tribby (2009) continues that it is desirable for the cooked note to be masked or overpowered by yoghurt flavor. Hence the panel may have been unable to pick up the cooked milk note because of the intensity of yoghurt flavor (in this study termed as yoghurt-like) in the samples presented. The table below gives the full list of descriptors generated for commercial Ghanaian-made vanilla-flavoured stirred yoghurt.

Table 4.6: Sensory language developed for descriptive analysis

TERM	DEFINITION	REFERENCE	ANCHOR
APPEARANCE (AP)			
Cream colour	Characteristic appearance of laughing cow cheese (intensity of cream colour)	Laughing cow cheese: midpoint	Light to Dark
Viscous	Resistance to flow	Full cream Ideal milk :Runny, Peak condensed milk:¾ on line scale	Runny to Thick
Particulate	Presence of particles when looking at the product		Not to Very
Oily	Thin film of oil droplets on the surface		Not to Very
Glossy	Shiny surface	Honey: Very	Not to Very
Homogeneity	Surface without grains or bumps (smooth)	Full cream Ideal milk: Very	Not to Very
TEXTURE (TX)			
Firmness	Resistance to pressure from a plastic spoon		Not to Very
Stringiness	Trailing between spoon edge and product container		Not to Very
Particulate	Presence of particles when product is in the mouth	Full cream Ideal milk: Smooth	Smooth to rough
Viscous	Resistance to flow in mouth	Full cream Ideal milk: Not, Peak condensed milk: Very	Not to Very
AROMA (AR)			
Vanilla	Characteristic aroma of vanilla ice cream	FanIce: Very	Not to Very
Plain Van	Characteristic aroma of plain yoghurt + vanilla essence	Zenos Plain yoghurt (60ml) + 3- 4 drops of Reyner's vanilla essence: Very	Not to Very
Yogurt-like	Characteristic aroma of plain yoghurt	Zenos Plain yoghurt: Very	Not to Very

FLAVOUR (FL)			
Sour	Basic taste		Not to Very
Sweet	Basic taste		Not to Very
Yoghurt	Characteristic flavour of plain yoghurt	Zenos plain yoghurt :Very	Not to Very
Vanilla	Characteristic flavour of FanIce	FanIce: Very	Not to Very
AFTEREFFECT (AF)			
Sour	Basic taste		Not to Very
Sweet	Basic taste		Not to Very
Oily			
Astringent	Dryness in mouth	Ceres grape juice	Not to Very
OTHER DESCRIPTORS			
AP- Yellow	Yellowish colour	BlueBand margarine	Light to Deep
TX-Lumpy	Presence of lumps in mouth		Not to Very
AR- Cheddar cheese	Characteristic aroma of cheddar cheese	Emborg cheddar cheese: Very	Not to Very
FL- Soybean	Characteristic flavor of soymilk	Alpro soymilk: Very	Not to Very
FL- Salty	Basic taste		Not to Very

Figures 4.3 and 4.4 give a graphical description of samples A to G. The modality, appearance, was used to describe the yoghurt samples when visually viewed (Fig 4.3). All the samples were considered as cream-coloured, however sample E was perceived to be the most-cream coloured yoghurt, followed by sample D. Sample F had the lowest score for cream colour, thus was the lightest-cream coloured yoghurt product among the samples. Sample D was described as the most viscous and oiliest sample, with sample B being identified as the least viscous yoghurt product and sample F, the least oily product when visually viewed. Amongst all the seven yoghurt brands (A to G), samples F and G were both the most homogenous samples. It is therefore not surprising that these two were also considered as the least particulate samples (Fig. 4.3).

Aroma and flavor modalities described samples as perceived nasally and the combined effect of nasal and taste respectively. In general, sample E had the lowest intensity scores for the attributes of aroma and flavor, except for the descriptor, FL- sour. This could affect acceptance of this sample by consumers since aroma and flavor are key aspects of yoghurt sensorial quality (Routray & Mishra, 2011), and consumers expect to perceive these attributes at certain optimum levels. Vanilla aroma and flavor were perceived much more strongly in sample A than the other samples, however it was rated as the least sour product. Sample F on the other hand was the sourest product and was perceived to give the most intense yoghurt aroma and flavor as well as PlainVan aroma. In terms of sweetness, sample B was the sweetest whereas samples E and F were the least sweet yoghurt brands (Fig. 4.3).

Texture was used as a modality for body and mouth-feel perception of the products. Figure 4.4 shows the web chart for samples with respect to this modality. Sample B had the least scores for firmness, stringiness and viscosity. When visually viewed, this sample was also perceived as a product with low viscosity (Fig. 4.3). This means that Sample B had an overall low textural consistency in comparison to the other products. Sample F on the other hand, was the smoothest product followed by sample A. Homogeneity is a textural (both visual and tactile) quality index of yoghurt; whereas graininess or particulates in yoghurt is considered as a defect which lowers consumer acceptance of the product (Tribby, 2009). Thus homogeneity of sample F this could likely boost its quality. Samples A, D and G were not significantly different with respect to viscosity. However, sample A had a higher score than the other two samples, thus can be rated as the most viscous sample. (Fig. 4.4).

Aftereffect was used to describe the after-feel and after-taste of the products as perceived by the panel (Fig. 4.4). Sample F had the most intense sour aftertaste and the least oily after-feel on swallowing. Both samples E and F gave the lowest sweet note whereas samples B and C gave the highest sweet after-taste note. Sample A, though was the oiliest yoghurt under this modality, was the least sour and least astringent. The product with the highest intensity for astringency was sample D followed by F.

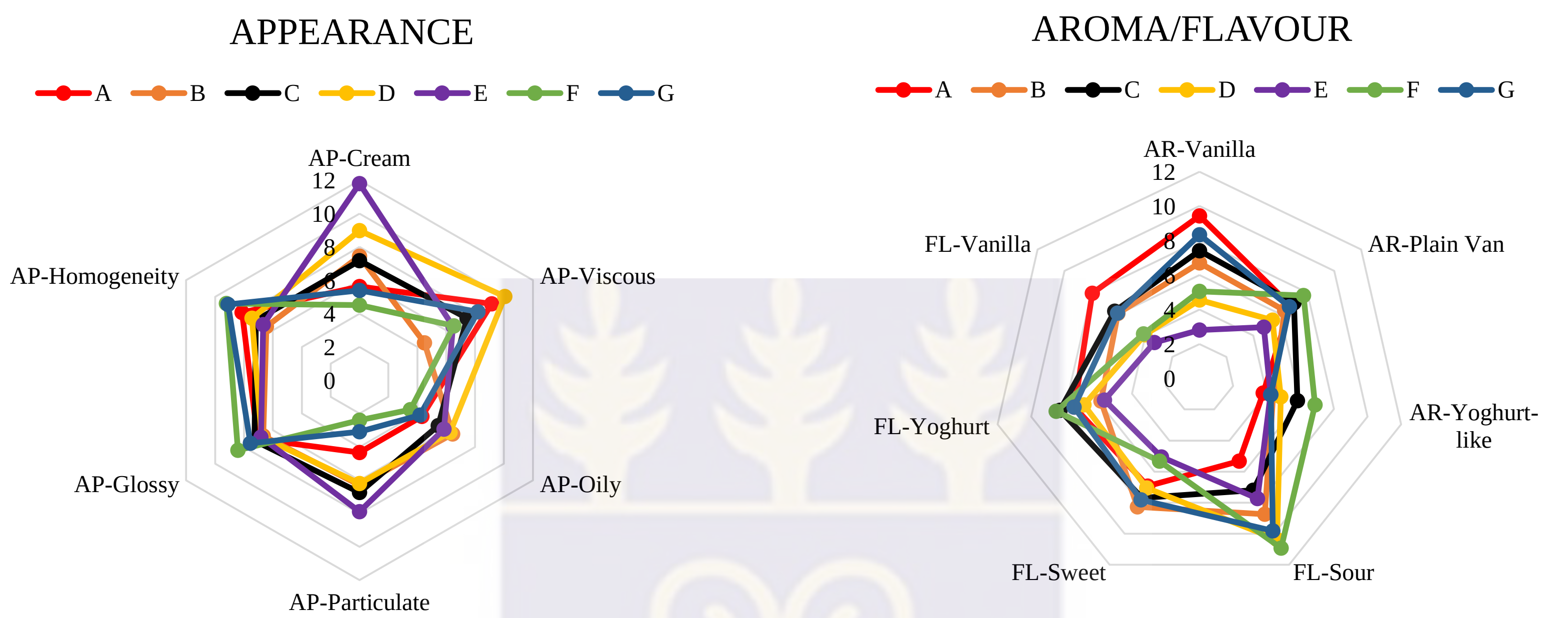


Figure 4.3: Sensory characteristics of yoghurt samples A- G using a spider web graph; appearance attribute **(left)** and aroma/flavor attribute **(right)**. All descriptors were significantly discriminating among samples ($p \leq 0.05$)
Abbreviations: AP= appearance, AR= aroma, FL= flavor

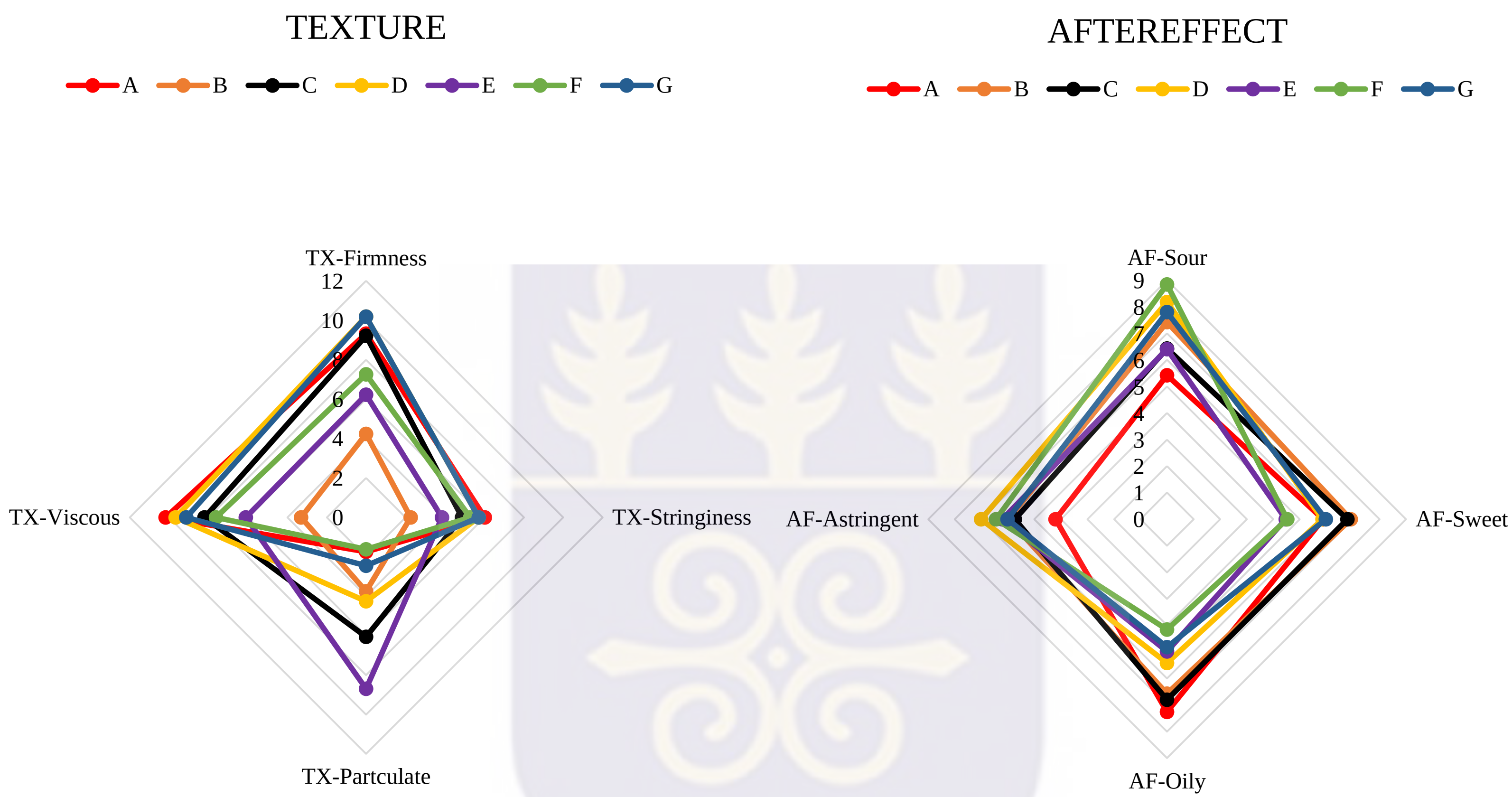


Figure 4.4: Sensory characteristics of yoghurt samples A- G using a spider web graph; texture attribute **(left)** and aftereffect attribute **(right)**. All descriptors were significantly discriminating among samples (p≤ 0.05)
Abbreviations: TX= texture, AF= aftereffect

Samples H to N were used to determine if descriptors generated from the first sample set were appropriate in determining the sensory profile of vanilla-flavoured stirred yoghurt on the Ghanaian market. The web plots below gives a representation of the profile of these samples based on descriptors obtained.

All the twenty-one (21) descriptors generated in the first set (samples A to G), and used for profiling were found to significantly discriminate among these samples (H to N) as well ($p \leq 0.05$) (Fig. 4.5 & 4.6). Other descriptors were identified with the latter samples and these were added to the list and evaluated. However, these new attributes developed were found to not significantly discriminate among the samples consistently ($p \leq 0.05$). Furthermore, they were found to produce very low intensity notes, meaning they were present but could be perceived minutely. Due to this, these attributes were not used for further analysis. These new descriptors were salty, soybean, yellow colour, lumpy and a cheddar cheese-like aroma. It is of importance to note that though yellow colour was generated as a descriptor, this attribute is an atypical colour of vanilla-flavoured yoghurt hence more identified as a sensory defect.

Aroma and flavor attributes of this set were found to be quite different in terms of perceived intensities as compared to the first set of samples. The samples in this set were generally perceived to produce low aroma and flavor notes than that from the first set of samples. And also, unlike the first sample set, these yoghurt samples were less particulate, stringy and astringent. From this set, the attributes identified to describe vanilla-flavoured stirred yoghurt were validated. These were the twenty-one descriptors which consistently discriminated among the samples over the test period and thus were used for subsequent tests.

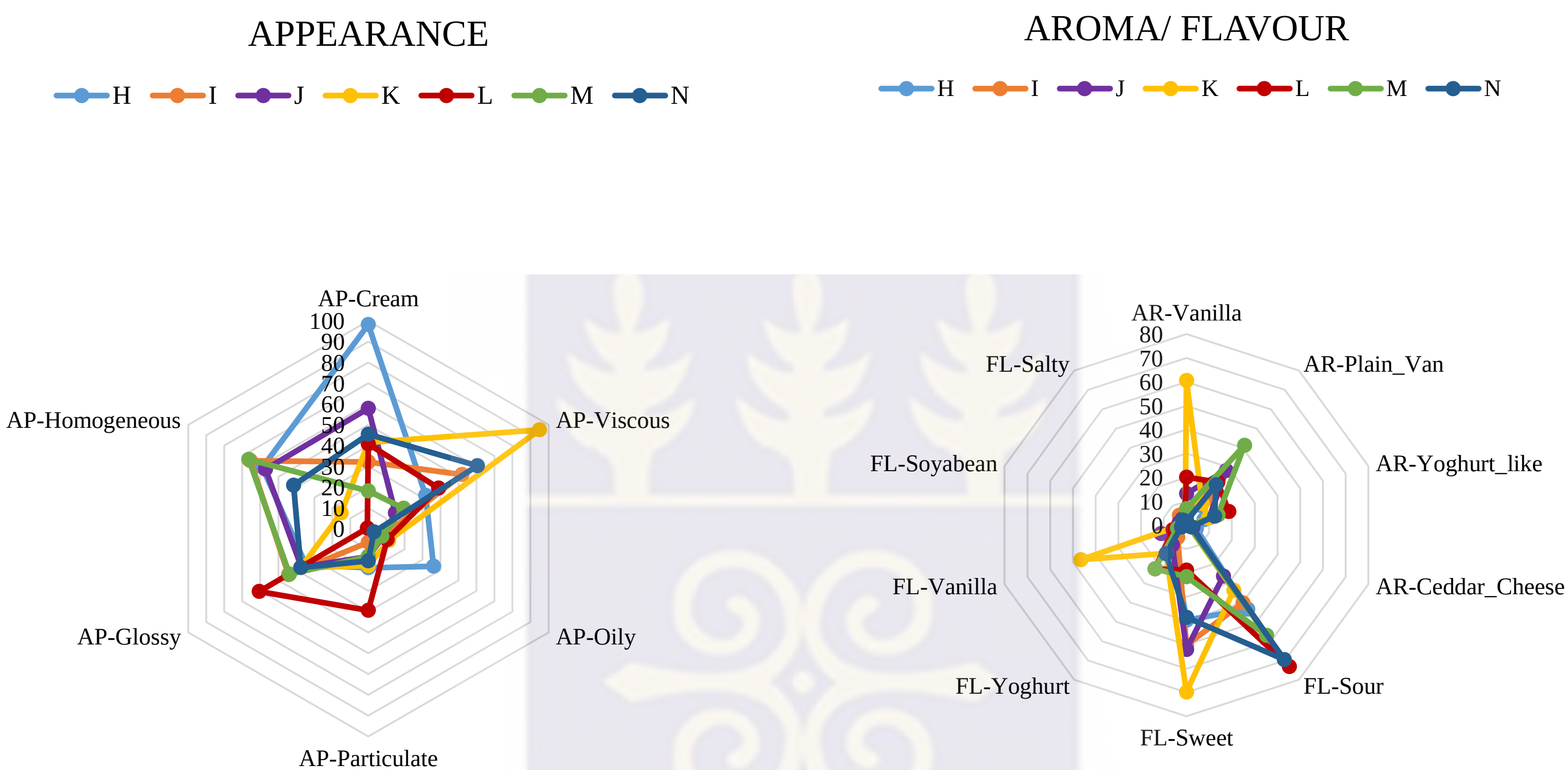


Figure 4.5: Sensory characteristics of yoghurt samples H- N using a spider web graph; appearance attribute **(left)** and aroma/flavor attribute **(right)**. **Abbreviations: AP= appearance, AR= aroma, FL= flavor**

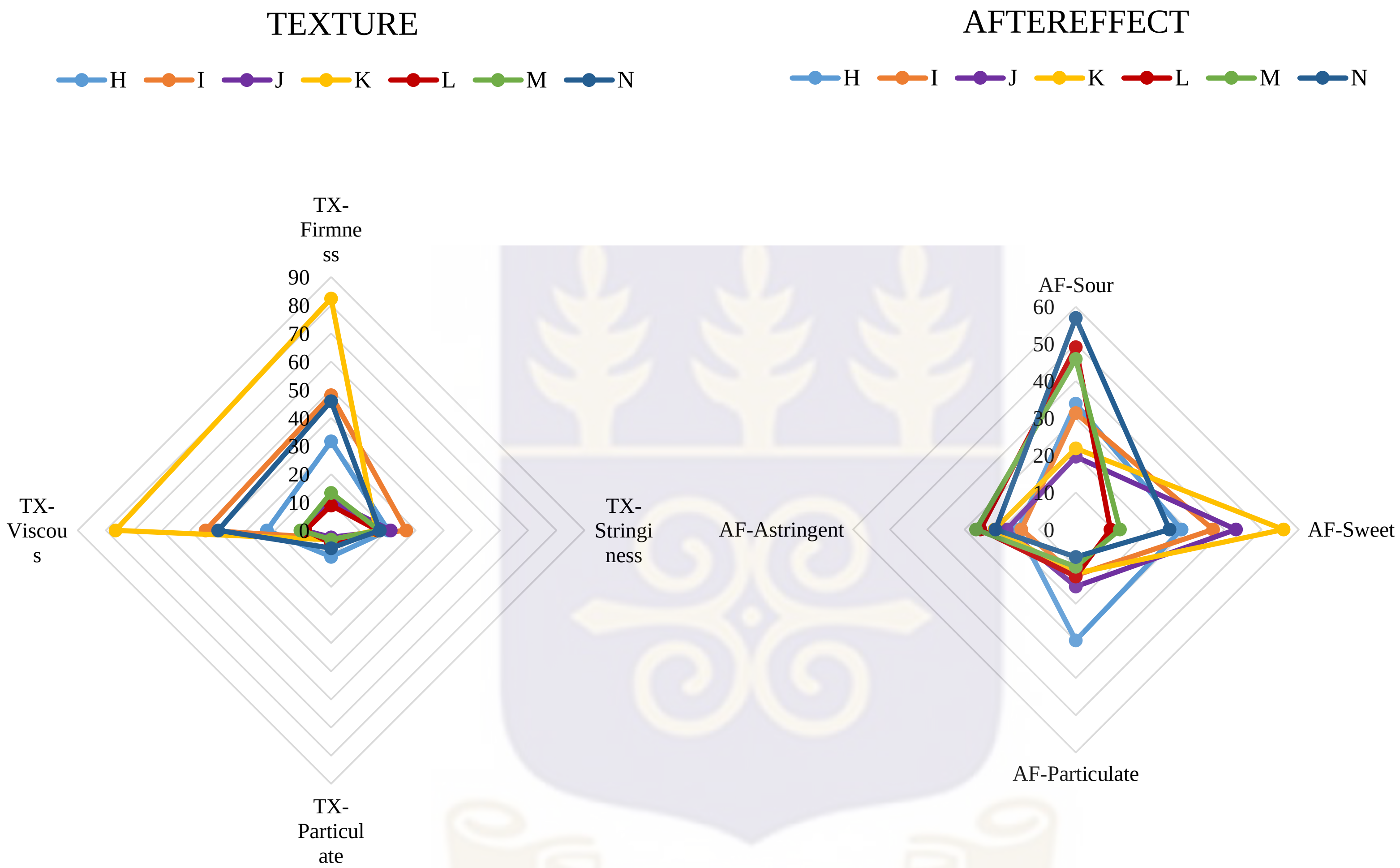


Figure 4.6: Sensory characteristics of yoghurt samples H-N using a spider web graph; texture attribute **(left)** and aftereffect attribute **(right)**. All descriptors were significantly discriminating among samples ($p \leq 0.05$)

4.2 Demographics of Consumers used for Preference Mapping

More than half the number of recruited consumers were females. Most of the consumers (91.8%) were students from the University of Ghana because of the proximity of the test centre (Nutrition and Food Science Sensory Lab, University of Ghana) to the consumers. About 85% of these consumers were between the ages of 18-24 years. During recruitment of consumers for the study, one of the criteria set for inclusion was that consumer's lowest educational level should be junior high school level. This was set because the test required consumers to individually read and answer questions in English. Since most of the consumers were students from the university their educational level was higher than a junior high school, with 85.2% and 11.5% reaching tertiary and postgraduate levels respectively.

Majority of the consumers (42.6%) were from the Akan-Forest areas (Akuapem, Akyem, Ashanti, Bono, etc.). Some foreigners also took part in the study, and were from Jamaica, Vietnam and Nigeria. The demographic characteristics of consumers are depicted in Table 4.8. All consumers were not allergic to yoghurt and were frequent consumers of the product. About 36.1% of them consumed yoghurt once every week with 32.8% consuming once every two weeks; and only 8.2% consumed yoghurt every day. This is not surprising since on the global front, daily consumption of yoghurt is attributed to countries such as France and Turkey; and in Africa, South Africa is the only country attributed with relatively high yoghurt consumption rates (DSM, 2015).

Most consumers indicated that strawberry and vanilla were their most preferred yoghurt flavourings, 41 and 39.4% respectively; and 4.9% preferred plain yoghurt with no added flavourings.

Table 4.7: Demographic characteristics and consumption characteristics of yoghurt consumers

BIODATA		FREQUENCY	
		N= 61	%
Sex			
	Female	33.0	54.1
	Male	28.0	45.9
Age (years)			
	18-24	52.0	85.3
	25-34	8.0	13.1
	35-44	1.0	1.6
Ethnicity			
	Akan- Coastal	5.0	8.2
	Akan-Forest	26.0	42.6
	Ewe	10.0	16.4
	Foreigner	4.0	6.6
	Ga/Adangbe	12.0	19.7
	Guan	1.0	1.6
	Northerner	3.0	4.9
Highest educational level			
	Postgraduate	7.0	11.5
	Senior high school	2.0	3.3
	Tertiary	52.0	85.2
Profession			
	Professional/Managerial/Administrative	4.0	6.6
	Between work	1.0	1.6
	Student	56.0	91.8
Consumption			
	Everyday	5.0	8.2
	Less than once a month	1.0	1.6
	Once a month	13.0	21.3
	Once a week	22.0	36.1
	Once every 2 weeks	20.0	32.8
Preferred flavouring			
	Banana	5.0	8.2
	Blueberry	1.0	1.6
	Chocolate	1.0	1.6
	No added flavour	3.0	4.9
	Pineapple	2.0	3.3
	Strawberry	25.0	41.0
	Vanilla	24.0	39.4

4.3 Consumer Preference Mapping

4.3.1 Description of yoghurt in product space

The PCA results showed that the first 2 PC significantly discriminated between the yoghurt samples and explained 73.49% of the sensory data variation. The squared cosine results showed that samples A, B, C, E, F and G were very well represented and clearly distinguished than sample D (Fig. 4.3). Table 4.7 indicates the sensory attributes that load strongly in the product space and can best describe the products with respect to PC1 and PC2 ($r \geq 0.7$). The first PC explained 42.47% of the variance and was predominantly described by samples B, E and G; with E being highly correlated to PC1. As shown in Figure 4.7, the PCA results show clear opposition between samples E and G; and samples B and E being correlated. With that, samples B and E, based on attribute loadings, were generally seen to possess similar characteristics. Both samples were best characterized as being cream in colour, oily, and particulate (in appearance and texture). On the other hand, Sample G was best described as a homogenous, stringy and viscous yoghurt product with a vanilla and plainVan aroma.

The second PC accounted for 31.02% of the variation in the sensory data. PC 2 described samples A, C and F, with the latter sample being highly correlated to the factor. The samples, A and C were opposite in loadings to sample F. The area where sample F was loaded was characterized by the attributes, glossy, yoghurt-like aroma, sour taste and astringent. Samples A and C, both had the same factor score and thus loaded at the same point in the product space (Fig. 4.7). These two samples were best characterized by the two sensory attributes, vanilla, and oily (Table 4.7). Sample D was not strongly loaded on either principal components (PC1 or PC2) as compared to the other samples.

Table 4.8: Sensory attributes strongly loading on factors

	FACTORS	
	PC1	**PC2**
Positive	AP-Cream	FL-Vanilla
	AP-Oily	AF-Oily
	AP-Particulate	
	TX- Particulate	
Negative	AP- Homogenous	AP- Glossy
	AR- Vanilla	AR- Yoghurt
	AR-PlainVan	FL-Sour
	FL- Yoghurt	AF- Sour
	TX- Stringiness	AF- Astringent
	TX- Viscous	

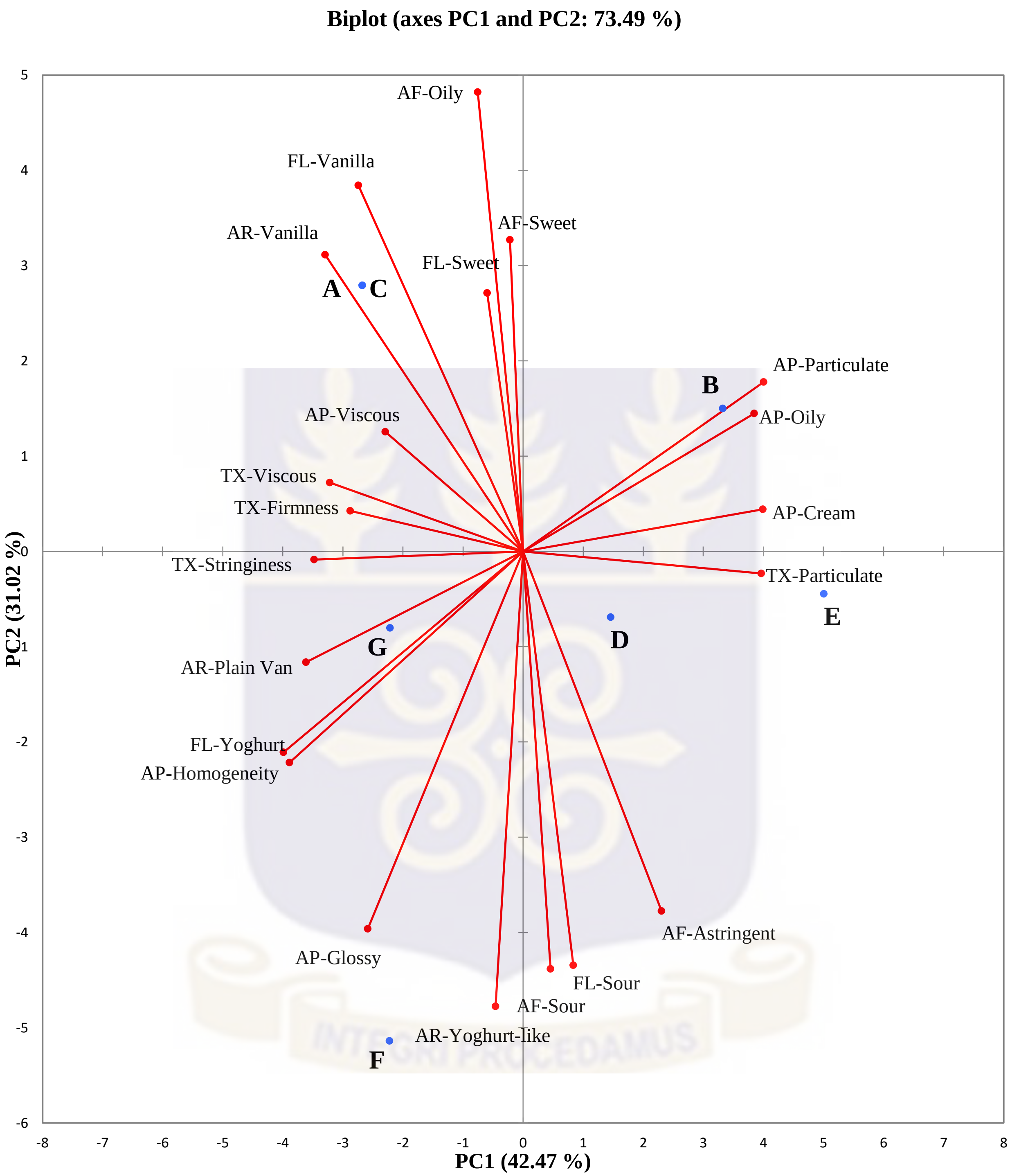


Figure 4.7: Principal component analysis showing the description of yoghurt samples A to G by the 21 sensory attributes in the first week of sampling. **AP**: appearance; **AR**: aroma; **FL**: flavor; **TX**: texture

4.3.2 Consumer Clustering

An Agglomerative Hierarchical Clustering was performed on the consumer preference data and this helped to identify three main clusters of consumers. The first (C1) and third clusters (C3) had 44.3% and 39.3% of the consumers respectively falling into these 2 groups. The smallest cluster was C2 with only 16.4% of the consumer population making up this cluster. Figure 4.8 below gives a graphical representation of consumer preference for the seven yoghurt products by the three clusters. From the diagram, it is observed that cluster 1 preferred samples D and G more than the other samples whereas cluster 2 had a preference for sample C and a dislike for samples A and E. It is also observed that cluster 3 were generally likers of the yoghurt samples and gave relatively high scores, above 5 for each product.

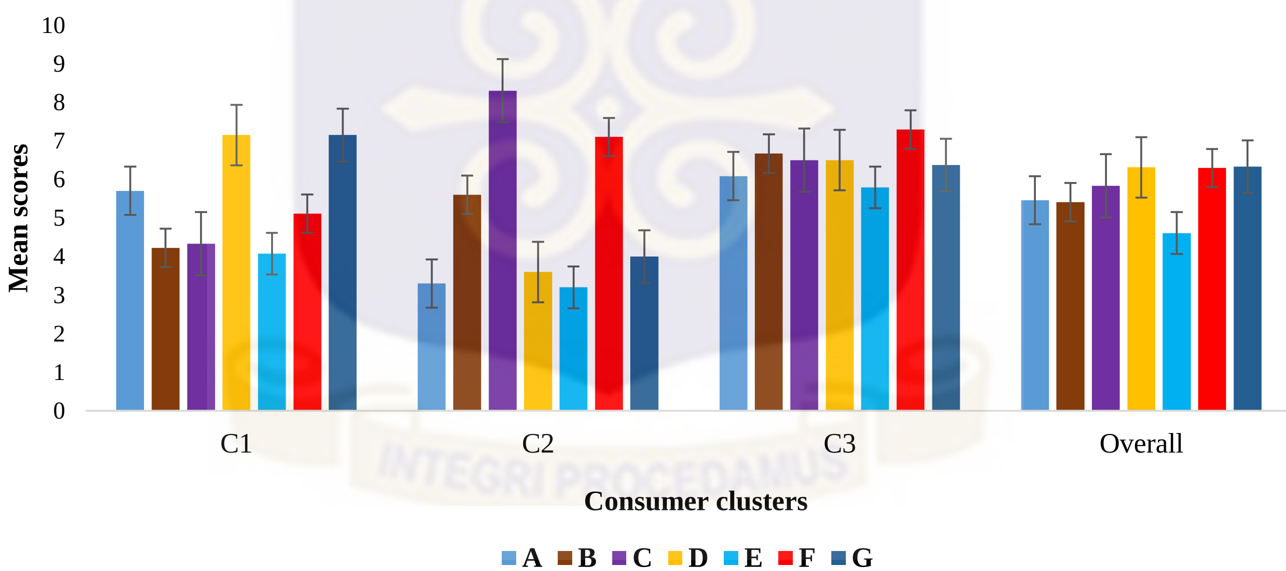


Figure 4.7: Consumer mean overall liking scores of yoghurt samples by the three clusters (1= dislike extremely to 9=like extremely). **C1**= cluster 1, **C2**= cluster 2, **C3**= cluster 3. The error bars represent between-product standard errors of the means

This is a typical consumer behavior to products with some being selective in their choices and others being less discriminating. A study by Lattey *et al.* (2009) showed similar consumer response to wine. Most of the consumers in that study scored wine samples higher than six on a nine-point hedonic scale while the other consumer groups had varying score ranges. King *et al.* (2012) also reported a similar finding; where majority of consumers in the study were general likers of white wine and were not particularly discriminating, while others showed preferences to specific wine styles. This response was attributed to the level of consumer knowledge of the product. Thus consumer grouping in this current study may also be due to knowledge of consumers on yoghurt or level of exposure (familiarity) to the product. The overall mean liking scores showed that samples D, F and G were generally preferred by consumers, and sample E was the least preferred yoghurt sample (Figure 4.8).

4.3.3 Consumer Modelling

Preference mapping was used to model the yoghurt consumer responses and also to identify attributes that drive liking of the yoghurt products. The diagram below shows the cluster loadings, consumer loadings and product scores about the space (Fig. 4.9). It was observed that most consumers go in the direction of samples F and G, while a few consumers seem to prefer sample E. This is the same as the average liking results reported in Figure 4.8.

Majority of the consumers (83.6%) had their preference scores for the products being represented as a vector model. In Figure 4.9, the consumers with vector models (red points) are seen well distributed about the product space. The vector model assumes that preference for each consumer increases linearly to the sensory attribute in its direction. This means that as the intensity of an attribute increases, the consumer liking of the product also increases. The other consumers had a quadratic model being indicated as their best model, in this case a saddle point (black points).

Results obtained showed that the best model for both clusters 1 and 3 was a vector model. Cluster 2 on the other hand, was identified as being a quadratic model with a saddle point, and was significantly different from the other two clusters ($p \leq 0.05$).

It can be seen that consumers in cluster 1 preferred sample F the most. Liking for this cluster was associated with the attributes glossy, yoghurt-like aroma, sourness and astringency. Cluster 2 on the other hand, had a preference for yoghurt products with vanilla flavour and oily after feel and least liked samples with high intensities of attributes cream, oily and particulate (in appearance) (Fig 4.10). This explains the saddle model associated with cluster 2. Sample C was the most liked product for this group, which was best characterized with vanilla flavor and oily aftereffect (Fig 4.7). The notes perceived for these two attributes for sample C were however not the most intense among the samples. Sample A was also characterized by these two attributes, but the cluster showed a dislike to it. From Figure 4.3, it is observed that sample A had the most intense note for these two attributes. This is to say that this group did prefer these attributes but to a certain optimum level. The saddle point as indicated for this cluster (Fig. 4.9) showed a dislike to samples characterized by particulate, oily and cream- coloured. Sample F was the second most preferred yoghurt for this cluster. This product was however the least particulate, oily and cream-coloured sample among all the samples (Figs 4.3 & 4.4). Hence the saddle point is interpreted thus, vanilla flavor and oily aftereffect at certain optimum notes are key drivers of liking for this consumer group, but attributes particulate, oily and cream-colour can negatively affect liking.

As seen in Figure 4.3, sample E had the least vanilla flavour, and was also the most particulate, oily and cream-coloured sample which may have contributed to its low acceptance by this cluster (C2). This sample was generally the least disliked yoghurt and was characterized as the most intense cream coloured product and had the lowest intensity for all but one of aroma and flavor descriptors, which may have generally affected its appeal to consumers. Tribby (2009) writes that an atypical colour of a yoghurt product can affect its acceptance by consumers. This is to say that when a yoghurt does not reflect its stated name, in this case vanilla-flavoured, it could affect consumer acceptance. It is possible that consumers' expectation for the colour of vanilla - flavoured stirred yoghurt is not an intense cream colour as that observed in sample E.

Figure 4.9 shows that cluster 3 had a preference for sample G. The cluster mostly based preference on textural consistency, specifically viscosity, firmness, stringiness, aroma/ flavor attributes (yoghurt flavor and plainvan aroma) and homogeneity (Fig. 4.10) This explains results as seen in Figure 4.8, which shows that this cluster gave relatively high scores to all samples. This is because most of the samples had high intensities for one or more of the mentioned attributes hence may have reduced discrimination among samples by these consumers. For example, sample F which had the highest liking score for this group had lower intensity scores for viscosity, firmness and stringiness but had the highest intensity scores for the other attributes (plainvan and yoghurt). Sample D also had a high liking score but as opposed to sample F, it had the highest scores for textural attributes and low scores for the other attributes driving liking for this group.

From the clustering, majority of the consumers were in cluster 1, which was represented as a vector model. This cluster (C1) was the most strongly represented consumer group in the direction of a product as shown on the biplot (Fig 4.10) This shows that as attributes in the direction of cluster 1 increases, the preference for the product in that direction should also increase; and as seen in Figs 4.9& 4.10, the direction of the vector for C1 is to sample F. The sensory properties which fall in this direction and thus are most likely to drive liking are glossiness, yoghurt-like aroma, sour flavor and aftereffect, and astringency

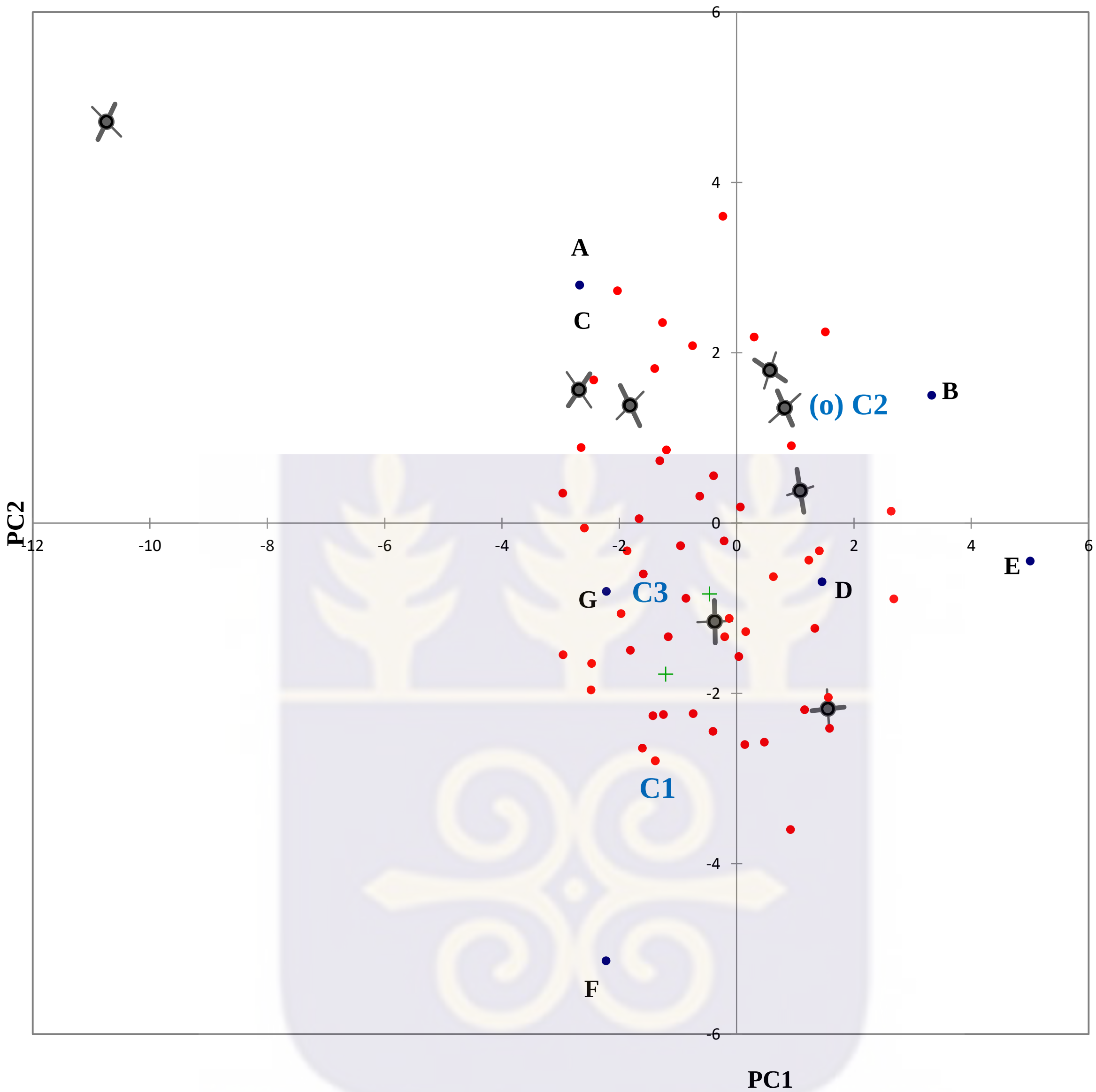


Figure 4.8: Preference mapping showing product loading, and preference scores for 61 consumers and consumer clusters. **C1**: cluster 1, the largest cluster of the consumer data reflecting a vector model; **C2**: the smallest segment of consumers showing a quadratic model; C3: cluster 3 showing a vector model. **A-G**: yoghurt samples

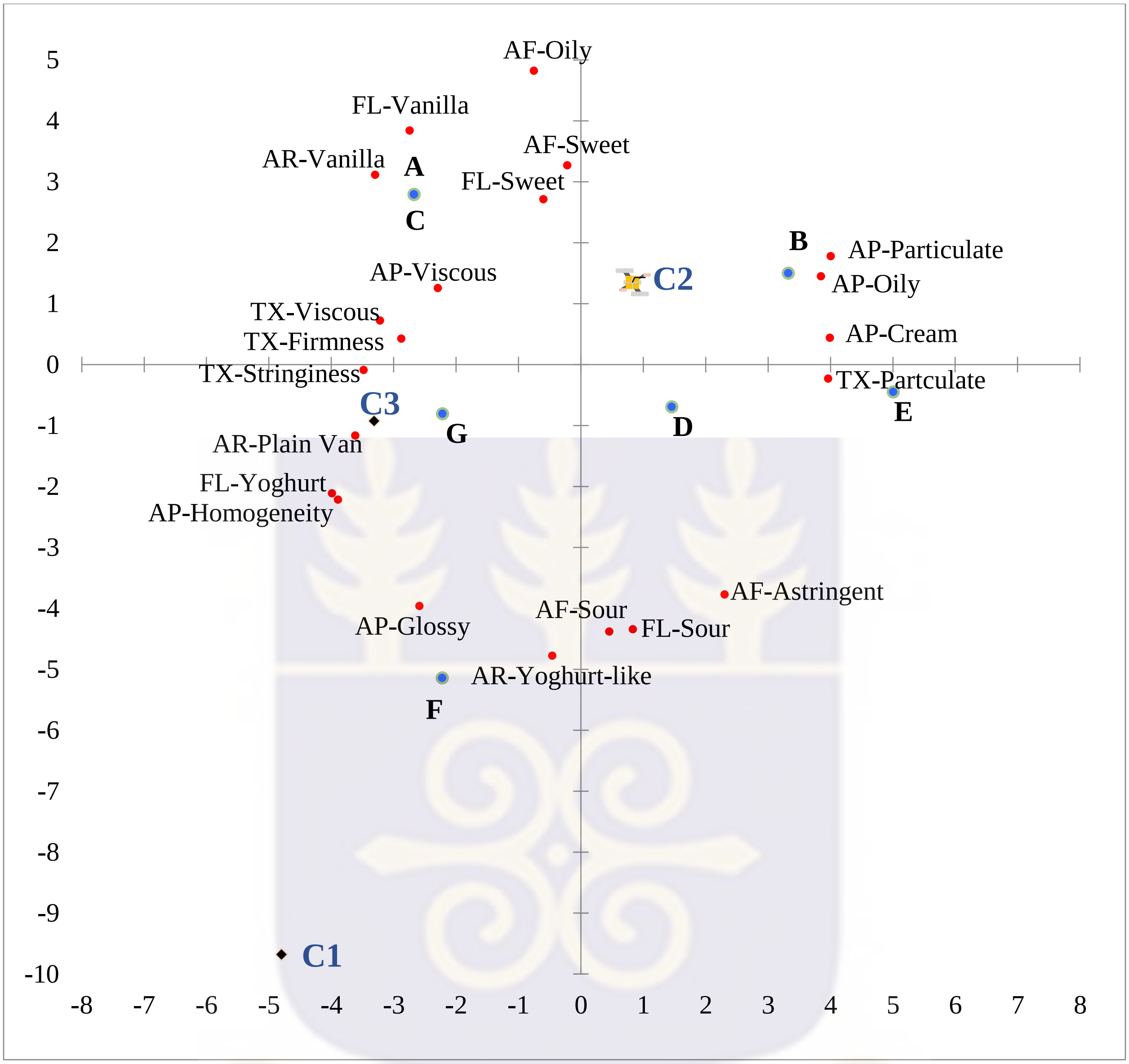


Figure 4.9: Preference mapping of vanilla flavoured stirred yoghurt samples showing sensory attributes and consumer clusters. **C1**: cluster 1, **C2**: cluster 2, **C3**: cluster 3; **A-G**: yoghurt samples

4.4 Attributes Driving Product Liking

Determining attributes that drive liking of a product is necessary to sensory quality assessment so as to help track characteristics of importance in order to satisfy and meet consumer requirements (Bayarri *et al.*, 2011). From preference mapping, the attributes that drive liking of vanilla-flavoured stirred yoghurt were found to be a glossy appearance, yoghurt-like aroma, sour flavor and aftereffect, as well as astringency (Fig. 4.10). This is to say that these attributes may affect the quality of vanilla- flavoured stirred yoghurt on the Ghanaian market as perceived by consumers. Derivation made from preference mapping is that as these attributes (glossy appearance, yoghurt-like aroma, sour flavor and aftereffect, and astringency) are increased in a product, the more likely consumers will prefer that product.

4.4.1 Glossy appearance

The first attribute found to drive liking of vanilla- flavoured stirred yoghurt on the Ghanaian market is a glossy appearance. The glossy appearance of the yoghurt samples, A to G, significantly differed from each other ($p \leq 0.05$). Sample F was significantly different from samples B, D and E, with the former being described as the glossiest product (Fig 4.3). Imram (2004) and Spence (2015), both write that visual cues contribute to consumer acceptance of a product, since the eyes are usually the first assessors of quality. Consumers usually use vision to perceive the initial quality of a product before any other senses are used, thus it is important for a product to appeal to consumers as an initial step to meeting their needs. Glossiness has been stated as one of many visual cues that affect consumer acceptance (Coggins *et al.*, 2007; Gvili *et al.*, 2015; Imram, 1999; Murakoshi *et al.*, 2013; Spence, 2015).

Gvili *et al.* (2015) also write that glossiness is usually used as an index of freshness for some products, and hence consumers look out for this as a quality index of the product. Macbean

(2010) stated that a glossy appearance is a key sensory attribute of stirred yoghurt. A study conducted by Bouteille *et al*. (2013) also showed that glossiness is a part of a composite of sensory attributes related to freshness sensation of yoghurt. This attribute with its interaction with other attributes was observed to contribute to the feel of how refreshing a yoghurt sample was to consumers; with higher intensities leading to higher acceptance by consumers. This correlates with findings of this study, with consumers also liking samples with high gloss intensities.

Glossiness is one visual attribute that is important in determining quality in not just yoghurt but in different other products as well, such as fruits (Péneau *et al.*, 2007), fish (Murakoshi *et al.*, 2013) and rice (Takeuchi *et al.*, 2007). Glossiness is usually achieved as a result of proper homogenization before heat treatment of milk. During homogenization, fat globules increase in number and these in effect increase reflection and scattering of light of the yoghurt. This same phenomena is also what causes the yoghurt to appear whiter in colour (Staff, 1998); and Sample F as shown in Figure 4.3 was described as the lightest cream coloured yoghurt products among the seven samples. This reflects that the homogenization process in making sample F may have been more efficient than the other samples.

4.4.2 Yoghurt-like aroma

The definition for this attribute is the characteristic aroma of plain yoghurt (Table 6). This is an expected outcome since yoghurt aroma is a major part of the properties of the product (Routray & Mishra, 2011). Yoghurt aroma is achieved as a result of the volatile and non- volatile metabolites generated, most especially during fermentation. The most dominant metabolite that contributes to this aroma is acetaldehyde (Beshkova *et al.*, 2003) with the combination of other carbonyl compounds such as diacetyl, acetoin and acetoin (Routray & Mishra, 2011). These compounds are produced during fermentation due to various factors. One of the major factors is the fermentation ability of starter culture used in its production. The symbiotic relationship between *Streptococcus thermophiles* and *Lactobacillus bulgaricus* leads to the breakdown of certain compounds which produces some metabolites such as the carbonyl compounds (Baglio, 2014; Routray & Mishra, 2011).

The potential for these microorganisms to grow and metabolize leads to a decrease in pH of the yoghurt (Akal & YetİşemİYen, 2016). A decreased pH favours these organisms in their activities leading to an increase in breakdown of compounds to produce these metabolites associated with yoghurt aroma (Routray & Mishra, 2011). In Table 4.9, it can be seen that sample F had a lower pH which may have been as a result of the activity of starter culture used in its production. The level of pH reached may give an indication of an increase in activity of the culture during fermentation which may have produced large amounts of metabolites which generated a stronger yoghurt aroma as perceived by the panel. Also, sample F is produced mainly from powdered milk, and in yoghurt production, powdered milk is usually added to increase solids non-fat which has an effect on the fermentation process. The increased solids non-fat leads to a longer duration for fermentation, thus longer fermentation activity by the organisms which will lead to more metabolites being produced during the increased time period (Sfakianakis & Tzia, 2014). The powdered milk component of sample F therefore, may also have contributed to the increased yoghurt aroma intensity attributed to it.

4.4.3 Sour flavor and Sour aftereffect

Preference mapping showed that consumers preferred yoghurt that are sour in flavor and aftereffect. Coggins *et al.* (2007) stated that sourness is one of many flavor descriptors that could be used in differentiating among yoghurt samples. This descriptor was indicated as an important index for expressing yoghurt quality. Also writes that sourness is the most important attribute that influences acceptance of fermented food products. Sourness is perceived as a result of acids produced during the fermentation and cooling process. Acids are generated during these processes as by-products of the metabolic reaction (Lee & Lucey, 2010). These acids include lactic acid, acetic acid and others, and consequently contribute to sourness perceived by consumers (Cheng, 2010; Routray & Mishra, 2011).

A study by Phosuksirikul *et al.* (2014) showed similar results to this study's findings. It was found that sourness affects overall liking of plain yoghurt. Consumers showed preference to yoghurt with high sour intensities. Sample D, F and G had the highest liking score for overall preference (Fig. 8); and these samples had high intensity scores for sourness. From results obtained through preference mapping, this is to say that the sourer a yoghurt product, the more likely to be preferred by consumers.

This claim may not necessarily be a true reflection for all consumers. High sour intensity may be appreciated and may increase continual consumption by some group of consumers however this intensity might not be favourable for other consumer populations and thus may be disliked. The consumer population used for this study were predominantly young adults between ages 18-34, and hence other age groups may have different response to this attribute. A study by Liem *et al.* (2004) showed that when different concentrations of citric acid was added to beverages during the baseline of the study, adults had a higher tolerance and maintained preference for beverages with increased acidity than children. Hence, children may have a different response to this attribute and preference for sourness may increase to a point and decline on further increase of this attribute. However, it has been found that with increased exposure to products with high sour intensities, children may begin to show increased preference (Liem & Mennella, 2003). During review of literature for this dissertation, studies in relation to heightened sour preferences of food products among Ghanaian children were not chanced upon and hence cannot be told if they are predisposed to such a claim.

It is also important to note that preference for a product thus determined attributes that drive liking of that product can be linked to geographical location or ethnic divisions of the consumers. Certain attributes may drive liking of a product in a particular region but may not give the same effect as consumers in other locations. From this study, high sour intensity was preferred by the test group who were predominantly Ghanaians. A study by Thompson *et al.* (2007) showed that African Americans showed a strong dislike for very sour tasting strawberry drinkable yoghurt. Another study conducted in four European countries (Poland, Greece, Netherlands, and Spain) showed that only 11% of the study population preferred sourness. There were regional variations to sourness, with consumers from Poland having higher preference for sour tasting products than consumers from Spain (Sijtsema *et al.*, 2012). Therefore this finding may apply to Ghanaian consumers only and thus gives justification to the rationale of the study.

Heightened sour flavor intensity showed an increase in its perception as an aftereffect. Samples recording high sour intensities showed a high sour aftertaste which for this study consumers showed preference for. A study by Gonzalez *et al.* (2011) showed similar findings with sourer samples having higher perceived sour aftertaste; however, sour aftertaste was not significant in discriminating among peach-flavored yoghurt in that study. Also, the study showed that sourness decreased liking; samples with decreased sour flavor intensity and their respective decreased sour aftertaste were preferred over intense sour-flavoured products. This is in contrast with findings from this study, which may be due to difference in consumer population, geographical preference and other related factors.

4.4.4 Astringent aftereffect

This attribute was defined as a dry sensation in the mouth after swallowing of the product. It was found that consumers prefer yoghurt with this attribute, and an increase in its perception may increase consumer liking. This is similar to findings made by Desai (2012) and Tomaschunas (2013), with the former indicating that consumers preferred Greek yoghurt with perceivable astringent feel and the latter showing that astringency is a driver of liking of plain yoghurts. This is contrary to findings by Bayarri *et al.* (2011) who found that astringency is negatively correlated to liking of yoghurt and yoghurt-like products by consumers. Also Gonzalez *et al*. (2011) found that yoghurt products identified with astringency and other attributes such as sourness and yeasty are less liked by consumers. Differences between current study and these previous studies may be due to variations in the tested yoghurt products, consumer preferences as a result of varying expectations to attributes and the study design.

Astringency is affected by pH levels reached in the yoghurt. King *et al.* (2003) stated that as pH increased, astringent aftertaste of yoghurt decreased. During yoghurt production, the fermentation process leads to decrease in pH of the milk being used (Chandan, 2007). Thus if fermentation is not properly achieved, can affect pH levels of the yoghurt and hence affect perception of some attributes such as astringency.

4.5 Yoghurt Quality Assessment

4.5.1 Sensory Quality of yoghurt

Routine analysis on the identified drivers of liking showed some level of inconsistencies over the study period. This was trend was observed in both yoghurt sample sets. As seen in Figure 4.11, sample F recorded the highest intensity score for glossy appearance among the sample set during the routine tests conducted in subsequent weeks, however, there were observed changes in these intensities over the period. This reflects some processing inconsistencies by its producers. Sample E on the other hand, showed a decrease in its glossiness over the study period, which indicates a poor maintenance of quality in terms of the attribute. Sample L in the second sample set showed a consistent glossy appearance during analysis even though its intensity score recorded was relatively lower.

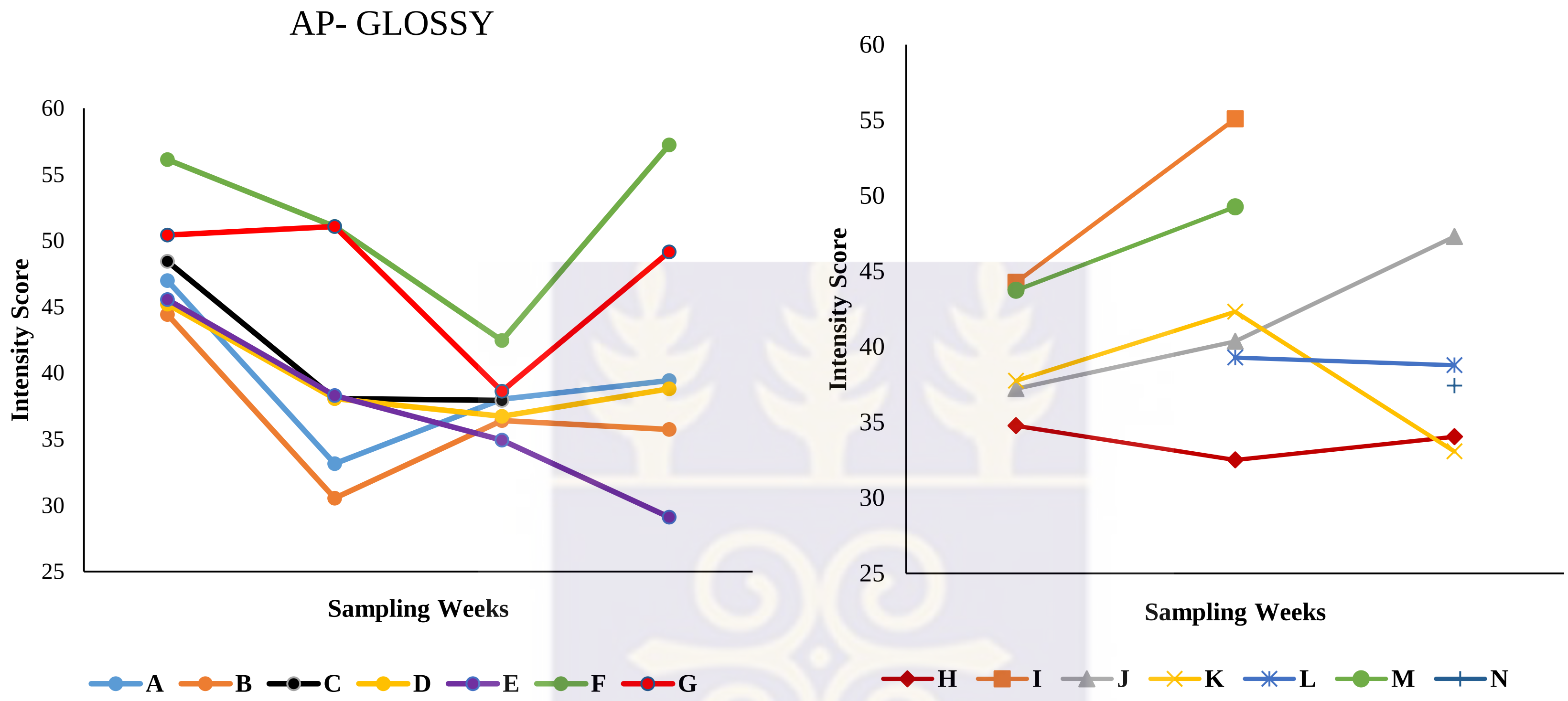
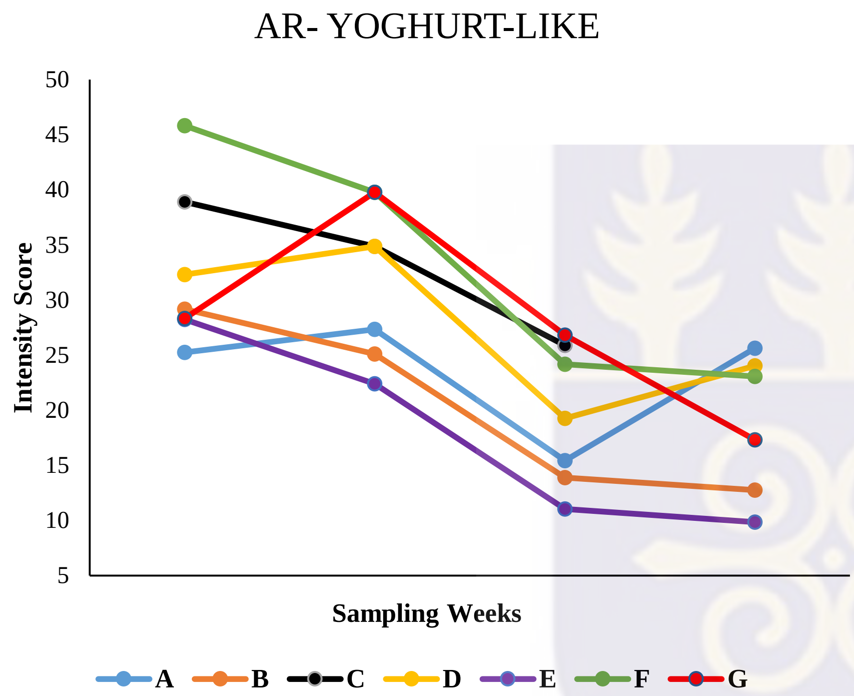


Figure 4.10: Quality monitoring of appearance (glossy) for yoghurt samples A to G (left); samples H to N (right)

The diagram below shows the level of inconsistency among samples in relation to the quality index, yoghurt-like aroma. Generally, all the samples did not show consistent results, most of the samples showed a decrease in intensity and others showed an increase over the study period. This could be an indicator of improper processing techniques resulting in fluctuating yoghurt quality. There is therefore a need for processors to take note and put effective strategies in place to ensure that yoghurt produced has an optimum level of yoghurt aroma intensity and also to ensure that this attribute is maintained so as to ensure consistent supply of good quality yoghurt to consumers.



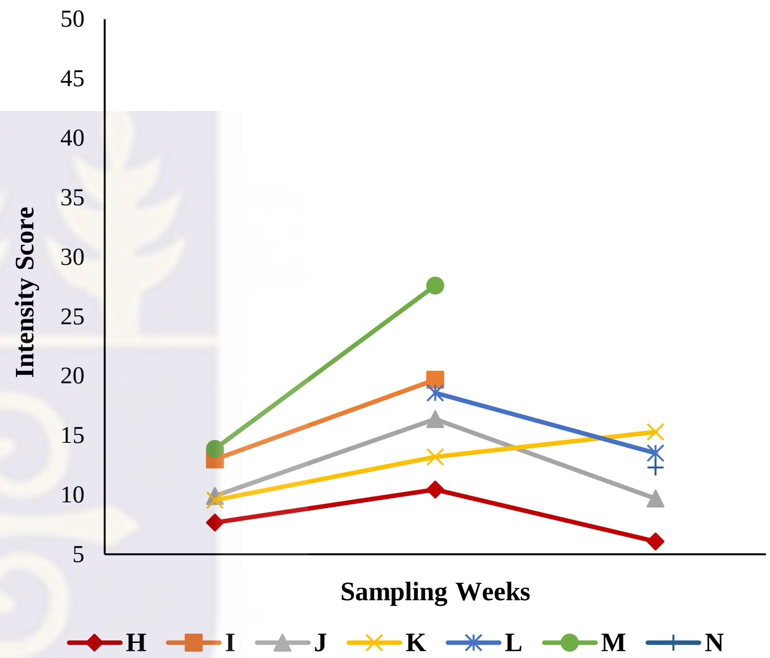


Figure 4.11: Quality monitoring of aroma (yoghurt-like) for yoghurt samples A to G (left); samples H to N (right)

Similar trends of inconsistencies were observed for sourness and astringency over the study period as well (Figs 4.13& 4.14). Samples G and I were the only two samples which maintained a consistent sour intensity; fluctuations in quality were observed for the other samples. This shows inconsistencies in processing and could be attributed to the quality and dosage of starter culture used (Abrar *et al.*, 2009), duration of fermentation or temperature of yoghurt mix during fermentation (Routray & Mishra, 2011).

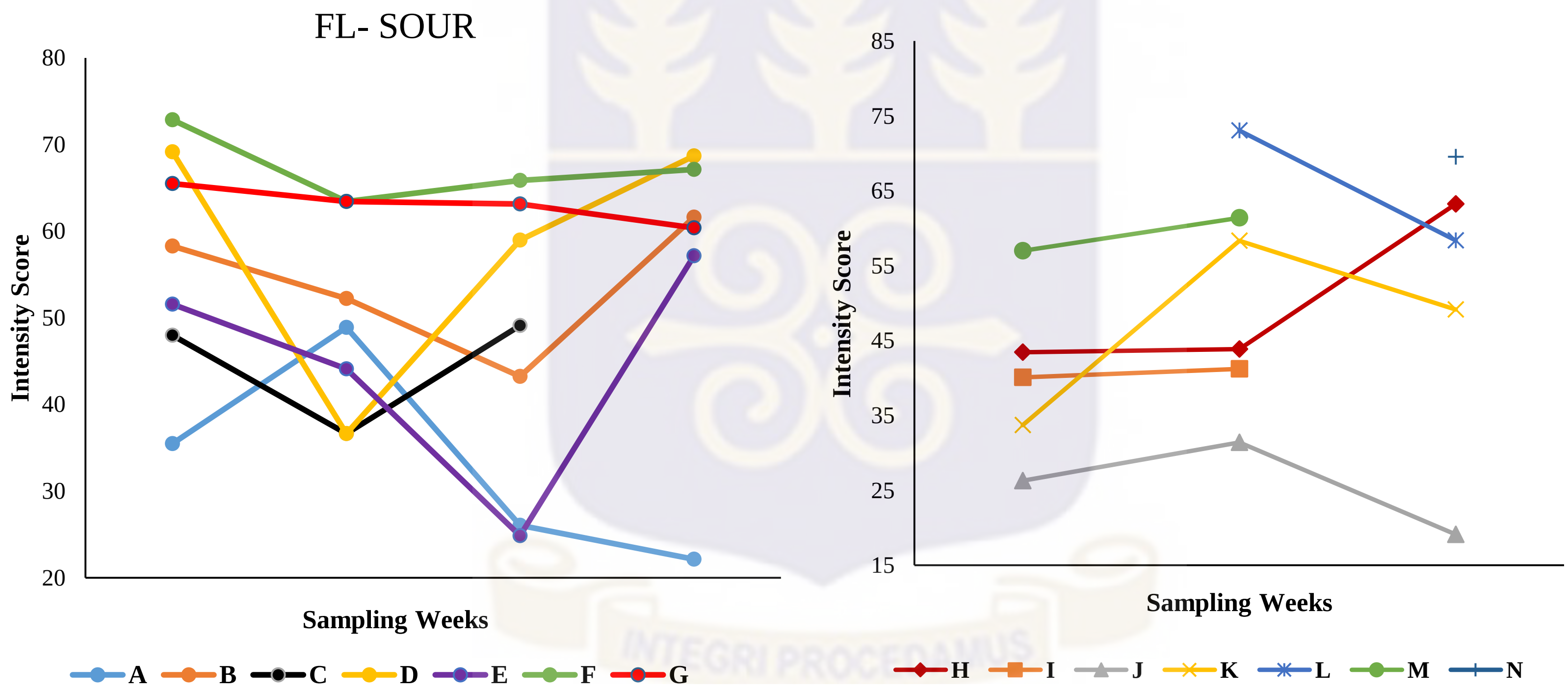


Figure 4.12: Quality monitoring of **flavour (sour)** for yoghurt samples A to G **(left)**; samples H to N (**right**)

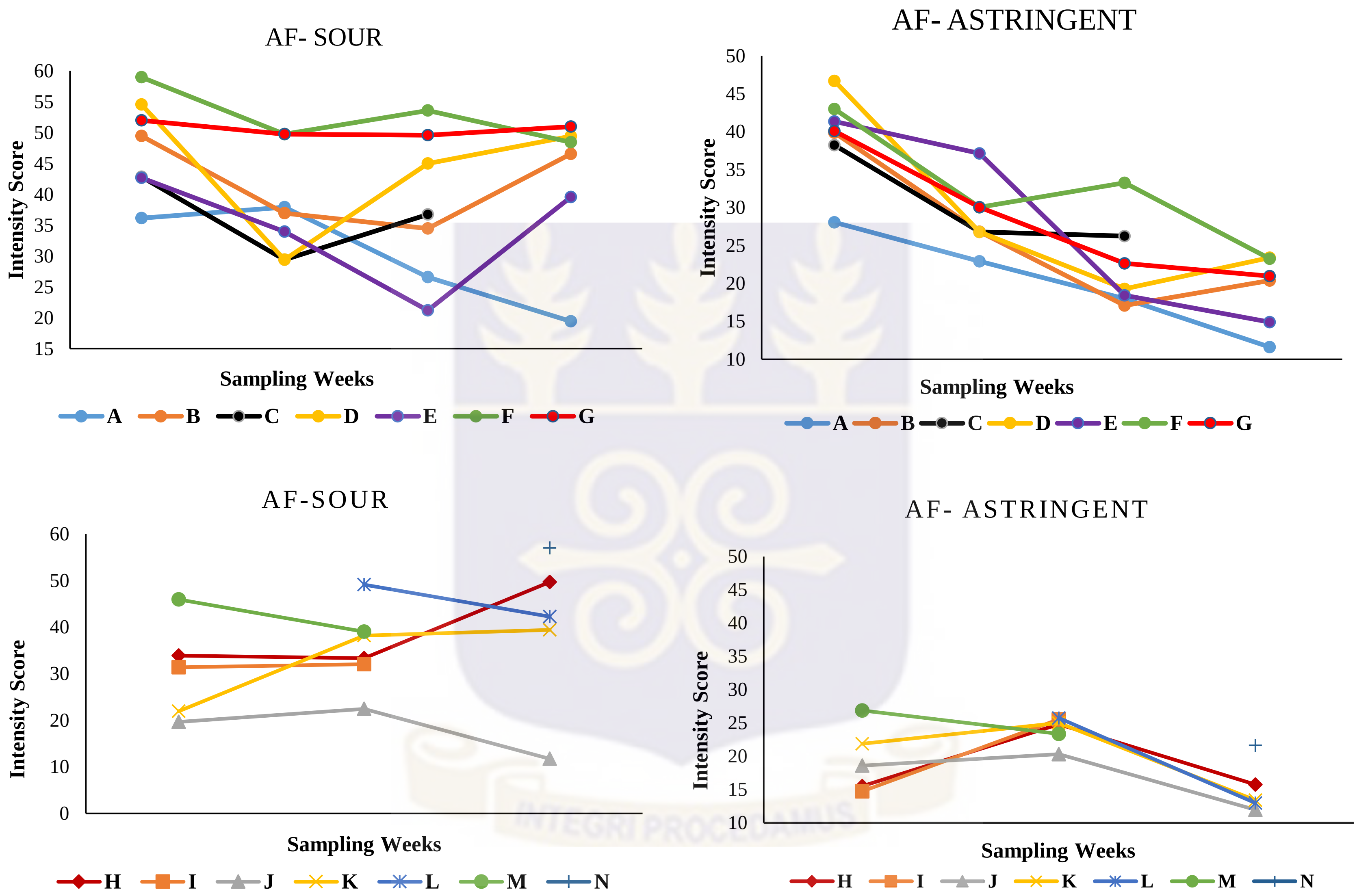


Figure 4.13: Quality monitoring of aftereffect-AF (sour and astringent) for yoghurt samples A to G (**above**); samples H to N (**below**)

4.5.2 Physicochemical Quality of Yoghurt Brands

4.5.2.1 pH

There were significant differences in physicochemical properties of the yoghurt samples (Table 9). The pH of the samples ranged between 3.86 to 4.84 for samples A to G (Table 4.9), and 4.10 to 5.60 for samples H to N (Table 4.11). Similar findings were made by De *et al.* (2014) who recorded pH values of 4.01 to 5.53 for bottled yoghurt sold in Kaduna Central market in Nigeria. Adubofuor *et al.* (2014) also recorded pH values ranging from 3.92 to 4.45 for vanilla-flavored stirred yoghurt sold on the market in Kumasi, Ghana. Gulzar *et al.* (2013) recorded low pH values of 3.86 to 4.11 for commercial yoghurt sold in Faisalabad, Pakistan; and a study by Chimezie *et al.* (2015) recorded pH values for yoghurt sold in schools in Rivers State, Nigeria to be as low as 2.38 to 3.1. These observed differences in pH was attributed to milk composition, fermentation process and starter culture dosage.

Sample F recorded the lowest pH, 3.86 to 4.14 throughout the study period. This was the only product made from solely powdered milk (Appendix 1.0) and thus its composition may have resulted in low pH values. The desired pH of yoghurt is stated to be less than 4.6 (Cheng, 2010; Lee & Lucey, 2010). Most of the samples met this requirement, however, samples I and J recorded values as high as 5.15 and 5.60 respectively. According to Lee & Lucey (2010), some yoghurt products achieve such pH values, usually, 5.2 to 5.4 when the milk used is treated with high heat. Similar to deductions made from sensory quality of the yoghurt samples, inconsistencies were observed in physicochemical properties as well. There were changes in pH of the samples over the study period. Acidification of yoghurt and thus consequent attained pH is important during processing especially in yoghurt flavor perception (Cheng, 2010). These fluctuations in pH may have contributed to some of the inconsistencies observed during sensory quality monitoring.

Table 4.7: pH and %lactic acid of stirred yoghurt samples A to G at 3 different sampling points

Prdt	pH			% Lactic acid		
	1	**2**	**3**	**1**	**2**	**3**
A	4.25±0.02^{de}	4.84±0.02^{a}	4.36±0.01^{b}	0.747±0.009^{bc}	0.726±0.005^{b}	0.756±0.009^{ab}
B	4.53±0.02^{bc}	4.40±0.02^{c}	4.36±0.02^{b}	0.735±0.010^{c}	0.753±0.005^{a}	0.735±0.010^{b}
C	4.68±0.02^{a}	4.70±0.01^{b}	4.48±0.04^{a}	0.735±0.014^{c}	0.741±0.005^{ab}	0.735±0.010^{b}
D	4.62±0.08^{ab}	4.33±0.02^{d}	4.35±0.01^{b}	0.771±0.010^{ab}	0.750±0.005^{a}	0.753±0.010^{ab}
E	4.32±0.04^{d}	4.18±0.01^{e}	4.41±0.02^{b}	0.795±0.010^{a}	0.747±0.009^{a}	0.735±0.005^{b}
F	4.14±0.00^{e}	4.18±0.02^{e}	3.86±0.03^{d}	0.759±0.014^{bc}	0.753±0.005^{a}	0.771±0.005^{a}
G	4.47±0.06^{c}	4.13±0.00^{f}	4.19±0.03^{c}	0.795±0.014^{a}	0.738±0.009^{ab}	0.741±0.005^{b}

Values in the same column with different superscripts are significantly different at α=0.05.
Abbreviation: Prdt= Product Code

4.5.2.2 Titrable acidity

According to Codex STAN 243-2003, titrable acidity expressed as percentage of lactic acid for yoghurt should be a minimum of 0.6%. All samples satisfied this requirement. Results obtained were similar to that found by Phosuksirikul *et al.* (2014), who recorded percent lactic acid of commercial fermented milk in Thailand within the ranges of 0.59 to 0.82. Olugbuyiro & Oseh (2011) also recorded values lower than minimum requirements, 0.22 to 0.50, for some market yoghurt products in Nigeria. Adubofuor *et al.* (2014) and Gulzar *et al.* (2013) on the other hand, recorded values above 0.8. High titrable acidity of yoghurt is obtained as a result of total solids content; with high solids content correlating with high lactic acid formation (Adubofuor *et al.*, 2014; Güler & Park, 2011; Gulzar *et al.*, 2013). Milk standardization during yoghurt production sees to increasing total solids content (Watson, 2017), hence if this is not properly achieved may affect lactic acid formation.

4.5.2.3 Colour

The L* value is an estimation of lightness, a*, and b* are a measure of red to green and yellow to blue coordinates of a food product respectively. These variables were used to describe the colour of the yoghurt products. The lowest L* value recorded in this study was 83.79, which was the observed estimate of whiteness of sample B during routine quality checks. Sample F recorded the highest L* value with 98.84. Sample F can therefore be said to be the lightest-coloured yoghurt amongst all the samples; this confirms sensory findings (Fig. 4.3).

The a* values recorded were a measure of greenness of the samples. During the first week of sampling for the first yoghurt sample set, sample F recorded the lowest a* value (Table 4.10). Results from subsequent test days showed that the sample maintained a low value. It can be therefore said that it maintained its quality with respect to this parameter. Sample D on the other hand recorded the highest value indicating a darker hue of this product. However, different hue intensities were recorded for this sample during subsequent tests. This shows a level of inconsistency in this product since findings reveal variations in its colour intensity. Sample H from the second sample set recorded the highest value for both a* and *b, with values at -9.80 and 32.55 respectively. This indicates that the sample had the strongest yellow hue as compared to the other samples. Such high taints of yellow is atypical to vanilla-flavoured yoghurt, and this could affect consumer acceptance of the product (Tribby, 2009). Samples F and G which were preferred by consumers showed low a* and *b values indicating lower taints of yellow in these products.

Tarakci *et al.* (2013) reported L*, a*, and b* values of a control yoghurt as 87.82, -4.66 and 9.31 respectively. This is similar to findings from this study with few deviations such as that reported for sample H. The differences in recorded values may have been as a result of milk used or techniques such as homogenization employed during processing (Güler & Park, 2011). Inconsistencies in L*, a*, and b* were also observed amongst products for each sampling week (Table 4.10). Samples A, B and D showed vast differences in recorded values during routine checks. All these give a reflection of the general quality maintenance of yoghurt on the market.

This indicates that there is a need for processors put appropriate measures in place to ensure consistent supply of quality yoghurt to consumers.

Table 4.8: Changes in colour matrices for stirred yoghurt samples A to G

P	L*			a*			b*		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
A	94.66±0.02^{bc}	94.48±0.08^{c}	92.88±0.32^{a}	-4.16±0.10^{ab}	-5.66±2.93	-3.79±0.02^{bc}	12.27±0.07^{c}	19.11±0.02^{b}	10.57±0.07^{d}
B	94.20±0.04^{c}	86.63±0.13^{g}	83.79±1.04^{c}	-4.38±0.02^{b}	-4.13±0.02	-3.52±0.40^{ab}	14.78±0.05^{c}	10.82±0.07^{f}	8.57±0.02^{g}
C	95.76±0.08^{bc}	97.75±0.17^{a}	92.76±0.05^{a}	-4.83±0.01^{c}	-5.21±0.03	-4.42±0.02^{d}	14.61±0.11^{b}	15.88±0.20^{c}	14.00±0.10^{c}
D	98.48±0.02^{a}	96.39±0.06^{b}	92.25±0.13^{ab}	-4.01±0.01^{ab}	-3.49±0.00	-3.46±0.06^{ab}	11.55±0.09^{c}	13.72±0.10^{d}	19.93±0.08^{a}
E	93.55±0.05^{c}	91.88±0.18^{f}	90.76±0.56^{b}	-9.02±0.02^{d}	-6.36±0.01	-4.15±0.09^{cd}	26.46±0.06^{a}	25.85±0.10^{a}	16.39±0.08^{b}
F	98.84±0.15^{a}	93.01±0.14^{e}	91.44±0.38^{ab}	-3.87±0.01^{a}	-3.53±0.05	-3.25±0.03^{a}	10.63±0.10^{c}	10.04±0.10^{g}	9.11±0.08^{f}
G	96.8±2.18^{ab}	93.69±0.67^{d}	92.63±0.74^{a}	-4.10±0.35^{ab}	-3.87±0.01	-3.31±0.25^{ab}	10.50±1.86^{c}	11.59±0.03^{e}	9.98±0.35^{e}

Values in the same column with different superscripts are significantly different at α=0.05.
Abbreviation: P= Product Code

Table 4.9: Physicochemical parameters of vanilla-flavoured stirred yoghurt samples H to N

Product	Ph	%Lactic	L*	a*	b*
H	$4.67±0.01^{c}$	$0.726±0.005^{abc}$	$85.84±0.03^{f}$	$-9.80±0.05^{g}$	$32.55±0.03^{a}$
I	$5.15±0.01^{b}$	$0.714±0.005^{bc}$	90.75±0.16c	$-3.23±0.03^{c}$	$11.66±0.10^{d}$
J	$5.60±0.01^{a}$	$0.705±0.010^{c}$	$88.19±0.36^{d}$	$-5.51±0.03^{f}$	$14.77±0.15^{c}$
K	$4.62±0.01^{d}$	$0.741±0.005^{a}$	$92.83±0.23^{a}$	$-4.23±0.02^{e}$	$14.69±0.03^{c}$
L	$4.10±0.01^{g}$	$0.738±0.009^{a}$	$85.15±0.24^{g}$	$-2.39±0.04^{a}$	$7.57±0.25^{f}$
M	$4.18±0.01^{f}$	$0.732±0.005^{ab}$	$87.38±0.03^{e}$	$-2.75±0.02^{b}$	$9.04±0.14^{e}$
N	$4.26±0.01^{e}$	$0.732±0.010^{ab}$	$92.06±0.26^{b}$	$-3.47±0.03^{d}$	$15.44±0.02^{b}$

Values in the same column with different superscripts are significantly different at α=0.05.

4.5.3 Microbial Quality of Yoghurt

4.5.3.1 Total Mesophilic and LAB Count

The total mesophilic count of microorganisms ranged from 4.73 to 11.58 log cfu/ml ($5.4×10^4$ to $3.8×10^{11}$ cfu/ml) (Tables 4.12 & 4.13). High bacterial count is expected because of starter culture, which is made up of microorganisms, used in yoghurt production. Results obtained were comparable to values recorded in studies done by Chimezie *et al.* (2015), De *et al.* (2014), Hemamali *et al.* (2016) and Worku *et al.* (2015). According to Codex Stan 243-2003, the minimum count for total microorganisms is 10^7 cfu/ml (8 log cfu/ml). Some samples did not meet this stated requirement and others reached very high counts. This could be due to differences in processing techniques such as starter culture dosage as well as fermentation duration employed by producers. Though the mesophilic count is set at a minimum of 10^7 cfu/ml (8 log cfu/ml), Worku *et al.* (2015) write that high mesophilic count may be an indicator of poor hygienic practices but not necessarily of a health risk. Hence very high counts may serve as an indicator of insanitary practices or handling by processors.

High lactic acid bacteria (LAB) count were also recorded for all samples. This was expected since the key microorganisms required in yoghurt formation are lactic acid bacteria. Findings from this study is comparable to that by Worku *et al.* (2015) who also observed LAB counts within 6.4 to 9.6 log cfu/ml for commercial yoghurt sold in Addis Ababa. It was however observed that sample B had non-determined LAB count during the second routine check (Table 4.12). This is to say that pH and lactic acid levels observed for this sample during this period may not necessarily have been produced by lactic acid bacteria in itself but by other lactic-acid producing bacteria. Hence could not be detected during microbial tests. This could be as a result of the microbial composition of starter culture used.

4.5.3.2 Hygiene indicators

The following, total coliform, faecal coliform and total *E. coli* were enumerated to serve as hygiene indices of the yoghurt samples. Some samples were found to be contaminated with coliforms (Tables 4.12 & 4.13) and these were recorded in high amounts. Routine checks on samples A to G showed that only two samples, B and G, maintained a satisfactory coliform count. Sample C recorded coliform count as high as 11.58 log cfu/ml. Adubofuor *et al.* (2014) also had some coliform counts for stirred yoghurt sold in Kumasi, Ghana. However, coliform count in their study was lower than that in this study. De *et al*. (2014), Onuorah & Obika (2016) and Worku *et al.* (2015), on the other hand recorded high coliform count in yoghurt samples as well. The presence of coliforms in yoghurt is attributed to poor hygienic practices by producers such as use of poor quality milk as well as insufficient pasteurization during product handling (El-Malt *et al.*, 2013).

Samples were found to be inconsistent in microbial quality. Faecal coliform for all samples, with the exception of sample F were satisfactory when the first quality check was done. Samples B, D and G maintained satisfactory levels of faecal coliform, whereas the other samples were found to be contaminated with high counts during the subsequent routine check. Sample F was the only yoghurt product found to be contaminated by *E. coli*. This is an indication of post processing contamination as a result of starter culture used or the storage temperature (El-Malt *et al.*, 2013). El-Malt *et al*. (2013) write that coagulase positive *Staphylococci* (CP-*Staph*) is an indication of poor practices by food processors and handlers. The presence of these microorganisms in the samples from this study gives a reflection of handling by processors.

4.5.3.3 Overall quality and safety indicators

According to Ghana Standards, yoghurt should not contain yeast cells (Ghana Standard 243-2003). Routine checks however showed the presence of yeast in samples B, C and D. Adubofuor *et al.* (2014) also recorded very high yeast cell counts for stirred yoghurt sold in Kumasi as well. Other investigators also found high incidence of yeast cells in yoghurt (De *et al.*, 2014; El-Malt *et al*., 2013; Okpalugo *et al.*, 2008; Onuorah & Obika, 2016; Varga, 2007). These were said to be as a result of poor hygienic practices and poor quality of milk. Yeasts and moulds are indicators of spoilage and hence their presence is indicative of the possible shelf-life duration of the product.

Results showed that none of the samples were detected to be contaminated with *Listeria monocytogenes*, *Salmonella* or *E. coli* O157. The low pH of yoghurt prevents growth of spoilage and pathogenic bacteria (Pal *et al.*, 2015), hence may have contributed to the findings from this study.

Table 4.10: Microbial quality assessment of yoghurt samples A to G

P	Microbial count (Log cfu/ml)														Microbial detection		
	TMC		LAB		T coli.		F. coli.		*E. coli*		CP *Staph*		Y&M		*Li*	*S*	*E*
	1	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**			
A	10.65±0.04	10.84±0.09^{b}	8.91±0.19	5.17±0.82^{c}	n	4.54±0.09^{bc}	n	2.50±0.28	n	n	3.28±0.06^{a}	n	n	3.69±0.12^{a}	n	n	n
B	8.09±4.41	8.36±0.04^{d}	3.25±4.60	n	n	n	n	n	n	n	n	1.85±0.57	n	n	n	n	n
C	8.00±0.02	11.58±0.29^{a}	9.42±0.11	7.24±0.34^{b}	4.54±0.09^{a}	5.68±0.14^{a}	n	2.48±0.68	n	n	3.22±0.03^{a}	1.50±0.28	n	1.65±2.33^{ab}	n	n	n
D	4.73±0.10	7.19±0.10^{e}	9.46±0.83	7.64±0.66^{b}	4.11±0.00^{c}	4.17±0.12^{c}	n	n	n	n	1.57±0.39^{b}	0.50±0.71	n	4.65±0.11^{a}	n	n	n
E	5.84±0.16	10.17±0.02^{a}	10.82±0.66	10.01±0.04^{a}	4.14±0.09^{ab}	4.69±0.09^{b}	n	1.81±0.05	n	n	n	0.50±0.71	n	n	n	n	n
F	6.10±0.008	10.84±0.05^{b}	4.24±5.99	7.14±0.05^{b}	3.39±0.55^{b}	4.23±0.12^{c}	0.50±0.70	2.65±0.07	n	2.15±0.21	n	2.98±0.19	n	n	n	n	n
G	5.24±0.18	6.18±0.15^{f}	5.07±0.16	5.75±0.01^{c}	n	n	n	n	n	n	n	1.15±1.63	n	n	n	n	n

Values in the same column with different superscripts are significantly different at α=0.05.
Abbreviations: P= Product Code, n= not detected, TMC= total mesophilic count, T. coli= total coliform
F. coli= faecal coliform, *E. coli= Escherichia coli,* CP *Staph.* = catalase- positive *Staphylococci*, LAB= lactic acid bacteria
Y&M= yeasts and moulds, *Li= Listeria monocytogenes, S= Salmonella, E= Escherichia coli O157*

Table 4.11: Microbiological quality of vanilla-flavoured stirred yoghurt samples H to N

Prdt	Microbial count (Log cfu/ml)							Microbial detection		
	TMC	LAB	T coli.	F. coli	*E. coli*	CP *Staph*	Y&M	*Li.*	*Sm.*	*E.c*
H	8.10±0.14^{c}	8.56±0.12^{b}	nd	nd	nd	nd	nd	nd	nd	nd
I	5.77±010^{e}	6.29±0.12^{d}	nd	1.00±1.41	1.15±0.21	nd	nd	nd	nd	nd
J	9.14±0.08^{b}	6.97±0.04^{c}	nd	nd	nd	nd	nd	nd	nd	nd
K	9.42±0.05^{ab}	9.66±0.06^{a}	nd	nd	nd	nd	nd	nd	nd	nd
L	9.63±0.02^{a}	9.63±0.04^{a}	nd	0.15±0.21	nd	nd	nd	nd	nd	nd
M	9.71±0.04^{a}	6.64±0.13^{cd}	nd	nd	nd	nd	nd	nd	nd	nd
N	7.71±0.05^{d}	4.38±0.07^{e}	nd	nd	nd	2.00±0.00	nd	nd	nd	nd

Values in the same column with different superscripts are significantly different at α=0.05.
Abbreviations: Prdt= Product Code, nd= not detected, TMC= total mesophilic count, T. coli= total coliform
F. coli= faecal coliform, *E. coli= Escherichia coli,* CP *Staph.* = catalase- positive *Staphylococci*, LAB= lactic acid bacteria
Y&M= yeasts and moulds, *Li= Listeria monocytogenes, Sm.= Salmonella, E.c= Escherichia coli O157*

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The study identified twenty-one (21) sensory attributes that could be used to describe commercial Ghanaian- produced vanilla flavoured stirred yoghurt. These descriptors included six (6) yoghurt appearance attributes, three (3) aroma attributes, four (4) flavor attributes, four (4) texture attributes and four (4) aftereffect yoghurt attributes.

From these attributes, five were identified as the key descriptors that drive consumer liking for stirred yoghurt. These were a glossy appearance, yoghurt-like aroma, sourness (in flavor and after-feel) and an astringent after-feel. These descriptors were reported as the sensory indices for quality assessment of yoghurt. It was also determined that the intensities of these attributes were linearly proportional to consumer acceptance of yoghurt products.

Assessment of yoghurt products showed inconsistencies in quality over the study period for sensorial, physicochemical and microbiological indices. Results from physicochemical tests showed that products were within acceptable limits, however, there were inconsistencies in recorded values within products for the different sampling periods. Analysis from this study also showed unsatisfactory microbiological quality of stirred yoghurt on the market. This was made evident with recorded microbial levels exceeding certain standards.

The overall outcome of yoghurt quality assessment from this study showed an emphasis is needed on quality control during processing as well as storage.

5.2 RECOMMENDATIONS

There is a need for government and regulatory bodies to offer training programs on Good Hygienic Practices (GHP) for yoghurt manufacturers to help ensure production of uncontaminated yoghurt products. These bodies should also monitor intermittently the manufacturing as well as hygienic practices of yoghurt producers to ensure that manufacturers are adhering to regulations. This will ensure that consumers receive safe and good quality yoghurt.

Further research should also be conducted using different consumer group(s) such as children and the elderly) as test subjects to determine if similar attributes will be identified as drivers of liking for vanilla-flavoured stirred yoghurt. These groups of consumers are an important consumer group with a potential large market size.

Follow-up studies can be conducted using attributes identified as drivers of liking to develop an optimum stirred yoghurt product that meets consumer expectation.

REFERENCES

Abrar, M., Anjum, F. R., Zahoor, T., Rahman, S. U., Hussain, S., & Ahmad, S. (2009). Chemical and sensory characteristics of yoghurts prepared by locally isolated and commercially imported starter cultures. *Milchwissenschaft*, *64*(4), 392–395.

Adubofuor, J., Dzigbordi B, & Wireku-Manu, F. D. (2014). Comparative studies on the qualities of seven brands of vanilla-flavoured stirred yoghurts produced within the Kumasi Metropolis of Ghana. *International Food Research Journal*, *21*(3), 1243–1248. Retrieved from http://www.ifrj.upm.edu.my/21 (03) 2014/58 IFRJ 21 (03) 2014 Abubofour 013.pdf

Agritrade. (2011). Nigerian and Ghanaian markets offer further growth potential for EU dairy exports. Retrieved February 28, 2017, from http://agritrade.cta.int/Agriculture/Commodities/Dairy/Nigerian-and-Ghanaian-markets-offer-further-growth-potential-for-EU-dairy-exports

Ahmadi, A., Milani, E., Madadlou, A., Mortazavi, S. A., Mokarram, R. R., & Salarbashi, D. (2014). Synbiotic yogurt-ice cream produced via incorporation of microencapsulated lactobacillus acidophilus (la-5) and fructooligosaccharide. *Journal of Food Science and Technology*, *51*(8), 1568–1574. https://doi.org/10.1007/s13197-012-0679-y

Aidoo, R., Nurah, G. K., Fialor, S. C., & Ohene, Y. (2009). Determinants of dairy consumption expenditure. *Journal of Science and Technology*, *29*(1), 87–96.

Akal, C., & YetİşemİYen, A. (2016). Use of whey powder and skim milk powder for the production of fermented cream. *Food Science and Technology (Campinas)*, *36*(4), 616–621. https://doi.org/10.1590/1678-457X.06816

AOAC. (2005). Official Methods of Analysis of AOAC INTERNATIONAL 18th ed., William Horwitz, Editor George W. Latimer, Jr., Assistant Editor, USA

Aswal, P., Shukla, A., & Priyadarshi, S. (2012). Yoghurt : Preparation , Characteristics and Recent Advancements. *Cibtech Journal of Bio-Protocols*, *1*(2), 32–44.

Baglio, E. (2014). Chemistry and Technology of Yoghurt Fermentation. *Springer*, 25–33. https://doi.org/10.1007/978-3-319-07377-4

Bayarri, S., Carbonell, I., Barrios, E. ., & Costell, E. (2011a). Impact of sensory differences on consumer acceptability of yoghurt and yoghurt-like products. *International Dairy Journal*, *21*, 111–118. https://doi.org/10.1016/j.idairyj.2010.09.002

Bayarri, S., Carbonell, I., Barrios, E. . X., & Costell, E. (2011b). Impact of sensory differences on consumer acceptability of yoghurt and yoghurt-like products. *International Dairy Journal*, *21*, 111–118. https://doi.org/10.1016/j.idairyj.2010.09.002

Beshkova, D. M., Simova, E. D., Frengova, G. I., Simov, Z. I., & Dimitrov, Z. P. (2003). Production of volatile aroma compounds by kefir starter cultures. *International Dairy Journal*, *13*(7), 529–535. https://doi.org/10.1016/S0958-6946(03)00058-X

Bølling Johansen, S., Ns, T., Øyaas, J., & Hersleth, M. (2009). Acceptance of calorie-reduced yoghurt: Effects of sensory characteristics and product information. *Food Quality and Preference*, *21*, 13–21. https://doi.org/10.1016/j.foodqual.2009.07.003

Bouteille, R., Cordelle, S., Laval, C., Tournier, C., Lecanu, B., This, H., & Schlich, P. (2013). Sensory exploration of the freshness sensation in plain yoghurts and yoghurt-like products. *Food Quality and Preference*, *30*(2), 282–292.

https://doi.org/10.1016/j.foodqual.2013.06.012

Bruzzone, F., Ares, G., & Giménez, A. (2013). Temporal aspects of yoghurt texture perception. *International Dairy Journal*, *29*, 124–134. https://doi.org/10.1016/j.idairyj.2012.10.012

Cano-Sancho, G., Perello´, G., Nadal, M., & Domingo, J. L. (2015). Comparison of Nutritional Composition of Two Edible Species of Cnidoscolus. *Journal of Food Composition and Analysis*, *42*, 71–77. https://doi.org/http://dx.doi.org/10.1016/j.jfca.2015.03.008

Centre for Food Safety. (2014). Microbiological Guidelines for Food: For ready-to-eat food in general and specific food items, *2014*(August), 38. Retrieved from http://www.cfs.gov.hk/english/food_leg/files/food_leg_Microbiological_Guidelines_for_Food_e.pdf

Chandan, R. C. (2007). *Manufacturing Yogurt and Fermented Milks*. *Manufacturing Yogurt and Fermented Milks*. https://doi.org/10.1002/9780470277812

Cheng, H. (2010). Volatile Flavor Compounds in Yogurt: A Review. *Critical Reviews in Food Science and Nutrition*, *50*, 938–950. https://doi.org/10.1080/10408390903044081

Chimezie, G. D., Gloria, L., & Ebere, I. (2015). Microbiological load of yoghurt sold in Omoku schools, Rivers State, Nigeria. *African Journal of Microbiology Research*, *9*(34), 1960–1963. https://doi.org/10.5897/AJMR2015.7556

Chipurura, B., Pswarayi, F., & Muchuweti, M. (2014). Sensory properties and consumer acceptance of a stirred-type yoghurt produced from baobab (. *African Journal of Food , Agriculture*, *Nutrition and Development*, *14*(2), 8695–8708. Retrieved from https://www.ajfand.net/Volume14/No2/Chipurura13020.pdf

Coggins, P. C., Schilling, M. W., Kumari, S., & Gerrard, P. D. (2007). CONVENTIONAL MILK YOGURT IN THE UNITED STATES. *Journal of Sensory Studies*, *23*(2008), 671–687.

Costell, E. (2002). A comparison of sensory methods in quality control. *Food Quality and Preference*, *13*(6), 341–353. https://doi.org/10.1016/S0950-3293(02)00020-4

De, N., Goodluck, T. M., & Bobai, M. (2014). Original Research Article Microbiological quality assessment of bottled yogurt of different brands sold in Central Market , Kaduna Metropolis , Kaduna , Nigeria. *International Journal of Current Microbiology and Applied Science*, *3*(2), 20–27.

De Brabandere, A. G., & De Baerdemaeker, J. G. (1999). Effects of process conditions on the pH development during yogurt fermentation. *Journal of Food Engineering*, *41*(3–4), 221–227. https://doi.org/10.1016/S0260-8774(99)00096-5

Desai, N. (2012). *Sensory properties and drivers of liking for Greek style yoghurts*. North Carolina State University. Retrieved from https://repository.lib.ncsu.edu/bitstream/handle/1840.16/8192/etd.pdf?sequence=2

Dlamini, A., Mamba, R., & Silaula, S. (2009). ATTRIBUTES AND CONSUMER ACCEPTANCE OF YOGHURT FLAVOURED WITH NON – CULTIVATED INDIGENOUS SWAZI FRUITS. *African Journal of Food , Agriculture, Nutrition and Development*, *9*(1), 636–651. Retrieved from http://teeal.ug.edu.gh/fulltext/207715

DSM. (2015). DAIRY GLOBAL INSIGHT SERIES: PATTERNS IN YOGURT CONSUMPTION. Retrieved from http://www.machineryworld.com/pdfs/dsm-yogurt-trends-consumption-patterns.pdf

El-Abbadi, N. H., Dao, M. C., & Meydani, S. N. (2014). Yogurt: Role in healthy and active aging. *American Journal of Clinical Nutrition*, *99*(5), 1263–1270. https://doi.org/10.3945/ajcn.113.073957

El-Malt, L. M. M., Abdel Hameed, K. G. G., & Mohammed, A. S. S. (2013). Microbiological evaluation of yoghurt products in qena city, Egypt. *Veterinary World*, *6*(7), 400–404. https://doi.org/10.5455/vetworld.2013.400-404

Fernandes, R. (Ed.). (2009). *MICROBIOLOGY HANDBOOK DAIRY PRODUCTS*. Surrey: Letterhead Food International Ltd. Retrieved from http://ssu.ac.ir/cms/fileadmin/user_upload/Daneshkadaha/dbehdasht/behdasht_imani/book/Microbiology_Handbook__Dairy_Products.pdf

Fernandez, M. A., & Marette, A. (2017). Potential Health Benefits of Combining Yogurt and Fruits Based on Their Probiotic and Prebiotic Properties. *Advances in Nutrition (Bethesda, Md.)*, *8*(1), 155S–164S. https://doi.org/10.3945/an.115.011114

Fisberg, M., & Machado, R. (2015). History of yogurt and current patterns of consumption. *Nutrition Reviews*, *73*, 4–7. https://doi.org/10.1093/nutrit/nuv020

Food Authority, N. (2009). Microbiological quality guide for ready-to-eat foods. Retrieved from http://www.foodauthority.nsw.gov.au/_Documents/scienceandtechnical/microbiological_quality_guide_for_RTE_food.pdf

Future Market Insights. (2014). Yoghurt Market - Global Industry Analysis, Size and Forecast, 2015 to 2025. Retrieved April 10, 2017, from http://www.futuremarketinsights.com/reports/yoghurt-market

García-Pérez, F. J., Lario, Y., Fernández-López, J., Sayas, E., Pérez-Alvarez, J. A., & Sendra, E. (2005). Effect of orange fiber addition on yogurt color during fermentation and cold storage. *Color Research and Application*, *30*(6), 457–463. https://doi.org/10.1002/col.20158

Ghana Standards 337. (2003). Milk and Milk Products Specification for yoghurt and sweetened yoghurt. Ghana Food and Drugs Board Library, Accra.

Ghana Standards (2016). GS 1161-2016. Milk and milk products- Specification for yoghurts and products heat treated after fermentation. Ghana Food and Drugs Board Library, Accra

Gilbert, R., de Louvois, J., Donovan, T., Little, C., Nye, K., Ribeiro, C., … Bolton, F. (2000). Guidelines for the microbiological quality of some ready-to-eat foods sampled at the point of sale. *Communicable Disease and Public Health*, *3*(3), 163–167. Retrieved from http://mb-labs.com/wp-content/uploads/2014/08/Micro-Limits-Ready-to-Eat-Foods.pdf

Glanville, J. M., Brown, S., Shamir, R., Szajewska, H., & Eales, J. F. (2015). The scale of the evidence base on the health effects of conventional yogurt consumption: Findings of a scoping review. *Frontiers in Pharmacology*, *6*(OCT), 1–12. https://doi.org/10.3389/fphar.2015.00246

Gonzalez, N. J., Adhikari, K., & Sancho-Madriz, M. F. (2011). Sensory characteristics of peach-flavored yogurt drinks containing prebiotics and synbiotics. *LWT - Food Science and Technology*, *44*(1), 158–163. https://doi.org/10.1016/j.lwt.2010.06.008

Grunert, K. G. (2005). Food quality and safety: consumer perception and demand. *European Review of Agricultural Economics*, *32*(3), 369–391. https://doi.org/10.1093/eurrag/jbi011

Güler, Z., & Park, Y. W. (2011). Characteristics of physico-chemical properties, volatile compounds and free fatty acid profiles of commercial set-type Turkish yoghurts Chemical properties of Turkish yoghurts. *Open Journal of Animal Sciences*, *1*(1), 1–9. https://doi.org/10.4236/ojas.2011.11001

Gulzar, M., Shahzad, F., Yaqub, M., & Zhoor, T. (2013). Quality Assessment of Yoghurt Produced At Large (Industrial) ans Small Scale. *The Journal of Animal and Plant Sciences*, *23*(August 2016), 58–61.

Gvili, Y., Tal, A., Amar, M., Hallak, Y., Wansink, B., & Giblin, M. (2015). Fresh from the tree : Implied motion improves food evaluation. *FOOD QUALITY AND PREFERENCE*, *46*, 160–165. https://doi.org/10.1016/j.foodqual.2015.07.015

Gyawali, R., & Ibrahim, S. A. (2016). Effects of hydrocolloids and processing conditions on acid whey production with reference to Greek yogurt. *Trends in Food Science & Technology*, *56*, 61–76. https://doi.org/10.1016/j.tifs.2016.07.013

Hemamali, K. K. G. U., Jayamanne, V. S., & Amarathunge, S. M. (2016). Physico-Chemical And Microbiological Quality Of Some Consumer Preferred Plain Set Yoghurts Sold In Matara Municipal Area Of Sri Lanka. *International Journal of Scientific Research*, *5*(1), 62–65.

Husain, I., Attiq-yr-Rahman, & Atkinson, N. (2009). Quality comparison of probiotic and natural yoghurt. *Pakistan Journal of Nutrition*, *8*(1), 9–12. Retrieved from http://scialert.net/qredirect.php?doi=pjn.2009.9.12&linkid=pdf

Imram, N. (1999). The role of visual cues in consumer perception and acceptance of a food product The role of visual cues in consumer perception and acceptance of a food product. *Nutrition and Food Science*, *99*(5), 224–230. https://doi.org/10.1108/00346659910277650

ISO 6785: Milk and milk products. Detection of *Salmonella*

ISO 11290-1: Horizontal method for the detection of *Listeria monocytogenes*- part 1: detection method/ amendment 1: modification of the isolation media, of the haemolysis test and inclusion of precision data

ISO 11290-2: Horizontal method for the detection of *Listeria monocytogenes*- part 2: detection method/ amendment 2

ISO 15214: Horizontal methods for the enumeration of mesophilic lactic acid bacteria- colony count technique at 30^{o}C

Jayasinghe, O., Fernando, S., Jayamanne, V., & Hettiarachchi, D. (2015). PRODUCTION OF A NOVEL FRUIT-YOGHURT USING DRAGON FRUIT (HYLOCEREUS UNDATUS L.). *European Scientific Journal*, *11*(3), 208–215. Retrieved from http://eujournal.org/index.php/esj/article/viewFile/4998/4802

Kechagia, M., Basoulis, D., Konstantopoulou, S., Dimitriadi, D., Gyftopoulou, K., Skarmoutsou, N., & Fakiri, E. M. (2013). Health benefits of probiotics: a review. *ISRN Nutrition*, *2013*, 481651. https://doi.org/10.5402/2013/481651

King, B., Arents, P., Derks, E. P., Duineveld, C. A. A., Boelrijk, A., & Burgering, M. J. M. (2003). Flavour perception and flavour release in fruit-flavoured yoghurt. *Flavour Research at the Dawn of the Twenty-First Century (Proc. 10th Weurman Flavour Research Symposium)*, (January), 164–169. Retrieved from %5C%5CRobsrv-05%5Creference manager%5CArticles%5C12508.pdf

King, E. S., Johnson, T. E., Bastian, S. E. P., Osidacz, P., & Francis, I. L. (2012). Consumer liking of white wines : segmentation using self-reported wine liking and wine knowledge. *International Journal of Wine Business Research*, *24*(1), 33–46. https://doi.org/10.1108/17511061211213774

Lattey, K. A., Bramley, B. R., & Francis, I. L. (2009). Consumer acceptability , sensory properties and expert quality judgements of Australian Cabernet Sauvignon and Shiraz wines. *Australian Journal of Grape and Wine Research*, *16*, 189–202. https://doi.org/10.1111/j.1755-0238.2009.00069.x

Lawless, H. T., & Heymann, H. (2010). *Sensory Evaluation of Food* (2nd ed.). New York: Springer Science & Business Media.

Lee, W. J., & Lucey, J. A. (2010). Formation and physical properties of yogurt. *Asian-Australasian Journal of Animal Sciences*, *23*(9), 1127–1136. https://doi.org/10.5713/ajas.2010.r.05

Liem, D. G., & Mennella, J. . (2003). Heightened sour preference during childhood. *Chemical Senses*, *28*, 173–180.

Liem, D. G., Westerbeek, A., Wolterink, S., Kok, F. J., & De Graaf, C. (2004). Sour taste preferences of children relate to preference for novel and intense stimuli. *Chemical Senses*, *29*(8), 713–720. https://doi.org/10.1093/chemse/bjh077

Macbean, R. D. (2010). Shelf Life of Yogurt. Retrieved May 29, 2017, from https://www.google.com.gh/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0ahUKEwjjvsTMoJTUAhVoKcAKHViOChcQFggwMAI&url=https%3A%2F%2Fwww.researchgate.net%2Ffile.PostFileLoader.html%3Fid%3D56567db260614b9f538b4567%26assetKey%3DAS%253A2998820080

Mahrous, H., & Abd-El-Salam, R. (2014). Production of a Functional Frozen Yoghurt Fortified with Omega-3 and Vitamin E. *American Journal of Food and Nutrition*, *2*(5), 77–84. https://doi.org/10.12691/AJFN-2-5-1

Mater, D. D. G., Bretigny, L., Firmesse, O., Flores, M. J., Mogenet, A., Bresson, J. L., & Corthier, G. (2005). Streptococcus thermophilus and Lactobacillus delbrueckii subsp. bulgaricus survive gastrointestinal transit of healthy volunteers consuming yogurt. *FEMS Microbiology Letters*, *250*(2), 185–187. https://doi.org/10.1016/j.femsle.2005.07.006

McGee, H. (2004). Fresh fermented milks and creams. In P. Dorfman, J. Greene, & A. McGee (Eds.), *Food and Cooking: The Science and Lore of the Kitchen* (pp. 45–51). New York: Scribner.

McKinley, M. C. (2005). The nutrition and health benefits of yoghurt. *International Journal of Dairy Technology*, *58*(1), 1–12. https://doi.org/10.1111/j.1471-0307.2005.00180.x

Murakoshi, T., Masuda, T., Utsumi, K., Tsubota, K., & Wada, Y. (2013). Glossiness and Perishable Food Quality : Visual Freshness Judgment of Fish Eyes Based on Luminance Distribution. *PLoS ONE*, *8*(3), 1–5. https://doi.org/10.1371/journal.pone.0058994

Nagpal, R., Kumar, A., Kumar, M., Behare, P. V., Jain, S., & Yadav, H. (2012). Probiotics, their health benefits and applications for developing healthier foods: A review. *FEMS Microbiology Letters*, *334*(1), 1–15. https://doi.org/10.1111/j.1574-6968.2012.02593.x

National Research Council (US) Subcommittee on Microbiological Criteria. (1985). *An Evaluation of the Role of Microbiological Criteria for Foods and Food Ingredients*. *National Academies Press (US)*. https://doi.org/10.17226/372

Nazni, P., & Komathi, K. (2014). QUALITY EVALUATION OF THE FRUIT PULP ADDED YOGHURT. *International Journal of Nutrition and Agriculture Research*, *1*(1), 48–54. Retrieved from http://www.ijnar.com/article/QUALITY EVALUATION OF THE FRUIT PULP ADDED YOGHURT..pdf

NMKL. (1999). Method No. 71. 5th ed

MKL. (2004). Method No. 44. 6th ed

NMKL. (2009). Method No. 66. 5th ed. pg. 2

NMKL. (2013). Method No. 86. 5th ed.

Okpalugo, J., Ibrahim, K., Izebe, K. S., & Inyang, U. S. (2008). Aspects of microbial quality of some milk products in Abuja Nigeria. *Tropical Journal of Pharmaceutical Research*, *7*(4), 1169–1177.

Olorunnisomo, O. A., Ososanya, T. O., & Adedeji, O. Y. (2014). Homogenization of milk and its effect on sensory and physico-chemical properties of yoghurt. *African Journal of Food Science*, *8*(9), 465–470. https://doi.org/10.5897/AJFS2014.1181

Olugbuyiro, J. A. O., & Oseh, J. E. (2011). Physico-chemical and sensory evaluation of market yoghurt in Nigeria. *Pakistan Journal of Nutrition*, *10*(10), 914–918. https://doi.org/10.3923/pjn.2011.914.918

Onuorah, S., & Obika, I. (2016). Microbial Quality Assessment of Some Branded yoghurts Sold in Onitsha North local Government Area of Anambra State , Nigeria. *American Journal of Life Science Researches*, *4*(1), 1–6. https://doi.org/10.21859/ajlsr-0401012

Ortinau, L. C., Culp, J. M., Hoertel, H. a, Douglas, S. M., & Leidy, H. J. (2013). The effects of increased dietary protein yogurt snack in the afternoon on appetite control and eating initiation in healthy women. *Nutrition Journal*, *12*(1), 71. https://doi.org/10.1186/1475-2891-12-71

Pal, M., Tefera, M., Tasew, A., Jergefa, T., & Deressa, A. (2015). Hygienic and Microbial Quality of Yoghurt Hygienic and Microbial Quality of Yoghurt. *Beverage& Food World*, *42*(4), 25–31.

Peneau, S., Brockhoff, P. B., Escher, F., & Nuessli, J. (2007). A comprehensive approach to evaluate the freshness of strawberries and carrots. *Postharvest Biology and Technology*, *45*, 20–29. https://doi.org/10.1016/j.postharvbio.2007.02.001

Peri, C. (2006). The universe of food quality. *Food Quality and Preference*, *17*, 3–8. https://doi.org/:10.1016/j.foodqual.2005.03.002

Phosuksirikul, S., Chaipojjana, R., Leejeerajumnean, A., & Samples, A. F. M. (2014). The Relations of Volatile Compounds , Some Parameters and Consumer Preference of Commercial Fermented Milks in Thailand. *Internal Journal of Biological, Biomolecular, Agricultural, Food& Biotechnological Engineering*, *8*(9), 1069–1072.

Pohjanheimo, T., & Sandell, M. (2009). Explaining the liking for drinking yoghurt: The role of sensory quality, food choice motives, health concern and product information. *International Dairy Journal*, *19*(459–466). https://doi.org/10.1016/j.idairyj.2009.03.004

Rahman, M. M., Hossain, K. M., & Rahman, S. M. M. (2016). Isolation , characterization , and properties study of probiotic lactic acid bacteria of selected yoghurt from Bangladesh. *African Journal of Microbiology Research*, *10*(1), 23–31. https://doi.org/10.5897/AJMR2015.7750

Routray, W., & Mishra, H. N. (2011). Scientific and Technical Aspects of Yogurt Aroma and Taste : A Review. *Comprehensive Reviews in Food Science and Food Safety*, *10*(4), 208–220. https://doi.org/10.1111/j.1541-4337.2011.00151.x

Sanders, M. E. (2003). Probiotics : Considerations for Human Health. *Nutrition Reviews*, *61*(3), 91–99. https://doi.org/10.131/nr.2003.marr.91

Savaiano, D. . (2014). Lactose digestion from yogurt: mechanism and relevance. *The American Journal of Clinical Nutrition*, *99*(June), 1251S–1255S. https://doi.org/10.3945/ajcn.113.073023.1

Sfakianakis, P., & Tzia, C. (2014). Conventional and Innovative Processing of Milk for Yogurt Manufacture; Development of Texture and Flavor: A Review. *Foods*, *3*(1), 176–193. https://doi.org/10.3390/foods3010176

Sharma, R. (2014). Market Trends in Yogurt Products. Retrieved April 10, 2017, from http://www.dairyaustralia.com.au/~/media/f4e14ea5a41f4bd29c6881d0d0bcdec1.pdf

Sijtsema, S. J., Reinders, M. J., Hiller, S. R. C. H., & Dolors Guàrdia, M. (2012). Fruit and snack consumption related to sweet, sour and salty taste preferences. *British Food Journal*, *114*(7), 1032–1046. https://doi.org/10.1108/00070701211241608

Singham, P., Birwal P, & Bk, Y. (2015). Importance of Objective and Subjective Measurement of Food Quality and their Inter-relationship. *J Food Process Technol*, *6*(6). https://doi.org/10.4172/2157-7110.1000488

Spence, & Spence, C. (2015). On the psychological impact of food colour. *Spence Flavour*, *4*(21), 1–16. https://doi.org/10.1186/s13411-015-0031-3

Staff, M. . (1998). Cultured milk &Fresh cheeses. In R. Early (Ed.), *Technology of Dairy Products* (2nd ed., p. 138). London: Blackie Academic & Professionals. Retrieved from https://books.google.com.gh/books?id=BuR28Y-S4SMC&pg=PA136&lpg=PA136&dq=what+makes+yogurt+give+a+glossy+appearance&source=bl&ots=9jB2-RvkTg&sig=kReELzetAE_xHx_OIi2b5_4SvtA&hl=en&sa=X&ved=0ahUKEwi45aXjlqTUAhVHY1AKHZGqAH4Q6AEIIzAA#v=onepage&q=what makes yog

Takeuchi, Y., Nonoue, Y., Ebitani, T., Suzuki, K., Aoki, N., & Sato, H. (2007). QTL Detection for Eating Quality Including Glossiness , Stickiness , Taste and Hardness of Cooked Rice, *242*, 231–242.

Tarakci, Z., Ugur, A., Hasan, T., & Dag, B. (2013). Influence of yogurt adding on physicochemical and sensorial properties of some lettuce types. *Journal of Food, Agriculture and Environment*, *11*(2), 208–212.

Thompson, J. L., Lopetcharat, K., & Drake, M. A. (2007). Preferences for commercial strawberry drinkable yogurts among African American, Caucasian, and Hispanic consumers in the United States. *Journal of Dairy Science*, *90*(11), 4974–87. https://doi.org/10.3168/jds.2007-0313

The Dairy Council (2013). The Nutritional Composition of Dairy Products. London.

Tomaschunas, M. (2013). *Sensory and consumer-oriented studies on the effect of fat in different food matrices A comparison between yoghurt , vanilla custard , Lyon-style and liver sausages*. *PhD thesis Univ Hohemheim*. Retrieved from http://opus.uni-hohenheim.de/volltexte/2014/956/pdf/Dissertation_Tomaschunas.pdf#page=51

Tomic, N., Dojnov, B., Miocinovic, J., Tomasevic, I., Smigic, N., Djekic, I., & Vujcic, Z. (2017). Enrichment of yoghurt with insoluble dietary fiber from triticale – A sensory perspective. *LWT - Food Science and Technology*, *80*, 59–66. https://doi.org/10.1016/j.lwt.2017.02.008

Tribby, D. (2009). Yoghurt. In S. Clark, M. Costello, M. Drake, & F. Bodyfelt (Eds.), *The Sensory Evaluation of Dairy Products* (2nd ed., pp. 191–223). New York: Springer Science & Business Media. https://doi.org/10.1007/978-0-387-77408-4

USLegal, Inc. (2017). Nutritional Quality Law and Legal Definition |. Retrieved June 20, 2017, from https://definitions.uslegal.com/n/nutritional-quality/

Varga, L. (2007). Microbiological quality of commercial dairy products. *Communicating Current Research and Educational Topics and Trends in Applied Microbiology*, 487–494.

Wandel, M., & Bugge, A. (1996). ENVlRONMENTAL CONCERN IN CONSUMER EVALUATlON OF FOOD QUALITY. *Food Quality and Preference*, *8*(1), 19–26. Retrieved from http://ac.els-cdn.com/S0950329396000043/1-s2.0-S0950329396000043-main.pdf?_tid=8d1a6a72-2351-11e7-851f-00000aab0f6c&acdnat=1492422062_70ad2593c3e695d6de792775235356e7

Wang, N. S. (2017). Yogurt Fermentation with Lactobacillus Cultures. Retrieved March 14, 2017, from https://www.eng.umd.edu/~nsw/ench485/lab8.htm

Watson, J. (2017). Yogurt - Yoghurt Manufacturing - Making - Production. Retrieved March 13, 2017, from http://www.dairyconsultant.co.uk/si-yoghurt.php

Weerathilake, W. A. D. ., Rasika, D. M. ., J.K.U., R., & Munasinghe, M. A. D. . (2014). The evolution, processing, varieties and health benefits of yogurt. *International Journal of*

Scientific and Research Publications, *4*(4), 1–10. Retrieved from http://www.ijsrp.org/research-paper-0414/ijsrp-p2855.pdf

Worku, K. F., Tefera, A. T., & Tuji, F. A. (2015). Comparative Analysis of Microbial Load of Commercially Prepared and Traditionally Homemade Yoghurt (Ergo) Retailed in Addis Ababa. *Advances in Life Sciences*, *5*(3), 58–63. https://doi.org/10.5923/j.als.20150503.02

World Health Organization and Food and Agriculture Organization of the United States. (2011). Codex Standard for Fermented Milks - CODEX STAN-243-2003. *Codex Alimentarius*, 1–11. Retrieved from http://www.fao.org/docrep/015/i2085e/i2085e00.pdf

APPENDICES

APPENDIX 1.0: PRODUCTS CHARACTERISTICS

Table 1: Characteristics of commercial yoghurt brands

Product	PP	MS	FDA REG
A	Producer	CM	y
B	Producer	CM	n
C	Producer	CM	n
D	Producer	CM	n
E	Producer	CM	n
F	Producer	PM	n
G	Supermarket	CM	y
H	Supermarket	CM	n
I	Supermarket	CM	y
J	Supermarket	CM	y
K	Supermarket	CM	y
L	Supermarket	CM	n
M	Supermarket	CM	y
N	Supermarket	CM	n

Abbreviations: PP- place of purchase; MS- milk source; CM- cow milk; PM- powdered milk FDA REG- Food& Drugs Authority Registered; y- yes; n- no

APPENDIX 2.0: CONSUMER RECRUITMENT CRITERIA

AGE	18 years and above
GENDER	Male or Female
ALLERGIES	Should not be allergic to yoghurt made from fresh milk and reconstituted powdered milk
EDUCATION	Junior High School qualification and above
PROXIMITY	Must be able to commute to Nutrition& Food Science Sensory Lab on University of Ghana Campus, Legon
CONSUMPTION LEVEL	Must consume at least once in a month

APPENDIX 3.0a: CONSUMER CONSENT FORM

PROJECT TITLE: DEFINING QUALITY OF GHANAIAN-MADE YOGHURT

DATE: 22^ND September, 2016

INVESTIGATOR: Elma Kontor- Manu

PURPOSE OF STUDY

This is a research study being undertaken to determine consumer preferences for eight Ghanaian-made yoghurts.

WHAT WILL BE DONE

If you agree to participate, your involvement will last approximately 30 minutes. You will be asked to fill a short questionnaire to give some basic information. After this, you will be served with eight samples and asked to give your judgement. You will drink some water in between sample tasting to cleanse your palate.

BENEFITS/ RISK OF STUDY

There are no personal benefits from participating in this study. Allergic reaction or intolerance to yoghurt is a potential risk. Therefore if you are allergic or intolerant to yoghurt, you are not eligible to participate. The samples pose no harm since they have being tested and are safe.

CONFIDENTIALITY

Records of participation in this research will be kept confidential. All paperwork with your details will be coded with only the investigator having access to it. In the event of a publication from this study, your identity will not be disclosed; all results will be reported in a summarized manner in such a way that you cannot be identified.

WITHDRAWAL FROM STUDY

Taking part in this research study is voluntary. You may choose not to take part at all. If you agree to participate in this study, you may stop participating at any time. You may choose to decline to answer any question(s) you choose. If you decide not to take part, or if you stop participating at any time, your decision will not result in any penalty or loss of benefits to which you may otherwise be entitled. Any data collected from you prior to withdrawal will be destroyed and not included in the study results.

CONTACT FOR ADDITIONAL INFORMATION

If you have any questions about this research project, please contact Elma Kontor- Manu on 0206373943 or mail to elmak.manu@gmail.com or ekontor-manu001@st.ug.edu.gh. You could also contact my supervisor, Dr Maame Yaakwaah Adjei on 0545525974 or mail to myblay@ug.edu.gh for clarifications.

VOLUNTEER AGREEMENT

"I have read all of the above, asked questions, received answers regarding participation in this study, and am willing to give consent to participate in this study. I will not have waived any of my rights by signing this consent form. Upon signing this consent form, I will receive a copy for my personal records."

____

Name of Volunteer

_________________________ _______________

Signature of volunteer Date

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

____

Name of Person who obtained Consent

__________________________ _______________

Signature of Person who obtained consent Date

APPENDIX 3.0b: CONSUMER QUESTIONNAIRE

INTRODUCTION

You are required to provide some information as requested below (circle what applies)

Gender a) Male b) Female

Age

a. 18- 24
b. 25- 34
c. 35- 44
d. 45- 54
e. 55- 64
f. above 65

Ethnic background

a. Ewe
b. Akan-Forest areas (Akuapem, Akyem, Ashanti's, Sefwi, Bono, etc.)
c. Akan-Coastal areas (Fantes, Nzema, Ahanta etc.)
d. Guan
e. Northern
f. Ga/Adangbe
g. Other, please specify……………………………………

Highest educational level

a. School leaver
b. Junior High School
c. Senior High School
d. Tertiary
e. Postgraduate
f. Other, please specify………………………….

Profession

a. Professional/Managerial/Administrator
b. Skilled (Tradesman/Artisan)
c. Unskilled (Labourer)
d. Retired
e. Stay at Home
f. Between work

g. Business owner/Self employed
h. Producer(Farmer and Fisherman)
i. Uniformed(Military/Policeman/Fire service/Prisons)
j. Student
l. Other, please specify …………………………

How often do you drink yoghurt?

a. Everyday
b. Once a week
c. Once every two weeks
d. Once a month
e. Less than once a month

What is your most preferred yoghurt flavouring?

a. Vanilla
b. Strawberry
c. Pineapple
d. Banana
e. No added flavor
f. Other, please specify …………………………

APPENDIX 3.0c: CONSUMER BALLOT SHEET

BALLOT SHEET FOR PREFERENCE TEST

FLAVOURED YOGHURT

Taster Number: Date:

Session Code:

INSTRUCTIONS (please read before you start)

You have been provided with seven (7) yoghurt samples. Please observe the samples in the order presented from left to right.

You will be served with four samples first, after which you will be requested to fill a questionnaire. The last three samples will be served right after.

Please rinse your mouth with the water provided before tasting

Rinse your mouth with water between tasting of samples to cleanse palate

For each attribute, rate the samples on a 9-point hedonic scale from like extremely to dislike extremely using the following numbers:

1= dislike extremely
2=dislike very much
3= dislike moderately
4= dislike slightly
5= neither like nor dislike
6= like slightly
7= like moderately
8= like very much
9= like extremely

Please avoid communicating with any of the other participants during the session.

No ties are allowed (two or more samples should not have the same rank)

You can ask the server(s) for assistance

OVERALL LIKING

Sample _____ ______ ______ ______

Rank _____ ______ ______ ______

FILL QUESTIONNARE

OVERALL LIKING

Sample _____ ______ ______

Rank _____ ______ ______

APPENDIX 4.0: Residual plots for Analysis of Variances

One-way ANOVA: pH versus prdt

```
Method

Null hypothesis         All means are equal
Alternative hypothesis  At least one mean is different
Significance level      α = 0.05

Equal variances were assumed for the analysis.


Factor Information

Factor  Levels  Values
prdt         7  ANY4, AYJ2, DYJ2, FDAYY2, NYV2, PYF2, VYUG2


Analysis of Variance

Source  DF   Adj SS    Adj MS  F-Value  P-Value
prdt     6  1.35600  0.226000  1898.40    0.000
Error   14  0.00167  0.000119
Total   20  1.35767


Model Summary

        S    R-sq  R-sq(adj)  R-sq(pred)
0.0109109  99.88%     99.82%      99.72%


Means

prdt     N     Mean    StDev          95% CI
ANY4     3  4.83667  0.01528  (4.82316, 4.85018)
AYJ2     3  4.32667  0.01528  (4.31316, 4.34018)
DYJ2     3    4.400    0.000  (  4.386,   4.414)
FDAYY2   3    4.130    0.000  (  4.116,   4.144)
NYV2     3  4.69667  0.00577  (4.68316, 4.71018)
PYF2     3  4.18333  0.00577  (4.16982, 4.19684)
```

VYUG2	3	4.1800	0.0173	(4.1665, 4.1935)

Pooled StDev = 0.0109109

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

prdt	N	Mean	Grouping
ANY4	3	4.83667	A
NYV2	3	4.69667	B
DYJ2	3	4.400	C
AYJ2	3	4.32667	D
PYF2	3	4.18333	E
VYUG2	3	4.1800	E
FDAYY2	3	4.130	F

Means that do not share a letter are significantly different.

One-way ANOVA: %lactic acid versus prdt

Factor Information

Factor	Levels	Values
prdt	7	ANY4, AYJ2, DYJ2, FDAYY2, NYV2, PYF2, VYUG2

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
prdt	6	0.001728	0.000288	6.79	0.002
Error	14	0.000594	0.000042		
Total	20	0.002322			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0065137	74.42%	63.46%	42.44%

Means

prdt	N	Mean	StDev	95% CI
ANY4	3	0.09600	0.00520	(0.08793, 0.10407)
AYJ2	3	0.10800	0.00900	(0.09993, 0.11607)
DYJ2	3	0.12300	0.00520	(0.11493, 0.13107)
FDAYY2	3	0.12000	0.00520	(0.11193, 0.12807)
NYV2	3	0.11700	0.00900	(0.10893, 0.12507)
PYF2	3	0.11100	0.00520	(0.10293, 0.11907)
VYUG2	3	0.12300	0.00520	(0.11493, 0.13107)

Pooled StDev = 0.00651372

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

prdt	N	Mean	Grouping
VYUG2	3	0.12300	A
DYJ2	3	0.12300	A
FDAYY2	3	0.12000	A
NYV2	3	0.11700	A
PYF2	3	0.11100	A B
AYJ2	3	0.10800	A B
ANY4	3	0.09600	B

Means that do not share a letter are significantly different.

One-way ANOVA: Total plate count versus brand

Method

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
brand	7	ARIY, AYJ, DYJ, FDAYY, NYV, PYF, VYUG

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
brand	6	51.90	8.650	3.10	0.082
Error	7	19.53	2.790		
Total	13	71.43			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.67019	72.66%	49.23%	0.00%

Means

brand	N	Mean	StDev	95% CI
ARIY	2	10.6540	0.0436	(7.8614, 13.4466)
AYJ	2	4.7263	0.1033	(1.9336, 7.5189)
DYJ	2	8.09	4.41	(5.29, 10.88)
FDAYY	2	5.238	0.175	(2.445, 8.030)
NYV	2	8.0041	0.0182	(5.2115, 10.7967)
PYF	2	5.837	0.159	(3.044, 8.629)
VYUG	2	6.1046	0.0675	(3.3120, 8.8972)

Pooled StDev = 1.67019

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

brand	N	Mean	Grouping
ARIY	2	10.6540	A
DYJ	2	8.09	A
NYV	2	8.0041	A
VYUG	2	6.1046	A
PYF	2	5.837	A
FDAYY	2	5.238	A
AYJ	2	4.7263	A

Means that do not share a letter are significantly different.

One-way ANOVA: Total coliform count versus brand

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
brand	6	57.5124	9.58539	204.60	0.000
Error	7	0.3280	0.04685		
Total	13	57.8403			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.216449	99.43%	98.95%	97.73%

Means

brand	N	Mean	StDev	95% CI
ARIY	2	0.000000	0.000000	(-0.361912, 0.361912)
AYJ	2	4.114	0.000	(3.752, 4.476)
DYJ	2	0.000000	0.000000	(-0.361912, 0.361912)
FDAYY	2	0.000000	0.000000	(-0.361912, 0.361912)
NYV	2	4.5404	0.1317	(4.1784, 4.9023)
PYF	2	4.1417	0.0883	(3.7797, 4.5036)
VYUG	2	3.389	0.550	(3.027, 3.751)

Pooled StDev = 0.216449

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

brand	N	Mean	Grouping
NYV	2	4.5404	A
PYF	2	4.1417	A B
AYJ	2	4.114	A B
VYUG	2	3.389	B
FDAYY	2	0.000000	C
DYJ	2	0.000000	C
ARIY	2	0.000000	C

Means that do not share a letter are significantly different.

One-way ANOVA: Faecal coliform count versus brand

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
brand	6	0.4286	0.07143	1.00	0.492
Error	7	0.5000	0.07143		
Total	13	0.9286			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.267261	46.15%	0.00%	0.00%

Means

brand	N	Mean	StDev	95% CI
ARIY	2	0.000000	0.000000	(-0.446872, 0.446872)
AYJ	2	0.000000	0.000000	(-0.446872, 0.446872)
DYJ	2	0.000000	0.000000	(-0.446872, 0.446872)
FDAYY	2	0.000000	0.000000	(-0.446872, 0.446872)
NYV	2	0.000000	0.000000	(-0.446872, 0.446872)
PYF	2	0.000000	0.000000	(-0.446872, 0.446872)
VYUG	2	0.500	0.707	(0.053, 0.947)

Pooled StDev = 0.267261

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

brand	N	Mean	Grouping
VYUG	2	0.500	A
PYF	2	0.000000	A
NYV	2	0.000000	A
FDAYY	2	0.000000	A
DYJ	2	0.000000	A
AYJ	2	0.000000	A
ARIY	2	0.000000	A

Means that do not share a letter are significantly different.

One-way ANOVA: Staphylococcus count versus brand

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
brand	6	28.5260	4.75433	217.64	0.000
Error	7	0.1529	0.02184		
Total	13	28.6789			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.147800	99.47%	99.01%	97.87%

Means

brand	N	Mean	StDev	95% CI
ARIY	2	3.2763	0.0649	(3.0292, 3.5234)
AYJ	2	1.573	0.385	(1.326, 1.820)
DYJ	2	0.000000	0.000000	(-0.247127, 0.247127)
FDAYY	2	0.000000	0.000000	(-0.247127, 0.247127)
NYV	2	3.2171	0.0260	(2.9700, 3.4642)
PYF	2	0.000000	0.000000	(-0.247127, 0.247127)
VYUG	2	0.000000	0.000000	(-0.247127, 0.247127)

Pooled StDev = 0.147800

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

brand	N	Mean	Grouping
ARIY	2	3.2763	A
NYV	2	3.2171	A
AYJ	2	1.573	B
VYUG	2	0.000000	C
PYF	2	0.000000	C
FDAYY	2	0.000000	C
DYJ	2	0.000000	C

Means that do not share a letter are significantly different.