DEVELOPMENT OF A PEANUT-BASED BEVERAGE: PROMOTING PEANUT CONSUMPTION IN MALAWI AND POSSIBLY BEYOND

by

AGGREY PEMBA GAMA

(Under the Direction of Koushik Adhikari)

ABSTRACT

The main goal of the project was to develop a nutritious and acceptable peanut-based beverage as a way of promoting peanut consumption and management of undernutrition in Malawi. To achieve this goal, six studies were conducted. The first and second studies were aimed at understanding the factors influencing food choices and peanut consumption in Malawi. Mood, health, price, preparation convenience, sensory appeal, and familiarity were the main factors influencing the food choices of Malawian consumers. The diversity of peanut products was limited, and demographic and socioeconomic variables had significant effects ($p < 0.05$) on peanut product preferences. The third study focused on sensory characterization of key Malawi peanut varieties. A Virginia peanut variety (ICGV-SM 90704), locally known as Nsinjiro, had the desired properties and therefore, was used for the beverage formulation. In the fourth study, a mixture of xanthan gum (66%) and lecithin (34%), at a usage level of 0.5% by weight of the beverage, was identified as the best colloidal stabilization system for the peanut beverage. Study five focused on optimizing the peanut-beverage formulation and determining consumer acceptability of the beverage prototypes. The optimal concentrations of peanut paste and malted milk powder, in a two-component mixture (16% of beverage by weight), were 60% and 40%, respectively. Finally, nutrient compositions of the two highly acceptable (overall liking score ≥ 7.5) peanut-based beverages were determined. One of the beverages (PBV-SMMP) had sorghum malted milk powder while the other (PBV-BMMP) had barley malted milk powder in addition to peanut paste, sugar, salt, xanthan gum, and water. The PBV-SMMP had a better nutrient profile than PBV-BMMP. A 237-mL (8 oz.) serving of the PBV-SMMP was an excellent source (% DV ≥ 20) of high-quality protein, total dietary fiber, phosphorus, calcium, molybdenum, and manganese and also, a good source (10 ≤ % DV< 20) of potassium and magnesium. Based on acceptability results, both PBV-BMMP and PBV-SMMP can potentially increase peanut consumption in Malawi and in other countries where the beverages could be equally acceptable. Subsequently, the PBV-SMMP may help in the management of undernutrition given its nutritional profile.

INDEX WORDS: Peanuts, Peanut-based beverage, Product development, Malnutrition, Nutritional value, Sensory properties, Consumer acceptability, Malawi

DEVELOPMENT OF A PEANUT-BASED BEVERAGE: PROMOTING PEANUT CONSUMPTION IN MALAWI AND POSSIBLY BEYOND

by

AGGREY PEMBA GAMA

B.S., University of Malawi, Malawi, 2007

M.S., University of Leeds, United Kingdom, 2012

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2019

DEVELOPMENT OF A PEANUT-BASED BEVERAGE: PROMOTING PEANUT CONSUMPTION IN MALAWI AND POSSIBLY BEYOND

by

AGGREY PEMBA GAMA

Major Professor: Koushik Adhikari
Committee: Casimir C. Akoh
Yen-Con Hung
Ronald B. Pegg
David A. Hoisington

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
May 2019

DEDICATION

To my wife Carol, my son Delight, and my daughter Rejoice. I shall always cherish your love and support.

ACKNOWLEDGEMENTS

I extend sincere thanks to my major advisor Dr. Koushik Adhikari for his remarkable guidance and encouragement. I thank my advisory committee members Dr. Casimir C. Akoh, Dr. Yen-Con Hung, Dr. Ronald B. Pegg, and Dr. David A. Hoisington for their valuable input and guidance. This study was made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of the Legume Scholars Associate Award, Cooperative Agreement Award No. AID-OAA-LA-17-00002, of the Feed the Future Innovation Lab for Collaborative Research on Grain Legumes AID-EDH-A-00-07-00005-00. The contents do not necessarily reflect the views of USAID or the United States Government. I also appreciate the cooperation and help of Paula Scott, Sue Ellen McCullough, Glenn Farrell, and my wonderful lab mates, Juyoung Kim and Shangci Wang. Above all, although words cannot suffice, I thank God for being faithful to His promises.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

As in many other countries within Sub-Saharan Africa (SSA), malnutrition, especially undernutrition, still remains a challenge in Malawi. A recent Malawi demographic and health survey has revealed that among children under the age of five, 37% are stunted, 11% are severely stunted, 12% are underweight, 3% are severely underweight and 64% are anemic [1]. Currently, the prevalence of iron, folate, zinc and vitamin A deficiencies have been estimated at 48.6%, 49.5%, 53.4% and 69.9%, respectively [2]. To reduce the prevalence rates of undernutrition, the Malawi Government is promoting dietary diversification by supporting production and access to highly nutritious foods [3]. Among the highly nutritious foods that Malawi is promoting are legumes, such as peanuts [4]. Unfortunately, despite the adequate supply, consumption of peanuts in Malawi is low (4.98kg/capita/yr.) [5].

Studies have shown that the development of acceptable food products is useful in promoting consumption of the ingredients [6]. For instance, development of peanut butter greatly improved consumption of peanuts in the United States (U.S.). Peanut butter currently accounts for about half of the edible form of peanuts in the country [7]. The same trend has been observed in other products. In a study on soybean consumption patterns in the United States of America (U.S.), it was found that consumption of soybean has been on the increase following the introduction of soy products, including tofu, soy milk, soy cheese, energy bars, and meat alternatives [8]. However, differences were noted when consumption trends for the individual soy food products were compared against each other. Perceived attributes of soy food products by consumers affected both consumption frequency and consumption quantity [8]. In Canada, it was found that when flavored milk was not an option, many children did not drink white (plain) milk [9]. These trends highlight the importance of sensory characteristics of foods. The sensory appeal of food is one of the dominant food choice motives irrespective of geographical, cultural or socioeconomic differences [10-14].

The main goal of the study was to develop a nutritious and acceptable peanut-based beverage for Malawi with the hope that it will lead to an increased consumption of peanuts. Compared to solid and semi-solid foods, beverages are easy to digest, appeal to all age groups, are convenient, and can be easily delivered in multiple flavor options. The specific objectives were to 1) determine the factors that influence food choices of Malawian consumers, 2) identify a peanut consumption pattern for Malawi, 3) determine the sensory properties of the six dominant Malawi peanut varieties, 4) determine an optimal colloidal stabilization system for a peanut-based beverage, 5) determine an optimal peanut-based beverage formulation for Malawian consumers, and 6) determine sensory and nutritional properties of the developed peanut-based beverage.

References

1. NSO (2016) Malawi Demographic and Health Survey Report. National Statistical Office. http://www.dhsprogram.com/pubs/pdf/PR73/PR73.pdf. Accessed 24 June 2016.

2. Verduzco-Gallo I, Ecker O, Pauw K (2014) Changes in food and nutrition security in Malawi: Analysis of recent survey evidence, vol 6. International Food Policy Research Institute.

3. MGDS-II (2011) Malawi Growth and Development Strategy. Malawi Government. http://www.mw.one.un.org/wp-content/uploads/2014/04/Malawi-Growth-and-Dedvelopment-Strategy-MGDS-II.pdf. Accessed 15 February 2017.

4. ASWAP (2011) Malawi Agricultural Sector Wide Approach. . ftp://ftp.fao.org/tc/tca/CAADP%20TT/CAADP%20Implementation/CAADP%20Post-Compact/Investment%20Plans/National%20Agricultural%20Investment%20Plans/Malawi%20Post%20Compact%20Investment%20Plan.pdf. Accessed 13 December 2015.

5. FAOSTAT (2014) Malawi Food Balance Sheet. http://www.fao.org/faostat/en/#data. Accessed 13 December 2015.

6. Delisle H (1990) Patterns of urban food consumption in developing countries: perspective from the 1980s. FAO. ftp://ftp.fao.org/es/esn/nutrition/urban/delisle_paper.pdf. Accessed 12 October 2015.

7. NPB (2015) History of Peanuts and Peanut Butter. National Peanut Board. http://nationalpeanutboard.org/peanut-info/history-peanuts-peanut-butter.htm. Accessed 16 March 2017.

8. Rimal A, Moon W, Balasubramanian SK. (2008). Soyfood consumption patterns: effects of product attributes and household characteristics. Journal of Food Distribution Research 39 (3):67-78

9. Henry C, Whiting SJ, Phillips T, Finch SL, Zello GA, Vatanparast H. (2015). Impact of the removal of chocolate milk from school milk programs for children in Saskatoon, Canada. Applied Physiology, Nutrition, and Metabolism 40 (3):245-250

10. Eertmans A, Victoir A, Notelaers G, Vansant G, Van den Bergh O. (2006). The Food Choice Questionnaire: Factorial invariant over western urban populations? Food quality and preference 17 (5):344-352

11. Fotopoulos C, Krystallis A, Vassallo M, Pagiaslis A. (2009). Food Choice Questionnaire (FCQ) revisited. Suggestions for the development of an enhanced general food motivation model. Appetite 52 (1):199-208

12. Januszewska R, Pieniak Z, Verbeke W. (2011). Food choice questionnaire revisited in four countries. Does it still measure the same? Appetite 57 (1):94-98

13. Jáuregui-Lobera I, Ríos PB. (2011). What motivates the consumer’s food choice? Nutricion Hosppitalaria 26 (6):1313-1321

14. Prescott J, Young O, O'neill L, Yau N, Stevens R. (2002). Motives for food choice: a comparison of consumers from Japan, Taiwan, Malaysia and New Zealand. Food quality and preference 13 (7):489-495

CHAPTER 2

LITERATURE REVIEW

Peanuts

Peanuts, also known as groundnuts (*Arachis hypogaea*), originated in South America and are now among the important oilseed crops in the world [1]. Besides being a source of nutrients for both humans and animals, peanuts also improve soil health through their ability to fix atmospheric nitrogen into the soil [2]. Therefore, peanuts are important in sustainable agriculture systems and are valuable in crop rotations. Over the past years, world peanut production has been steadily increasing and is currently estimated at 47.1 million with China, India, Nigeria, and the United States of America (U.S.) being the top producers. Peanuts are even more important in developing countries [3]. As shown in Figure 2.1, of the total world peanut production, 91.4% comes from Asia and Africa [3]. Considering the total peanut production in Africa, almost half (48.8%) of the peanuts are grown in Western Africa [3].

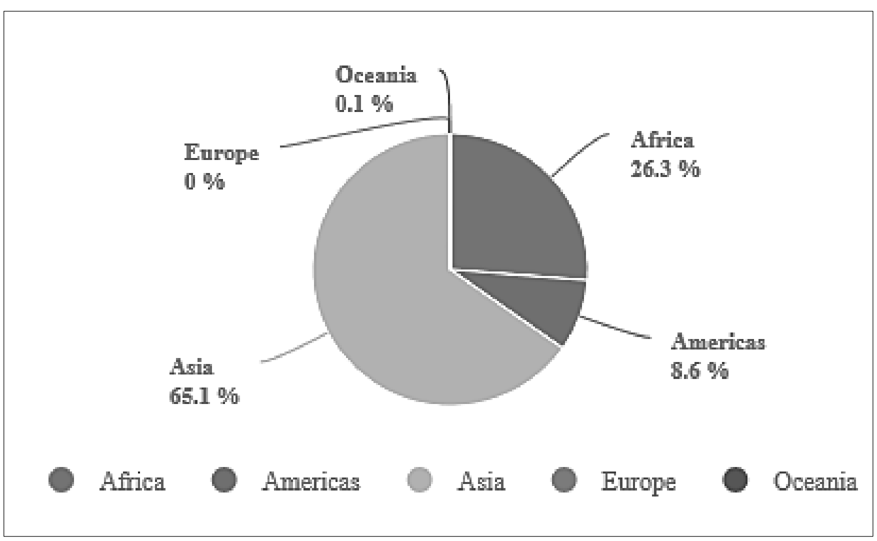

Figure 2.1. World peanut production by regions [3].

In Malawi, peanuts are the most widely cultivated legume accounting for 25% of the income of smallholder farmers [4]. Malawi is sub-divided into eight agro-ecological zones. These ecological zones form the Agricultural Development Divisions (ADDs), and peanuts are grown in most of the ADDs. However, peanut production is concentrated in the central part of Malawi as shown in Figure 2.2 [4].

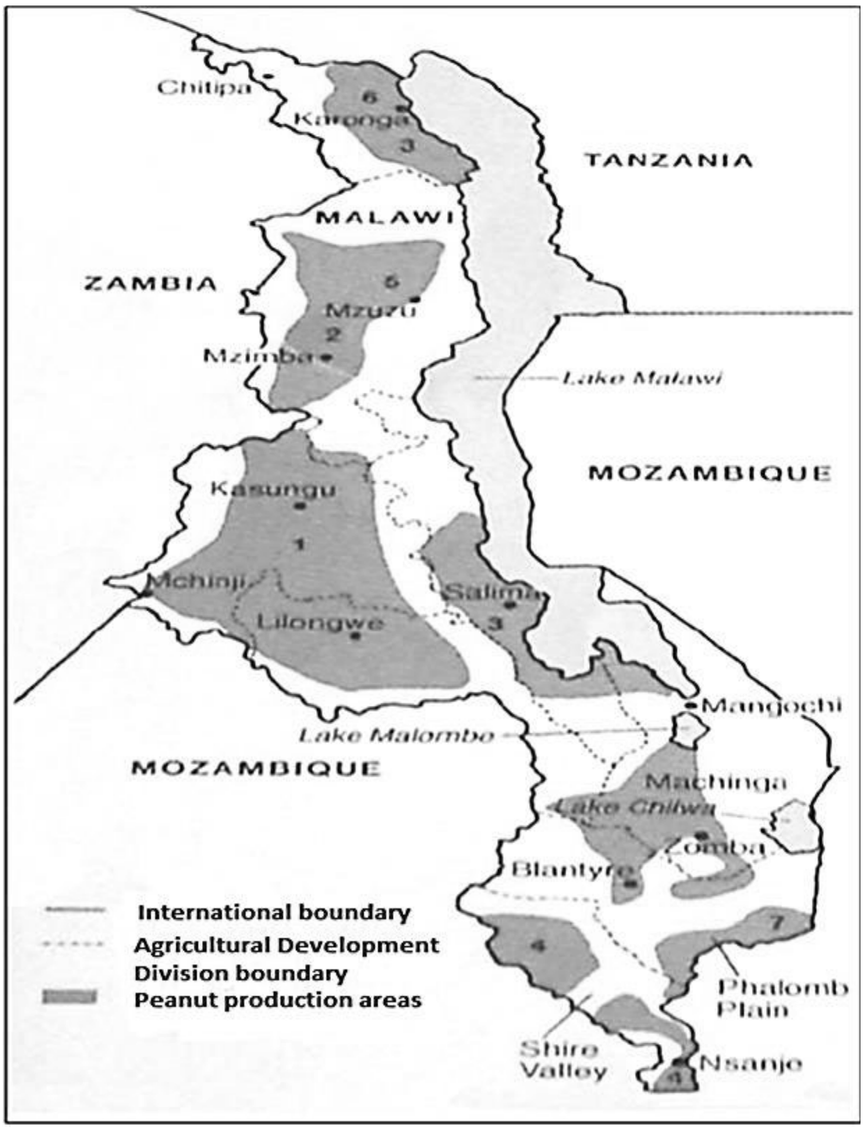

Figure 2.2. Peanut production areas in Malawi [4].

Many different peanut varieties are grown throughout the world but, they mostly fall under four main market types. The four market types are Runner, Virginia, Spanish, and Valencia [5]. The market types have some differences in terms of seed size, flavor, and nutrient composition [6]. As a result, the peanuts also differ in their utilization. For examples, Runners are mostly used for peanut butter production in the U.S. while Virginia peanuts are mostly used for snack products like roasted peanuts due to their large kernel sized [6]. Spanish peanuts are better suited for oil extraction due to their high oil content, and Valencia peanuts are more suited for all natural peanut butter and fresh use as boiled peanuts, among other snacks, since they are sweet [6].

Since 1968, over 14 peanut varieties (Virginia, Spanish, and Valencia market types) have been released in Malawi and improvements in resistance to rosette, wide adaptation, and yield maximization have been achieved [7]. Although high oleic peanut varieties are being grown in other countries like the U.S. [8], such peanut varieties are not available in Malawi. Currently, based on adoption rates by farmers, Chalimbana, CG7, Nsinjiro, Kakoma, Baka, and Chitala are the dominant Malawi peanut and are shown in Table 2.1 [9].

Table 2.1. Description of the dominant Malawi peanut varieties.

Variety	Market type	Year released	100 seed weight (g)	Adoption (%)
Chalimbana (Local)	Virginia	1968	81	39
CG7 (ICGV-SM 83708)	Virginia	1990	62	30
Nsinjiro (ICGV-SM 90704)	Virginia	2000	45	20
Kakoma (JL 24)	Spanish	2000	45	7
Baka (ICG 12991)	Spanish	2001	36	0.5
Chitala (ICGV-SM 99568)	Spanish	2005	45	0.2

Unlike the agronomic and proximate nutrient composition information, little is known about the sensory properties of the Malawi peanut varieties. One of the primary drivers of peanut consumption is the sensory appeal, especially flavor after thermal processing [10].

However, just like the nutrient composition of peanuts, studies have shown that flavor in peanuts is also affected by genotype, among other factors [11,12]. For instance, Lykomitros et al. [13] found that Virginia type peanuts develop more intense roasted aromas than Runner-type peanuts, and this was attributed to possible differences in the concentrations of Maillard reaction precursors. Such differences have also been reported in several other studies comparing flavor profiles of peanuts from different origins, market types, varieties, and grades [14-18]. Therefore, sensory profiling of the Malawi peanut varieties can potentially influence peanut utilization, and is valuable, especially to food product developers. Plant breeders could also use the same information to inform new projects aimed at improving the sensory properties of the peanut varieties. It is hypothesized that different Malawi peanut varieties will have different sensory properties.

Peanuts and nutrition

Malnutrition, as a result of deficient or excess intake of energy, macronutrients, and micronutrients remains a global challenge [19,20]. Unlike excess intake, a deficient intake of nutrients (undernutrition) is more prevalent in developing countries especially among children [21]. Worldwide, 52 million under-five children are wasted (low weight for height), 17 million are severely wasted, and 155 million are stunted (low height for age) [20]. More than 90% of the stunted children in the world live in Africa and Asia as shown in Figure 2.3 [22]. Approximately, 45% of deaths among children aged below five years are related to undernutrition especially in developing countries [20].

In Malawi, the prevalence rate for undernutrition is higher than the average rate for Africa. A recent Malawi demographic and health survey has revealed that among the children under the age of five, 37% are stunted, 11% are severely stunted, 12% are underweight, 3% are severely underweight, and 64% are anemic [23]. Currently, the prevalence of iron, folate, zinc, and vitamin A deficiency has been estimated to be 48.6%, 49.5%, 53.4%, and 69.9% respectively [24].

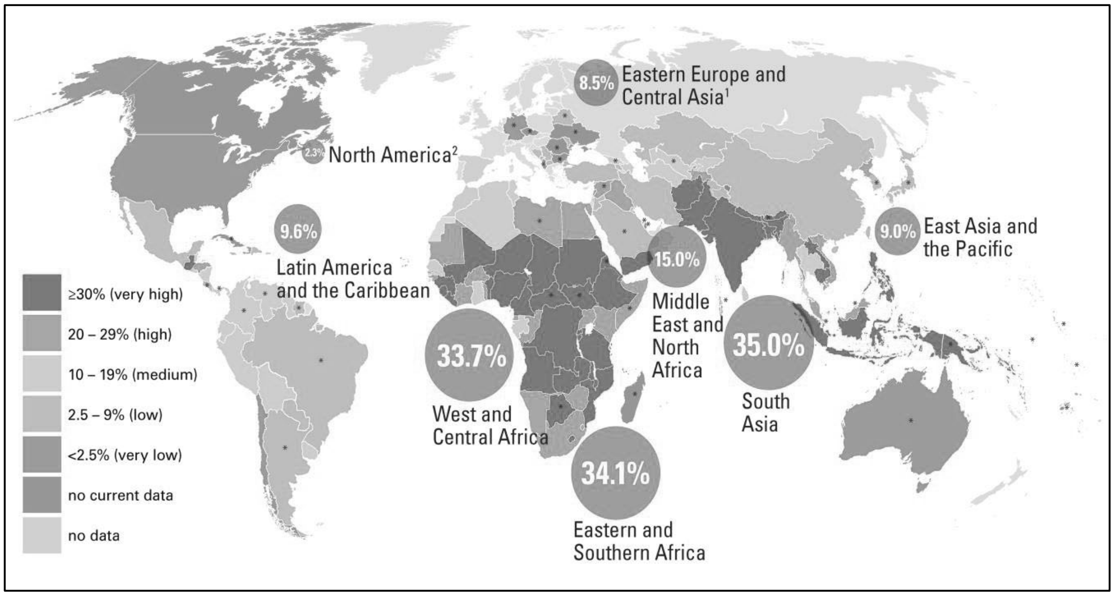

Figure 2.3. Prevalence rates of stunting in children [22].

To address the malnutrition challenge, the United Nations (UN) declared the years 2016 to 2025 as a decade for action on nutrition [20]. Currently, WHO is working with UN member States and other partners to achieve "universal access to effective nutrition interventions and healthy diets from sustainable and resilient food systems" [20]. Among the sustainable, resilient, and nutritious food sources are legumes like peanuts [25,26]. Peanuts are a valuable source of proteins, fats, vitamins, and minerals for human and animal nutrition. Peanuts, on average, contain 48% fat, 26% protein, 17% carbohydrates, 2% fiber, 2% ash and 1% of vitamins, and minerals which include vitamin E, niacin, folate, manganese, magnesium and phosphorus [27,28]. As a result, peanuts are used in formulations of ready-to-use therapeutic foods (RUTFs) for treating malnutrition [29,30]. Peanuts also contain bioactive substances such as flavonoids, resveratrol, and plant sterols which have been associated with decreased risk of coronary heart disease (CHD) and reduced cancer risk [31,32]. Many studies have been done on the health benefits deriving from peanut consumption. For instance, Griel et al. [33] found that peanut users have a higher intake of micronutrients, lower intake of saturated fat and cholesterol, and lower BMI despite peanuts being energy dense. FAO [34] postulated that daily consumption of a handful (~30g) of peanuts could be helpful in the management of malnutrition in developing countries.

Although consumption of peanuts has many health benefits, peanuts, in general, are deficient in some minerals like calcium, and indispensable amino acids, especially lysine, threonine and methionine [35]. To correct the nutrient imbalance, blending of peanuts with milk, cereals, or with other legumes like soy is recommended [35]. Unfortunately, soy has more anti-nutrition factors and the soy proteins induce undesirable flavors, which negatively affects consumer acceptability [36-38]. Therefore, a blend of peanuts and milk may have better nutritional and sensory properties.

Utilization of peanuts

Utilization of peanuts, globally, varies from region to region. Peanuts can be eaten raw, used in recipes as an ingredient, or made into cooking oil, peanut butter, candy bars, and cookies, among other products [39]. Peanuts are also used in formulating ready-to-use therapeutic foods (RUTFs) such as Plumpy'Nut by Nutriset, for treating malnutrition [29,30]. George Washington Carver is credited for his great contribution to the development of peanut products. His research developed 300 products and 105 ways of using peanuts in soups, puree, bread, candy, cheeses, coffee, cookies, cakes, puddings, ice creams, cutlets, patties, sausages, omelets, macaroni, stuffing, wafers, bars, and doughnuts, among others [40]. At the University of Georgia, peanuts have been used to develop products like white and whole peanut bread, cookies, cakes, doughnuts, yeast products, pies, desserts, peanut milk, yoghurt, cheese type products, soups, peanut burgers, peanut noodles, fermented peanut pastes, coated nuts, RUTFs, and beverages, among others [40].

Worldwide, peanuts are mostly consumed in solid (snacks) or semi-solid form (pastes) and rarely as a liquid in the form of beverage. Compared to solid and semi-solid foods, beverages are convenient, easy to digest, appeal to all age groups, and can be easily delivered in multiple flavor options. Therefore, peanut-based beverages have a higher potential of promoting peanut consumption more especially now that consumers are more interested in beverages that have health benefits [41,42]. Considering the competitive advantage of beverages over solid and semi-solid foods, development studies of peanut-based beverages have been on-going for many years, with notable continual improvements in the physicochemical, nutritional and sensory characteristics of the resultant products [36,43-47]. Just in 2018, peanut "milk" manufactured by Steuben Foods Inc., Elma, NY, USA and marketed as Elmhurst milked peanuts was launched in the U.S. However, there are no published reports regarding the sensory properties of the product. Depending on the ingredients, peanut-based beverages can be complex colloidal systems which ultimately affect the sensory properties of the beverage. To overcome some of these challenges, previous studies have used defatted peanut flour [36,45,48] or peanut protein isolates [43,47] in formulating the beverage. However, there are still challenges especially with the sensory properties and ultimately, the consumer acceptability of the peanut-based beverages. As a result, peanut-based beverages are rarely found on the market, even in developed countries. It is hypothesized that through product optimization techniques, it is possible to develop an acceptable and stable peanut-based beverage even when non-defatted peanuts are used.

In Malawi, it is estimated that of the total peanut production, 36% is directly consumed, 30% is used by manufacturing industry, 17% is exported as a primary commodity, 9% is used for seed, and 8% is wasted [49]. Figure 2.4 shows an overview of the peanut value chain in Malawi. Peanuts have been part of the Malawian diet for many years mostly as an ingredient in traditional dishes. In most Malawian households, peanuts are mostly consumed as flour in relish and porridge, and some are just boiled or roasted [50]. According to FAOSTAT [49], the average annual consumption of peanuts (shelled equivalent) per person in Malawi is 4.98 kg (~13g/day), and this is low. The reasons behind the low peanuts consumption are not known because peanut consumption patterns, consumption frequencies, and the factors influencing peanut consumption in Malawi have not been determined. It is hypothesized that socioeconomic variables are affecting peanut consumption in Malawi.

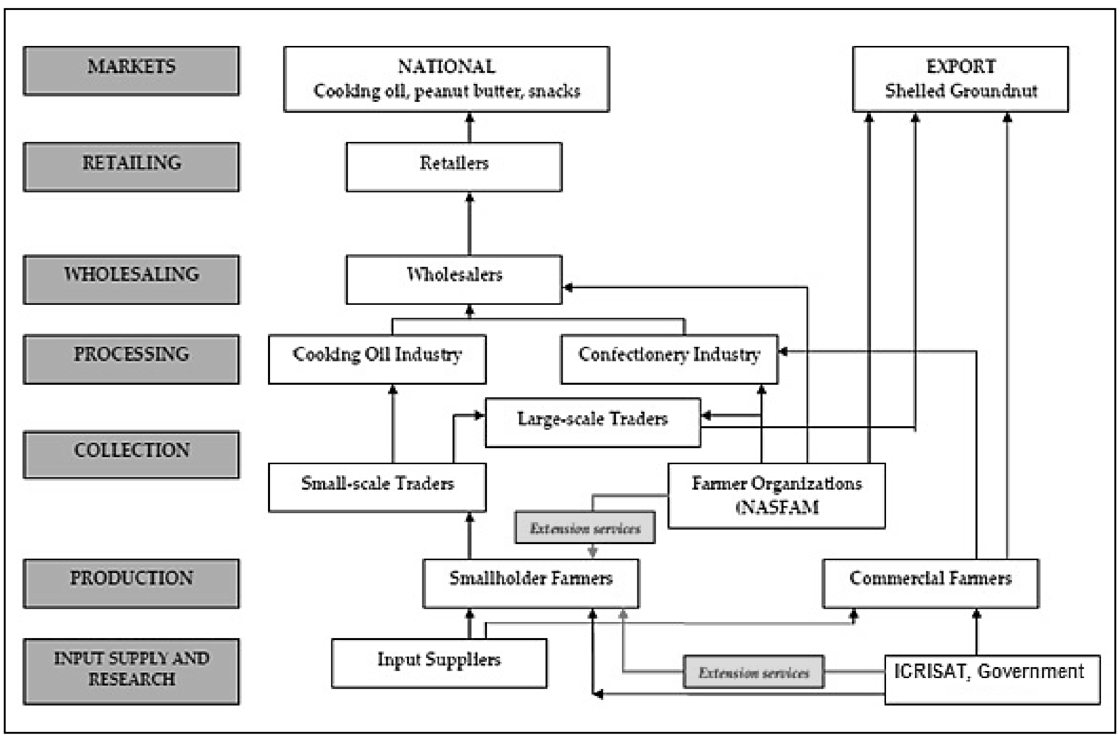

Figure 2.4. Peanut value chain in Malawi [50].

Food product development and consumption

Development of attractive, convenient and acceptable processed foods is useful in promoting consumption [4]. For instance, in a study on soy consumption patterns in the U.S. by Rimal et al. [51] showed that consumption of soy has been on the increase with the introduction of soy products including tofu, “soymilk,” soy cheese, energy bars, and meat alternatives. Likewise, the development of peanut butter significantly improved consumption of peanuts in the U.S. Peanut butter currently accounts for about half of the edible form of peanuts in the country [52]. In a study on flavored milk in the U.S. by Patterson et al. [53], it was found that removing flavored milk from schools resulted in a 62% reduction in milk consumption by kids in kindergarten through 5th grade, a 50% reduction in milk consumption by adolescents in 6th through 8th grades, and a 37% reduction in milk consumption in adolescents in 9th through 12th grades. In another study in Canada, it was also found that when flavored milk was not an option, many children did not take white (plain) milk or if they did, they frequently threw it away[54]. These trends highlight the vital role of food product development in promoting consumption which eventually creates demand for raw materials such as agricultural commodities. Therefore, the development of more acceptable peanut-based products can promote consumption as well as the agricultural production of peanuts.

Role of consumers in product development

The success of any new product ultimately depends on the consumer. To develop successful new products, the voice of the consumer must be heard and incorporated into the product design [55]. Consumers have needs and wants. Prospects of success are high if a product satisfies the consumer needs and wants [56]. Ulwick [57] argued that consumers do not know what they want such that trying to ask them what they want may be a waste of time. However, even though consumers may not always be able to express their wants, it is important to understand how they perceive products, how their needs are shaped and influenced and how they make product choices [55]. This is why consumer perceptions, wants, and needs are incorporated in the product development process as shown in Figure

2.5. If more consumers are satisfied with the product, there will be more demand resulting in business growth and increased demand for the raw materials.

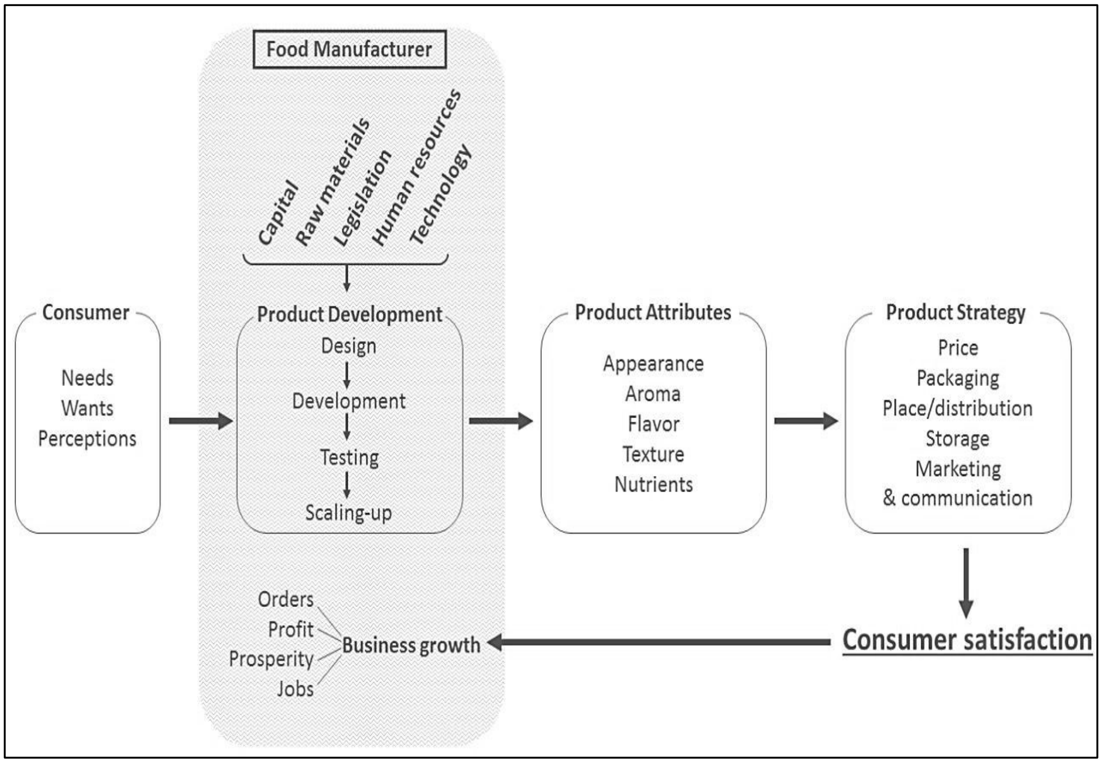

Figure 2.5. Overview of new food product development process.

Besides the use of consumer insights in product development, understanding consumer needs, wants and perceptions also help in developing effective health nudging strategies. Food choices of consumers have health-related implications [19,58]. Currently, most governments are using health nudging to steer people toward healthy food choices [59]. Nudges are approaches to law and policy that steer people in specific directions without compromising the people's freedom of choice [58]. Therefore, an understanding of why people eat what they eat could help in identifying hindrances to food consumption, and possible ways of promoting the consumption of certain foods.

Many studies on food choice determinants, mainly in Europe and Asia, have been done using a 36 item Food Choice Questionnaire (FCQ) developed by Steptoe et al. [60]. Health, mood, sensory appeal, natural content, familiarity, weight control, price, convenience, and ethical concern were identified as the factors that potentially influence the food choices of consumers [61-64]. In these studies, some variations across nationalities, in both the dominant food choice motives and the factor structures, were also observed. Besides the evidence that food choice determinants vary across nationalities, such studies have not been done in Sub-Saharan Africa, including Malawi. It is hypothesized that Malawian consumers are different from those in developed countries such that both the factor structure and factor ranking will be different from what was found by Steptoe et al. [60] in Britain.

Food product formulation and optimization

Most food products contain multiple ingredients and therefore, they are mixtures. As a result, mixture designs are usually used during food product formulation when trying to find blends of two or more ingredients that would give the desired product properties [65]. In a mixture design, the response is assumed to depend only on the relative proportions of the ingredients present in the mixture. The total amount is held constant, and the value of the response changes when the proportions of the ingredients making up the mixture changes [65]. Therefore, unlike in factorial designs, the change in the response is a function of the joint blending property of the ingredients in the mixture.

The process of identifying a combination of ingredients that give the maximum desired response or produces a sensory perception similar to a targeted benchmark is called optimization [66]. When a benchmark or predesignated sensory profile is known, product matching is used. Product matching is a well-known sensory technique used to compare sensory characteristics of a product, especially after reformulation [67]. The need for reformulation could be necessitated by the change of ingredient suppliers, change of ingredients to meet emerging consumer preferences or part of a product improvement strategy among others.

In food product development the most common goal is to maximize consumer acceptability, and this is determined through affective tests. To identify drivers of consumer acceptability, food products are usually characterized using trained panelists and instrumental techniques[68]. However, there are other novel methods for sensory characterization of food products using consumers during product development. These methods were developed to speed up the food product development process and to reduce costs associated with descriptive and instrumental analyses[69,70]. Two of these methods involve the use of a check-all-that-apply (CATA) question and Just-About-Right (JAR) scale, respectively [71]. CATA is one of the most novel, simple, reproducible and valid options for sensory characterization of a wide range of products using consumers [70]. The consumers are asked to select from a list of terms all those that they consider as applicable for describing a sample. Although CATA is easy and provides valid and repeatable information [72,73], it does not enable the product developer to identify the preferred intensity of the sensory attributes. Therefore, it is difficult to make adjustments to the formulation [71]. Unlike CATA, JAR provides information on sensory attribute intensities. By using the JAR question, a product developer can determine the optimum intensity of a sensory attribute by asking consumers if they consider a sensory attribute to be too strong, too weak or just-about-right [74]. Therefore, concurrent use of both CATA and JAR questions during food product development could provide more insights into the consumers' hedonic responses.

References

1. Fletcher SM, Shi Z (2016) An overview of world peanut markets. In: Peanuts. Elsevier, pp 267-287
2. Peoples M, Herridge D, Ladha J (1995) Biological nitrogen fixation: an efficient source of nitrogen for sustainable agricultural production? In: Management of Biological Nitrogen Fixation for the Development of More Productive and Sustainable Agricultural Systems. Springer, pp 3-28
3. FAOSTAT (2017) Groundnuts production http://www.fao.org/faostat/en/#data/QC. Accessed 31 March 2019
4. FAO (2012) Analysis of incentives and disincentives for groundnuts in Malawi. . http://www.fao.org/3/a-at565e.pdf. Accessed 12 December 2015
5. Barkley NA, Upadhyaya HD, Liao B, Holbrook CC (2016) Global resources of genetic diversity in peanut. In: Peanuts. Elsevier, pp 67-109
6. NPB (2018) Peanuts Fun Facts. https://www.nationalpeanutboard.org/peanut-info/fun-facts.htm. Accessed 13 February 2018
7. Saka A, Mtukuso A, Daudi A (2006) Agricultural Technologies Released by the Ministry of Agriculture and Food Security-2000-2005.
8. Derbyshire E (2014) A review of the nutritional composition, organoleptic characteristics and biological effects of the high oleic peanut. International journal of food sciences and nutrition 65 (7):781-790
9. ICRISAT (2013) Tropical Legume Farming in Malawi. http://www.icrisat.org/TropicalLegumesII/pdfs/November-2013.pdf. Accessed 13 January 2016

10. Schirack A, Drake M, Sanders T, Sandeep K (2006) Characterization of Aroma-Active Compounds in Microwave Blanched Peanuts. Journal of food science 71 (9)

11. Sanders T, Pattee H, Vercellotti J, Bett K (1995) Advances in peanut flavor quality. Advances in peanut science:528-553

12. Neta E, Sanders T, Drake M (2010) Understanding peanut flavor: a current review. Handbook of fruit and vegetable flavors:985

13. Lykomitros D, Fogliano V, Capuano E (2016) Flavor of roasted peanuts (Arachis hypogaea)-Part I: Effect of raw material and processing technology on flavor, color and fatty acid composition of peanuts. Food Research International 89:860-869

14. Bett K, Vercellotti J, Lovegren N, Sanders T, Hinsch R, Rasmussen G (1994) A comparison of the flavor and compositional quality of peanuts from several origins. Food chemistry 51 (1):21-27

15. Isleib TG, Pattee HE, Tubbs RS, Sanders TH, Dean LO, Hendrix KW (2015) Intensities of sensory attributes in high-and normal-oleic cultivars in the uniform peanut performance test. Peanut Science 42 (2):83-91

16. Pattee H, Isleib T, Gorbet D, Giesbrecht F (2002) Sensory comparison of runner peanut market grades from selected varieties. Peanut Science 29 (2):146-149

17. Young ND, Sanders TH, Drake MA, Osborne J, Civille GV (2005) Descriptive analysis and US consumer acceptability of peanuts from different origins. Food quality and preference 16 (1):37-43

18. Ng EC, Dunford NT (2009) Flavour characteristics of peanut cultivars developed for southwestern United States. International journal of food science & technology 44 (3):603-609

19. WHO (2016) The Double Burden of Malnutrition. http://apps.who.int/iris/bitstream/10665/255413/1/WHO-NMH-NHD-17.3-eng.pdf?ua=1. Accessed 14 July 2017

20. WHO (2018) Malnutrition. https://www.who.int/news-room/fact-sheets/detail/malnutrition. Accessed 2 January 2019

21. WHO (2011) WHO, nutrition experts take action on malnutrition. https://www.who.int/nutrition/pressnote_action_on_malnutrition/en/. Accessed 2 January 2019

22. UNICEF (2018) Levels and trends in child malnutrition. https://www.who.int/nutgrowthdb/jme_unicef_who_wb.pdf. Accessed 2 January 2019

23. NSO (2016) Malawi Demographic and Health Survey Report. National Statistical Office. http://www.dhsprogram.com/pubs/pdf/PR73/PR73.pdf. Accessed 24 June 2016

24. Verduzco-Gallo I, Ecker O, Pauw K (2014) Changes in food and nutrition security in Malawi: Analysis of recent survey evidence, vol 6. International Food Policy Research Institute,

25. Foyer CH, Lam H-M, Nguyen HT, Siddique KH, Varshney RK, Colmer TD, Cowling W, Bramley H, Mori TA, Hodgson JM (2016) Neglecting legumes has compromised human health and sustainable food production. Nature plants 2 (8):16112

26. FAO (2014) Healthy and sustainable food systems are crucial to fight hunger and malnutrition. http://www.fao.org/news/story/en/item/212554/icode/. Accessed 2 January 2019

27. Davis JP, Dean LL (2016) Peanut composition, flavor and nutrition. In: Peanuts. Elsevier, pp 289-345

28. Ronzio RA (2003) The encyclopedia of nutrition and good health. Infobase Publishing,

29. UNICEF (2017) Ready-to-use Therapeutic Food: Current Outlook. https://www.unicef.org/supply/files/Ready-to-use_Therapeutic_Food_Current_Outlook.pdf. Accessed 4 March 2019

30. Wagh VD, Deore BR (2015) Ready to use therapeutic food (RUTF): An overview. Advances in Life Sciences and Health 2 (1):1-15

31. Awad AB, Chan KC, Downie AC, Fink CS (2000) Peanuts as a source of β-sitosterol, a sterol with anticancer properties. Nutrition and cancer 36 (2):238-241

32. Sanders TH, McMichael RW, Hendrix KW (2000) Occurrence of resveratrol in edible peanuts. Journal of agricultural and food chemistry 48 (4):1243-1246

33. Griel AE, Eissenstat B, Juturu V, Hsieh G, Kris-Etherton PM (2004) Improved diet quality with peanut consumption. Journal of the American College of Nutrition 23 (6):660-668

34. FAO (1990) Patterns of Urban Food Consumption in Developing Countries: Perspective from the 1980's ftp://ftp.fao.org/es/esn/nutrition/urban/delisle_paper.pdf. Accessed 21 December 2015

35. Singh B, Singh U (1991) Peanut as a source of protein for human foods. Plant Foods for Human Nutrition 41 (2):165-177

36. Deshpande R, Chinnan M, McWatters K (2008) Optimization of a chocolate-flavored, peanut–soy beverage using response surface methodology (RSM) as applied to consumer acceptability data. LWT-Food Science and Technology 41 (8):1485-1492

37. Gonzalez E, Draganchuk M (2003) Flavoring nutrition bars. Cereal foods world 48 (5):250

38. Roberts WA (2003) Ingredients in Use: Soy Proteins. http://www.preparedfoods.com/articles/104919-ingredients-in-use-soy-proteins. Accessed 14 February 2016

39. Stalker T, Wilson RF (2015) Peanuts: genetics, processing, and utilization. Elsevier,

40. Chinnan MS (2011) Peanut Further Processing. http://athenaeum.libs.uga.edu/bitstream/handle/10724/33677/Chinnan-PeanutProcessing-GAPnutTour2011-RevSep28.pdf?sequence=1. Accessed 12 January 2016

41. Corbo MR, Bevilacqua A, Petruzzi L, Casanova FP, Sinigaglia M (2014) Functional beverages: the emerging side of functional foods: commercial trends, research, and health implications. Comprehensive reviews in food science and food safety 13 (6):1192-1206

42. Siro I, Kápolna E, Kápolna B, Lugasi A (2008) Functional food. Product development, marketing and consumer acceptance—A review. Appetite 51 (3):456-467

43. Chompreeda P, Haruthaithanasan V, Oupadissakoon C, Suknak K (1989) Development of a chocolate flavored peanut beverage. Journal of Food Science 54 (5):1359-1360

44. Galvez FCF, Resurreccion AV, Koehler PE (1990) Optimization of processing of peanut beverage. Journal of Sensory Studies 5 (1):1-17

45. Hinds MJ, Beuchat LR, Chinnan MS (1997) Properties of a thermal-processed beverage prepared from roasted partially defatted peanuts. International journal of food science & technology 32 (3):203-211

46. Rubico S, Phillips R, Resurreccion A, Beuchat L (1989) Nutritional, microbiological, and sensory qualities of a peanut beverage prepared using various processes. Journal of food science 54 (6):1540-1543

47. Rustom I, López-Leiva M, Nair BM (1996) UHT-Sterilized Peanut Beverages: Kinetics of Physicochemical Changes during Storage and Shelf-Life Prediction Modeling. Journal of food science 61 (1):198-203

48. Howard BM, Hung YC, McWatters SK (2010) Analysis of ingredient functionality and formulation optimization of an instant peanut beverage mix. J Food Sci 75 (1):S8-19. doi:10.1111/j.1750-3841.2009.01380.x

49. FAOSTAT (2017) Malawi food balance sheet. http://www.fao.org/faostat/en/#data/QC. Accessed 31 March 2019

50. Cuddeford V (2013) Issue Pack: Groundnut value chain in Malawi. . http://www.farmradio.org/radio-resource-packs/package-97-growing-groundnuts/groundnut-value-chain-in-malawi-production/. Accessed 14 December 2015

51. Rimal A, Moon W, Balasubramanian SK (2008) Soyfood consumption patterns: effects of product attributes and household characteristics. Journal of Food Distribution Research 39 (3):67-78

52. NPB (2015) History of Peanuts and Peanut Butter. National Peanut Board. http://nationalpeanutboard.org/peanut-info/history-peanuts-peanut-butter.htm. Accessed 16 March 2017

53. Patterson J, Saidel M (2009) The removal of flavored milk in schools results in a reduction in total milk purchases in all grades, K-12. Journal of the American Dietetic Association 109 (9):A97

54. Henry C, Whiting SJ, Phillips T, Finch SL, Zello GA, Vatanparast H (2015) Impact of the removal of chocolate milk from school milk programs for children in Saskatoon, Canada. Applied Physiology, Nutrition, and Metabolism 40 (3):245-250

55. Van Kleef E, van Trijp HC, Luning P (2005) Consumer research in the early stages of new product development: a critical review of methods and techniques. Food quality and preference 16 (3):181-201
56. Slater SF, Narver JC (2000) Intelligence generation and superior customer value. Journal of the academy of marketing science 28 (1):120-127
57. Ulwick AW (2002) Turn customer input into innovation. Harvard business review 80 (1):91-97, 126
58. Leng G, Adan RA, Belot M, Brunstrom JM, de Graaf K, Dickson SL, Hare T, Maier S, Menzies J, Preissl H (2016) The determinants of food choice. Proceedings of the Nutrition Society:1-12
59. Wilson AL, Buckley E, Buckley JD, Bogomolova S (2016) Nudging healthier food and beverage choices through salience and priming. Evidence from a systematic review. Food Quality and Preference 51:47-64
60. Steptoe A, Pollard TM, Wardle J (1995) Development of a measure of the motives underlying the selection of food: the food choice questionnaire. Appetite 25 (3):267-284
61. Eertmans A, Victoir A, Notelaers G, Vansant G, Van den Bergh O (2006) The Food Choice Questionnaire: Factorial invariant over western urban populations? Food quality and preference 17 (5):344-352
62. Fotopoulos C, Krystallis A, Vassallo M, Pagiaslis A (2009) Food Choice Questionnaire (FCQ) revisited. Suggestions for the development of an enhanced general food motivation model. Appetite 52 (1):199-208
63. Januszewska R, Pieniak Z, Verbeke W (2011) Food choice questionnaire revisited in four countries. Does it still measure the same? Appetite 57 (1):94-98

64. Prescott J, Young O, O'neill L, Yau N, Stevens R (2002) Motives for food choice: a comparison of consumers from Japan, Taiwan, Malaysia and New Zealand. Food quality and preference 13 (7):489-495

65. Cornell JA (2011) Experiments with mixtures: designs, models, and the analysis of mixture data, vol 403. John Wiley & Sons,

66. Moskowitz HR (1983) Product testing and sensory evaluation of foods: Marketing and R&D approaches. vol MOS 641 (BV 905.7). Food & Nutrition Press, Inc.,

67. Carpenter RP, Lyon DH, Hasdell TA (2012) Guidelines for sensory analysis in food product development and quality control. Springer Science & Business Media,

68. Meilgaard MC, Carr BT, Civille GV (2006) Sensory evaluation techniques. CRC press,

69. Ares G (2015) Methodological challenges in sensory characterization. Current Opinion in Food Science 3:1-5

70. Varela P, Ares G (2012) Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterization. Food Research International 48 (2):893-908

71. Jaeger SR, Hunter DC, Kam K, Beresford MK, Jin D, Paisley AG, Chheang SL, Roigard CM, Ares G (2015) The concurrent use of JAR and CATA questions in hedonic scaling is unlikely to cause hedonic bias, but may increase product discrimination. Food quality and preference 44:70-74

72. Ares G, Antúnez L, Bruzzone F, Vidal L, Giménez A, Pineau B, Beresford MK, Jin D, Paisley AG, Chheang SL (2015) Comparison of sensory product profiles generated by trained assessors and consumers using CATA questions: Four case studies with complex and/or similar samples. Food Quality and Preference 45:75-86

73. Bruzzone F, Vidal L, Antúnez L, Giménez A, Deliza R, Ares G (2015) Comparison of intensity scales and CATA questions in new product development: Sensory characterisation and directions for product reformulation of milk desserts. Food Quality and Preference 44:183-193

74. Lawless HT, Heymann H (2013) Sensory evaluation of food: principles and practices. Springer Science & Business Media

CHAPTER 3

FACTORS INFLUENCING FOOD CHOICES OF MALAWIAN CONSUMERS: A FOOD CHOICE QUESTIONNAIRE APPROACH[1]

[1] Gama, A.P., Adhikari, K. and D.A. Hoisington. 2018. *Journal of Sensory Studies*. 33: e12442. Reprinted here with permission of the publisher.

Abstract

A consumer survey was conducted to identify the factors that influence food choices in Malawi. Consumer segments were also identified and characterized based on the determined food choice motives and the consumers' demographic and socioeconomic data. Using a Food Choice Questionnaire (FCQ) it was determined that mood, health, price and preparation convenience, sensory appeal, and familiarity were the main factors influencing food choices of Malawian consumers. However, other factors are also influencing food choices in Malawi that were not revealed by the FCQ. Unlike in most affluent societies, the sensory appeal of food was not the most dominant food choice motive in Malawi. In general, the factor structure and factor ranking were different from those found in developed countries as hypothesized. Four consumer clusters emerged, comprising 33%, 30%, 24% and 13% of the sample and the consumers' demographic and socioeconomic profiles had a significant effect ($p < 0.05$) on the cluster composition. Given the importance of identifying food choice determinants when developing new food products and designing nutrition interventions programs, among others, this study is useful in many ways. A consideration of the different consumer segments and their characteristics will be helpful in designing effective nutrition interventions, health nudges, food marketing strategies, and new food products, among others. Furthermore, the study provides useful insights on how to modify the FCQ for developing nations like Malawi.

1. Introduction

The double burden of malnutrition, defined as the coexistence of under-nutrition with over-nutrition and diet-related non-communicable diseases, is a global challenge [1]. Apart from socioeconomic, demographic, biological, and environmental factors, behavioral factors such as lifestyle and food choices are a major concern in efforts towards eradicating the double burden of malnutrition [2,1]. Therefore, most governments are using health nudging to steer people towards healthy lifestyles and food choices [3]. Nudges are approaches to law and policy that steer people in certain directions without compromising the people's freedom of choice [2]. To develop effective health nudging strategies, for modifiable behaviors such as unhealthy food consumption, an understanding of food choice determinants, is essential.

Many studies on food choice determinants, mainly in Europe and Asia, have been done using a 36 item Food Choice Questionnaire (FCQ) developed by Steptoe et al. [4]. Health, mood, sensory appeal, natural content, familiarity, weight control, price, convenience, and ethical concern were identified as the factors that potentially influence food choices of consumers [5-8]. In these studies, some variations across nationalities, in both the dominant food choice motives and the factor structures, were also observed. Besides the evidence that food choice determinants vary across nationalities, such studies have not been done in Sub-Saharan Africa, including Malawi, which is a land-locked country in Southeastern Africa. Consequently, strategies for promoting consumption of various nutritious foods have been developed based on assumptions other than facts, resulting in poor outcomes [9]. For instance, Malawi has been implementing various nutrition intervention programs for many years now but, prevalence of malnutrition is still very high. A recent Malawi demographic and health survey has revealed that among the children under the age of five, 37% are stunted, 11% are severely stunted, 12% are underweight, 3% are severely underweight, and 64% are anemic [10]. For the general population in Malawi, the prevalence of iron, folate, zinc, and vitamin A deficiencies are estimated to be 48.6%, 49.5%, 53.4% and 69.9% respectively [11]. Despite the availability of various nutritious foods, similar trends have been found in other countries within sub-Saharan Africa, especially countries in southern part of Africa [12]. Therefore, an understanding of why people eat what they eat could help in identifying hindrances to food consumption, and possible ways of promoting consumption of certain foods.

Given the knowledge gap, a consumer survey was conducted to identify the food choice determinants in Malawi. Furthermore, consumer segments and their related characteristics were identified and, the effect of consumers' socioeconomic and demographic profiles on food choice motives was also assessed. It was hypothesized that Malawian consumers are different from those in developed countries such that both the factor structure and factor ranking will be different from what was found by Steptoe et al. [4] in Britain. The objective of the study was to understand what factors determine food choices in the sub-Saharan country of Malawi. The results provide useful information to nutritionists, food scientists, food companies, and policymakers in Malawi and other countries that have relatively similar dietary patterns to Malawi. Furthermore, this is the first food choice study in Sub-Saharan Africa where the FCQ was used. Therefore, the results also provide useful insights on the adequacy of the FCQ in identifying food choice determinants in countries like Malawi.

2. Materials and methods

2.1. Procedure and subjects

A consumer survey was conducted in three major cities (Lilongwe, Blantyre, and Mzuzu) of Malawi. Each city is located in one of the three regions of Malawi, and the residents in these cities are diverse in terms of their demographic and socioeconomic profiles (Table 3.1). Therefore, the locations were selected to achieve a better national representative sample of Malawian consumers. Invitations to participants were sent through flyers, posters, and billboards where the aims of the study and the inclusion criteria, among others, were briefly described.

Table 3.1. Summary of demographic and socioeconomic information of the respondents (n = 489).

	Proportion (%)
Gender	
Male	68
Female	32
Age	
18 – 20 yrs.	10
21 – 29 yrs.	41
30 – 39 yrs.	32
40 – 49 yrs.	12
≥ 50 yrs.	5
Highest Education Level	
None	1
Primary (Pre-high school)	12
Secondary (High school)	51
Tertiary (Post-high school)	36
Occupation	
Full-time job	40
Self-Employment	27
Menial Job	14
Student	14
None	5
Monthly Income (MK)[a]	
< 100,000 (Low)	78
100,000 - 499,999 (Medium)	18
≥500,000 (High)	4

[a] 1 US Dollar ($) = 700 Malawian Kwacha (MK)

In each city, participants came to one designated place and completed a questionnaire in the presence of the researchers. There were 169 participants recruited in Lilongwe (Centre), 162 in Blantyre (South) and 158 in Mzuzu (North). The minimum required sample size was determined mathematically using the following formula as described by Smith [13]:

$$\text{Required sample size} = \frac{(\text{Z score})^2 \text{ x Standard deviation x } (1 - \text{ Standard deviation})}{(\text{margin of error})^2}$$

At 95% confidence level (Z score = 1.96), a standard deviation of 0.5, and a margin of error of ±5%, one would need a sample size of at least 385. Therefore, a sample size of 489 participants, used in this study, was considered to be sufficient. The demographic information of the participants is summarized in Table 3.1. Only Malawian adults (aged 18 or above) who make independent food choice decisions were allowed to participate. All human subjects ethical procedures were followed as approved by the University of Georgia's institutional review board (IRB ID: STUDY00004112).

2.2. Data collection tool

The questionnaire was provided in English, the official language, and Chichewa, a major local language in Malawi. The questionnaire was translated into the local language and back-translated into English by two independent translators for accuracy and good language equivalence. The questionnaire had three sections (Appendix A). The first section was based on the 36 item FCQ developed by Steptoe et al. [4]. However, to increase the sensitivity of the measurement scale, a 7-point bipolar Likert-type importance scale was used, as suggested by Fotopoulos et al. [6], instead of the original unipolar 4-point scale. In the second section, the respondents were asked to identify additional items that they consider to be important while making food choices. This item was presented to the respondents as an open-ended question. These additional items were summarized, and their frequencies are reported. The last section was about participants' demographic and socioeconomic data.

2.3. Data analysis

The differences in means and proportions were assessed by one-way analysis of variance (ANOVA) and χ^2 tests, respectively. Tukey's honest significant difference test (HSD) was used for means separation. Exploratory Factor Analysis (EFA) was used to reveal a food choice factor pattern. The factors were extracted using principal components method followed by promax rotation. Cronbach's α coefficient was used to determine the internal consistency of the constructs. Hierarchical Cluster Analysis (HCA) by Ward's method was used to establish the number of consumer clusters (segments) based on the overall importance assigned to the identified food choice factors. Likelihood of a consumer to be or not to be in a particular cluster, based on gender, age, education level, occupation, and monthly income, was determined using binary logistic regression analysis. Regression coefficients were estimated using maximum likelihood estimation and have been reported with Wald χ^2- statistics and odds ratios. The logistic model used is represented as follows:

$$\mathrm{P}[Y_i = 1|X] = \frac{1}{1 + e^{-(\beta_0 + \sum_{i=1}^{n} \beta_i X_i)}}$$

The binary dependent response (Y_i) for participant *i* takes a value of 1 if the participant is in the specified cluster otherwise, it takes the value of 0. Vectors of the exploratory variables are represented by X_i while the intercept and variable coefficients are represented by β_0 and β_i (i = 1, 2, …n), respectively. For modeling purposes only, age was categorized as young (< 30 y) and old (≥ 30 y), education level as higher level (post-high school education) and lower level (high school and below), monthly income as lower earners (low income) and higher earners (Medium and high income), and occupation was categorized as 'full-time job' and other occupations (self-employed, menial jobs, students, and none). All statistical analyses were done in XLSTAT 2017 (Addinsoft, New York).

3. Results

3.1. Factor pattern

Key indicators for appropriateness of the factor analysis were satisfactory. Bartlett test of sphericity gave a χ^2 value of 2163.2 ($p < 0.0001$) indicating that the R-matrix was not an identity matrix. The Kaiser-Meyer-Olkin index (KMO index), on the adequacy of the sample, was 0.854 indicating that the sample size was adequate. Both eigenvalues over 1 and the scree test results were considered to determine the number of factors. Items with factor loadings (r) ≥ 0.4 and loading only on one factor were retained as initially done by Steptoe et al. [4]. Consequently, 15 items were deleted from the original questionnaire. Table 3.2 summarizes the results of the factor analysis performed on the final 21 item FCQ.

The best solution revealed five factors namely, mood, health, price and preparation convenience, sensory appeal, and familiarity. The five factors accounted for 50.39% of the total variability. As suggested by De Vellis [14], the reliability of the constructs for each of the factors was acceptable (0.8 > Cronbach's $\alpha \geq 0.6$), although the coefficients were relatively lower than those found in the original study. However, the overall reliability of the final 21 item FCQ was good (Cronbach's α = 0.83). When compared to the structure reported by Steptoe et al. [4], items related to ethical concern, items 20 (*comes from countries I approve of politically*), 32 (*has the country of origin clearly marked*), and 19 (*is packaged in an environmentally friendly way*), had very low factor loadings (< 0.04). The same was the case with items 2 (*contains no additives*) and 23 (*contains no artificial ingredients*) under natural content, as well as items 3 (*is low in calories*) and 7 (*is low in fat*) under weight control. As a result, these factors are not in the Malawi factor pattern.

Except for familiarity and sensory appeal, the items that loaded on the other factors, like mood and health, were not exactly the same as those that loaded on such factors, in the original study by Steptoe et al. [4]. In the present study, items 16 (*helps me cope with stress*) and 24 (*keeps me awake/alert*) are missing under mood, resulting in only four items as opposed to six items that were in the original study. Although the health factor still has six items, item 5 (*contains natural ingredients*) was under natural content, and item 17 (*helps me control my weight*) was under weight control, in the original study. The two replaced items, 9 (*is high in fiber and roughage*) and 30 (*Is good for my skin/teeth/hair/nails, etc.*), had factor loadings of < 0.4 in this study. Considering all price related items in the original study, only item 12 (*is good value for money*) is missing in this study. All items related to preparation convenience, items 1 (*is easy to prepare*) and 15 (*can be cooked very simply*) loaded on one dimension with price related items. Therefore, the dimension was named "price and preparation convenience." Interestingly, all items related to purchase convenience, items 11 (*Is easily available in shops and supermarkets*) and 35 (*can be bought in shops close to where I live or work*) had factor loadings of < 0.4 in this study.

Table 3.2. Food choice factor pattern for Malawi in comparison to that of the original FCQ study done in the UK.

Malawi, n = 489					**Steptoe et al. (1995), n = 358**	
Factor/Item	**Mean ± SD**	***r***	**Variance Explained,%**	**Cronbach α coefficient**	**Factor/Item**	**Cronbach α coefficient**
1 – Mood			23.70	0.70	*1 - Health*	0.87
34. Helps me to cope with life	5.7 ± 1.5	0.74			22. Contains a lot of vitamins and minerals	
26. Helps me relax	5.7 ± 1.6	0.67			29. Keeps me healthy	
13. Cheers me	6.5 ± 0.9	0.62			10. Is nutritious	
31. Makes me feel good	6.0 ± 1.2	0.54			27. Is high in protein	
					30. Is good for my skin/teeth/hair/nails etc.	
					9. Is high in fiber and roughage	
2 – Health			8.98	0.70	*2 - Mood*	0.83
27. Is high in protein	5.7 ± 1.5	0.68			16. Helps me to cope with stress	
22. Contains a lot of vitamins and minerals	6.0 ± 1.4	0.61			34. Helps me to cope with life	
17. Helps me control my weight	5.9 ± 1.4	0.60			26. Helps me to relax	
5. Contains natural ingredients	5.9 ± 1.5	0.58			24. Keeps me awake/alert	
29. Keeps me healthy	5.4 ± 1.7	0.57			13. Cheers me up	
10. Is nutritious	6.5 ± 1.0	0.45			31. Makes me feel good	
3 – Price & Preparation Convenience			6.58	0.61	*3 - Convenience*	0.81
6. Is not expensive	5.6 ± 1.6	0.86			1. Is easy to prepare	
36. Is cheap	5.7 ± 1.6	0.57			15. Can be cooked very simply	
1. Is easy to prepare	6.2 ± 1.2	0.52			28. Takes no time to prepare	
15. Can be cooked very simply	5.8 ± 1.5	0.47			35. Can be bought in shops close to where I live or work	
					11. Is easily available in shops and supermarkets	
4 – Familiarity			5.69	0.60	*4 - Sensory appeal*	0.70
21. Is like the food I ate when I was a child	4.3 ± 2.0	0.77			14. Smells nice	

Table 3.2. (Continued)

Malawi, n = 489					Steptoe et al. (1995), n = 358	
Factor/Item	**Mean ± SD**	***r***	**Variance Explained,%**	**Cronbach α coefficient**	**Factor/Item**	**Cronbach α coefficient**
33. Is what I usually eat	5.1 ± 1.7	0.63			25. Looks nice	
8. Is familiar to me	5.6 ± 1.7	0.47			18. Has a pleasant texture	
					4. Tastes good	
5 – Sensory appeal			5.44	0.61	*5 - Natural Content*	0.84
4. Tastes good	5.6 ± 1.6	0.78			2. Contains no additives	
14. Smells nice	5.8 ± 1.4	0.76			5. Contains natural ingredients	
25. Looks nice	5.7 ± 1.6	0.52			23. Contains no artificial ingredients	
18. Has a pleasant texture	6.2 ± 1.2	0.51				
					6 - Price	0.82
					6. Is not expensive	
					36. Is cheap	
					12. Is good value for money	
					7 - Weight control	0.79
					3. Is low in calories	
					17. Helps me control my weight	
					7. Is low in fat	
					8 - Familiarity	0.70
					33. Is what I usually eat	
					8. Is familiar to me	
					21. Is like the food I ate when I was a child	
					9 - Ethical Concern	0.70
					20. Comes from countries I approve of politically	
					32. Has the country of origin clearly marked	
					19. Is packaged in an environmentally friendly way	

Based on aggregated mean ratings, calculated using means for all items loading on each factor, the five factors were ranked as shown in Figure 3.1. In general, there was a significant difference ($F_{4,16} = 3.58$, $p < 0.05$) in the importance attached to these factors by Malawian consumers with mood being the most dominant food choice motive. The ranking is different from that reported by Steptoe et al. [4] where sensory appeal was the most dominant food choice motive followed by health, price, convenience, natural content, weight control, mood, ethical concern and lastly, familiarity. Just like in Britain, familiarity was also the least important factor among the identified food choice determinants in this study.

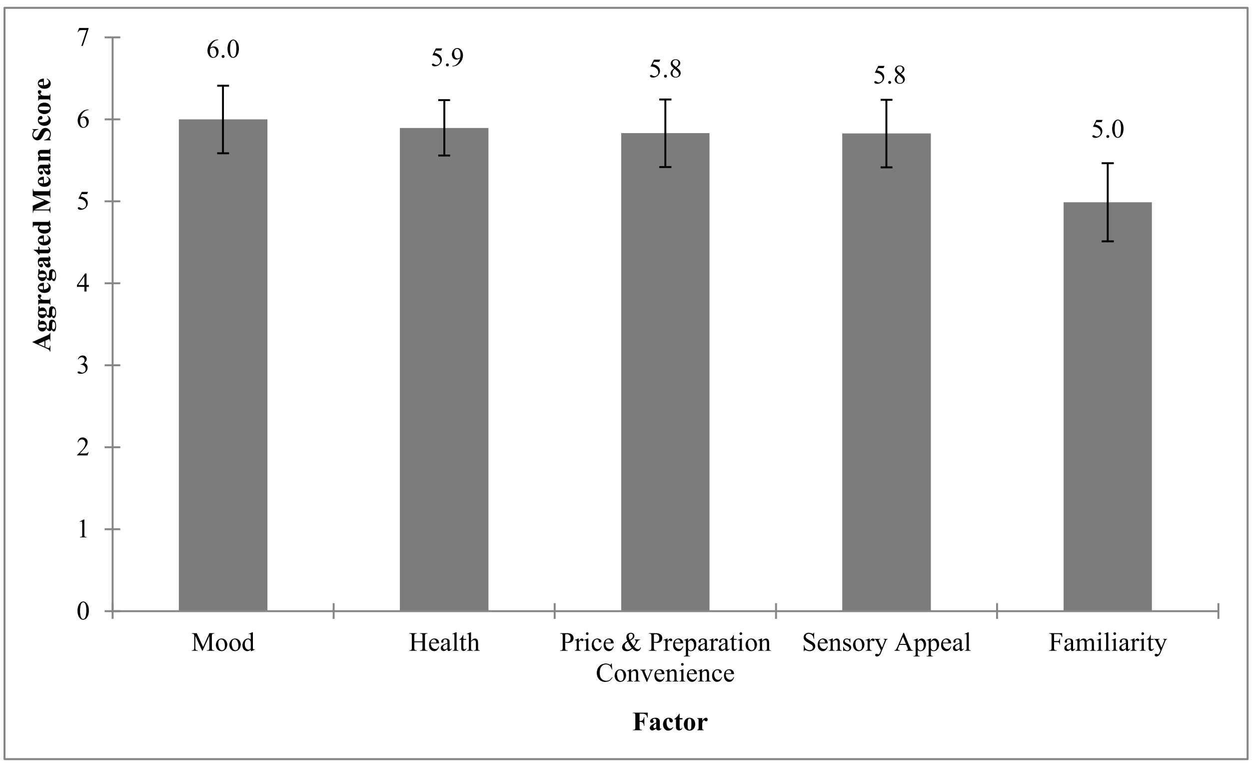

Figure 3.1. Ranking of food choice motives by their aggregated mean scores (1= extremely unimportant to 7= extremely important). The figure shows the differences in the overall importance ratings of the identified food choice motives.

3.2. Other food choice motives

Figure 3.2 shows the other items that are considered important by Malawian consumers when making their food choices. Majority of the respondents (77%) want food that is "filling" and will make them feel satiated.

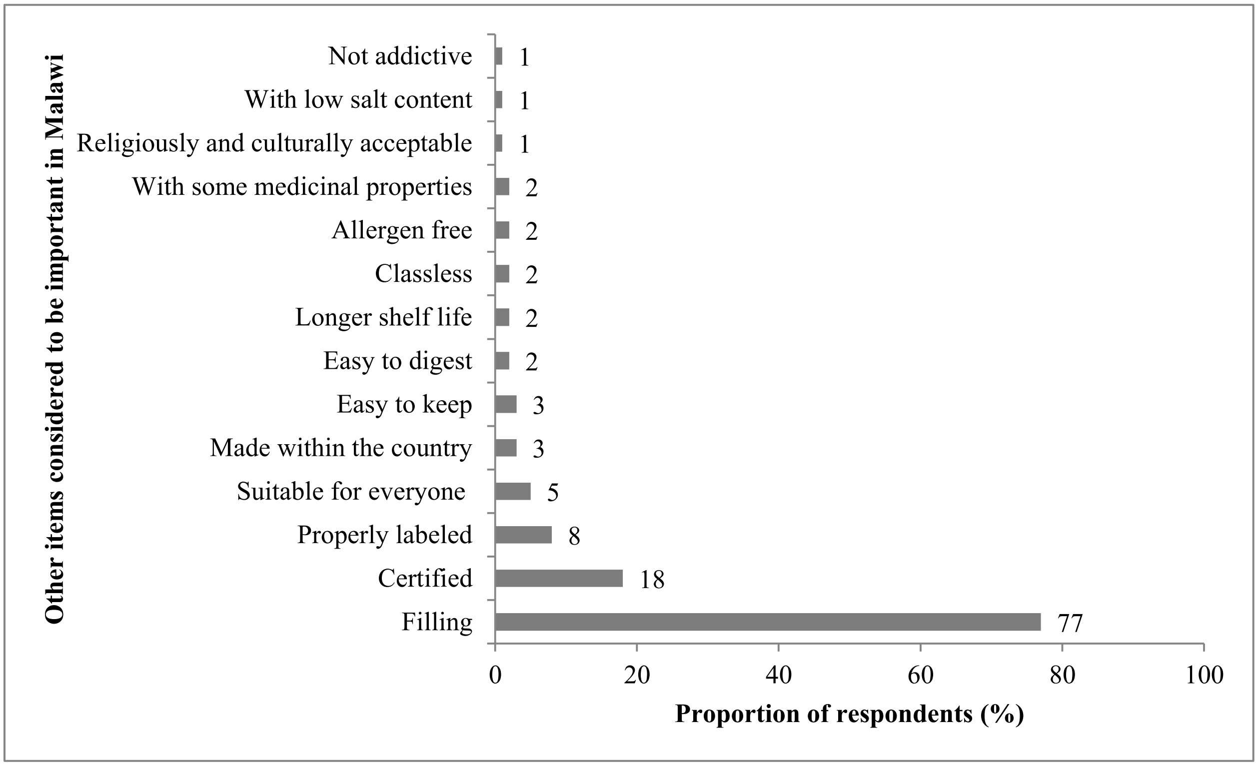

Figure 3.2. Additional items considered to be important by Malawian consumers (n = 489). The figure shows other additional items mentioned by the respondents as being important when they are making food choices. The items have been reported with their respective frequencies (proportion of respondents who mentioned the item).

3.3. Influence of demographic and socioeconomic variables on food choice motives

The importance ratings of the food choice motives were significantly ($p < 0.05$) influenced by gender, education level, and occupation (Table 3.3). Monthly income and the age of consumers had no significant effect on any of the food choice motives. Gender had a significant effect only on familiarity ($F_{1,487} = 7.4$, $p < 0.05$). Women were more concerned about familiarity than men. Education level had a significant effect only on health ($F_{3,485} = 10.3$, $p <$

0.05). Consumers with post-high school education were more concerned about health than those in the low education categories. Occupation had a significant effect only on mood ($F_{4, 484} = 5.4$, $p < 0.05$). Unlike all other occupation categories, students and those with full-time jobs were less concerned about mood.

Table 3.3. Effect of consumer demographic and socioeconomic variables on the food choice factors.

Variable	Mean factor scores				
	Mood	Health	Price & Preparation convenience	Sensory appeal	Familiarity
Gender					
Female	0.03 ± 0.97[a]	0.06 ± 0.94[a]	-0.10 ± 1.10.[a]	0.100 ± 0.89[a]	0.18 ± 0.96[a]
Male	-0.01 ± 1.01[a]	-0.03 ± 1.03[a]	0.05 ± 0.95[a]	-0.05 ± 1.05[a]	-0.09 ± 1.01[b]
Age					
≥50 yrs.	0.26 ± 0.77[a]	0.22 ± 0.95[a]	0.22 ± 0.83[a]	0.30 ± 0.96[a]	0.20 ± 1.01[a]
40 to 49 yrs.	0.08 ± 0.77[a]	0.19 ± 0.64[a]	0.15 ± 0.76[a]	0.04 ± 0.88[a]	0.13 ± 0.91[a]
30 to 39 yrs.	-0.02 ± 1.01[a]	-0.05 ± 1.00[ab]	0.04 ± 1.06[a]	-0.07 ± 1.03[a]	0.06 ± 1.01[a]
21 to 29 yrs.	0.01 ± 0.92[a]	0.03 ± 1.00[a]	-0.02 ± 0.98[ab]	-0.00 ± 1.01[a]	-0.11 ± 1.01[a]
18 to 20 yrs.	-0.18 ± 1.46[a]	-0.28 ± 1.30[b]	-0.32 ± 1.13[b]	0.04 ± 1.04[a]	0.00 ± 1.01[a]
Education level					
Post-High school	-0.12 ± 1.02[a]	0.31 ± 0.79[a]	0.06 ± 0.92[a]	0.16 ± 0.94[a]	-0.23 ± 0.99[a]
High school	0.00 ± 1.01[a]	-0.16 ± 1.09[b]	-0.04 ± 1.05[a]	-0.15 ± 1.01[a]	0.08 ± 1.02[a]
Pre-high school	0.36 ± 0.79[b]	-0.17 ± 0.94[b]	0.07 ± 0.96[a]	0.20 ± 0.99[a]	0.38 ± 0.80[a]
None	0.02 ± 0.98[ab]	-0.98 ± 1.14[b]	-0.79 ± 1.13[a]	-0.41 ± 1.49[a]	-0.05 ± 0.82[a]
Occupation					
Full-time job	-0.14 ± 0.97[a]	0.05 ± 0.97[a]	-0.04 ± 1.07[a]	-0.07 ± 1.01[a]	-0.05 ± 0.97[ab]
Self-employed	0.12 ± 0.90[b]	-0.03 ± 0.95[a]	0.06 ± 0.93[a]	0.10 ± 0.99[a]	0.16 ± 0.94[a]
Menial job	0.38 ± 0.74[b]	-0.10 ± 0.96[a]	0.08 ± 0.94[a]	-0.10 ± 0.97[a]	0.10 ± 1.01[a]
Student	-0.27 ± 1.37[a]	-0.01 ± 1.22[a]	-0.12 ± 1.09[a]	0.04 ± 1.11[a]	-0.24 ± 1.07[b]
None	0.15 ± 0.80[b]	0.04 ± 1.02[a]	0.12 ± 0.94[a]	0.13 ± 0.76[a]	-0.10 ± 1.23[ab]
Monthly income					
Low	0.04 ± 1.02[a]	-0.04 ± 1.03[a]	-0.01 ± 1.00[a]	-0.02 ± 1.02[a]	0.08 ± 1.01[a]
Medium	-0.11 ± 0.91[a]	0.11 ± 0.89[a]	0.06 ± 1.01[a]	0.05 ± 0.93[a]	-0.33 ± 0.94[b]
High	-0.27 ± 1.05[a]	0.22 ± 0.90[a]	-0.05 ± 0.96[a]	0.23 ± 0.93[a]	0.01 ± 0.91[ab]

[ab] Mean factor scores with different superscripts within each sub-column are significantly different ($p < 0.05$).

3.4. Consumer segments and characteristics

Factor scores of the five identified food choice motives were used for the cluster analysis. Figure 3.3 shows the four clusters that effectively segment Malawian consumers. Food choices of consumers in cluster 1 (CL1) were influenced by mood, health, price and preparation convenience, familiarity and sensory appeal. Consumers in cluster 2 (CL2) were indifferent to all the identified factors while those in clusters 3 (CL3) and 4 (CL4) were more concerned about familiarity and health, respectively. CL3 is the largest consumer segment (33%) followed by CL1 (30%), CL4 (24%) and lastly CL2 (13%).

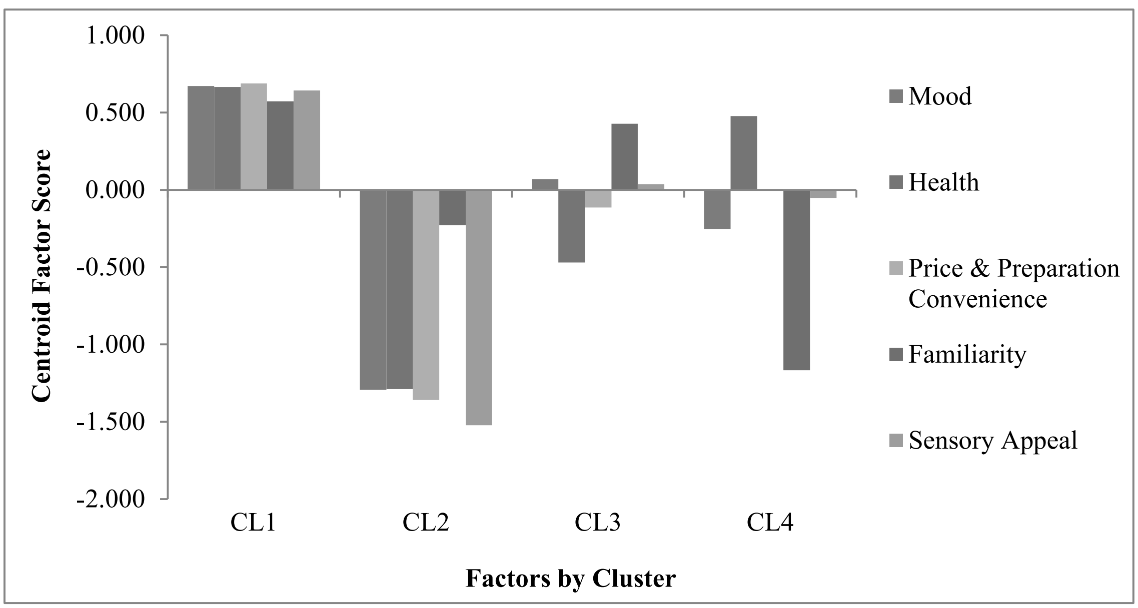

Figure 3.3. Consumer clusters based on FCQ food choice factors' scores. The figure shows the consumer segments and how the consumers in each segment rated each of the food choice motives in general.

Table 3.4. Logistic regression estimates for demographic and socioeconomic variables influencing cluster composition.

Predictor	Cluster 1 Odds ratio [CI]	χ^2	Pr>χ^2	Cluster 2 Odds ratio [CI]	χ^2	Pr>χ^2	Cluster 3 Odds ratio [CI]	χ^2	Pr>χ^2	Cluster 4 Odds ratio [CI]	χ^2	Pr>χ^2
Gender												
Male vs. Female	0.739 [0.504 1.083]	2.413	0.120	1.197 [0.807 1.774]	0.800	0.371	0.929 [0.633 1.361]	0.144	0.704	1.506 [1.007 2.252]	3.974	**0.046**
Age												
<30 yrs. vs. ≥30 yrs.	1.391 [0.947 2.041]	2.834	0.092	0.689 [0.467 1.017]	3.512	0.061	1.150 [0.783 1.690]	0.509	0.476	0.626 [0.415 0.946]	4.947	**0.026**
Education level												
High school and below vs. Post-high school	1.408 [0.939 2.111]	2.738	0.098	0.536 [0.350 0.820]	8.272	**0.004**	0.547 [0.365 0.819]	8.568	**0.003**	1.928 [1.289 2.884]	10.199	**0.001**
Occupation												
Full-time employment vs. Other occupations	1.335 [0.908 1.962]	2.158	0.142	0.700 [0.471 1.040]	3.119	0.077	0.931 [0.638 1.361]	0.135	0.713	0.950 [0.640 1.411]	0.065	0.799
Monthly income												
Low vs. Medium & High	0.557 [0.336 0.923]	5.150	**0.023**	0.909 [0.538 1.535]	0.128	0.721	1.060 [0.653 1.721]	0.056	0.812	1.867 [1.124 3.101]	5.811	**0.016**

Pred (CL1) = 1 / (1 + exp (-[- 0.141-0.585*Monthly income-Medium & High])).
Pred (CL2) = 1 / (1 + exp (-[0.475 - 0.625*Education level-Post high school])).
Pred (CL3) = 1 / (1 + exp (-[0.214 - 0.604*Education level-Post high school])).
Pred (CL4) = 1 / (1 + exp (-[-0.467 + 0.409*Sex-Male - 0.468*Age-old + 0.656*Education level-Post high school + 0.624*Monthly income-Medium & High])).
P-values in bold are significant at 5% significance level; CI = 95% confidence interval.

Except for occupation, the rest of the demographic and socioeconomic variables, gender, age, education level, and monthly income, were significant predictors ($p < 0.05$) of the likelihood that a consumer belongs or does not belong to a particular cluster (Table 3.4). The likelihood of a consumer to be in CL1 was affected by monthly income. Higher earners (consumers in medium and high-income category) were 0.557 times less likely to be in CL1 than those with low monthly incomes when all other factors are held constant. The likelihood of a consumer to be in CL2 and CL3, respectively, was affected by education level. With all other factors being constant, consumers with post-high school education were 0.536 times less likely to belong to CL2 than those in the low education level category. Likewise, such consumers were 0.547 times less likely to belong to CL3 than consumers in the low education level category. The likelihood of a consumer to be in CL4 was affected by gender, age, education level, and monthly income. Men were 1.506 times more likely to be in CL4 than women with all other factors being constant. Based on age, older consumers (≥ 30 y) were 0.626 times less likely to be in CL4 than younger consumers (< 30 y). Consumers with post-high school education were 1.928 times more likely to be in CL4 than those in the low education level category. Finally, higher earners were 1.867 times more likely to be in CL4 than low earners.

4.0. Discussion

Unlike in the study by Steptoe et al. [4], the best factor solution revealed five factors instead of nine. The absence of some factors, such as ethical concern, has also been reported in Greece by Fotopoulos et al. [6] and in New Zealand by Prescott et al. [8]. Just like in Malawi, other studies also found different factor patterns to that of the original study as well as variations in the dominant food choice motives [5,7]. It is believed that sensory appeal of foods is the most dominant food choice motive, likely based on findings of many studies in developed countries [5,15,7,4]. However, this is not the case in Malawi. The sensory appeal of food was ranked second from last indicating its little influence on food choices of Malawian consumers. The findings portray the apparent differences that exist between consumers in developed countries and Malawian consumers. This is also evident from the many other important items, identified in this study that Malawian consumers consider when making food choices. The factor structure found in this study also suggests that some FCQ items may have a different connotation or implication in Malawi. For instance, items 5 (*contains natural ingredient*s) and 17 (*helps me control my weight*) might have been viewed as components of healthy foods by Malawian consumers. As a result, these two items loaded on the health factor.

The additional items found in this study could be related to survival, safety assurance, patriotism, and conformity, among others. For instance, the need for more filling food could be a survival strategy. Persistent food shortages and poverty in Sub-Saharan Africa limits food choices of consumers [16]. Under such circumstances, abating hunger may be the consumer's main priority. This could also be the reason why the sensory appeal of food is not as dominant in Malawi as it is in affluent nations. The need for safety assurance could be the reason why Malawian consumers want products that are certified and properly labeled. Although certification does not deliver a guarantee of food safety nor prevent food safety incidents, it reduces the risk of food safety failures [17]. For manufactured products, the Malawi Government, through Malawi Bureau of Standards (MBS), has been encouraging consumers in Malawi to buy and consume only certified products [18]. Also, the Government has been encouraging consumers in Malawi to buy products made in the country as one way of strengthening the local industry [19]. It is, therefore, worth noting that some consumers in

Malawi are now considering these government initiatives when making food choices. Although only 1% of the test population indicated that their food choice is driven by religious and cultural beliefs, it is worth noting that culture and religion plays a role in food choices [20,21]. Other studies have also suggested conformity to religious beliefs and search for quality assurance as potential food choice determinants [6,15,22]. The inclusion of the additional items that were identified in the open-ended section of the questionnaire of this study could make the FCQ more relevant in other sub-Saharan countries as well.

The four consumer segments identified in this study confirm that even within the same population, factors influencing food choices can be different [6]. One extreme (CL1) had consumers who are concerned about many factors when making food choices and the other extreme (CL2), had consumers who do not care much about any of the identified factors. This demonstrates why a product may be acceptable by some and rejected by other consumers within the same population. In marketing, targeting a particular consumer segment other than trying to please everyone is the recommended approach [23]. As a result, manufacturers usually target specific consumer segments that are profitable for them. However, for nutrition interventions, achieving broader initiative goals should be a priority. Consequently, consumer segments that are not economically better-off may still be targeted. The factor composition of CL2 also suggests that there might be other factors influencing food choices of Malawian consumers that could not be revealed using the current 36 item FCQ, as already discussed.

This study also confirms the existence of differences in food choice motivations among consumers due to demographic and socioeconomic factors. Such differences could have many implications in designing nutrition intervention programs among others. For instance, it has been suggested that nutrition interventions are more successful when women are the target since they influence household diets [24-26]. However, according to this study, familiarity greatly influences food choices of Malawian women compared to men. This could affect the women's openness to try new foods as reported in many other studies linking familiarity and food neophobia [27,28]. As a result, other nutrition interventions, like those encouraging consumption of new commercial fortified foods, may not be readily adopted by the women. The findings have also shown that younger male consumers, with post-high school education and higher monthly incomes, who are more likely to be in CL4 indicated that health is their greatest motivation. Most health nudges are designed to encourage consumption of healthy foods. Therefore, there is an apparent need for more nutrition education targeting particularly Malawian women and the older consumers, in general, so that health could become their dominant food choice motive.

5. Conclusion

The factors influencing food choices of Malawian consumers are mood, health, price and preparation convenience, sensory appeal, and familiarity. However, the 36 item FCQ did not reveal all the factors that influence food choices of Malawian consumers. Therefore, there is need to modify the FCQ to make it more adequate for countries such as Malawi. Gender, age, education level, and monthly income of consumers significantly influenced food choice motives in Malawi. Therefore, food choice motives should not be considered in isolation from consumers' demographic and socioeconomic profiles. As hypothesized, Malawian consumers are different from those in developed countries like Britain. Therefore, the current one size fits all approach, in initiatives aimed at promoting consumption of various foods, should change to a more tailor-made approach.

In this study, the sample size was statistically adequate, and the demographic and socioeconomic profiles of the participants were a relatively good representation of Malawian consumers. However, the authors acknowledge the limitation that the sample size was small when compared to the national population. The findings are therefore suggestive of the likely national trend rather than being conclusive. However, being the first study of its kind in Malawi, the results have provided good insights on factors that influence food choices of Malawian consumers. Future studies can therefore, build on the findings of this study to further test and incorporate the identified additional items into the FCQ, preferably using a larger sample size. Another limitation of the study is that it was done in only one sub-Saharan country in Southeastern Africa. Countries such as Zambia, Mozambique, and Tanzania would likely benefit from such a study.

References

1. WHO (2016) The Double Burden of Malnutrition. http://apps.who.int/iris/bitstream/10665/255413/1/WHO-NMH-NHD-17.3-eng.pdf?ua=1. Accessed 14 July 2017

2. Leng G, Adan RA, Belot M, Brunstrom JM, de Graaf K, Dickson SL, Hare T, Maier S, Menzies J, Preissl H (2016) The determinants of food choice. Proceedings of the Nutrition Society:1-12

3. Wilson AL, Buckley E, Buckley JD, Bogomolova S (2016) Nudging healthier food and beverage choices through salience and priming. Evidence from a systematic review. Food Quality and Preference 51:47-64

4. Steptoe A, Pollard TM, Wardle J (1995) Development of a measure of the motives underlying the selection of food: the food choice questionnaire. Appetite 25 (3):267-284

5. Eertmans A, Victoir A, Notelaers G, Vansant G, Van den Bergh O (2006) The Food Choice Questionnaire: Factorial invariant over western urban populations? Food quality and preference 17 (5):344-352

6. Fotopoulos C, Krystallis A, Vassallo M, Pagiaslis A (2009) Food Choice Questionnaire (FCQ) revisited. Suggestions for the development of an enhanced general food motivation model. Appetite 52 (1):199-208

7. Januszewska R, Pieniak Z, Verbeke W (2011) Food choice questionnaire revisited in four countries. Does it still measure the same? Appetite 57 (1):94-98

8. Prescott J, Young O, O'neill L, Yau N, Stevens R (2002) Motives for food choice: a comparison of consumers from Japan, Taiwan, Malaysia and New Zealand. Food quality and preference 13 (7):489-495

9. Battersby J (2016) What's driving sub-Saharan Africa's malnutrition problem? . http://theconversation.com/whats-driving-sub-saharan-africas-malnutrition-problem-55579. Accessed 13 April 2017

10. NSO (2016) Malawi Demographic and Health Survey Report. National Statistical Office. http://www.dhsprogram.com/pubs/pdf/PR73/PR73.pdf. Accessed 24 June 2016

11. Verduzco-Gallo I, Ecker O, Pauw K (2014) Changes in food and nutrition security in Malawi: Analysis of recent survey evidence, vol 6. International Food Policy Research Institute,

12. FAO (2015) Regional Overview of Food Insecurity in Africa. Food and Agriculture Organization. http://www.fao.org/3/a-i4635e.pdf. Accessed 20 March 2017

13. Smith S (2013) Determining Sample Size: How to Ensure You Get the Correct Sample Size. https://www.qualtrics.com/blog/determining-sample-size/. Accessed 14 June 2015

14. De Vellis RF (2012) Scale development: Theory and applications. In. Sage, Los Angeles, pp 109–110

15. Honkanen P, Frewer L (2009) Russian consumers' motives for food choice. Appetite 52 (2):363-371

16. Clover J (2003) Food security in sub-saharan Africa: feature. African security review 12 (1):5-15

17. GFSI (2011) Enhancing Food Safety Through Third Party Certification. http://www.mygfsi.com/gfsifiles/GFSI_White_Paper_-_Enhancing_Food_Safety_Through_Third_Party_Certification.pdf. Accessed 13 April 2017

18. MBS (2016) Press Release on Certified and Pre-certified Products in Malawi. Malawi Bureau of Standards. http://www.mbsmw.org/. Accessed 13 January 2017

19. MOIT (2016) Buy Malawi Strategy. Malawi Government. http://www.moit.gov.mw/downloads/quick/Buy%20Malawi%20Strategy.pdf. Accessed 13 April 2017

20. Kittler PG, Sucher KP, Nelms M (2011) Food and culture. Cengage Learning,

21. Anderson EN (2014) Everyone eats: Understanding food and culture. NYU Press,

22. Lindeman M, Väänänen M (2000) Measurement of ethical food choice motives. Appetite 34 (1):55-59

23. Wedel M, Kamakura WA (2002) Introduction to the special issue on market segmentation. International Journal of Research in Marketing 19 (2002):181 - 183

24. Robinson T (2008) Applying the socio-ecological model to improving fruit and vegetable intake among low-income African Americans. Journal of community health 33 (6):395-406

25. Dunneram Y, Jeewon R (2015) Healthy diet and nutrition education program among women of reproductive age: a necessity of multilevel strategies or community responsibility. Health promotion perspectives 5 (2):116

26. IFPRI (2010) Agriculture, Nutrition, Health; Exploiting the Links. International Food Policy Research Institute http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/7220/filename/7221.pdf. Accessed 14 April 2017

27. Hwang J, Lin T-N (2010) Effects of food neophobia, familiarity, and nutrition information on consumer acceptance of Asian menu items. Journal of hospitality marketing & management 19 (2):171-187

28. Veeck A (2010) Encounters with extreme foods: Neophilic/neophobic tendencies and novel foods. Journal of Food Products Marketing 16 (2):246-260

CHAPTER 4

PEANUT CONSUMPTION IN MALAWI: AN OPPORTUNITY FOR INNOVATION[1]

[1] Gama, A.P., Adhikari, K. and D.A. Hoisington. 2018. *Foods*. 7: 112.
Reprinted here with permission of the publisher.

Abstract

Peanuts are a valuable source of nutrients but, peanut consumption patterns, consumption frequencies, and the factors influencing peanut consumption in Malawi are not known. The study surveyed consumers to fill this knowledge gap and to assess Malawian consumers' readiness to try new food products. Out of the 489 respondents surveyed, all but 3 consumed peanuts (in any form). The majority (70.4%) consumed peanuts at least three times in a week. Chi-square test showed that demographic and socioeconomic variables had significant effects ($p < 0.05$) on peanut product preferences, the frequency of peanut consumption and readiness to try new foods. For instance, women mostly preferred peanut flour compared to men, and peanut butter was the most preferred form for younger consumers. Logistic regression analysis showed that consumers with high school education or below were 2.35 times more likely to eat peanuts more often than consumers with post-high school education. Among the participants that were ready to try new foods (54%), men and those with post-high school education were 1.90 and 2.74 times more likely to try new foods than their respective counterparts In general, the diversity of peanut products on the Malawian market is limited, and socioeconomic restrictions are overriding consumer preferences. Therefore, future peanut-based food products innovations should explore ways to overcome such restrictions.

1. Introduction

Prevalence of malnutrition, especially under-nutrition, is high in Sub-Saharan Africa (SSA) compared to the developed countries. Between 1990 and 2014, there has been a 24% overall increase in the number of undernourished people in SSA. As a way of addressing undernutrition, governments in the region are implementing initiatives designed to increase production of and access to nutritious foods [1]. For instance, the Malawian government is promoting dietary diversification by supporting production and consumption of underutilized yet nutritious foods like peanuts [2].

Peanuts are a valuable source of proteins, fats, vitamins, and minerals for human and animal nutrition. Peanut kernels, on average, contain 48% fat, 26% protein, 17% carbohydrates, 2% fiber, 2% ash and 1% of vitamins and minerals which include vitamin E, niacin, folate, manganese, magnesium and phosphorous [3]. Peanuts also contain bioactive substances such as flavonoids, resveratrol, and phytosterols which have been associated with decreased risk of coronary heart disease (CHD) and reduced cancer risk [4,5]. Many studies have been done on the health benefits derived from peanut consumption. For instance, Griel et al. [6] found that peanut users have a higher intake of micronutrients, lower intake of saturated fat and cholesterol, and lower body mass index (BMI) despite peanuts being energy dense. FAO [7] suggested that a handful (~30g) of peanuts a day could be enough to address most malnutrition cases in developing countries. Unfortunately, peanut consumption in Malawi is quite low (~13g/day.) although production is relatively high [8]. The reasons behind the low peanuts consumption are not known because peanut consumption patterns, consumption frequencies, and the factors influencing peanut consumption in Malawi have not been determined.

Although making food choices is a complex process, it is known that consumers choose foods or food products that meet their needs and wants [9,10]. The consumer needs and wants ultimately influence food choices and consumption patterns. Unfortunately, identification of the motivating factors that would make people consume more nutritious foods like peanuts is often overlooked. Nutrition interventions aimed at promoting consumption of particular foods in SSA have been mostly done considering only health benefits although studies, especially in developed countries, have shown that health is just one of the several factors that influence food choices [11-14]. Furthermore, the interventions are not tailored for different target groups although evidence shows that food consumption patterns, preferences, and dominant food choice motives vary among nationalities, cultures and socio-demographic profiles [12,15,13,14,16].

Given the above, a consumer survey was conducted to identify the peanut consumption patterns, consumption frequencies, and the factors that influence consumption of peanuts in Malawi. Furthermore, the effect of consumers' demographic and socioeconomic profiles on peanut consumption, peanut preferences, and readiness of Malawian consumers to try new foods was also investigated. Although the results are based on a survey from Malawi, they could also be useful to other nutritionists, food scientists, policymakers, food companies, and food marketers in Sub-Saharan Africa, especially countries in southern Africa with relatively similar dietary patterns to Malawi.

2. Materials and methods

2.1. Procedure and subjects

A consumer survey was conducted in three major cities (Lilongwe, Blantyre, and Mzuzu) of Malawi. Invitations to participants were sent through flyers, posters, and billboards where the aims of the study and the inclusion criteria, among others, were briefly described. In each city, participants came to one designated place and completed a questionnaire in the presence of the researchers. There were 169 participants recruited in Lilongwe (Centre), 162 in Blantyre (South) and 158 in Mzuzu (North). The participants were diverse in their gender, age, education level, occupation, and monthly incomes. Only Malawian adults (aged 18 or above) who make independent food choice decisions participate. All human subjects ethical procedures were followed as approved by the University of Georgia's Institutional Review Board (IRB Approval Number: STUDY00004112).

2.2. Data collection tool

The questionnaire was provided in English, the official language, and Chichewa, the main local language in Malawi. The questionnaire was translated into the local language and back-translated into English by two independent translators for accuracy and good language equivalence. The questionnaire had three sections (Appendix B). The first section was on peanut consumption and preferences followed by a section on food neophobia. In the first section, participants were asked to mention all the peanut products that they consume, and how often they consume the peanut products. Then, they were asked to mention their most preferred peanut form or product and to give reasons for their choice. In the food neophobia section, participants were asked if they would try new (unfamiliar) foods or food products. For those who indicated that they would not try new foods, their reasons for fearing new foods and what could compel them, if possible, to try new foods were solicited through open-ended questions. The last section was about the participants' demographic and socioeconomic information. Data on gender, age, highest education level, occupation, and monthly incomes were collected.

2.3. Data analysis

Frequency distributions were generated, and the differences in proportions were assessed using χ^2 test or Fisher's exact test where theoretical cell counts were less than 5. Likelihood of a consumer to like a particular peanut product, based on gender, age, education level, occupation, and monthly income, was determined using binary logistic regression analysis. Regression coefficients were estimated using maximum likelihood estimation and are presented with odds ratios (ORs) and Wald χ^2- statistics. The ORs are point estimates obtained by exponentiating the estimate. The OR indicates the likely change in the probability of the response factor if there is a one unit increase in the level of the predictor variable when all other variables are held constant. When the OR is equal to 1, there is no effect of the unit variation of the predictor on the response factor. A large deviation of the OR values from one signifies a greater effect on change in the occurrence probability of the response factor and vice versa. The Wald χ^2- statistic is the test statistic for the hypothesis test that an individual predictor's estimate (regression coefficient) is zero given the rest of the predictors are in the model. The Wald χ^2- statistic is the squared ratio of the estimate to the standard error of the respective predictor [17]. The logistic model used in this study is represented as follows:

$$\mathrm{P}[Y_i = 1|X] = \frac{1}{1 + e^{-(\beta_0 + \sum_{i=1}^{n} \beta_i X_i)}}$$

The binary dependent response (Y_i) for participant i takes a value of 1 if the participant likes the specified peanut product otherwise, it takes the value of 0. Vectors of the exploratory variables are represented by X_i while the intercept and variable coefficients are represented by β_0 and β_i (i = 1, 2 …n), respectively. For modeling purposes only, age was categorized as young (<

30 years) and old (≥ 30 years), education level as higher level (post-high school education) and lower level (high school and below), monthly income as lower earners (low income) and higher earners (Medium and high income), and occupation was categorized as ‘full-time job’ and other occupations (self-employed, menial jobs, students, and none). A similar analysis was done to estimate the likelihood that a consumer will try new foods or not and whether a consumer is likely to eat peanuts or peanuts products more often (at least thrice a week) or less often (at most once a week). All statistical analyses were done in XLSTAT 2017 (Addinsoft, New York).

3. Results

3.1. Study participants

The demographic and socioeconomic information of the participants is shown in Table 4.1. Of the 489 participants, there were more men (68%) than women, and most of the participants were aged between 21 and 39 (73%).

3.2. Peanut consumption and preference

Out of the 489 respondents surveyed, all but 3 consumed peanuts, peanut products, or both. The three who indicated that they do not eat peanuts and peanut products were due to allergies. The most frequently mentioned forms of peanut consumption were roasted peanuts (65%), peanut flour (64%), and peanut butter (63%) as shown in Figure 4.1. However, the most preferred forms were peanut butter (33%), peanut flour (31%), and roasted peanuts (19%). A summary of peanut product preference by gender, age, education level, occupation, and monthly income is shown in Table 4.1.

Table 4.1. Summary of demographic, socioeconomic information of the respondents, and their respective frequencies for peanut products consumption, preference, and readiness to try new foods.

Variable	Total Respondents % (n = 489)	Ready to Try New Foods % (n = 264)	Consumption Frequency (%)			Preference Frequency (%)					
			Everyday (n = 143)	≥ 3 times/ week (n = 201)	Once/ week (n = 144)	PB (n = 161)	PF (n = 151)	RP (n = 95)	BP (n = 33)	RwP (n = 26)	PCO (n = 23)
Gender											
Male	68 (333)	73 (194)	64 (91)	69 (139)	70 (101)	65 (104)	58 (88)	79 (75)	64 (21)	88 (23)	87 (20)
Female	32 (156)	27 (70)	36 (52)	31 (62)	30 (43)	35 (57)	42 (63)	21 (20)	36 (12)	12 (3)	13 (3)
Age											
18 – 20 yrs.	10 (49)	10 (27)	15 (22)	6 (12)	12 (17)	16 (25)	10 (15)	6 (6)	3 (1)	8 (2)	9 (2)
21 – 29 yrs.	41 (200)	45 (117)	37 (53)	44 (89)	39 (56)	45 (73)	33 (49)	43 (41)	49 (16)	30 (8)	52 (12)
30 – 39 yrs.	32 (156)	29 (77)	30 (43)	35 (70)	31 (45)	29 (46)	36 (55)	32 (30)	30 (6)	46 (12)	22 (5)
40 – 49 yrs.	12 (59)	12 (32)	12 (17)	10 (19)	14 (20)	8 (13)	12 (18)	15 (14)	18 (6)	8 (2)	13 (3)
≥ 50 yrs.	5 (25)	4 (11)	6 (8)	5 (11)	4 (6)	2 (4)	9 (14)	4 (4)	0 (0)	8 (2)	4 (1)
Highest Education Level											
None	1 (5)	1 (2)	1 (1)	1 (3)	1 (1)	1 (1)	1 (2)	2 (2)	0 (0)	0 (0)	0 (0)
Primary (Pre-high school)	12 (59)	6 (16)	19 (27)	10 (20)	6 (9)	6 (10)	20 (30)	13 (12)	6 (2)	8 (2)	0 (0)
Secondary (High school)	51 (249)	45 (120)	59 (85)	53 (106)	41 (59)	50 (80)	52 (79)	50 (48)	42 (19)	38 (10)	83 (19)
Tertiary (Post-high school)	36 (176)	48 (126)	21 (30)	36 (72)	52 (75)	43 (70)	26 (40)	35 (33)	52 (17)	54 (14)	17 (4)
Occupation											
Full-time job	40 (196)	48 (127)	35 (50)	40 (80)	46 (66)	38 (61)	36 (55)	46 (44)	43 (14)	46 (12)	47 (11)
Self-Employment	27 (132)	25 (67)	34 (48)	27 (54)	22 (31)	24 (39)	28 (42)	32 (30)	30 (10)	27 (7)	22 (5)
Menial Job	14 (68)	8 (20)	11 (16)	17 (35)	12 (18)	12 (19)	22 (33)	12 (11)	9 (3)	4 (1)	9 (2)
Student	14 (68)	17 (44)	14 (20)	10 (21)	18 (26)	22 (35)	8 (12)	8 (8)	15 (5)	19 (5)	9 (2)
None	5 (25)	2 (6)	6 (9)	6 (11)	2 (3)	4 (7)	6 (9)	2 (2)	3 (1)	4 (1)	13 (3)
Monthly Income (MK)[a]											
< 100,000 (Low)	78 (381)	75 (197)	81 (116)	80 (161)	71 (102)	78 (126)	80 (121)	73 (69)	64 (21)	77 (20)	96 (22)
100,000 - 499,999 (Medium)	18 (88)	21 (55)	14 (20)	16 (33)	24 (34)	18 (28)	17 (26)	19 (18)	33 (11)	19 (5)	0 (0)
≥500,000 (High)	4 (20)	4 (12)	5 (7)	5 (7)	5 (8)	4 (7)	3 (4)	8 (8)	3 (1)	4 (1)	4 (1)

[a] 1 US Dollar ($) = 700 Malawian Kwacha (MK). Numbers in parenthesis correspond to the number of observations.
PB= Peanut butter, PF = Peanut flour, RP = Roasted peanuts, BP = Boiled peanuts, RwP = Raw peanuts, PCO = Peanut cooking oil.

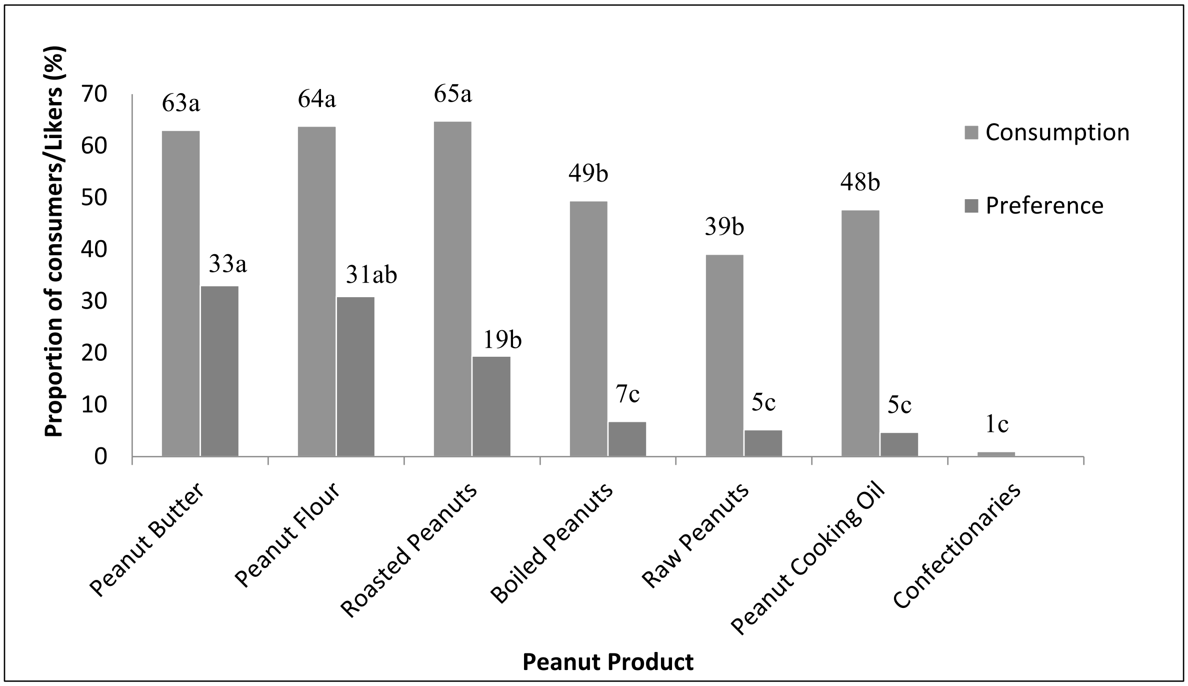

Figure 4.1. Peanut products and their respective consumption and preference frequencies. Unlike for preference, the sum of consumption frequencies is more than 100% because multiple responses were allowed. Values followed by similar letters (a, b, or c) indicate no significant difference ($p > 0.05$).

The majority (70.4%) consumed peanuts (in any form) at least three times in a week. Peanut flour and peanut butter were the most preferred peanut forms for those that consume peanuts at least three times a week or more (Figure 4.2). Consumers who eat peanuts at least once a week mostly liked peanut butter and roasted peanuts. A summary of peanut consumption frequency by gender, age, education level, occupation, and monthly income is shown in Table 4.1.

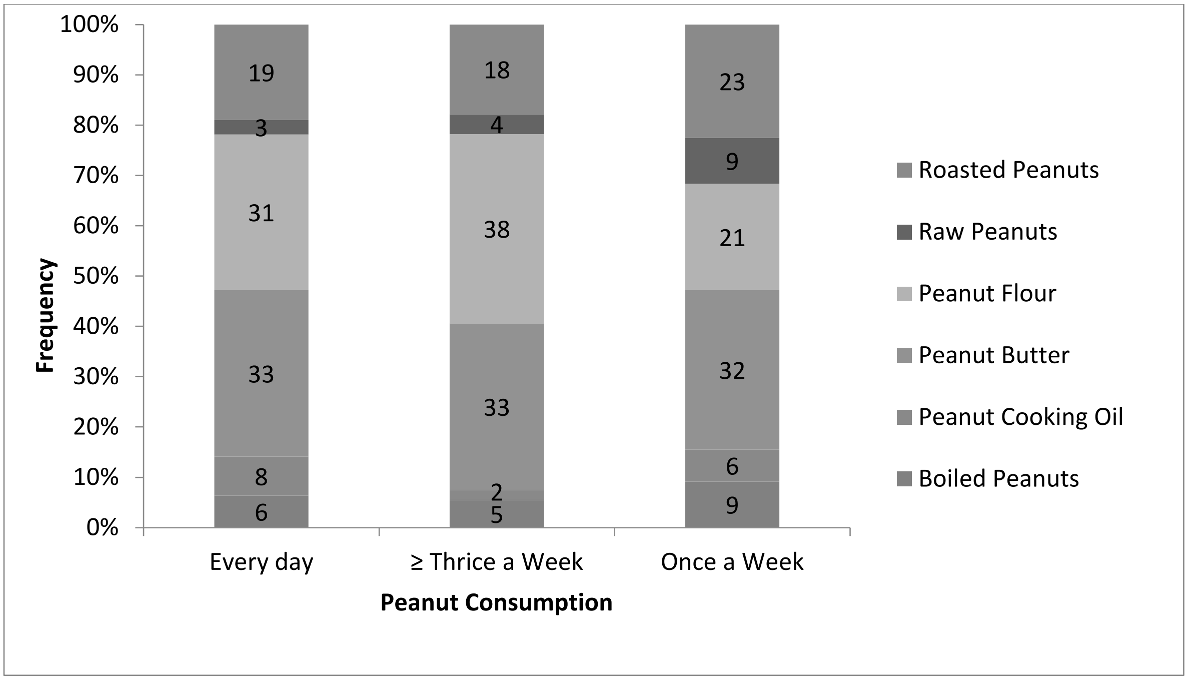

Figure 4.2. Peanut consumption rate related to consumer preference for the various peanut products. Frequency is the proportion of respondents categorized based on their most preferred peanut products.

3.3. Drivers of peanut preferences

All of the three most preferred peanut products were considered to be very nutritious (Figure 4.3). Distinctively, peanut flour preference was mainly due to its versatility since it can be used to season many other foods. The preference for roasted peanuts was primarily due to price and preparation convenience because it is cheap and easy to prepare. Peanut butter was the most preferred form of peanut consumption due to its sensory appeal and that it is energy-dense. Notably, preference for both raw and boiled peanuts was mainly due to their perceived ability to enhance reproductive health.

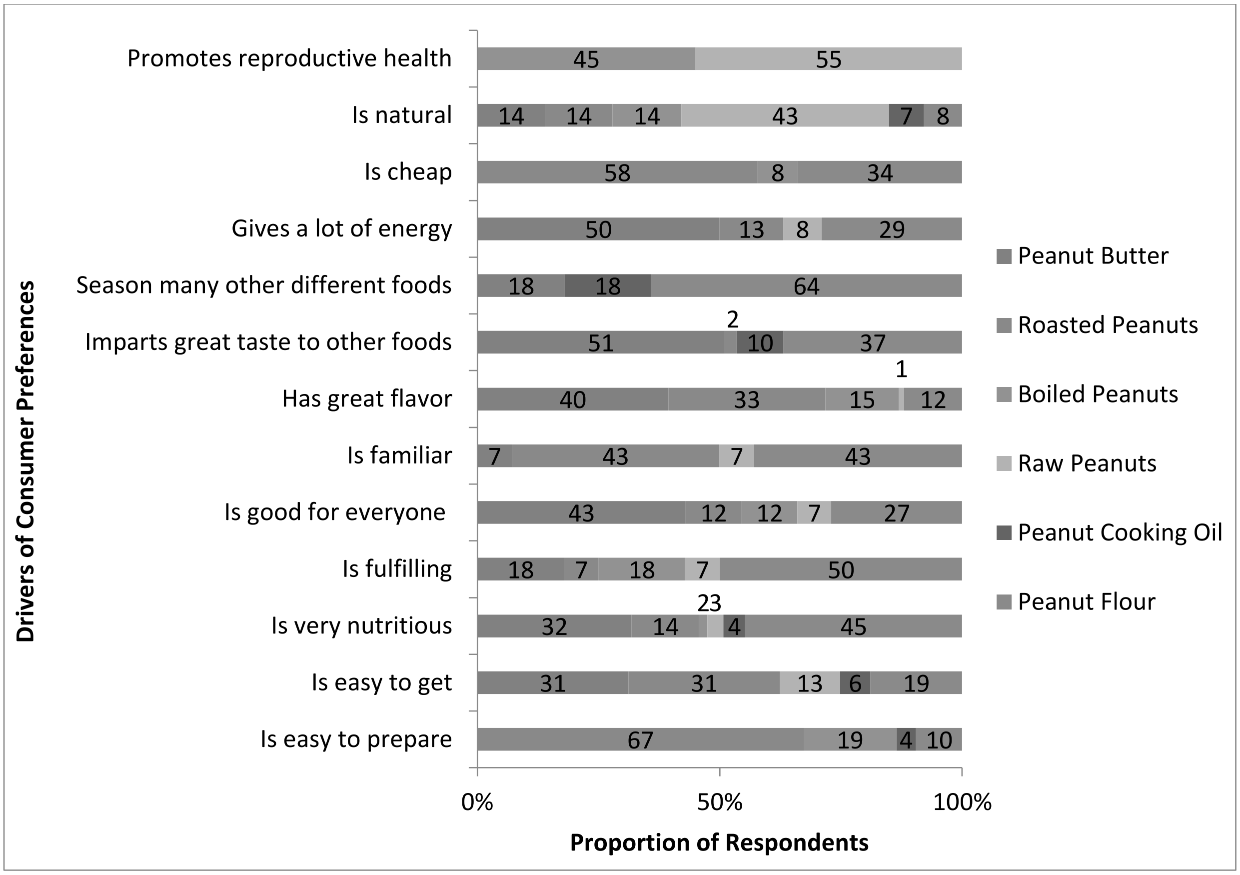

Figure 4.3. Reasons behind consumer preferences for the various peanut products. Frequency is the proportion of respondents who gave the reason, categorized based on their most preferred peanut products.

3.4. Readiness to try new foods

There was a significant difference between the proportions of neophobic and neophilic respondents ($p < 0.05$). Fifty-four percent of the respondents indicated that they were willing to try new food products for the first time. For participants that were ready to try new foods, a frequency summary by gender, age, education level, occupation, and monthly income is shown in Table 4.1. The consumers who were not ready to try new foods (neophobic consumers) had concerns about safety in general (81%), nature of the ingredients (13%), and allergens (6%). As a result, safety assurance and knowledge about the ingredients were the most frequently mentioned factors that would compel them to try new foods despite their food neophobic dispositions (Figure 4.4). However, a few consumers (6%) indicated that nothing could compel them to try new foods.

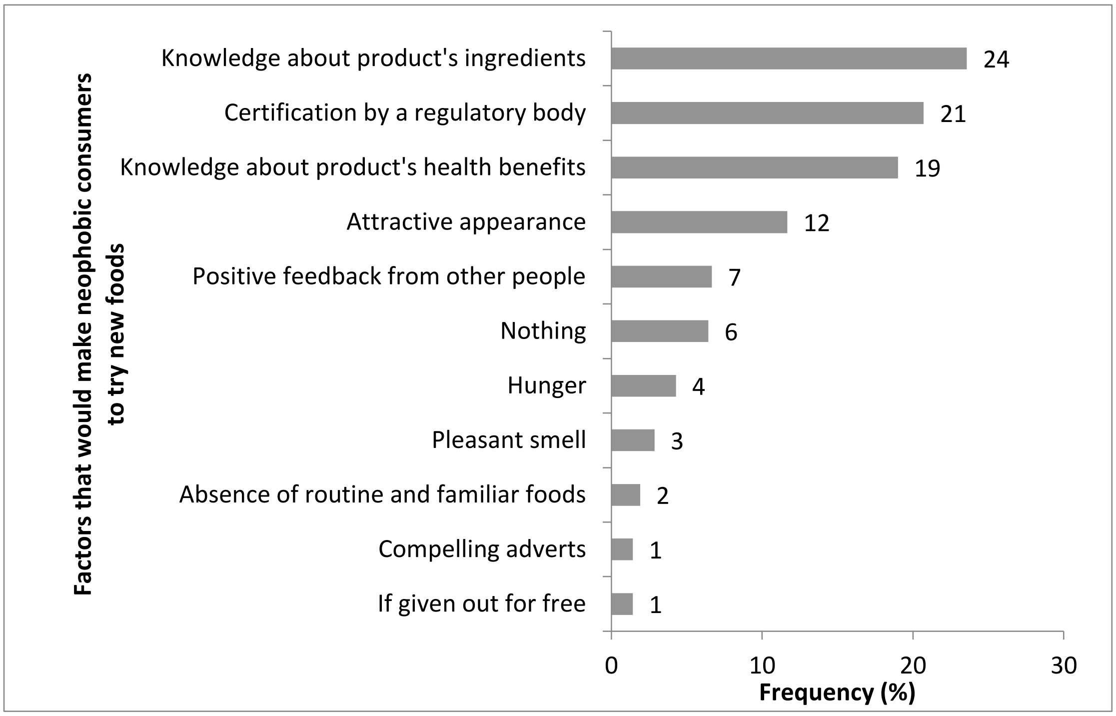

Figure 4.4. Compelling reasons for ignoring fear for new foods as indicated by the neophobic consumers (n = 225).

3.5. Effect of demographic and socioeconomic variables on peanut preference

Differences were noted in the associations between preferences for the various peanut products and the demographic and socioeconomic variables (Table 4.2). Gender, age, education level, occupation, and monthly income, respectively, had significant associations with consumer preference for peanut cooking oil ($p < 0.05$). Men were 2.56 times more likely to like peanut cooking oil than women when all other factors were held constant.

Table 4.2. Logistic regression estimates for demographic and socioeconomic variables influencing peanut product preference.

Predictor	Peanut Butter Odds ratio [CI]	Peanut Butter χ^2 $p>\chi^2$	Peanut Flour Odds ratio [CI]	Peanut Flour χ^2 $p>\chi^2$	Roasted Peanuts Odds ratio [CI]	Roasted Peanuts χ^2 $p>\chi^2$	Boiled Peanuts Odds ratio [CI]	Boiled Peanuts χ^2 $p>\chi^2$	Raw Peanuts Odds ratio [CI]	Raw Peanuts χ^2 $p>\chi^2$	Peanut Cooking Oil Odds ratio [CI]	Peanut Cooking Oil χ^2 $p>\chi^2$
Gender												
Male vs. Female	1.30 [0.88, 1.91]	1.755 0.185	1.86 [1.27, 2.74]	9.937 **0.002**	2.15 [1.42, 3.24]	13.184 **0.000**	1.15 [0.78, 1.70]	0.510 0.475	3.80 [2.31, 6.24]	27.817 **< 0.0001**	2.56 [1.57, 4.17]	14.176 **0.000**
Age												
<30 yrs. vs. ≥30 yrs.	1.70 [1.15, 2.51]	6.984 **0.008**	1.71 [1.15, 2.52]	7.183 **0.007**	1.09 [0.74, 1.62]	0.205 0.651	1.25 [0.82, 1.91]	1.115 0.291	2.17 [1.43, 3.29]	13.352 **0.000**	1.63 [1.06, 2.51]	5.005 **0.025**
Education level												
High school and below vs. Post-high school	1.54 [1.03, 2.28]	4.493 **0.034**	1.70 [1.12, 2.59]	6.209 **0.013**	1.34 [0.89, 2.02]	1.927 0.165	1.56 [1.03, 2.37]	4.344 **0.037**	2.99 [1.93, 4.63]	24.153 **< 0.0001**	2.05 [1.26, 3.34]	8.394 **0.004**
Occupation												
Full-time employment vs. Other occupations	1.18 [0.80, 1.74]	0.665 0.415	1.17 [0.79, 1.74]	0.621 0.431	1.48 [1.00, 2.18]	3.928 **0.047**	1.24 [0.83, 1.86]	1.088 0.297	1.27 [0.85, 1.87]	1.370 0.242	2.04 [1.34, 3.09]	11.133 **0.001**
Monthly income												
Low vs. Medium & High	1.06 [0.65, 1.75]	0.060 0.807	1.23 [0.74, 2.03]	0.628 0.428	1.43 [0.88, 2.32]	2.131 0.144	2.05 [1.21, 3.45]	7.205 **0.007**	2.30 [1.34, 3.95]	9.107 **0.003**	4.33 [2.02, 9.27]	14.209 **0.000**

Probability values (*p*) in bold are significant at 5% significance level; CI = 95% confidence interval.

Prediction Equations: Peanut butter = 1 / (1 + exp (-[0.01 + 0.53*Age-young + 0.43*Education level-Post high school])).

Peanut flour = 1 / (1 + exp (-[-0.41 + 0.62*Gender-Female + 0.53*Age-old + 0.53*Education level- High school & below])).

Roasted peanuts = 1 / (1 + exp (-[0.09 + 0.76*Gender-Male + 0.39*Occupation-Fulltime])).

Boiled peanuts = 1 / (1 + exp (-[0.69 + 0.44*Education level-Post high school + 0.72*Monthly income-Medium & High])).

Raw peanuts = 1 / (1 + exp (-[0.49 + 1.34*Gender-Male + 0.78*Age-old + 1.10*Education level-Post high school + 0.83*Monthly income-Low])).

Peanut cooking oil = 1 / (1 + exp (-[-2.20 + 0.94*Gender-Male - 0.490*Age-old + 0.72*Education level-High school & below + 0.71*Occupation-Fulltime + 1.47*Monthly income-Low])).

However, younger consumers, irrespective of gender, were 1.63 times more likely to like peanut cooking oil than older consumers. Likewise, consumers with high school education or below, those with full-time jobs, and the consumers with lower monthly incomes, respectively, were 2.05, 2.04, and 4.33 times more likely to prefer peanut cooking oil than their counterparts.

Preference for raw peanuts was significantly ($p < 0.05$) influenced by each of the assessed demographic and socioeconomic variables except occupation. Men were 3.80 times more likely to prefer raw peanuts than women. Likewise, older consumers, those with post-high school education, and consumers with lower monthly incomes, respectively, were 2.17, 2.99, and 2.30 times more likely to like raw peanuts than their counterparts.

Gender, age, and education level, respectively, had a significant influence on preference for peanut flour ($p < 0.05$). Women, those with high school education or below, and older consumers, respectively, were 1.86, 1.70, and 1.71 times more likely to prefer peanut flour compared to their counterparts.

Preference for boiled peanuts was significantly influenced by education level and monthly incomes ($p < 0.05$). Consumers with post-high school education were 1.56 times more likely to like boiled peanuts than those in lower education level category. Likewise, consumers with higher monthly incomes were 2.046 times more likely to prefer boiled peanuts compared to consumers with lower monthly incomes.

Gender and occupation, respectively, had a significant influence on preference for roasted peanuts ($p < 0.05$). Men and those that had full-time jobs were 2.15 and 1.48 times more likely to like roasted peanuts compared to their respective counterparts.

Finally, preference for peanut butter was significantly influenced by age and education level, respectively ($p < 0.05$). Consumers with post-high education and those that were younger were 1.54 and 1.70 times more likely to prefer peanut butter than their respective counterparts.

3.6. Effect of demographic and socioeconomic variables on peanut consumption frequency

As shown in Table 4.3, peanut consumption frequency, irrespective of peanut form, was significantly influenced by education level only ($p < 0.05$). Consumers with high school education or below were 2.35 times more likely to eat peanuts (in any form) more often than consumers in the high education level category.

Table 4.3. Logistic regression estimates for demographic and socioeconomic variables influencing peanut consumption frequency and readiness to try new foods, respectively.

Predictor	**Peanut Consumption Frequency** Odds ratio [CI]	χ^2 $P > \chi^2$	**Readiness to Try New Foods** Odds ratio [CI]	χ^2 $P > \chi^2$
Gender				
Male vs. Female	1.12	0.301	1.90	9.603
	[0.75, 1.65]	0.583	[1.27, 2.84]	**0.002**
Age				
<30 yrs. vs. ≥30 yrs.	1.01	0.005	1.38	2.401
	[0.69, 1.50]	0.945	[0.92, 2.06]	0.121
Education level				
High school and below	2.35	17.301	2.74	21.796
vs. Post- high school	[1.57, 3.51]	**< 0.0001**	[1.79, 4.18]	**< 0.0001**
Occupation				
Full-time employment vs.	1.20	0.819	2.02	11.824
Other occupations	[0.81, 1.77]	0.366	[1.35, 3.02]	**0.001**
Monthly income				
Low vs. Medium & High	1.16	0.337	1.04	0.018
	[0.71, 1.90]	0.561	[0.62, 1.75]	0.893

Probability values (p) in bold are significant at 5% significance level; CI = 95% confidence interval.

Prediction Equations: Consumption frequency = 1 / (1 + exp (-[-0.59 + 0.85*Education level- high school and below])).

Readiness to try new foods = 1 / (1 + exp (-[0.40 + 0.64*Gender-Male + 1.01*Education level-Post high school + 0.71*Occupation-Fulltime])).

3.7. Effect of demographic and socioeconomic variables on readiness to try new foods

Gender, education level, and occupation, respectively, had a significant effect on readiness to try new foods as shown in Table 4.3 ($p < 0.05$). Men were 1.90 times more likely to try new foods than women. Likewise, consumers with post-high school education and those with full-time jobs were 2.74 and 2.02 times more likely to try new foods compared to their respective counterparts.

4. Discussion

Based on the findings, it is evident that the diversity of peanut products in Malawi is limited. Unlike in other countries where peanuts are eaten in many different forms, peanuts in Malawi are consumed in a few typical customary forms such as peanut flour, raw, boiled, and roasted peanuts. As expected, these are peanut products that that are easy to prepare within households either for consumption or for vending. George Washington Carver is credited for his significant contribution to the development of peanut products. His research developed 300 products and 105 ways of using peanuts in soups, puree, bread, candy, cheeses, coffee, cookies, cakes, puddings, ice creams, cutlets, patties, sausages, omelets, macaroni, stuffing, wafers, bars, and doughnuts, among others [18,19]. The absence of most of these peanut-based products on the Malawian market is an opportunity for peanut products diversification. The limited diversity of peanut products on the Malawian market is likely one of the factors contributing to the low peanut consumption.

The mismatch between consumption and preferences is also an opportunity for innovation. One would expect a food product that is mostly preferred to be the most consumed product as well. However, as found in this study, peanut butter which was the most preferred peanut product was third when the products were ranked based on consumption. Consumers indicated that they preferred peanut products like peanut flour, boiled peanuts, and roasted peanuts because they were cheap and easy to prepare but no one mentioned these as reasons for his or her peanut butter preference. Deductively, it is likely that peanut butter consumption is hindered by its relatively high price and inconvenient preparation process. Therefore, new peanut-based products that could have the desired sensory properties like peanut butter, affordable, and convenient are likely to succeed on the Malawian market.

The significant effect of demographic and socioeconomic variables on peanut products preference provides useful insights into Malawian consumers' characteristics and their peanut consumption patterns. The significant demographic and socioeconomic effects can also serve as a basis for classifying the peanut products in Malawi. Peanut flour could be classified as a product for women, older consumers, and those in the low education level category (High school education and below). Roasted peanuts are for men and those with full-time jobs. Peanut butter is for younger consumers and those with post-high school education. Boiled peanuts are for consumers with post-high school education and those with higher monthly incomes. Raw peanuts are for men, older consumers, those with post-high school education, and consumers with lower monthly incomes. Peanut cooking oil seemed to be preferred by men in general, younger consumers, those in the low education level category (High school education and below), consumers with full-time jobs, and those with lower monthly incomes. This might be related to flavor of foods cooked or fried in peanut oil rather than just preference for the oil itself.

The effect of demographic and socioeconomic variables on peanut consumption has also been found in studies done in other countries. For instance, just like in Malawi, men were also found to be the dominant consumers of raw peanuts in Ghana and two southern states of the

U.S., respectively[20,21] . Men consider peanuts, especially raw peanuts, as an aphrodisiac [21]. Therefore, it is not surprising that enhancement of reproductive health was the most frequently mentioned reason for preferring raw and boiled peanuts. Peanuts are a rich natural source of L-arginine. This amino acid helps improve sexual function by relaxing blood vessels [22].

The reasons behind peanut preferences in Malawi are related to health (nutritious, good for reproductive health, provides energy), convenience (easy to prepare, easy to get, good for everyone), familiarity (is familiar), sensory appeal (great flavor, fulfilling, imparts great taste to other foods), price (is cheap), natural content (is natural), and versatility (can be used to season many other foods). Other studies also found that health, convenience, familiarity, price, sensory appeal and natural content of foods as factors that influence food choices of consumers in general [11-13,23,14,24]. Therefore, only versatility is the unique factor identified in this study. Peanut flour was considered to be highly versatile among all the peanut products identified in this study. In Malawi, peanut flour is added to many other different foods such as vegetables, fish, corn flour porridge, sweet potatoes, plantains, rice, and corn grits. It can also be used to make peanut sauce (Thendo) by mixing the peanut flour with other ingredients such as tomatoes.

The significant effect of demographic and socioeconomic factors on peanut consumption frequency and readiness to try new foods provides further insights into the characteristics of Malawian consumers. The findings have shown that Malawian consumers with post-high school education eat peanut products less often compared to those in the low education level category. Whether the peanuts are replaced with other equally nutritious foods or snacks is not known. Consumers with post-high school education were also more ready to try new foods than those in the low education level category. Likewise, men and those with full-time jobs were more ready to try new foods compared to their respective counterparts. Based on this study, the neophilic consumers have high purchasing power since they have higher monthly incomes compared to their respective counterparts. Therefore, targeting them with new commercial food products, which meets their needs and wants, could be feasible. Food neophobic individuals consider novel or unfamiliar foods as a threat and therefore, they react negatively to these products [25]. Food neophobia restricts marketability of new food products, is a possible barrier to a balanced diet, and could restrict change towards a healthier diet [26-28]. Therefore, food products marketing strategies should be devised to target this segment of neophobic consumers when promoting new food products. Apart from the few consumers, those that nothing can compel them to try new foods, most of the food neophobic consumers are just being cautious. Addressing their fears, by providing safety assurance and declaring the product's ingredients, among others, could yield positive results. Veeck [25] noted that food neophobia could be described as an individual and a social trait. Therefore, as found in this study, a referral from a trusted friend or close family member may persuade a food neophobic person to sample an unfamiliar food product. However, further studies should be done to determine the effectiveness of the factors, identified in this study, which could compel a neophobic individual to try new foods. Unlike the approach used in this study, such further studies should use a validated tool developed by Pliner et al. [29] for measuring food neophobia to maximize the reliability of the findings.

5. Conclusion

This study has provided useful information on peanut consumption in Malawi, the reasons for peanut product preferences, and the differences in consumer preferences for the various peanut forms based on demographic and socioeconomic factors. The limited diversity of peanut products on the Malawian market is an opportunity for innovation. Given that socioeconomic restrictions are overriding consumer preferences, future peanut-based food products innovations should, therefore, explore ways to strike a balance between price and the other food choice motives. Furthermore, proper marketing strategies should be developed to target neophobic consumers.

In this study, the sample size was statistically adequate, and the socioeconomic profiles of the participants were a relatively good representation of Malawian consumers. However, the authors acknowledge the limitation that the sample was demographically unbalanced when compared to the national population distribution. Therefore, the findings are suggestive of the likely national trend rather than being conclusive. However, this is the first study of its kind in Malawi. Therefore, the results have provided good insights into Malawian consumers' peanut consumption patterns, preferences, and their readiness to try new foods. Future studies can build on the findings of this study to further explore issues related to peanut consumption and food neophobia in Malawi, preferably using a purposive sampling plan to balance the demographic composition of the participants.

References

1. FAO (2015) Regional Overview of Food Insecurity in Africa. Food and Agriculture Organization. http://www.fao.org/3/a-i4635e.pdf. Accessed 20 March 2017
2. MG (2017) Malawi Growth And Development Strategy-III. Malawi Government. https://cepa.rmportal.net/Library/government-publications/the-malawi-growth-and-development-strategy-mgds-iii. Accessed 15 February 2018
3. Ronzio RA (2003) The encyclopedia of nutrition and good health. Infobase Publishing,
4. Awad AB, Chan KC, Downie AC, Fink CS (2000) Peanuts as a source of β-sitosterol, a sterol with anticancer properties. Nutrition and cancer 36 (2):238-241
5. Sanders TH, McMichael RW, Hendrix KW (2000) Occurrence of resveratrol in edible peanuts. Journal of agricultural and food chemistry 48 (4):1243-1246
6. Griel AE, Eissenstat B, Juturu V, Hsieh G, Kris-Etherton PM (2004) Improved diet quality with peanut consumption. Journal of the American College of Nutrition 23 (6):660-668
7. FAO (1990) Patterns of Urban Food Consumption in Developing Countries: Perspective from the 1980's ftp://ftp.fao.org/es/esn/nutrition/urban/delisle_paper.pdf. Accessed 21 December 2015
8. FAOSTAT (2014) Malawi Food Balance Sheet. http://www.fao.org/faostat/en/#data. Accessed 13 December 2015
9. Slater SF, Narver JC (2000) Intelligence generation and superior customer value. Journal of the academy of marketing science 28 (1):120-127

10. Van Kleef E, van Trijp HC, Luning P (2005) Consumer research in the early stages of new product development: a critical review of methods and techniques. Food quality and preference 16 (3):181-201
11. Eertmans A, Victoir A, Notelaers G, Vansant G, Van den Bergh O (2006) The Food Choice Questionnaire: Factorial invariant over western urban populations? Food quality and preference 17 (5):344-352
12. Fotopoulos C, Krystallis A, Vassallo M, Pagiaslis A (2009) Food Choice Questionnaire (FCQ) revisited. Suggestions for the development of an enhanced general food motivation model. Appetite 52 (1):199-208
13. Januszewska R, Pieniak Z, Verbeke W (2011) Food choice questionnaire revisited in four countries. Does it still measure the same? Appetite 57 (1):94-98
14. Prescott J, Young O, O'neill L, Yau N, Stevens R (2002) Motives for food choice: a comparison of consumers from Japan, Taiwan, Malaysia and New Zealand. Food quality and preference 13 (7):489-495
15. James D (2004) Factors influencing food choices, dietary intake, and nutrition-related attitudes among African Americans: application of a culturally sensitive model. Ethnicity and Health 9 (4):349-367
16. Anderson EN (2014) Everyone eats: Understanding food and culture. NYU Press,
17. Cameron AC, Trivedi PK (2005) Microeconometrics: methods and applications. Cambridge university press,
18. Carver GW (1983) How to grow the peanut and 105 ways of preparing it for human consumption. Eastern National Park and Monument Association for Tuskegee Institute, National Historical Site, George Washington Carver National Monument,

19. Chinnan MS (2011) Peanut Further Processing. http://athenaeum.libs.uga.edu/bitstream/handle/10724/33677/Chinnan-PeanutProcessing-GAPnutTour2011-RevSep28.pdf?sequence=1. Accessed 12 January 2016

20. Jolly C, Hinds M, Lindo P, Ligeon C, Weiss H (2002) Determinants of boiled peanuts consumption in two southern states of the US. Journal of Peanut Science 31 (1):1-7

21. Jolly CM, Awuah RT, Fialor SC, Agyemang KO, Kagochi JM, Binns AD (2008) Groundnut consumption frequency in Ghana. International Journal of Consumer Studies 32 (6):675-686

22. Stanislavov R, Nikolova V (2003) Treatment of erectile dysfunction with pycnogenol and L-arginine. Journal of Sex &Marital Therapy 29 (3):207-213

23. Jáuregui-Lobera I, Ríos PB (2011) What motivates the consumer's food choice? Nutricion Hosppitalaria 26 (6):1313-1321

24. Steptoe A, Pollard TM, Wardle J (1995) Development of a measure of the motives underlying the selection of food: the food choice questionnaire. Appetite 25 (3):267-284

25. Veeck A (2010) Encounters with extreme foods: Neophilic/neophobic tendencies and novel foods. Journal of Food Products Marketing 16 (2):246-260

26. Schickenberg BA (2010) Towards strategies to stimulate first time trial of unfamiliar healthful food products. Maastricht university,

27. Knaapila A, Silventoinen K, Broms U, Rose RJ, Perola M, Kaprio J, Tuorila HM (2011) Food neophobia in young adults: genetic architecture and relation to personality, pleasantness and use frequency of foods, and body mass index—a twin study. Behavior genetics 41 (4):512-521

28. Johns N, Edwards JS, Hartwell H (2011) Food neophobia and the adoption of new food products. Nutrition & Food Science 41 (3):201-209

29. Pliner P, Hobden K (1992) Development of a scale to measure the trait of food neophobia in humans. Appetite 19 (2):105-120

CHAPTER 5

SENSORY CHARACTERIZATION OF DOMINANT MALAWI PEANUT VARIETIES[1]

[1] Gama, A.P. and K. Adhikari. Submitted to *Journal of Food Science,* 12/20/19.

Abstract

Although sensory appeal influences peanut consumption, peanut varieties are mostly selected based on agronomic traits. As a result, the sensory properties of peanut varieties, especially in southern Africa, are not known. Therefore, the primary objective of the study was to determine the sensory properties of the Malawi peanut varieties and the volatile compounds associated with roasted peanut flavor. Six dominant Malawi peanut varieties (Chalimbana, CG7, Nsinjiro, Kakoma, Baka, and Chitala) were evaluated in this study. All peanut samples were shelled and then, roasted in a convection oven to reach medium doneness as indicated by the surface color lightness (L) value of ~50. A hybrid descriptive analysis (DA) was done to determine the sensory profile of the roasted peanuts. Volatile compounds were extracted from equilibrated ground peanut sample using headspace-solid phase microextraction (HS-SPME) technique and analyzed by gas chromatography-mass spectrometry (GC-MS). Analysis of Variance (ANOVA) of the DA data showed significant differences ($p < 0.05$) in the sensory profiles of the peanut varieties. Nsinjiro and Baka had a significantly higher intensity of roasted peanutty aroma and flavor ($p < 0.05$). The GC-MS results showed that pyrazines and furans were the dominant volatile compounds but, their respective concentrations, in the evaluated peanut varieties, were significantly different ($p < 0.05$). Among the pyrazines, 2-ethyl-3,5-dimethyl pyrazine was strongly correlated with roasted peanutty flavor ($r = 0.927$) just like 2,5 dimethyl pyrazine ($r = 0.916$). Therefore, 2-ethyl-3,5-dimethyl pyrazine and 2,5-dimethyl pyrazine production pathways could provide more insights into the origins of roasted peanut flavor. The findings of this study can help food product developers, who have no access to sensory and analytical analyses, to identify Malawi peanut varieties that are suitable for various food

applications. Furthermore, plant breeders could also use the findings to inform new projects aimed at improving the sensory properties of the peanut varieties.

1. Introduction

Peanuts (*Arachis hypogaea*) are among the important oilseed crops in the world [1]. Peanuts are even more important in developing countries. Of the total world peanut production, 92% comes from Africa, Asia, and South America [2]. Peanuts are a valuable source of proteins, fats, vitamins, and minerals for human and animal nutrition [3]. Many studies have shown the numerous health benefits deriving from peanut consumption, including benefits beyond basic nutrition. As a functional food, peanut consumption has been associated with a decreased risk of having coronary heart disease (CHD), cancer, type 2 diabetes, and unhealthy body mass index (BMI), among others [4-9]. As a result, promotion of peanuts consumption is one component of nutrition intervention programs, especially in Sub-Saharan Africa where malnutrition remains a significant challenge and cases of non-communicable diseases (NCDs) are increasing [10,11].

One of the primary drivers of peanut consumption is the sensory appeal, especially flavor after thermal processing [12]. However, just like the nutrient composition of peanuts, studies have shown that flavor in peanuts is also affected by genotype, among other factors [13,14]. For instance, Lykomitros et al. [15] found that Virginia type peanuts develop more intense roasted aromas than Runner type peanuts, and this was attributed to likely differences in the concentrations of Maillard reaction precursors. Such differences have also been reported in several other studies comparing flavor profiles of peanuts from different origins, market types, varieties, and grades [16-20]. Therefore, the need for proper selection of peanut varieties to meet various food applications cannot be overemphasized. Unfortunately, studies aimed at characterizing sensory properties of peanuts have not been done in Sub-Saharan Africa. For instance, over fourteen peanut varieties have been released in Malawi since 1968, and mostly they were developed to improve yield and resistance to diseases and pests [21]. Currently, based on adoption rates by farmers, Chalimbana, CG7, Nsinjiro, Kakoma, Baka, and Chitala are the dominant peanut varieties in Malawi [22]. However, unlike the agronomic information, little is known about the sensory properties of any peanut variety in Malawi.

Given the above, the sensory characteristics and flavor compounds of the dominant Malawi peanut varieties were determined in this study. The findings can potentially influence the utilization of the peanut varieties. Therefore, the study is valuable especially to food product developers and food marketers. Furthermore, plant breeders could also use the same information to inform new projects aimed at improving the sensory properties of the peanut varieties.

2. Materials and methods

2.1. Sample preparation

Six dominant Malawi peanut varieties were evaluated in this study. Based on adoption rates by farmers, Chalimbana, CG7, Nsinjiro, Kakoma, Baka, and Chitala are currently the dominant peanut varieties in Malawi [22], and all of them were normal-oleic varieties. The peanut samples for all the varieties, except Chalimbana, were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Malawi. Chalimbana peanut samples were obtained from Department of Agricultural Research Services, Chitedze research station, in Malawi. All samples were pure seed-grade peanuts from the 2015-2016 planting season, and the same agro-ecological zone (Lakeshore and Upper Shire Valley zone). All peanut samples were shelled and then, batches (1 Kg) of each sample were roasted in a convection oven (KitchenAid Superba, KEBS208, Benton Harbor, MI, USA) to reach medium doneness, indicated by surface color lightness (L) value of 50 ± 1. The batch size was chosen to ensure a single layer of peanuts on the roasting wire racks for uniform roasting. The L-value of 50 ± 1 has been identified as the ideal color for roasted peanut flavor [23,24]. Four color readings were taken for each of the roasted peanuts using a calibrated benchtop ColorFlex Spectrophotometer (HunterLab, Reston, VA, USA) as done by Wang et al. [25]. The variety details [26], roasting conditions, and mean L values for the samples are summarized in Table 5.1. After roasting, the peanuts were cooled to room temperature (24 ± 1 °C) by a cooling fan and were then blanched in an Ashton peanut blancher (Model EX, Ashton Food Machinery Co., Newark, NJ, USA). The blanched peanut samples were manually sorted to remove discolored and broken kernels. The sorted samples were then vacuum-packaged after flushing with nitrogen. All samples were stored at -20 °C till further use in descriptive and gas chromatography-mass spectroscopy (GC-MS) analyses. A day before the descriptive or GC-MS analysis, samples were moved from the storage, equilibrated at 24 °C for 12 h, and stored in Ziploc bags (S. C. Johnson & Son, Inc., Racine, WI, USA).

Table 5.1. Description of the peanut varieties and their roasting conditions.

Variety	Market type	100 seed weight (g)	Temperature (°C)	Time (min)	Lightness (L)
Chalimbana (Local)	Virginia	81	162.8	35	49.78
CG7 (ICGV-SM 83708)	Virginia	62	162.8	30	49.33
Nsinjiro (ICGV-SM 90704)	Virginia	45	162.8	25	49.04
Kakoma (JL 24)	Spanish	45	162.8	25	49.33
Baka (ICG 12991)	Spanish	36	162.8	20	49.77
Chitala (ICGV-SM 99568)	Spanish	45	162.8	25	49.98

2.2. Descriptive analysis

A hybrid descriptive analysis method was used [27]. Evaluation of appearance, aromatics, flavor, texture, feeling factors, and after-taste, of the medium roasted peanuts (L = 50 ± 1), was done by six highly trained panelists at the University of Georgia, Griffin Campus' Sensory Evaluation & Consumer Laboratory. Approval from the University's institutional review board (IRB) was obtained (STUDY00004112) before collecting the sensory data. All the panelists (4 women and 2 men) were adults, and had more than 12 y (about 1440 h) of experience in descriptive analysis of peanut products. Before the tests, two orientation sessions, each lasting for 2 h, were conducted to decide on a lexicon for the roasted peanuts. The panel decided the final list of descriptors, definitions, and references through consensus (Table 5.2). Twenty-three attributes were evaluated. These were sweet aromatic aroma, roasted peanutty aroma, oily aroma, overall oxidized aroma, cardboard aroma, fishy aroma, painty aroma, brownness, raw/beany flavor, roasted peanutty flavor, burnt flavor, oily flavor, bitter taste, sour taste, salty taste, sweet taste, fructurability, crispness, crunchiness, tooth packing, astringency, roasted peanutty after-taste, and burnt after-taste. All the samples were tested in partitioned booths under incandescent light at 24 °C according to a randomized complete block design with three replications. About 10 g of each peanut sample was served and scored using a 0 to 150-point scale with 5-point increments. Water and unsalted crackers (Kroger Co., Cincinnati, OH, USA) were used to cleanse the palate before evaluating each sample, and a 2-min break (computer-programmed) was also included between samples, in each session. The data were collected using Compusense Cloud (Compusense Inc., Guelph, Ontario, Canada).

Table 5.2. Descriptors for descriptive analysis of the peanuts.

Attributes	Definition	Reference (s) intensity
Aromatics		
Roasted peanutty	The aroma associated with medium-roasted peanuts	Peanut butter (Kroger Co., Cincinnati, OH, USA) = 55 Dark roasted peanuts[a] (L= 36.9) = 95
Sweet aromatic	The aroma associated with sweet material such as caramel, vanilla, molasses, fruit	Peanut butter (Kroger Co., Cincinnati, OH, USA) = 30 Peanut butter cookie (The bakery, Walmart Inc., USA) = 70
Oily aroma	The aroma associated with vegetable oil	Virgin peanut oil (Bell Plantation Inc., Tifton, GA, USA) = 15 Soybean vegetable oil (Walmart, Inc., USA) = 40
Overall oxidized	The aroma associated with rancid fats and oils.	Oxidized virgin peanut oil[b] = 5 Oxidized oil[c] = 60
Cardboard	The aroma associated with somewhat oxidized fats and oils and reminiscent of wet cardboard	Wet cardboard= 40
Fishy	The aroma associated with trimethylamine, cod liver oil or old fish	Cod liver oil (Walgreen Co., Deerfield, IL, USA) = 80
Painty	The aroma associated with linseed oil, oil-based paint	Boiled linseed oil (W.M. Barr & Co., Inc., Memphis, TN, USA) = 115
Appearance		
Brown color	The intensity of brown color from light to dark brown	Paint chips: GLD 502 = 20 GLD 508 = 80 GLD 515 = 105
Flavors		
Raw/beany	The flavor associated with raw peanuts	Raw peanuts (Food Depot, Stockbridge, GA, USA) = 40
Roasted peanutty	The flavor associated with medium roasted peanuts	Peanut butter (Kroger Co., Cincinnati, OH, USA) = 55 Dark roasted peanuts[a] (L=36.9) = 100
Burnt	The flavor associated with very dark roast, burnt starches, and carbohydrates (burnt toast or espresso coffee)	Dark roasted peanuts[a] (L=36.9) = 100
Oily	The flavor associated with peanut oil after expectoration	Virgin peanut oil (Bell Plantation Inc., Tifton, GA. USA) = 30
Bitter	The taste on the tongue associated with bitter agents such as caffeine solution	0.05% caffeine solution= 20 0.08% caffeine solution= 50 0.15% caffeine solution= 100
Sour	The taste on the tongue associated with acid solutions	0.05% citric acid solution= 20 0.08% citric acid solution= 50 0.15% citric acid solution= 100
Salty	The taste on the tongue associated with sodium chloride solutions	0.2% sodium chloride solution= 25 0.35% sodium chloride solution= 50 0.5% sodium chloride solution= 85

Table 5.2. (Continued)

Attributes	Definition	Reference (s) intensity
Sweet	The taste on the tongue associated with sucrose solution	2% caffeine solution= 20 5% caffeine solution= 50 10% caffeine solution= 100
Texture		
Fracturability	The force with which the sample breaks	Corn chips (Frito Lay, Plano, TX, USA) = 55
Crispness	Amount of force needed and intensity of sound (high pitch) generated from chewing a sample with incisors	Corn chips (Frito Lay, Plano, TX, USA) = 70
Crunchiness	The force needed and amount of sound (lower pitch) generated from chewing a sample with molars	Corn chips (Frito Lay, Plano, TX, USA) = 75
Tooth packing	The degree to which product sticks on the surface of molars	Raw peanuts (Food Depot, Stockbridge, GA, USA) = 40
Feeling factors		
Astringent	The puckering or drying sensation on the mouth or tongue surface	0.05% alum solution= 20 0.08% alum solution= 50
Aftertaste		
Roasted peanutty	The flavor associated with medium roasted peanuts	Peanut butter (Kroger Co., Cincinnati, OH, USA) = 55 Dark roasted peanuts[a] (L=36.9) = 100
Burnt	The flavor associated with very dark roast, burnt starches, and carbohydrates (burnt toast or espresso coffee)	Dark roasted peanuts[a] (L=36.9) = 100

[a] Prepared by roasting Gourmet raw peanuts until they were dark ($L < 40$).

[b] Prepared by microwaving 250 mL vegetable oil (Kroger Co., Cincinnati, OH, USA) at high heat for 3 min and then cooling to room temperature.

[c] Prepared by microwaving 250 mL virgin peanut oil (Bell Plantation Inc., Tifton, GA. USA) at high heat for 3 min and then cooling to room temperature.

2.3. GC-MS analysis

Volatile compounds were extracted from equilibrated ground peanut sample using headspace-solid phase microextraction (HS-SPME) technique and then, analyzed on a GC-MS as described by Wang et al. [28]. The samples were ground to a powder using a coffee grinder (Hamilton Beach Co., Southern Pines, NC, USA). Approximately 1.5 g of the ground sample was transferred into a 20 mL screw-cap vial fitted with a polytetrafluoroethylene septum. To each vial, 20 µL of 0.045 mg/mL of 1,3-dichlorobenzene (Sigma-Aldrich, St. Louis, MO, USA) was added as an internal standard (IS). The final concentration of the IS in the sample was 600 µg/Kg. The sample vials were then equilibrated at 50 °C, for 15 min, in the autosampler (Model GC sampler 80, Agilent Technologies, Santa Clara, CA, USA). The equilibration was done under agitation at 250 rpm. After the equilibration, a 50/30 µm divinylbenzene/ carboxen/polydimethylsiloxane fiber was exposed to the sample headspace for 40 min at 50 °C. The volatile compounds were desorbed from the fiber, at 250 °C for 5 min, onto the GC-MS (Model 7890A, Agilent Technologies, Santa Clara, CA, USA) in a splitless mode.

The compounds were separated on an HP-5MS column (30 m × 250 µm × 0.25 µm) and detected by a mass detector (Model 5977A, Agilent Technologies, Santa Clara, CA, USA). Helium gas, at a flow rate of 1 mL/min, was used as a carrier gas. The column was maintained at 40 °C for 5 min, raised to 116 °C at a rate of 2 °C /min, and finally to 200 °C at a rate of 6 °C /min. The mass detector scanned a mass range (m/z) from 30 to 400 at a scan speed of 1.562 u/s. Temperatures for MS source and MS quadrupole were 230 °C and 150 °C, respectively. Identification of compounds was based on mass spectra database (NIST/EPA/NIH mass spectral library, version 2.2, 2014) and Kovats indices (KI). The KI indices were calculated based on the retention times of a series of n-alkanes (C7 to C30). Concentrations of the compounds were calculated based on their relative peak areas to that of the internal standard, 1,3-dichlorobenzene. All samples were analyzed in duplicate.

2.4. Statistical analysis

The data were first analyzed using analysis of variance (ANOVA). One-way ANOVA was used to analyze the GC-MS data. Three-way ANOVA was used to analyze the descriptive sensory data with panelist and replication as random variables (mixed model). Post-hoc mean separations were carried out using Tukey's honestly significant difference test at a significance level of 0.05 ($p < 0.05$). To identify the key characteristics of each sample, a product characterization function, in XLSTAT statistical software, was applied to both the sensory and GC-MS data. The computations are based on ANOVA models and the discriminating power of all the descriptors is determined for each sample [29]. The model coefficients have been reported in this study. Large model coefficient for a particular descriptor indicates high discrimination effect (key characteristic), whether positive or negative. Finally, multiple factor analysis (MFA) was done to show the pattern of relationship between the sensory and GC-MS data sets. All statistical analyses were done in XLSTAT (ver 2018; Addinsoft, New York, NY).

3. Results and discussion

3.1. Descriptive analysis

Based on ANOVA, roasted peanutty aroma and flavor, oily flavor, burnt flavor, raw or beany flavor, astringency, bitter taste, fructurability, brownness, sweet taste, and burnt aftertaste had significant discriminating power ($p < 0.05$). As expected of freshly roasted peanuts, overall oxidized flavor and other off-flavors (cardboard, fishy, and painty) were close to zero. In general, Nsinjiro and Baka had significantly higher intensities of roasted peanutty aroma and flavor (Table 5.3). CG7 and Chalimbana had significantly higher intensities of oily flavor while Chitala had a significantly higher intensity of fructurability. Considering the model coefficients for each sample, as shown in Table 5.3, Chalimbana had more of oily flavor but, less brownness, burnt flavor, and astringency. CG7 had more of oily flavor, raw or beany flavor, and a sweet taste but, less of astringency, bitter taste, burnt flavor, and burnt aftertaste. Nsinjiro had more of the roasted peanutty flavor. However, it also had more of the burnt flavor, sour taste, and astringency. Kakoma had less of sweet and oily aroma intensities. Baka also had more of the roasted peanutty flavor, burnt flavor, burnt aftertaste, and a bitter taste. However, Baka had less oily flavor, fructurability and crispness intensities. Finally, Chitala had less oily flavor but more fructurability.

Considering the significant attributes, the roasted peanutty flavor had significant positive correlations with a burnt flavor, bitter taste, and burnt aftertaste, respectively (Table 5.4). The burnt flavor had a significant negative correlation with oily flavor but, positive correlations with a bitter taste and burnt aftertaste. Contrary to expectation, brownness had no significant correlation with roasted peanutty flavor and aroma. Other studies have reported significant correlations between flavor and color of roasted peanuts [24,30,31]. Considering that both color development and roasted peanut flavor are mainly due to Maillard reaction [23,31], it was expected that color would have a significant correlation with roasted peanut flavor. However, the correlation was not found in this study. This confirms the findings of Lykomitros et al. [32] who suggested that the correlation between color and roasted peanut flavor is not universal.

Table 5.3. Mean intensity scores and model coefficients for the sensory attributes of freshly roasted peanuts.

	Samples					
Attributes	**Baka**	**Chalimbana**	**CG7**	**Chitala**	**Kakoma**	**Nsinjiro**
Aromatics						
Roasted peanutty	[2.03][1] 55.3^{a}	[0.63] 53.9^{b}	[-2.97] 50.3^{b}	[-0.43] 52.8^{b}	[-2.13] 51.1^{b}	[2.87] 56.1^{a}
Sweet aromatic	[0.96] 21.9^{a}	[0.99] 22.0^{a}	[-0.14] 20.8^{a}	[0.12] 21.1^{a}	[**-2.64**] 18.3^{a}	[0.72] 21.7^{a}
Oily aroma	[0.21] 14.7^{a}	[0.81] 15.3^{a}	[0.51] 15.0^{a}	[0.24] 14.7^{a}	[**-1.73**] 12.8^{a}	[-0.03] 14.5^{a}
Overall oxidized	[-0.97] 0.8^{a}	[-097] 0.8^{a}	[-0.44] 1.4^{a}	[1.53] 3.3^{a}	[1.26] 3.1^{a}	[-0.41] 1.4^{a}
Cardboard	[-0.36] 0.6^{a}	[-0.36] 0.6^{a}	[0.18] 1.1^{a}	[0.44] 1.4^{a}	[1.01] 1.9^{a}	[-0.92] 0.3^{a}
Fishy	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
Painty	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
Appearance						
Brown color	[4.07] 68.9^{a}	[**-9.26**] 55.6^{b}	[2.97] 67.8^{a}	[-4.53] 60.3^{a}	[3.81] 68.6^{a}	[2.94] 67.8^{a}
Flavors						
Raw/beany	[-0.75] 1.1^{b}	[-0.45] 1.1^{b}	[**1.25**] 2.3^{a}	[-1.02] 1.4^{b}	[0.75] 1.8^{b}	[0.22] 1.2^{b}
Roasted peanutty	[**4.99**] 61.1^{a}	[-4.17] 51.9^{b}	[-3.34] 52.8^{b}	[-1.37] 54.7^{b}	[-1.64] 54.5^{b}	[**5.53**] 61.6^{a}
Burnt	[**8.26**] 17.0^{a}	[**-4.54**] 4.2^{b}	[**-5.11**] 3.6^{b}	[-0.64] 8.1^{ab}	[-2.3] 6.4^{ab}	[**4.36**] 13.1^{a}
Oily	[**-1.71**] 13.3^{ab}	[**1.33**] 15.5^{a}	[**1.33**] 15.5^{a}	[**-0.87**] 10.3^{b}	[0.26] 14.5^{a}	[-0.34] 13.9^{ab}
Bitter	[**1.67**] 11.4^{a}	[-1.10] 8.6^{b}	[**-1.67**] 8.1^{b}	[0.30] 10.0^{b}	[-0.30] 9.4^{b}	[1.10] 10.8^{b}
Sour	[-0.28] 0.3^{a}	[-0.54] 0.0^{a}	[-0.54] 0.3^{a}	[-0.01] 0.6^{a}	[0.02] 0.6^{a}	[**1.36**] 1.1^{a}
Salty	[-0.11] 11.7^{a}	[-0.44] 11.4^{a}	[-4.11] 11.4^{a}	[0.39] 12.2^{a}	[-0.68] 11.1^{a}	[1.26] 13.1^{a}
Sweet	[-1.07] 15.0^{b}	[0.59] 16.7^{b}	[**2.29**] 18.4^{a}	[1.16] 17.2^{b}	[-1.61] 14.5^{b}	[-1.37] 14.7^{b}
Texture						
Fracturability	[**-3.89**] 41.4^{b}	[-0.82] 44.5^{ab}	[-0.29] 45.0^{ab}	[**4.44**] 50.3^{a}	[-0.56] 44.7^{ab}	[1.11] 46.4^{ab}
Crispness	[**-3.64**] 38.6^{a}	[1.13] 42.2^{a}	[0.56] 41.7^{a}	[-0.84] 40.3^{a}	[0.26] 41.4^{a}	[2.53] 43.6^{a}
Crunchiness	[-1.85] 46.7^{a}	[2.03] 50.5^{a}	[1.78] 50.3^{a}	[-1.85] 46.7^{a}	[-0.18] 48.3^{a}	[0.08] 48.6^{a}
Tooth packing	[-1.03] 16.7^{a}	[1.20] 18.9^{a}	[2.33] 20.0^{a}	[0.37] 18.1^{a}	[-1.00] 16.7^{a}	[-1.87] 15.8^{a}
Feeling factors						
Astringent	[0.32] 11.9^{b}	[**-1.61**] 10.0^{b}	[**-1.88**] 9.7^{b}	[0.59] 12.2^{b}	[0.89] 12.5^{b}	[**1.69**] 13.3^{a}
Aftertaste						
Roasted peanutty	[1.26] 43.3^{a}	[-3.74] 38.3^{a}	[-0.71] 41.4^{a}	[-2.64] 39.4^{a}	[[1.52] 43.6^{a}	[4.32] 46.4^{a}
Burnt	[**6.04**] 10.0^{a}	[-2.82] 3.3^{b}	[**-4.76**] 1.4^{b}	[-0.32] 5.8^{ab}	[-0.06] 6.1^{ab}	[1.91] 8.1^{a}

^{ab} Different superscripts within the same row indicate significant differences among the means ($p < 0.05$).
[1] Values in brackets are model coefficients and those in bold, within the same column, are significant ($p < 0.05$).

Table 5.4. Pearson correlations among the significant sensory attributes.

Attributes	B	RF	RPF	BF	OF	BT	ST	A	BAT	Fracturability
Roasted peanutty aroma (RPA)	-0.065	-0.593	0.774	0.772	-0.554	0.772	-0.529	0.482	0.703	-0.164
Brownness (B)		0.521	0.557	0.459	-0.336	0.359	-0.418	0.411	0.415	-0.370
Raw/Beany flavor (RF)			-0.249	-0.453	0.619	-0.550	0.102	-0.225	-0.507	-0.146
Roasted peanutty flavor (RPF)				**0.953**[1]	-0.766	**0.916**	-0.660	0.720	**0.870**	-0.245
Burnt flavor (BF)					**-0.885**	**0.965**	-0.627	0.649	**0.962**	-0.328
Oily flavor (OF)						**-0.932**	0.488	-0.695	**-0.907**	0.046
Bitter taste (BT)							-0.686	0.790	**0.962**	-0.136
Sweet taste (ST)								-0.765	-0.736	0.349
Astringent (A)									0.684	0.237
Burnt aftertaste (BAT)										-0.372

[1]Values in bold indicate significant correlation ($p < 0.05$).

As found in this study, significant differences in the flavor of peanuts roasted to the same final surface color are possible [24]. Therefore, relying only on the surface color to predict roasted peanut flavor of different varieties may be misleading.

It is apparent that Baka and Nsinjiro, which had significantly higher scores on roasted peanutty flavor ($p < 0.05$), had a bitter taste, burnt flavor, and a burnt aftertaste. On the other hand, CG7 and Chalimbana, which had significantly lower scores on roasted peanutty flavor, had a raw or beany flavor. A similar trend was reported by Lykomitros et al. [15]. Virginia peanuts, which had higher scores on roasted peanut attributes also, had significantly higher scores for bitter taste and lower scores for raw or beany flavor. The bitter test, burnt flavor, and burnt aftertaste are attributes associated with scorching while the raw or beany flavor and sweetness are attributes associated with insufficient roasting. Since all samples were roasted to similar final surface color, the findings suggest that Chalimbana, CG7, Chitala, and Kakoma peanuts develop the roasted flavor at a much slower rate compared to Baka and Nsinjiro. Therefore, they could be roasted in a more aggressive time-temperature profile, to deliver roasted flavors similar to Baka and Nsinjiro. However, the findings could also be an indication that Baka and Nsinjiro contain a higher concentration of precursors for Maillard reactions. Maillard reaction is a key source of compounds that are associated with roasted peanut flavor [14,33-36].

3.2. GC-MS analysis

The GC-MS analysis detected and identified a total of 38 volatile compounds that were resolved. The compounds were subsequently categorized into ten groups (Table 5.5). Among the ten groups, pyrazines and furan derivatives were the two major groups in all the six samples, accounting for approximately 42% and 20% of total volatiles that were resolved in this study, respectively. Among the pyrazines, 2,5-dimethyl pyrazine was more dominant while 2,3-dihydro-benzofuran was the primary furan derivative in all the samples. Significant differences in the concentration of volatile compounds, in all the ten groups, were found ($p < 0.05$). Considering the model coefficients for each sample, as shown in Table 5.5, Baka had more alkanes, benzene derivatives, and pyrazines. Chalimbana had more aldehydes, furan derivatives, pyridines, and pyrroles while CG7 had more alcohols only. Kakoma had more alcohols, aldehydes, alkanes, ketones, and pyridines while Nsinjiro had more furan derivatives and pyrazines. Ironically, terpenes (D-Limonene) were found in Chitala only.

The aldehydes, ketones, alkanes, benzenes, furans, pyrazines, pyridines, pyrroles, and terpenes identified in this study have also been reported in several other studies [14,28,33-36]. The identified compounds are mostly generated in peanuts through Maillard reaction, caramelization, Strecker degradation, and lipid oxidation [14]. Among the identified compounds, pyrazines and lipid oxidation products (aldehydes, ketone, alkanes, and alcohols) have received much attention [12,14,33]. In general, lipid oxidation products have been identified as the source of the undesirable off-flavors in peanuts [14,28]. On the other hand, pyrazines have been associated with the desirable roasted peanut flavor [14,32,34,36]. All the peanut varieties that had higher scores on roasted peanutty flavor in this study (Baka and Nsinjiro) also had higher intensities of pyrazines compared to the other peanut varieties.

Table 5.5. Mean concentration and model coefficients for the volatile compounds of freshly roasted peanuts.

		Mean ± SD (µg/Kg)					
Compound	**KI[1]**	**Baka**	**Chalimbana**	**CG7**	**Chitala**	**Kakoma**	**Nsinjiro**
Alcohols							
1-Octen-3-ol	978	6 ± 1	11 ± 1	15 ± 0	19 ± 1	15 ± 2	9 ± 0
1-Pentanol	748	ND	6 ± 0	6 ± 0	9 ± 1	7 ± 0	ND
Total Alcohols		[**-11**][2] 6 ± 1 [d]	[0.1] 18 ± 0 [c]	[**3**] 21 ± 0 [bc]	[**11**] 28 ± 0 [a]	[**5**] 23 ± 2 [b]	[**-8**] 9 ± 0 [d]
Aldehydes							
2,4-Decadienal	1307	ND	8 ± 0	5 ± 0	13 ± 1	ND	ND
Heptanal	901	ND	4 ± 0	3 ± 0	9 ± 1	5 ± 0	ND
Hexanal	801	12 ± 1	28 ± 0	27 ± 1	27 ± 3	26 ± 1	16 ± 0
Nonanal	1101	21 ± 2	58 ± 4	44 ± 3	78 ± 0	53 ± 2	26 ± 1
Total aldehydes		[**-44**] 33 ± 2[d]	[**21**] 98 ± 5[b]	[3] 80 ± 2[c]	[**49**] 126 ± 2[a]	[**7**] 84 ± 1[c]	[**-35**] 42 ± 1[d]
Alkanes							
Tridecane	1293	8 ± 1	5 ± 0	6 ± 0	8 ± 0	8 ± 1	4 ± 0
Undecane	1097	16 ± 1	14 ± 1	14 ± 0	18 ± 1	16 ± 1	15 ± 1
Total alkanes		[**3**] 25 ± 0[a]	[**-3**] 19 ± 1[b]	[**-3**] 19 ± 0[b]	[**3**] 25 ± 1[a]	[**2**] 24 ± 1[a]	[**-2**] 20 ± 1[b]
Benzene derivatives							
Acetophenone	1059	7 ± 2	5 ± 0	4 ± 0	14 ± 1	5 ± 0	5 ± 0
Benzaldehyde	953	58 ± 2	24 ± 1	32 ± 1	67 ± 1	36 ± 1	37 ± 1
Benzeneacetaldehyde	1038	41 ± 3	21 ± 2	19 ± 1	75 ± 2	22 ± 1	31 ± 0
Benzeneacetaldehyde, .alpha.-ethylidene-	1029	18 ± 1	ND	ND	ND	ND	ND
4-Ethylacetophenone	1049	ND	12 ± 0	7 ± 0	15 ± 0	14 ± 0	ND
Total benzene derivatives		[**29**] 124 ± 2[b]	[**-33**] 62 ± 2[d]	[**-33**] 62 ± 2[d]	[**76**] 171 ± 2[a]	[**-18**] 77 ± 2[c]	[**-21**] 74 ± 2[c]
Furan derivatives							
2-Furanmethanol	833	26 ± 2	24 ± 2	32 ± 1	41 ± 2	26 ± 2	37 ± 1
Benzofuran, 2,3-dihydro-	1214	131 ± 1	182 ± 2	65 ± 5	196 ± 8	70 ± 7	150 ± 3
Furan, 2-pentyl-	989	9 ± 0	18 ± 0	16 ± 1	39 ± 2	16 ± 0	11 ± 1
Furfural	827	42 ± 1	80 ± 7	63 ± 5	84 ± 6	68 ± 0	75 ± 2
Total furan derivatives		[**-42**] 208 ± 4[c]	[**55**] 305 ± 8[b]	[**-74**] 177 ± 12[c]	[**109**] 360 ± 18[a]	[**-71**] 180 ± 8[c]	[**22**] 272 ± 7[b]
Ketones							
2-Decanone	1002	ND	7 ± 0	7 ± 1	ND	ND	6 ± 0
2-Nonanone	962	ND	ND	9 ± 0	17 ± 1	15 ± 1	ND
3-Nonen-2-one	1135	ND	ND	27 ± 0	63 ± 3	46 ± 4	ND
3-Octen-2-one	940	ND	ND	ND	25 ± 1	21 ± 2	ND
3-Ethylcyclopentanone	901	ND	13 ± 1	ND	ND	ND	ND

Table 5.5. (Continued)

Compound	KI[1]	Mean ± SD (µg/Kg)					
		Baka	**Chalimbana**	**CG7**	**Chitala**	**Kakoma**	**Nsinjiro**
Total ketones		[**-43**] 0^{e}	[**-22**] 21 ± 1^{d}	[0.6] 43 ± 1^{c}	[**62**] 105 ± 6^{a}	[**38**] 81 ± 7^{b}	[**-37**] 6 ± 0^{e}
Pyrazines							
Pyrazine, 2,5-dimethyl-	908	400 ± 2	309 ± 0	328 ± 7	369 ± 2	374 ± 7	463 ± 8
Pyrazine, 2-ethenyl-6-methyl-	929	6 ± 1	34 ± 2	10 ± 1	6 ± 0	31 ± 1	6 ± 0
Pyrazine, 2-ethyl-5-methyl-	994	ND	ND	49 ± 1	62 ± 4	ND	43 ± 3
Pyrazine, 2-methoxy-6-methyl-	1055	ND	ND	ND	16 ± 1	ND	ND
Pyrazine, 2-methyl-6-(1-propenyl)-, (E)-	1093	ND	ND	10 ± 0	ND	ND	ND
Pyrazine, 2-ethyl-3,5-dimethyl-	1074	102 ± 8	50 ± 4	60 ± 2	81 ± 4	49 ± 3	111 ± 2
Pyrazine, methyl-	818	30 ± 1	28 ± 2	42 ± 1	43 ± 1	26 ± 0	46 ± 1
Total pyrazines		[7] 538 ± 13^{bc}	[**-110**] 421 ± 8^{e}	[**-33**] 498 ± 13^{cd}	[**46**] 577 ± 12^{b}	[**-50**] 481 ± 11^{d}	[**139**] 670 ± 14^{a}
Pyridines							
Pyridine, 2-pentyl-	1188	37 ± 2	84 ± 8	50 ± 4	87 ± 6	92 ± 4	61 ± 2
Total pyridines		[**-32**] 37 ± 2^{c}	[**15**] 84 ± 8^{a}	[**-19**] 50 ± 4^{bc}	[**19**] 87 ± 6^{a}	[**24**] 92 ± 4^{a}	[**-7**] 61 ± 2^{b}
Pyrroles							
1H-Pyrrole, 1-(2-furanylmethyl)-	998	ND	18 ± 0	10 ± 1	13 ± 1	ND	6 ± 0
1H-Pyrrole, 1-ethyl-	822	8 ± 0	14 ± 1	11 ± 0	12 ± 2	ND	ND
1H-Pyrrole, 1-methyl-	739	42 ± 2	159 ± 11	81 ± 4	87 ± 5	46 ± 1	62 ± 3
1H-Pyrrole, 3-methyl-	847	5 ± 1	ND	8 ± 0	7 ± 1	5 ± 0	8 ± 0
1H-Pyrrole-2-carboxaldehyde	926	15 ± 4	23 ± 0	12 ± 1	18 ± 1	17 ± 1	21 ± 1
1H-Pyrrole-2-carboxaldehyde, 1-methyl-	976	ND	ND	ND	ND	ND	13 ± 0
2-Acetylpyrrole	949	31 ± 1	28 ± 2	34 ± 1	40 ± 2	31 ± 3	48 ± 2
Total pyrroles		[**-56**] 100 ± 8^{c}	[**86**] 242 ± 14^{a}	[1] 157 ± 7^{b}	[**23**] 179 ± 8^{b}	[**-57**] 99 ± 5^{c}	[3] 158 ± 7^{b}
Terpenes							
D-Limonene	1023	0	0	0	29 ± 2	0	0
Total terpenes		[**-5**] 0^{b}	[**-5**] 0^{b}	[**-5**] 0^{b}	[**24**] 29 ± 2^{a}	[**-5**] 0^{b}	[**-5**] 0^{b}

[1] KI = Kovats indices calculated based on a 30 m HP-5MS column used in this experiment.
[abcde] Different superscripts within the same row indicate significant differences among means ($p < 0.05$).
[2] Values in brackets are model coefficients, and those in bold, within the same column, are significant ($p < 0.05$).

3.3. Correlations between GC-MS and sensory profiles

Multiple factor analysis (MFA) revealed the relationship between sensory attributes and volatile compounds of the samples (Figure 5.1). The actual correlation values are given in Table 5.6. The 2,5-dimethyl pyrazine and 2-ethyl-3,5-dimethyl pyrazine were close to roasted peanutty flavor, burnt flavor, and bitter taste. Nsinjiro and Baka were highly correlated with these roasted peanuts attributes. Sweet taste had a significant correlation with 1-ethyl-1H-pyrrole ($r = 0.814$). However, the 1-ethyl-1H-pyrrole may not be responsible for the sweet taste. Chalimbana and CG7 were on the opposite side of roasted peanutty flavor, and were close to the sweet taste, raw/beany flavor, and oily flavor. Aldehydes, alcohols, and ketones were close to overall oxidized and cardboard aromatics, and these were also on the opposite side of roasted peanutty flavor. Chitala and Kakoma were in this region of the MFA map.

Despite the peanut samples having similar surface color readings ($L = 50 \pm 1$) as a result of different roasting times, Baka and Nsinjiro were the only samples with higher intensity of roasted peanutty flavor and other roasted peanuts related attributes. Therefore, it is not surprising that Baka and Nsinjiro had more pyrazines than the other samples. Pyrazines, especially 2,5-dimethyl pyrazine, were highly associated with roasted peanutty flavor [25,34]. However, the pyrazines are not solely responsible for the roasted peanutty flavor [14,37]. In this study, 2-ethyl-3,5-dimethyl pyrazine was also strongly correlated with roasted peanutty flavor ($r = 0.927$) just like 2,5 dimethyl pyrazine ($r = 0.916$). Baker et al. [34] suggested that when choosing a single pyrazine in correlation to flavor, 2,5-dimethyl pyrazine is an excellent sensory prediction compound for peanut products roasted above 150 ^{o}C. However, based on this study, 2-ethyl-3,5-dimethyl pyrazine could be a good predictor of roasted peanutty flavor too.

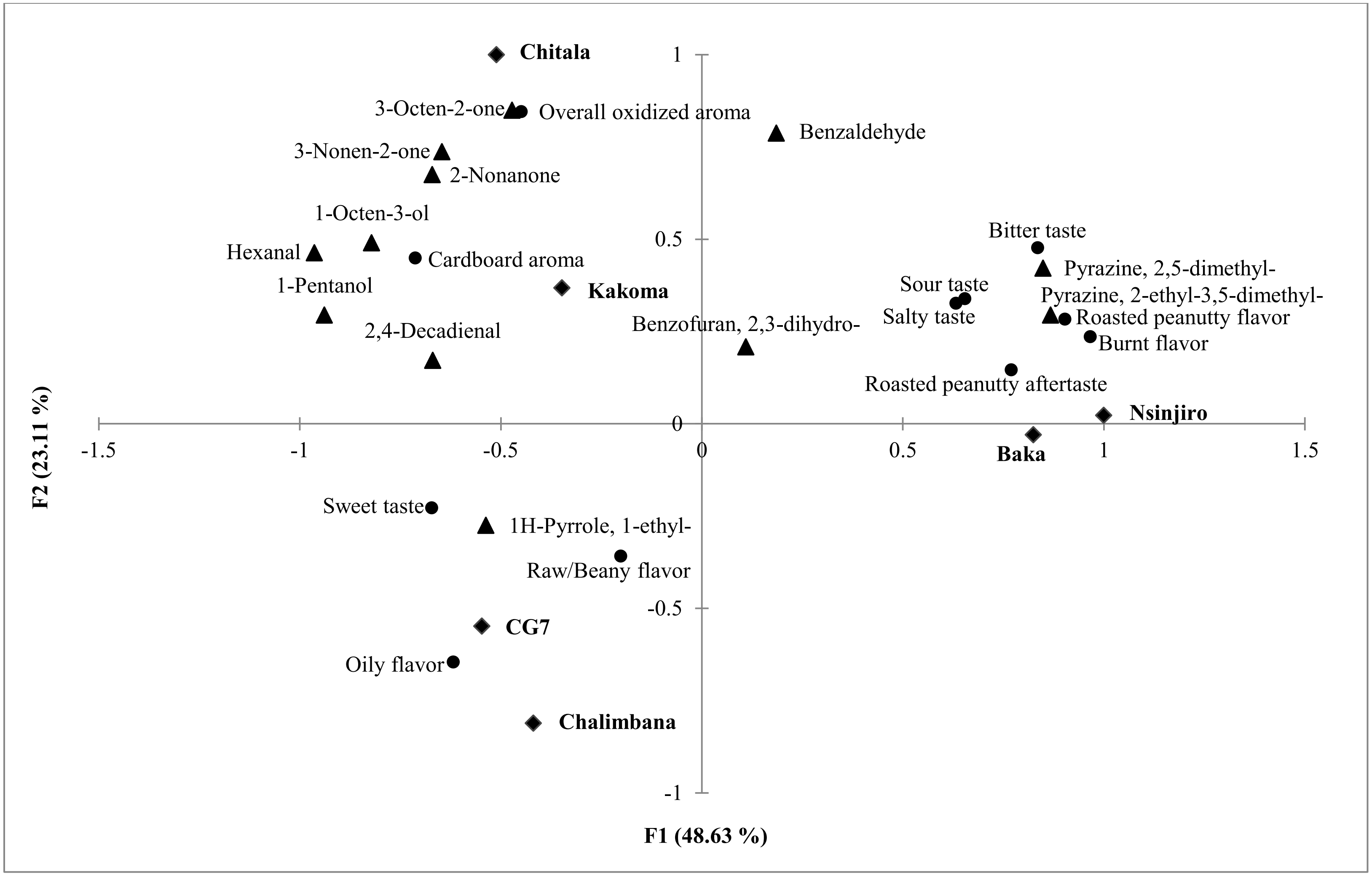

Figure 5.1 Correlation map of sensory and GC-MS profiles for the freshly roasted peanuts. The plot includes items that had significant correlations only, and was done after re-scaling factor loadings for each sample. ▲= GC-MS; ● = Descriptive; ♦ = Sample.

Table 5.6. Pearson correlations between the volatile compounds and sensory attributes.

Compound[1]	**RF**	**RPF**	**BF**	**OF**	**CA**	**OA**	**BT**	**SOT**	**ST**	**SWT**	**RPA**
1H-Pyrrole, 1-ethyl-	-0.383	-0.566	-0.395	0.253	-0.015	-0.216	-0.442	-0.732	-0.313	**0.814**	**-0.904**
1-Octen-3-ol	0.157	-0.673	-0.677	0.294	0.756	**0.818**	-0.527	-0.215	-0.207	0.520	-0.461
1-Pentanol	0.012	**-0.856**	-0.784	0.413	0.771	0.684	-0.634	-0.468	-0.471	0.498	-0.712
2,4-Decadienal	-0.438	-0.618	-0.512	0.213	0.189	0.297	-0.407	-0.396	-0.048	0.735	**-0.867**
2-Nonanone	0.161	-0.473	-0.445	0.032	**0.894**	**0.923**	-0.295	-0.176	-0.261	0.270	-0.242
3-Nonen-2-one	0.031	-0.438	-0.394	-0.044	**0.844**	**0.938**	-0.228	-0.149	-0.179	0.286	-0.288
3-Octen-2-one	-0.191	-0.273	-0.203	-0.229	0.784	**0.974**	0.018	0.004	-0.098	-0.041	-0.199
Benzaldehyde	-0.645	0.398	0.557	**-0.860**	0.143	0.418	0.638	0.065	0.308	-0.040	-0.006
Benzofuran, 2,3-dihydro-	**-0.866**[a]	0.104	0.196	-0.293	-0.424	-0.022	0.317	0.160	0.477	0.062	-0.401
Hexanal	0.271	**-0.962**	**-0.966**	0.740	0.595	0.423	**-0.880**	-0.481	-0.492	0.640	-0.705
Pyrazine, 2,5-dimethyl-	-0.099	**0.916**	0.788	-0.658	-0.418	0.048	**0.826**	**0.897**	0.790	-0.691	**0.869**
Pyrazine, 2-ethyl-3,5-dimethyl-	-0.378	**0.927**	**0.883**	-0.759	-0.650	-0.219	**0.857**	0.662	**0.830**	-0.371	0.602

[1] Only compounds that had atleast one significant correlation with any sensory attribute have been included.
[a] Values in bold indicate significant correlation ($p < 0.05$).
RF = Raw/Beany flavor; RPF = Roasted peanutty flavor; BF = Burnt flavor; OF = Oily flavor; CA = Cardboard aroma; OA = Overall oxidized aroma; BT = Bitter taste; SOT = Sour taste; ST = Salty taste; SWT = Sweet taste; RPA = Roasted peanutty after-taste.

The 2-ethyl-3,5-dimethyl pyrazine has a nutty roasted odor of coffee and coffee products while the 2,5-dimethyl pyrazine has nutty cocoa like odor [38]. Schirack et al. [12] also identified 2-ethyl-3,5-dimethyl pyrazine as one of the high impact aroma active compounds in peanuts when aroma extract dilution analysis (AEDA) was used. Therefore, apart from the 2,5-dimethyl pyrazine, determination of 2-ethyl-3,5-dimethyl pyrazine could be useful for food processors who have no access to sensory panels when identifying suitable raw materials for various applications. Industries mostly rely on instrument-based methods, such as measurement of surface color, to determine the degree of roasting in peanuts and then, to predict roasted peanut flavor intensity and consumer acceptability. Unfortunately, this study and other studies have shown that surface color measurement may not be a good predictor of roasted peanut flavor [24,32,34].

Roasted peanutty flavor is one of the significant factors that influence consumer acceptability especially for snacks like roasted peanuts [25,30]. Therefore, the roasted peanutty flavor could also be an important attribute for peanut-based confectionaries and beverages. Based on this study, Nsinjiro and Baka could be the best peanut varieties, in Malawi, for applications requiring a strong roasted peanutty flavor. On the other hand, Chitala, Kakoma, CG7, and Chalimbana could be the best varieties for applications that require a weak roasted peanutty flavor. However, if both a weak roasted peanutty flavor and a strong oily flavor are required, then CG7 and Chalimbana could be the best varieties for such applications.

4. Conclusion

Among the evaluated samples, Baka and Nsinjiro are the peanut varieties with higher intensities of the roasted peanut attributes. However, further studies should be done to determine and optimize the degree of roasting of the other samples that would give comparable sensory properties to those of Baka and Nsinjiro. The optimization studies will be valuable to food processors in preventing over-dependence on specific peanut varieties in various applications. Therefore, such studies would help in reducing direct and hidden costs associated with restrictive raw material procurement as well as food waste. Beside 2,5 dimethyl pyrazine, 2-ethyl-3,5-dimethyl pyrazine was also found to be highly associated with roasted peanutty flavor. Therefore, identification of precursors of 2-ethyl-3,5-dimethyl pyrazine could provide more insights into the origins of roasted peanut flavor.

References

1. Fletcher SM, Shi Z (2016) An overview of world peanut markets. In: Peanuts. Elsevier, pp 267-287
2. FAOSTAT (2017) Groundnuts production http://www.fao.org/faostat/en/#data/QC. Accessed 31 March 2019
3. Davis JP, Dean LL (2016) Peanut composition, flavor and nutrition. In: Peanuts. Elsevier, pp 289-345
4. Griel AE, Eissenstat B, Juturu V, Hsieh G, Kris-Etherton PM (2004) Improved diet quality with peanut consumption. Journal of the American College of Nutrition 23 (6):660-668
5. Awad AB, Chan KC, Downie AC, Fink CS (2000) Peanuts as a source of β-sitosterol, a sterol with anticancer properties. Nutrition and cancer 36 (2):238-241
6. Sanders TH, McMichael RW, Hendrix KW (2000) Occurrence of resveratrol in edible peanuts. Journal of agricultural and food chemistry 48 (4):1243-1246
7. Ros E (2010) Health benefits of nut consumption. Nutrients 2 (7):652-682
8. Jiang R, Manson JE, Stampfer MJ, Liu S, Willett WC, Hu FB (2002) Nut and peanut butter consumption and risk of type 2 diabetes in women. Jama 288 (20):2554-2560
9. Wien M, Oda K, Sabaté J (2014) A randomized controlled trial to evaluate the effect of incorporating peanuts into an American Diabetes Association meal plan on the nutrient profile of the total diet and cardiometabolic parameters of adults with type 2 diabetes. Nutrition journal 13 (1):10
10. FAO (2015) Regional Overview of Food Insecurity in Africa. Food and Agriculture Organization. http://www.fao.org/3/a-i4635e.pdf. Accessed 20 March 2017

11. Dalal S, Beunza JJ, Volmink J, Adebamowo C, Bajunirwe F, Njelekela M, Mozaffarian D, Fawzi W, Willett W, Adami H-O (2011) Non-communicable diseases in sub-Saharan Africa: what we know now. International journal of epidemiology 40 (4):885-901

12. Schirack A, Drake M, Sanders T, Sandeep K (2006) Characterization of Aroma-Active Compounds in Microwave Blanched Peanuts. Journal of food science 71 (9)

13. Sanders T, Pattee H, Vercellotti J, Bett K (1995) Advances in peanut flavor quality. Advances in peanut science:528-553

14. Neta E, Sanders T, Drake M (2010) Understanding peanut flavor: a current review. Handbook of fruit and vegetable flavors:985

15. Lykomitros D, Fogliano V, Capuano E (2016) Flavor of roasted peanuts (Arachis hypogaea)-Part I: Effect of raw material and processing technology on flavor, color and fatty acid composition of peanuts. Food Research International 89:860-869

16. Bett K, Vercellotti J, Lovegren N, Sanders T, Hinsch R, Rasmussen G (1994) A comparison of the flavor and compositional quality of peanuts from several origins. Food chemistry 51 (1):21-27

17. Isleib TG, Pattee HE, Tubbs RS, Sanders TH, Dean LO, Hendrix KW (2015) Intensities of sensory attributes in high-and normal-oleic cultivars in the uniform peanut performance test. Peanut Science 42 (2):83-91

18. Pattee H, Isleib T, Gorbet D, Giesbrecht F (2002) Sensory comparison of runner peanut market grades from selected varieties. Peanut Science 29 (2):146-149

19. Young ND, Sanders TH, Drake MA, Osborne J, Civille GV (2005) Descriptive analysis and US consumer acceptability of peanuts from different origins. Food quality and preference 16 (1):37-43

20. Ng EC, Dunford NT (2009) Flavour characteristics of peanut cultivars developed for southwestern United States. International journal of food science & technology 44 (3):603-609

21. Saka A, Mtukuso A, Daudi A (2006) Agricultural Technologies Released by the Ministry of Agriculture and Food Security-2000-2005.

22. ICRISAT (2013) Tropical Legume Farming in Malawi. http://www.icrisat.org/TropicalLegumesII/pdfs/November-2013.pdf. Accessed 13 January 2016

23. Pattee HE, Giesbrecht FG, Young CT (1991) Comparison of peanut butter color determination by CIELAB L*, a*, b* and Hunter color-difference methods and the relationship of roasted peanut color to roasted peanut flavor response. Journal of agricultural and food chemistry 39 (3):519-523

24. McDaniel KA, White BL, Dean LL, Sanders TH, Davis JP (2012) Compositional and mechanical properties of peanuts roasted to equivalent colors using different time/temperature combinations. Journal of food science 77 (12):C1293-C1299

25. Wang S, Adhikari K, Hung YC (2017) Acceptability and Preference Drivers of Freshly Roasted Peanuts. Journal of food science 82 (1):174-184

26. Simtowe F, Shiferaw B, Abate T, Kassie M, Monyo E, Madzonga O, Silim S, Muricho G (2009) Assessment of the current situation and future outlooks for the groundnut sub-sector in Malawi. International crops research institute for the Semi-Arid Tropics

27. Grosso N, Resurreccion A (2002) Predicting consumer acceptance ratings of cracker-coated and roasted peanuts from descriptive analysis and hexanal measurements. Journal of Food Science 67 (4):1530-1537

28. Wang S, Adhikari K, Hung Y-C (2017) Effects of short storage on consumer acceptability and volatile compound profile of roasted peanuts. Food Packaging and Shelf Life 13:27-34

29. XLSTAT (2017) Sensory product characterization in Excel tutorial. https://help.xlstat.com/customer/en/portal/articles/2062304-sensory-product-characterization-in-excel-tutorial?b_id=9283. Accessed 14 February 2019

30. Lee C, Resurreccion A (2006) Predicting sensory attribute intensities and consumer acceptance of stored roasted peanuts using instrumental measurements. Journal of food quality 29 (4):319-338

31. Schirack AV, Drake M, Sanders TH, Sandeep K (2006) Impact of microwave blanching on the flavor of roasted peanuts. Journal of sensory studies 21 (4):428-440

32. Lykomitros D, Fogliano V, Capuano E (2016) Flavor of roasted peanuts (Arachis hypogaea)—Part II: Correlation of volatile compounds to sensory characteristics. Food Research International 89:870-881

33. Warner K, Dimick P, Ziegler G, Mumma R, Hollender R (1996) 'Flavor-fade'and Off-Flavors in Ground Roasted Peanuts As Related to Selected Pyrazines and Aldehydes. Journal of food science 61 (2):469-472

34. Baker G, Cornell J, Gorbet D, O'keefe S, Sims C, Talcott S (2003) Determination of pyrazine and flavor variations in peanut genotypes during roasting. Journal of food science 68 (1):394-400

35. Liu X, Jin Q, Liu Y, Huang J, Wang X, Mao W, Wang S (2011) Changes in volatile compounds of peanut oil during the roasting process for production of aromatic roasted peanut oil. Journal of food science 76 (3):C404-C412

36. Williams JE, Duncan SE, Williams RC, Mallikarjunan K, Eigel III WN, O'Keefe SF (2006) Flavor fade in peanuts during short-term storage. Journal of food science 71 (3):S265-S269

37. Chetschik I, Granvogl M, Schieberle P (2010) Quantitation of key peanut aroma compounds in raw peanuts and pan-roasted peanut meal. Aroma reconstitution and comparison with commercial peanut products. Journal of agricultural and food chemistry 58 (20):11018-11026

38. Burdock GA (2016) Fenaroli's handbook of flavor ingredients. CRC press,

CHAPTER 6

OPTIMIZATION OF EMULSIFIER AND STABILIZER CONCENTRATIONS IN A MODEL PEANUT-BASED BEVERAGE SYSTEM: A MIXTURE DESIGN APPROACH[1]

[1] Gama, A.P., Hung, Y.C. and K. Adhikari. 2019. *Foods*. 8: 116. Reprinted here with permission of the publisher.

Abstract

Colloidal stability, physicochemical, and rheological properties are among the critical determinants of sensory quality of beverages. The present study investigated the effects of lecithin, xanthan gum, propylene glycol alginate and their combinations on the colloidal stability, physicochemical, and rheological properties of a model peanut-based beverage. A simplex centroid mixture design was applied, and the visual stability, centrifuge stability, physicochemical properties (soluble solids, pH, water activity, color), and rheological parameters (flow behavior and viscosity) of the samples were determined. All the evaluated parameters were significantly affected ($p < 0.05$) by the type and quantity of emulsifier or stabilizer used. At 0.5% total usage level, the optimum stabilizer and emulsifier combination was that of 66% xanthan gum and 34% lecithin. A further increase of lecithin in the mixture caused a decrease in the colloidal stability of the sample. Irrespective of emulsifier and stabilizer type and quantity, all samples exhibited shear-thinning flow behavior with samples containing xanthan gum being more pseudoplastic than the others. The prediction model for visual stability index, found in this study, may be used by the industry to formulate similar beverages for better colloidal stability.

1. Introduction

Worldwide, the demand for health-promoting foods is growing due to an increase in the burden of non-communicable diseases and more consumer awareness in matters of diet and health [1]. Among such health-promoting foods are plant-based food products especially from legumes like soy and peanuts. Over the past years, there has been more interest in legume-based beverages to replace or supplement cow milk consumption. For instance, several attempts have been made to develop peanut-based beverages [2-8]. As a result of such attempts, notable continual improvements in the physicochemical, nutritional and sensory characteristics of the resultant peanut-based beverages have been achieved. However, there are still challenges especially with sensory properties and colloidal stability of the peanut-based beverages.

Depending on the ingredients, peanut-based beverages can be complex colloidal systems which in turn affect the sensory and rheological properties. In general, food products are mostly systems of mixed components (heterogeneous) and therefore, often involve colloidal systems such as foams, emulsions, and suspensions among others [9]. The stability of such colloidal systems is vital for the maintenance of desired quality and rheological characteristics of the food products [10-12]. A colloidal system is said to be stable if it shows little or no aggregation of particles and phase separation within a defined period. Unfortunately, food colloids are at a higher free energy level and therefore, they are thermodynamically unstable with a tendency to aggregate and separate [13].There are different modes of colloidal instability, and these include creaming and sedimentation due to the influence of gravity, aggregation due to attractive interparticle forces leading to either flocculation or coagulation, and coalescence if the interfacial film ruptures. A further mode of instability is Ostwald ripening or disproportionation due to differences in chemical potential of molecules in droplets or bubbles and those in the bulk phase [10,13].

Given the above, efforts have been made to prevent colloidal instability in food products through the use of emulsifiers and stabilizers. An emulsifier is an amphiphilic surface active chemical compound that facilitates the making of an emulsion and promotes short-term stability by rapidly adsorbing at the new interface created during emulsification [9]. Therefore, emulsifiers reduce interfacial tension and prevent immediate re-coalescence of the newly formed particles or droplets. On the other hand, a stabilizer confers long-term stability of the emulsion, once it is formed, through either adsorption or non-adsorption mechanism [10]. Little is known about the emulsifiers or stabilizers that would be effective in stabilizing peanut-based beverages especially those using whole peanuts and not defatted peanut flour. Most emulsion stabilization systems in plant-based beverages involve the use of lecithin (emulsifier), propylene glycol alginate (both emulsifier and stabilizer), and xanthan gum (stabilizer) [14,15].. Therefore, the present study was undertaken to evaluate the effect of the lecithin, propylene glycol alginate, and xanthan gum, and their interactions on the colloidal stability, physicochemical and rheological properties of a model non-defatted peanut-based beverage. The emulsifier, stabilizer, or their combination that would be optimum in preventing colloidal instability of the product was also determined. The study could be beneficial to food product developers considering that determination of the optimum stabilizer, emulsifier, or stabilizer and emulsifier combination in a product provides economic benefits by decreasing the stabilizer and emulsifier concentrations in the formulation as suggested by Dogan et al. [16]. Furthermore, the colloidal stability, physicochemical, and rheological properties partly determine sensory properties of food products and therefore, are determinants of consumer acceptability.

2. Materials and Methods

2.1. Preparation of the model peanut-based beverages

Peanut paste, dry non-fat milk powder, sugar, salt, propylene glycol alginate (PGA), xanthan gum (XG) and lecithin were used to prepare the model peanut-based beverages. Lecithin is an emulsifier, PGA is an adsorption stabilizer, and XG is a non-adsorption stabilizer. Peanut paste was prepared by passing blanched medium roasted (lightness, L=50 ± 1) Virginia peanuts (ICGV-SM 90704 variety, 45% oil content) through a colloidal mill (Model M-MS-3, Morehouse Industries, Los Angeles, CA, USA) two times. The peanuts were roasted at 162.8 °C (325 F) for 25 minutes using a convection oven (KitchenAid Superba, KEBS208) and then, blanched using an Ashton peanut blancher (Model EX, Ashton Food Machinery Co., Newark, NJ, USA). The peanuts were obtained from ICRISAT Malawi while the dry non-fat milk powder, sugar, and salt were obtained from Walmart Inc. (Bentonville, AR, USA). PGA and XG were obtained from TIC Gums (Belcamp, MD, USA while lecithin was obtained from NOW® (Bloomingdale, IL, USA).

The model peanut-based beverage had 72.48% water, 15% roasted peanut paste, 7% sugar, 5% dry non-fat milk powder, 0.5% stabilizer, emulsifier or their combination, and 0.02% salt. The concentration of oil and protein in each sample were 6.75 and 5%, respectively. Eight samples, including a control, (S00, S01, S02, S03, S04, S05, S06, and S07) were prepared in duplicate. The respective ingredients were first mixed for 60 s in a blender and homogenized at 28,000 rpm for 60 s using an OMNI GLH-01 homogenizer (OMNI International, Kennesaw, GA, USA) before heating at 85 °C for 5 min on a hot plate. The heating was done under closed conditions while stirring with a magnetic stirrer to prevent evaporation loss and fouling. The beverages were cooled to 25 °C in a water bath, and all analyses were done with the samples at this temperature.

2.2. Determination of stability indices

Visual stability and centrifuge stability of the samples were evaluated. For visual stability, 100 mL samples were put in graduated cylinders for 24 hours at 25 °C. The samples were then visually observed for separation, under gravitational force, into layers as done by Hinds, Beuchat and Chinnan [5]. When a line of demarcation was observed, the ratio of the height of the top layer to a total height of beverage was determined and used to calculate visual stability index (*VSI*) through equation 1. If no separation was observed, the visual stability index had a value of 1. A similar formula was used to calculate the centrifuge stability index (*CSI*) except that separation of 40 mL samples, in 50 mL corning tubes was by centrifugal force of 3234 x g (Centrifuge model 5804, Eppendorf AG, Hamburg, Germany). Readings were taken at seven different centrifugation durations (0, 1, 2, 3, 4, 5, and 6 min).

$$VSI \text{ or } CSI = 1 - \left(\frac{Height\ of\ supernatant}{Total\ height\ of\ colloidal\ mixture}\right) \quad (1)$$

2.3. Measurement of viscosity and flow behavior

Viscosity of 200-ml samples, at 25 °C, was measured using a programmable Brookfield digital viscometer (Model LV DV-II, Version 5.0, Brookfield Engineering Laboratories, Inc., Stoughton, MA) fitted with an LV spindle No. 2. A 250-mL low form Pyrex beaker was used as a sample holder, as recommended by the LV DV-II viscometer operation manual. Viscosity readings were taken at six different spindle speeds (10, 20, 30, 40, 50, and 60 rpm). Readings, at each spindle speed, were taken at three minutes of running the samples on the viscometer. Flow behavior was deduced graphically and by calculating the viscosity ratio as recommended in the Brookfield labs Inc. guide [17]. The viscosity ratio was viscosity reading at 10 rpm to that at 60 rpm spindle speed. Readings at 60 rpm were reported as viscosities of the samples because, under the test conditions, the 60 rpm was equivalent to a shear rate of 50 s^{-1} [17]. The 50 s^{-1} is considered as the shear rate in the mouth [18,19].

2.4. Measurement of color, pH, water activity, and soluble solids

The color of the samples was measured using a calibrated benchtop ColorFlex Spectrophotometer (HunterLab, Reston, Va.) with a D65 light source at a 45^{o} viewing angle. Measurements for *L* (lightness), *a* (redness), and *b* (yellowness) were taken. The total soluble solids (°Brix), pH, and water activity (a_w) of the samples were determined using a digital refractometer (ATAGO, PR-101, Atago USA, Inc, Bellevue, WA, USA), a pH meter (Accumet AE 150, Accumet Engineering, Inc., Westford, MA, USA), and a water activity meter (AQUALAB, Series 3, v2.3, METER, Pullman, WA, USA), respectively. All the measurements were done in triplicate.

2.5. Experimental design and statistical analysis

A simplex centroid mixture design was used in this study. The design was generated using JMP package software (Version 5.0.1a, SAS Institute, Inc., Cary, NC, USA) and is given in Table 6.1. Equation 2 was fitted to predict *VSI* using the data obtained from the experiment. β_1, β_2, β_3, β_{12}, β_{13}, and β_{23} are the coefficients for each term and X_1, X_2, and X_3 are proportions of lecithin, propylene glycol alginate, and xanthan gum, respectively. A three-way interaction ($X_1X_2X_3$) and two-way interaction (X_2X_3) terms were not included in the model because their respective effects was not significant ($p > 0.05$).

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 \quad (2)$$

Table 6.1. Simplex centroid mixture design for the emulsifier and stabilizers.

	Gum and Emulsifier Proportions (%)		
Sample codes	**Lecithin (X_1)**	**PGA (X_2)**	**XG (X_3)**
S00 (Control)	0	0	0
S01	100	0	0
S02	0	100	0
S03	0	0	100
S04	50	50	0
S05	50	0	50
S06	0	50	50
S07	33.3	33.4	33.3

The prediction equations were obtained using JMP Pro (Version 13.0, SAS Institute, Inc., U.S.A.) for each response. Response surface plots were generated using Design-Expert software (Version 11.0, Stat-Eas Inc., Minneapolis, MN, USA). XLSTAT 2017 (ver. 19.01; Addinsoft, New York, USA) was used to run a one-way analysis of variance (ANOVA) followed by Tukey's honest significant difference test (HSD) to determine significant differences among the samples. Pearson's correlation test was used to identify properties that had a significant association with *VSI*.

3. Results and Discussion

3.1. Effect on physicochemical properties

The physicochemical properties of the samples are given in Table 6.2. The °Brix values of the samples varied between 13.7 and 15.8 °Brix. There were no statistically significant differences in the °Brix values of samples S02 and S03 compared to the control (S00). However, the °Brix values of samples S01, S04, S05, S06, and S07 were significantly higher than the control ($p < 0.05$). The pH values of the samples ranged from 6.11 to 6.26, and all samples had significantly lower pH values compared to the control. All samples had similar a_w readings (0.99) to that of the control except sample S03 which had a significantly lower a_w ($p < 0.05$). However, all the samples had a_w readings above 0.95. Therefore, all the samples could be classified as having high water activity. Unlike the control and S02, which had similar lightness (L) values, the rest of the samples had significantly higher L values with sample S06 being the lightest. Significant differences ($p < 0.05$) were also found in the yellowness (b) intensities of the samples with sample S06 having the highest yellowness intensity (18.52). However, all the samples had statistically similar intensities of redness (a) as the control. The observed effect of the emulsifiers and different stabilizers on the physicochemical properties was not peculiar. Other studies have also reported similar changes in °Brix, pH, a_w and color of beverages and other aqueous systems [16,20-22]. The molecular structure of the stabilizers or emulsifier, their water absorption capacity, their interactions with each other and with the other ingredients in the beverage may have resulted in the observed effects on the physicochemical properties [16,21,23,24].

3.2. Effect on flow properties

All the evaluated samples exhibited shear thinning flow behavior (Figure 6.1). However, deducing from the viscosity ratios (Table 6.2), the degree of shear-thinning of the samples was significantly different ($p < 0.05$). The viscosity ratios ranged from 1.38 to 4.10. All samples containing XG (S03, S05, S06, and S07) had relatively higher viscosity ratios than the other samples. The high viscosity ratios signified a high degree of shear-thinning. Other studies investigating the effect of gums on the rheology of beverages have also found shear-thinning flow behavior when XG is used [16,18,25]. High molecular weight and unique rigid rod-like conformation might contribute to the higher shear-thinning behavior of beverages thickened with XG-based thickeners [26,27]. In the present study, the degree of shear-thinning (pseudoplasticity) of the samples containing XG decreased with the addition of PGA. Other studies have found that unlike XG, PGA displays a low degree of shear-thinning in solution and promotes creaminess (sensation typical of fat-containing foods) without significant rheological changes [28]. Yilmazer et al. [29] reported that when XG was partially replaced by PGA, emulsions were more fluid-like and exhibited reduced viscosity. The relatively lower viscosities and viscosity ratios of samples containing PGA, in the present study, is therefore consistent with the findings of the other studies [28,29]. For the general population, a high degree of the shear-thinning flow behavior of the samples containing XG is a desirable property because it makes swallowing easier [30]. However, for consumers who might have disorders like dysphagia (a condition where swallowing is difficult), thicker but less shear-thinning products are desirable to avoid choking [25].

Table 6.2. Physicochemical and rheological properties of the model peanut-based beverages.

Sample	pH	°Brix	a_w	Viscosity (mPa-s)	*VSI*	Viscosity ratio	Color		
							L	*a*	*b*
S00	6.26 ± 0.01^{a}	14.00 ± 0.14^{c}	0.99 ± 0.00^{a}	8.23 ± 0.04^{f}	0.92 ± 0.00^{c}	1.91 ± 0.01^{f}	65.12 ± 0.08^{d}	5.66 ± 0.25^{ab}	17.51 ± 0.08^{de}
S01	6.18 ± 0.01^{b}	15.65 ± 0.07^{a}	0.99 ± 0.00^{a}	5.23 ± 0.04^{h}	0.82 ± 0.00^{d}	2.14 ± 0.01^{e}	67.06 ± 0.08^{b}	5.67 ± 0.02^{ab}	17.32 ± 0.06^{e}
S02	6.11 ± 0.01^{d}	13.90 ± 0.14^{c}	0.99 ± 0.00^{a}	11.38 ± 0.03^{e}	0.98 ± 0.00^{b}	1.38 ± 0.00^{g}	65.04 ± 0.12^{d}	5.88 ± 0.05^{a}	17.95 ± 0.03^{bc}
S03	6.12 ± 0.01^{d}	13.70 ± 0.14^{c}	0.98 ± 0.00^{b}	65.70 ± 0.01^{a}	1.00 ± 0.00^{a}	4.10 ± 0.00^{a}	66.33 ± 0.08^{c}	5.71 ± 0.17^{ab}	18.07 ± 0.10^{b}
S04	6.13 ± 0.01^{cd}	14.80 ± 0.14^{b}	0.99 ± 0.00^{a}	6.99 ± 0.01^{g}	0.98 ± 0.00^{b}	1.39 ± 0.00^{g}	66.18 ± 0.16^{c}	5.59 ± 0.04^{ab}	17.80 ± 0.02^{bcd}
S05	6.19 ± 0.01^{b}	15.80 ± 0.28^{a}	0.99 ± 0.00^{a}	54.55 ± 0.07^{c}	1.00 ± 0.00^{a}	3.55 ± 0.00^{b}	66.96 ± 0.03^{b}	5.42 ± 0.00^{ab}	17.71 ± 0.03^{cd}
S06	6.16 ± 0.01^{bc}	15.40 ± 0.00^{ab}	0.99 ± 0.00^{a}	55.68 ± 0.04^{b}	1.00 ± 0.00^{a}	3.29 ± 0.00^{c}	67.53 ± 0.06^{a}	5.32 ± 0.22^{b}	18.52 ± 0.13^{a}
S07	6.16 ± 0.01^{bc}	15.70 ± 0.14^{a}	0.99 ± 0.00^{a}	35.89 ± 0.01^{d}	1.00 ± 0.00^{a}	2.95 ± 0.00^{d}	66.98 ± 0.01^{b}	5.25 ± 0.08^{b}	17.85 ± 0.08^{bc}

[abcdefgh] Common letter in each column indicates no statistical difference at 5% significance level.

a_w = Water activity, *VSI* = Visual stability index; *L* = Lightness; *a* = Redness; *b* = Yellowness.

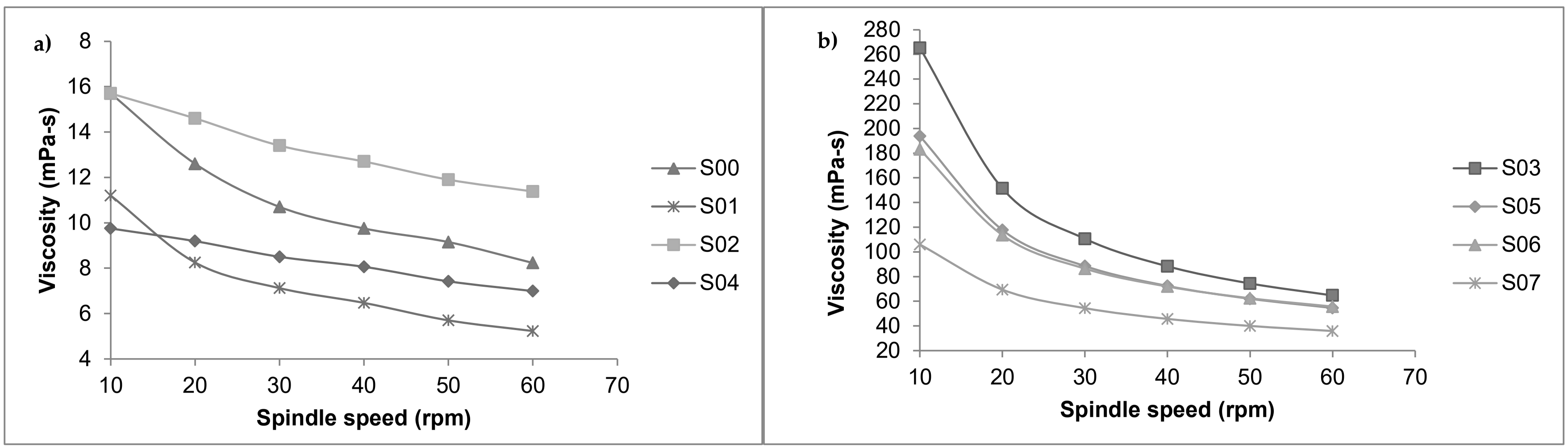

Figure 6.1. Change in viscosity as a function of shear rate (spindle speed). **a)** Low viscosity samples; **b)** High viscosity samples.

3.3. Effect on viscosity and colloidal stability

The viscosity and *VSI* of the samples ranged from 5.23 to 65.70 mPa-s and 0.82 to 1.00, respectively (Table 6.2). All sample containing XG (S03, S05, S06, and S07) had relatively higher viscosity and were the most stable (*VSI* =1). Therefore, it is not surprising that viscosity had a significant positive association with *VSI* (r = 0.74, p = 0.036). The significant positive association of *VSI* with viscosity confirms the mechanism through which non-adsorbing biopolymers (polysaccharides) stabilize food systems. The rates of creaming or sedimentation, Brownian motion, and particle collisions, respectively, are inversely related to the viscosity of the bulk phase [10,31]. However, the increase in viscosity of the bulk phase, by adding more thickener, does not always have a stabilizing effect. At some specific high biopolymer concentrations, depletion flocculation can be induced. It has been reported that when the separation distance between surfaces of colloidal particles, dispersed in a polymer solution, closely approaches the 'diameter' of the polymer molecules, the polymer chains are excluded from the gap between the particle surfaces [31]. The exclusion happens because the number of possible configurations that the polymer molecule, within the gap, can take is reduced resulting in a reduction in entropy. The reduction in entropy is against the second law of thermodynamics and therefore, a system will always strive to maximize its entropy [13]. After the polymer molecules have been depleted from the gap, there is relatively a higher polymer concentration in the bulk solution causing an osmotic pressure imbalance. The solvent then diffuses from the gap into the bulk solution thus drawing the particles much more closely to each other, which is technically called depletion flocculation [10,13]. Therefore, any attempts to keep on increasing the total gum concentration, in the peanut-based beverage samples, should be done with caution.

Considering the nature of the evaluated samples, spoilage made it practically impossible to observe the samples, under room temperature conditions, for more than a day.

Therefore, to further accelerate the separation process, a centrifugal force was applied, and a similar separation trend like that observed under gravitational force was also found. Samples containing XG (S03, S05, and S06) remained stable even after six minutes of centrifugation (Figure 6.2).

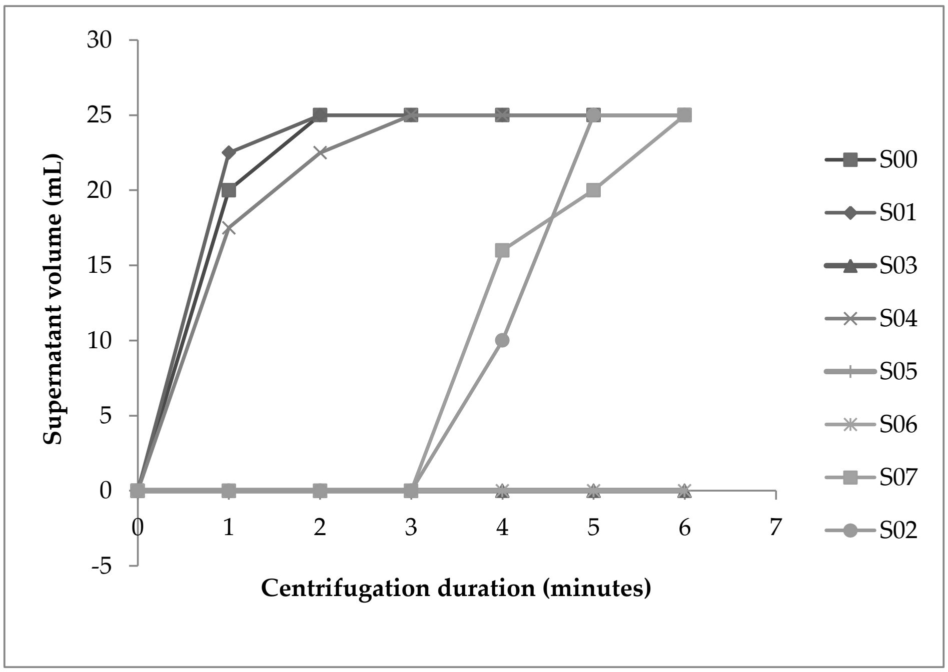

Figure 6.2. Separation behavior of the peanut-based beverages under centrifugal force of 3234 x g

Sedimentation was the mode of colloidal instability in this study. All previous attempts to develop peanut-based beverages used defatted peanuts probably to avoid creaming and coalescence among other reasons [2-8]. In the present study, non-defatted peanuts were used but, creaming was not observed in the samples including the control. The absence of creaming, even in the control sample, suggests that the homogenization efficiency was good and that there are other inherent emulsifiers in the beverage system. Considering the ingredients that were used, the likely emulsifiers may have been proteins like β-casein in milk. β-casein is a high molecular weight emulsifier but also a good stabilizer through its electrostatic and steric stabilization mechanisms [32,33]. The charge of β-casein gives the electrostatic repulsion while the protruding chains of the adsorbed β-casein provide the steric stability of emulsified fat particles [9,13].

3.4. Optimization and prediction model

Table 6.3 shows summary statistics of the prediction model for *VSI*. All model assumptions were satisfied. The model explained 99.5% (Adj. R^2 = 0.985) of the variation in *VSI* of the samples and was the best fit since the RSME (0.0043) was less than 0.05. Therefore, maintaining all the other factors constant, the model may be used to predict *VSI*, based on the different stabilizer and emulsifier combinations. As previously discussed, the parameter estimates (coefficients) values of the model terms also confirm that XG had a greater positive effect on *VSI* likely as a result of the significant increase in viscosity of the samples.

Table 6.3. Effect of emulsifier and stabilizers on the visual stability index (*VSI*) of the peanut-based beverages.

Term	**Estimate**	**95% CI**	χ^2	***P***	**VIF**
X_1 (Lecithin)	0.82	0.81-0.84	6086.72	< 0.0001	0.9913
X_2 (PGA)	0.98	0.97-1.00	8678.29	< 0.0001	0.8295
X_3 (XG)	1.00	0.99-1.02	9017.56	< 0.0001	0.8295
$X_1 * X_2$	0.30	0.23-0.37	38.53	< 0.0001	20.9249
$X_1 * X_3$	0.34	0.27-0.41	48.86	< 0.0001	20.9249
Model Fit Statistics					
R^2		0.9950			
Adjusted R^2		0.9849			
RMSE		0.0043			

CI = Confidence interval; *P* = Probability; VIF = Variance inflation factor; RMSE = Square root of the variance of the residuals

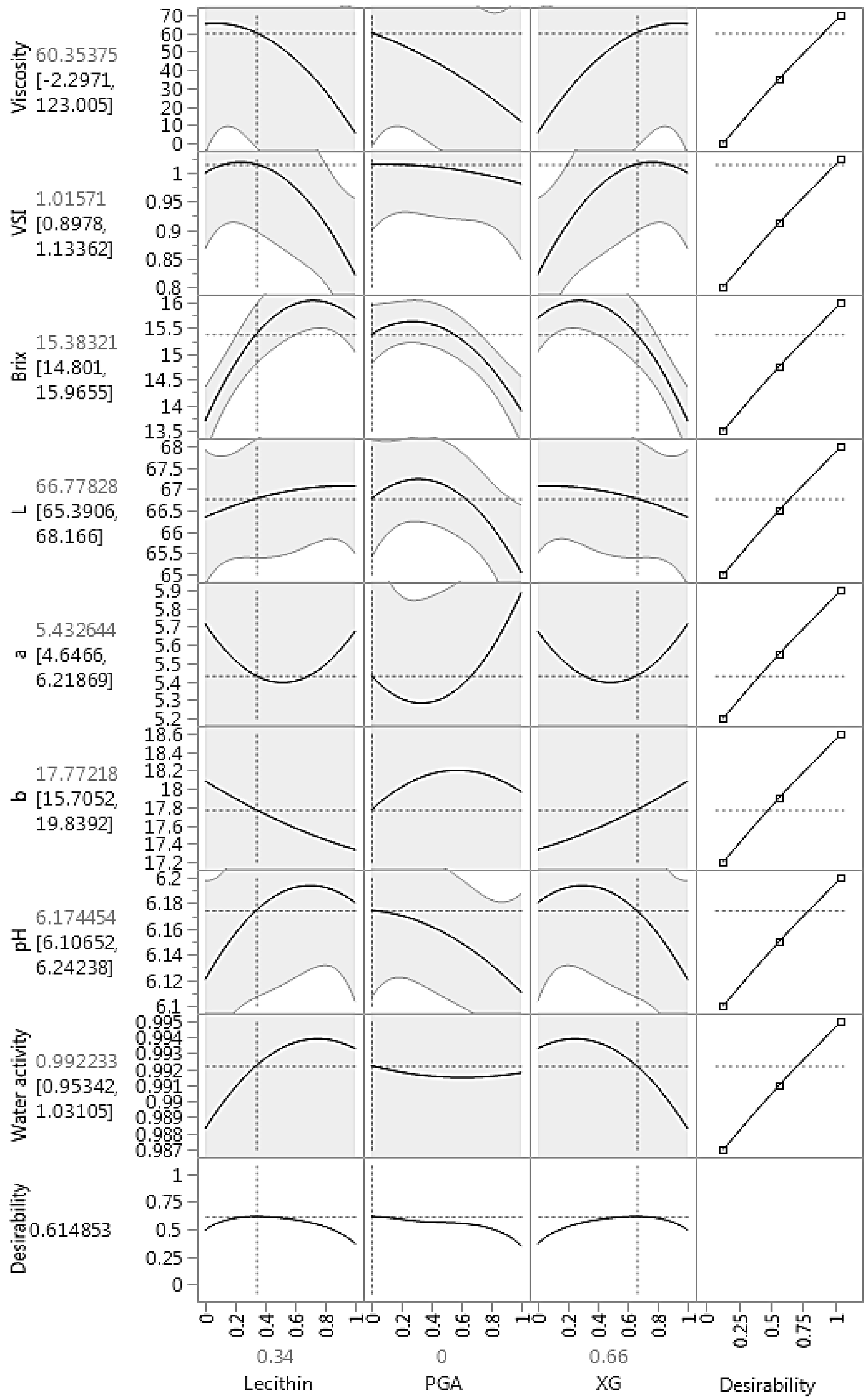

Figure 6.3. Optimal prediction profiles of the effect of the different emulsifier and stabilizers on the various properties of the model peanut-based beverage.

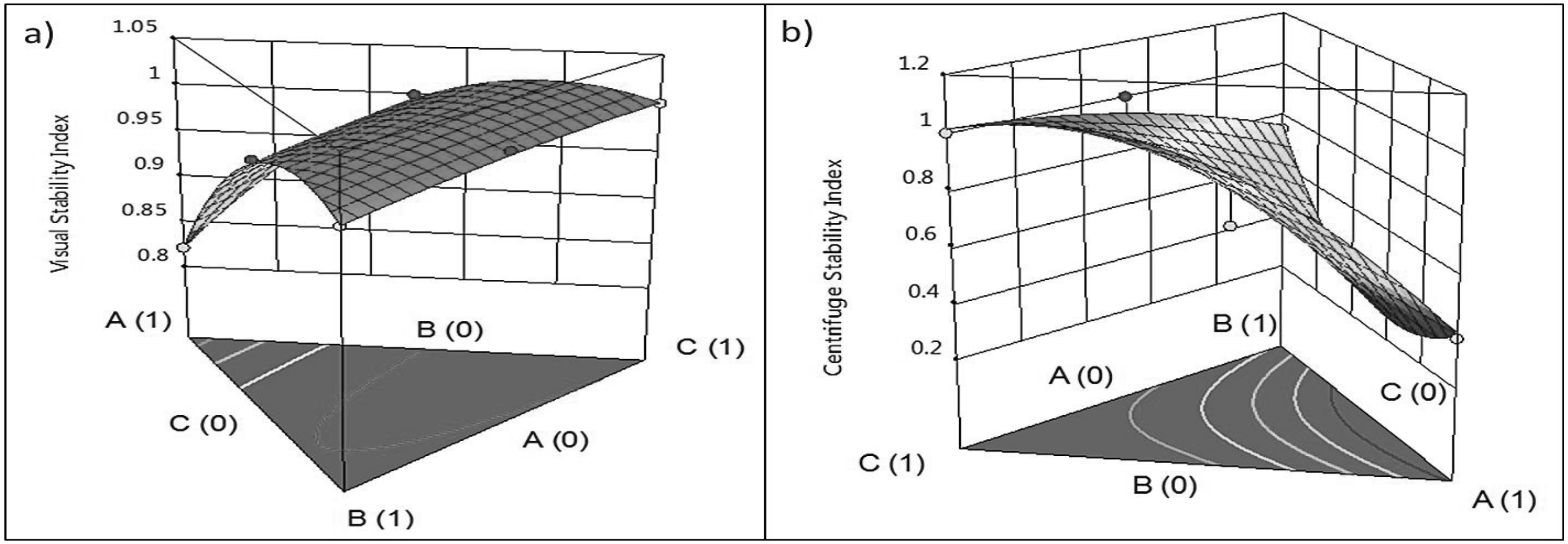

Figure 6.4. Ternary and surface contour plots showing the effect of the stabilizer-emulsifier systems on **a)** visual stability index (*VSI*) and **b)** centrifuge stability index (*CSI*) of the model peanut-based beverage. A = Lecithin; B = PGA; C = XG.

Although viscosity had a significant positive correlation with *VSI*, a viscosity of above 65 mPa-s would make the product too thick and therefore, not very ideal for a beverage. Therefore, considering both *VSI* and viscosity, a combination of lecithin (0.34) and xanthan gum (0.66) was optimal (Figure 6.3). The prediction model for *VSI* is also consistent with this finding (Table 6.3). Although lecithin on its own had a negative effect on *VSI (*Figure 6.4a*)* and *CSI* (Figure 6.4b), it moderated the effect of XG, and their combination had a positive effect on the colloidal stability of the samples.

4. Conclusions

The colloidal stability, physicochemical, and rheological properties of the peanut-based beverages were affected by the amount and type of the stabilizer or emulsifier used. In this study, a mixture design was applied to obtain the optimum stabilizer and emulsifier combination for the peanut-based beverage. The optimum stabilizer and emulsifier combination was that of 66% xanthan gum and 34% lecithin at 0.5% usage level by weight of the beverage. The use of the lecithin alone resulted in a decrease in viscosity, *VSI*, and *CSI* of the samples. The prediction model found in this study may be used in industry to achieve colloidal stability of similar beverages. However, further studies should be done to determine the sensory characteristics and consumer acceptability of the stabilized peanut-based beverages.

References

1. Sethi S, Tyagi SK, Anurag RK (2016) Plant-based milk alternatives an emerging segment of functional beverages: a review. Journal of food science and technology 53 (9):3408-3423

2. Chompreeda P, Haruthaithanasan V, Oupadissakoon C, Suknak K (1989) Development of a chocolate flavored peanut beverage. Journal of Food Science 54 (5):1359-1360

3. Deshpande R, Chinnan M, McWatters K (2008) Optimization of a chocolate-flavored, peanut–soy beverage using response surface methodology (RSM) as applied to consumer acceptability data. LWT-Food Science and Technology 41 (8):1485-1492

4. Galvez FCF, Resurreccion AV, Koehler PE (1990) Optimization of processing of peanut beverage. Journal of Sensory Studies 5 (1):1-17

5. Hinds MJ, Beuchat LR, Chinnan MS (1997) Properties of a thermal-processed beverage prepared from roasted partially defatted peanuts. International journal of food science & technology 32 (3):203-211

6. Rubico S, Phillips R, Resurreccion A, Beuchat L (1989) Nutritional, microbiological, and sensory qualities of a peanut beverage prepared using various processes. Journal of food science 54 (6):1540-1543

7. Rustom I, López-Leiva M, Nair BM (1996) UHT-Sterilized Peanut Beverages: Kinetics of Physicochemical Changes during Storage and Shelf-Life Prediction Modeling. Journal of food science 61 (1):198-203

8. Howard BM, Hung YC, McWatters SK (2010) Analysis of ingredient functionality and formulation optimization of an instant peanut beverage mix. J Food Sci 75 (1):S8-19. doi:10.1111/j.1750-3841.2009.01380.x

9. Dickinson E (1992) Introduction to food colloids. Oxford University Press,

10. Dickinson E (2009) Hydrocolloids as emulsifiers and emulsion stabilizers. Food hydrocolloids 23 (6):1473-1482

11. Dickinson E (1993) Towards more natural emulsifiers. Trends in Food Science & Technology 4 (10):330-334

12. Garti N (1999) What can nature offer from an emulsifier point of view: trends and progress? Colloids and Surfaces A: Physicochemical and Engineering Aspects 152 (1-2):125-146

13. Walstra P (2003) Physical chemistry of foods. Marcel Decker. Inc, New York:397 - 450

14. Paquin P (2009) Functional and speciality beverage technology. Elsevier,

15. Piorkowski DT, McClements DJ (2014) Beverage emulsions: Recent developments in formulation, production, and applications. Food Hydrocolloids 42:5-41

16. Dogan M, Toker OS, Aktar T, Goksel M (2013) Optimization of gum combination in prebiotic instant hot chocolate beverage model system in terms of rheological aspect: mixture design approach. Food and Bioprocess Technology 6 (3):783-794

17. Brookfield (2014) More solutions to sticky problems. http://www.brookfield.nl/fileadmin/assets-brookfield/documents/More_Solutions_2014.pdf. Accessed 4 March 2018

18. Cho HM, Yoo B (2015) Rheological characteristics of cold thickened beverages containing xanthan gum–based food thickeners used for dysphagia diets. Journal of the Academy of Nutrition and Dietetics 115 (1):106-111

19. Bourne M (2002) Food texture and viscosity: concept and measurement. Elsevier,

20. Yanes M, Durán L, Costell E (2002) Rheological and optical properties of commercial chocolate milk beverages. Journal of Food Engineering 51 (3):229-234

21. Dogan M, Toker OS, Goksel M (2011) Rheological behaviour of instant hot chocolate beverage: part 1. Optimization of the effect of different starches and gums. Food Biophysics 6 (4):512-518

22. Torres MD, Moreira R, Chenlo F, Vázquez MJ (2012) Water adsorption isotherms of carboxymethyl cellulose, guar, locust bean, tragacanth and xanthan gums. Carbohydrate polymers 89 (2):592-598

23. Dogan M, Kayacier A, Ic E (2007) Rheological characteristics of some food hydrocolloids processed with gamma irradiation. Food Hydrocolloids 21 (3):392-396

24. Toker OS, Dogan M, Canıyılmaz E, Ersöz NB, Kaya Y (2013) The effects of different gums and their interactions on the rheological properties of a dairy dessert: a mixture design approach. Food and bioprocess technology 6 (4):896-908

25. Kim H, Hwang HI, Song KW, Lee J (2017) Sensory and rheological characteristics of thickened liquids differing concentrations of a xanthan gum-based thickener. Journal of texture studies 48 (6):571-585

26. Garcıa-Ochoa F, Santos V, Casas J, Gomez E (2000) Xanthan gum: production, recovery, and properties. Biotechnology advances 18 (7):549-579

27. Urlacher B, Noble O (1997) Xanthan gum. In: Thickening and gelling agents for food. Springer, pp 284-311

28. Pettitt DJ, Wayne JEB, Nantz JJR, Shoemaker CF (1995) Rheological properties of solutions and emulsions stabilized with xanthan gum and propylene glycol alginate. Journal of food science 60 (3):528-531

29. Yilmazer G, Carrillo AR, Kokini JL (1991) Effect of propylene glycol alginate and xanthan gum on stability of o/w emulsions. Journal of food science 56 (2):513-517
30. Nakauma M, Ishihara S, Funami T, Nishinari K (2011) Swallowing profiles of food polysaccharide solutions with different flow behaviors. Food Hydrocolloids 25 (5):1165-1173
31. Napper DH (1983) Polymeric stabilization of colloidal dispersions, vol 3. Academic Pr,
32. Singh H (2011) Aspects of milk-protein-stabilised emulsions. Food Hydrocolloids 25 (8):1938-1944
33. Robins MM, Watson AD, Wilde PJ (2002) Emulsions—creaming and rheology. Current opinion in colloid & interface science 7 (5-6):419-425

CHAPTER 7

OPTIMIZATION OF PEANUT-BASED BEVERAGES[1]

[1] Gama, A.P. and K. Adhikari. To be submitted to *LWT-Food Science and Technology*.

Abstract

In the current study, mixture design and product matching approaches were used to optimize peanut-based beverages. Optimization focused on maximizing overall consumer acceptability by varying two independent variables, peanut paste (PP) and malted milk powder (MMP), that constituted 16% of the beverage by weight. Two types of MMP, barley malted milk powder (BMMP) and sorghum malted milk powder (SMMP), were used. The optimal combination of the PP and any type of MMP, in the two-component mixture, were 60% and 40%, respectively. Maintaining all other factors constant, model validation results showed that the model can predict overall liking of the peanut-based beverages with 96% accuracy when the proportions of PP and MMP are known. The samples that were perceived to be thick, creamy, and smooth had a significantly higher ($p < 0.05$) overall liking scores while those that were perceived to be watery, grainy, and whitish in color had lower overall liking scores. The study has confirmed that consumer perceptions towards the product attributes have a direct impact on overall liking. Therefore, utilizing consumer feedback during the development process can potentially increase overall liking scores of the resultant products.

1. Introduction

Malnutrition and non-communicable diseases such as cancer and cardiovascular diseases remain a global challenge [1]. To address this challenge, governments worldwide have devised strategies to promote health by nudging people to consume more nutritious foods and maintain a healthy lifestyle. Currently, the world health organization (WHO) is working with united nations (UN) member States and other partners to find effective nutrition interventions and healthy diets from sustainable and resilient food systems [2]. Among the sustainable, resilient, and nutritious food sources are legumes like peanuts [3]. Peanuts are among the most important legumes in the world for being a relatively cheap source of good fat (mostly mono and polyunsaturated fatty acids), highly digestible proteins, vitamins, minerals, and other bioactive compounds [4]. Unfortunately, food choices are not influenced by anticipated health benefits only but also the sensory appeal of food, among others [5-8]. For instance, a study in Canada found that when chocolate flavored milk was not an option, many children were not drinking milk despite being nutritious [9]. Therefore, consumer acceptability is critical because nutritious foods that no one will be willing to consume have insignificant health-related benefits.

Development of food products with acceptable sensory properties help in promoting consumption. For instance, development of peanut butter significantly improved consumption of peanuts in the U.S., which currently accounts for about half of the edible form of peanuts in the country [10]. To develop acceptable products, consumer needs and wants must be incorporated into the product design [11]. Prospects of success are high if a product satisfies those needs and wants [12]. Therefore, peanut-based beverages were developed and optimized based on consumers' preferences in this study.

Compared to solid and semi-solid peanut products like peanut butter, peanut-based beverages have a higher potential of promoting peanut consumption since they are convenient, easy to digest, appeal to all age groups, can be delivered in multiple flavor options, and are ready to drink without need of a carrier. Therefore, it is not surprising that studies aimed at developing peanut-based beverages have been on-going for many years [13-19]. However, there are still challenges especially with the sensory properties and ultimately, the consumer acceptability of the peanut-based beverages. Hence, such products are rarely found on the market, even in developed countries. Unlike the previous studies where defatted peanut flour [18,19,17] or peanut protein isolates [14,16] were used, the present study utilized non-defatted peanut paste and sorghum or barley malted milk powders into the formulation to maximize both the sensory and nutritional properties. To the best knowledge of the authors, this is the first time such a formulation has been developed and tested.

2. Materials and methods

2.1. Sample preparation

Water, peanut paste (PP), sugar, salt, malted milk powder (MMP), and xanthan gum, were used in preparing the beverage samples. Sugar and salt were obtained from Chipiku Plus Stores in Lilongwe, Malawi. The stabilizer was donated by TIC Gums (Belcamp, MD, USA). Virginia type peanuts (ICGV-SM 90704) were obtained from ICRISAT, Malawi and used to make the PP. The peanuts were medium roasted (Lightness, L = 50 ± 1), manually blanched, sorted, and then milled into a fine paste using a colloidal mill (Hebei Iron-Lion milling machinery Co. Ltd, China). Two types of MMP were used depending on the formulation specifications. The first type (BMMP) was a mixture of malted barley powder with non-fat dry milk powder while the other one (SMMP) had malted sorghum powder instead of the malted barley powder. The ingredients were mixed using a blender and then, homogenized at 28,000 rpm for one minute using an OMNI GLH-01 homogenizer (OMNI International, Kennesaw, GA, USA). The beverage mix was pasteurized at 85 ^{o}C for 5 minutes in a steam jacketed pot, hot filled in bottles, and immediately cooled in an ice bath. The samples were kept at 4 ^{o}C until subsequent evaluations.

2.2. Study design

2.2.1. Step I: Product optimization

Based on preliminary beverage preparation trials and literature review [13-19], levels of sugar, stabilizer, salt, and water were pre-determined and fixed (actual proportions have not been disclosed because of patent prospects). To determine the levels of PP and BMMP, a non-constrained two-component mixture design was used. The total concentration of the two components was fixed at 16% of the beverage by weight. Design combinations were generated using Design-Expert software (Version 11.0, Stat-Eas Inc., Minneapolis, MN, USA).

2.2.2. Step II: Prediction model validation

The optimal and two other sub-optimal formulations were used to validate the overall liking prediction model generated in step I. The experimentally determined overall liking scores for the samples were statistically compared with their respective predicted values from the mathematical model found in step I.

2.2.3. Step III: Product matching

Four formulations containing SMMP were prepared and compared with the optimal BMMP formulation validated in step II (*Target*). The change of malted milk type from BMMP to SMMP was necessitated by the low cost and extensive use of sorghum in Sub-Saharan Africa as opposed to barley [20]. Two types of SMMP were used and they are herein referred to as SMMP-1 (Malted sorghum powder: Non-fat dry milk powder = 1:20) and SMMP-2 (Malted sorghum powder: Non-fat dry milk powder = 1:30).

2.3. Product evaluations

Consumer acceptability evaluations of the products were done at a central location by Malawian consumers aged 18 and above and without any known food allergies or intolerances (Appendix C). For each step, the products were evaluated by different panels, each comprising 40 consumers. Apart from hedonic responses in all the three steps, consumer perceptions towards key attribute intensities were identified using a 5-point Just-About-Right (JAR) scale [21] in step I (Appendix D), and samples were characterized through a Check-All-That-Apply (CATA) question in step III (Appendix E). CATA question consists of a list of terms that a respondent selects, if they consider it appropriate, to describe a product [22]. Consumers, at each step, independently evaluated all the available samples. Pictures of the testing environment are given in Appendix F. Coded samples at 7 ^{o}C (~ 30 mL) were presented monadically following a completely randomized balanced block design. Protocols for the sensory tests were approved by the University of Georgia's Institutional Review Board (IRB Approval Number: STUDY00004112).

2.4. Statistical analysis

For step I, regression analysis was used to analyze the data, and the following polynomial equation was fitted:

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_{12} X_1 X_2$$

Y is the predicted response (overall liking); β_1, β_2, and β_{12} are the coefficients for each term while X_1 and X_2 are the coded proportions of PP and BMMP, respectively. The predicted equation for the response variable and the surface plot were generated using Design-Expert software (Version 11.0, Stat-Eas Inc., Minneapolis, MN, USA). Optimization of the independent variable levels was achieved by desirability maximization [23] of the response factor using a numerical optimization procedure of the Design-Expert software. To identify the product attributes that had either a positive or negative impact on the overall liking scores, penalty analyses were done using the JAR responses and overall likings scores.

For step II, experimentally determined mean overall liking scores were compared with the mathematically predicted (theoretical) value using a two-tailed one-sample t-test. Model validity was deduced from the calculated coefficients of variation, relative errors and the coefficient of determination (R^2) between the predicted and actual values.

For step III, differences in mean hedonic scores were assessed by one-way analysis of variance (ANOVA). Tukey's honest significant difference test (HSD) was used for means separation. CATA data were analyzed using Cochran's Q test followed by McNemar (Bonferroni) method for pairwise comparisons [22]. Mean impact analysis was done to assess the effect of the CATA responses on overall liking mean scores of the samples. Except for the product optimization, all the statistical analyses were done using XLSTAT 2017 (ver 19.04; Addinsoft, NY, USA).

3. Results and discussion

3.1. Product optimization and model validation

As the PP proportion in the mixture was increasing, the overall liking score was also increasing until the inflection point when the score started to drop (Figure 7.1a). The mean overall liking scores for the samples ranged from 5.55 to 7.45. Generally, samples that had only PP or BMMP in the mixture were the least liked while the sample that had equal proportions of PP and BMMP was the most liked. As shown in Figure 7.2, most consumers rated the sample with equal proportions of PP and BMMP as having the right levels of brownness (68%), sweetness (71%), thickness (71%), roasted peanut aroma (76%), saltiness (79%), and roasted peanut flavor (84%). Just as shown in Figure 7.2, penalty analysis results also showed that the sample that had no PP was penalized for not having enough roasted peanut aroma, roasted peanut flavor, thickness, and brownness. On the other hand, the sample that had just PP in the mixture was penalized for having less sweetness and too much roasted peanut aroma, roasted peanut flavor, thickness, brownness, and saltiness.

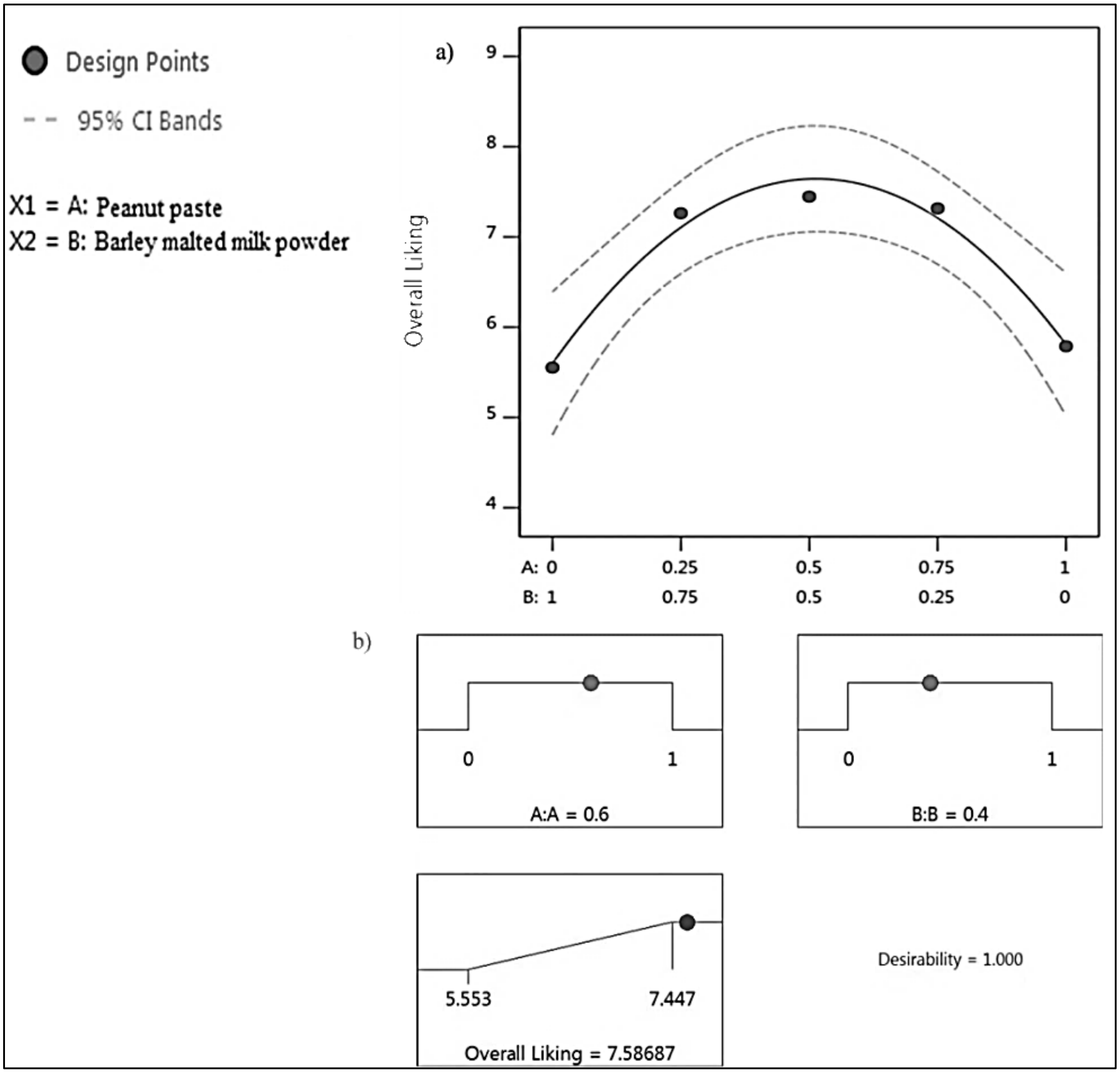

Figure 7.1 a) Plot showing the effect of levels of the independent variables (peanut paste and barley malted milk powder) on overall liking score of the peanut beverage; **b)** Graphical representation of the optimized levels of the independent variables.

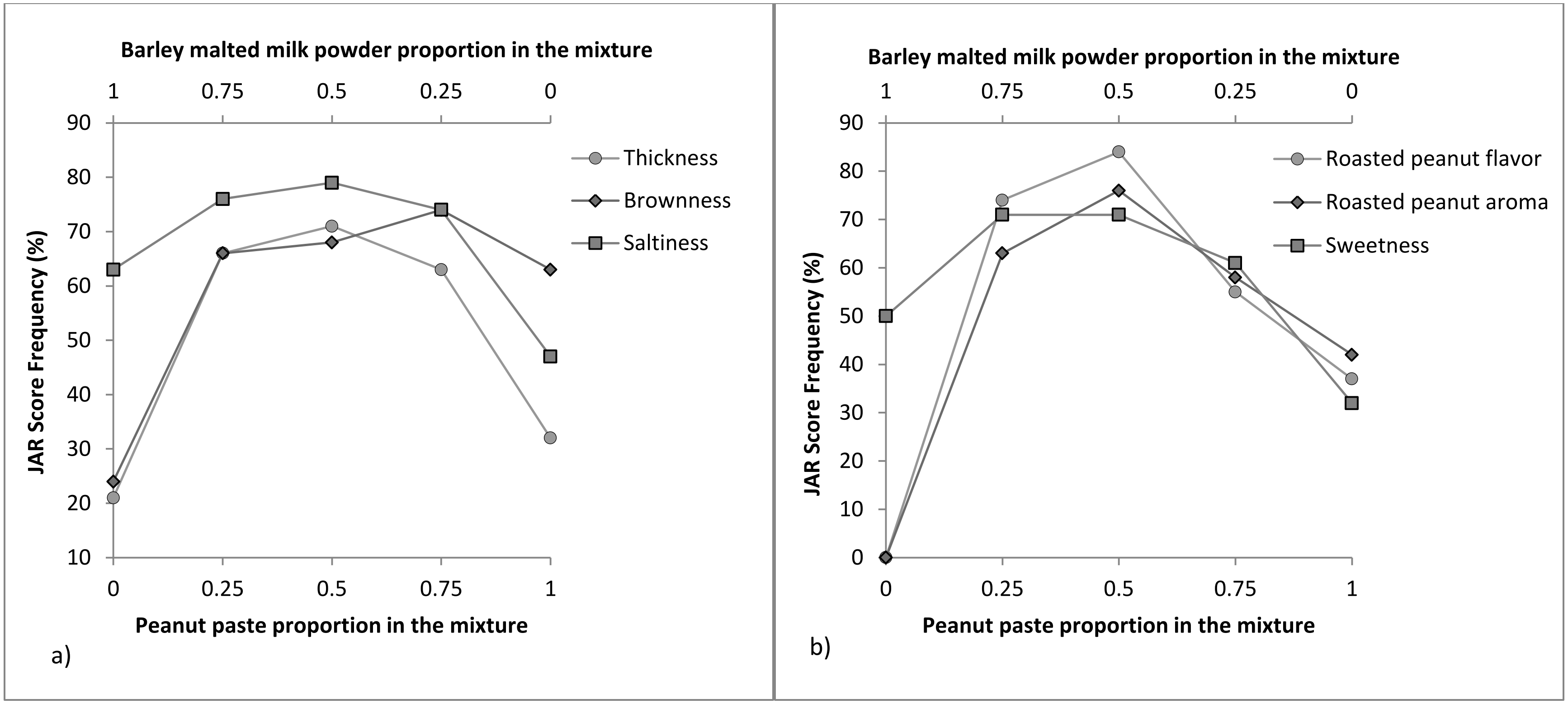

Figure 7.2. Effect of mixture composition on the consumers' perception of sensory attributes intensities. JAR score frequency reflects the percentage of consumers who rated the intensity of an attribute as Just-About-Right. a) Plot for thickness, brownness, and saltiness; b) plot for roasted peanut flavor, roasted peanut aroma, and sweetness.

Among all the possible models for the response factor, only a quadratic model was significant (Table 7.1). The quadratic model explained 97.7% (Adj. $R^2 = 0.955$) of the variation in the overall liking scores of the samples. The quadratic response trend is evident in Figure 7.1a. After fitting the quadratic model, the prediction equation for the response factor was as follows:

$$Overall\ liking = 5.81A + 5.60B + 7.76AB$$

Table 7.1. Model summary statistics.

Source	Sum of Squares	df	Mean Square	F-value	*p*-value
Mean vs. Total	222.68	1	222.68	-	-
Linear vs. Mean	0.0276	1	0.0276	0.0245	0.8855
Quadratic vs. Linear	3.29	1	3.29	85.80	0.0115*
Cubic vs. Quadratic	0.0017	1	0.0017	0.0225	0.9052
Quartic vs. Cubic	0.0750	1	0.0750	-	-
Residual	0.0000	0		-	-
Total	226.08	5	45.22	-	-

*Indicates a significant difference at 5% significance level.

The optimal proportions of the PP (A) and the BMMP (B), in the two-component mixture, were 0.6 and 0.4, respectively (Figure 7.1b). Results of model validation study showed no significant difference ($p > 0.05$) between the predicted and actual overall liking scores (Table 7.2). Therefore, it is not surprising that there was very small variation between the experimental and predicted values with none of the coefficients of variation exceeding 5% (Table 7.2). As anticipated, the optimal formulation had a higher overall liking score (7.53) than the other sub-optimal formulations. The model predicted the actual overall liking scores with 96% accuracy ($R^2 = 0.96$). Therefore, the mathematical model can be used to predict overall liking of various formulations of the peanut-based beverages based on PP and BMMP mixture composition.

Table 7.2. Predicted and experimental values for overall liking of the model validation formulations.

Product	Mixture composition		Overall liking Score			CV (%)	Relative error (%)
	PP	BMMP	Predicted	Actual[1]	*p*-Value		
Optimal	0.60	0.40	7.59	7.53	0.617	0.56	0.80
S1-1	0.15	0.85	6.62	6.45	0.406	1.29	1.85
S1-2	0.70	0.30	7.38	7.28	0.468	0.96	1.37

[1]Mean value based on responses of 40 consumers; CV = Coefficient of variation; PP = Peanut paste; BMMP = Barley malted milk powder.

In a mixture design, the response is assumed to depend only on the relative proportions of the ingredients present in the mixture. The total amount is held constant, and the value of the response changes when the proportions of the ingredients making up the mixture changes [24]. Therefore, unlike in factorial designs, the change in the response is a function of the joint blending property of the ingredients in the mixture. For instance, consumers in this study perceived different intensities of sweetness among the samples although all the samples had the same sugar concentration. This blending property of ingredients in the mixture also affected other attributes resulting in either a positive or negative effect on the overall liking scores.

The quadratic trend in the overall liking of the beverage as the peanut paste proportion in the mixture was increasing displays a typical consumer response pattern. Even for generally acceptable attributes like sweetness, consumer acceptability does not follow a linear trend. Beyond a certain optimal level, the sweetness is considered to be appalling, and the degree of liking starts to drop. A similar pattern has been observed in this study where samples were not liked for either having too much or too little of an attribute. Having more peanut paste in the beverage would likely guarantee more of the health benefits related to peanut consumption. However, the study has shown and confirmed through the model validation that going beyond a peanut paste proportion of 0.6, in the two-component mixture, would compromise consumer acceptability of the beverage. Ultimately, if no-one will consume the product, the nutrients will be of no benefit.

Although health is one of the food choice motives, it is usually overpowered by sensory appeal. Food is not just eaten for its nutritional value. More often, eating is a source of pleasure and comfort [25]. Several studies have identified the sensory appeal of food as one of the most universal and dominant food choice motives even in developing countries [5,26,6,27,8]. Foods that do not have acceptable sensory properties are infrequently consumed. For instance, despite the health benefits, the global consumption of vegetables is generally low because, among other factors, most vegetables are not appealing [28-30].

3.2. Product matching

Significant differences ($p < 0.05$) among the samples were found in all the evaluated parameters except flavor (Table 7.3). Among the samples with SMMP (S2-1, S2-2, S2-3, and S2-4), only S2-2 was similar to the *Target* in terms of aroma, texture, and overall liking.

Table 7.3. Mean hedonic scores for the samples in comparison to the *Target.*

	Mixture composition				Mean				
Product	PP	BMMP	SMMP-1	SMMP-2	Appearance	Aroma	Flavor	Texture	Overall Liking
S2-1	0.6	0.0	0.0	0.4	6.4^{b}	6.4^{b}	6.4^{a}	6.6^{b}	6.5^{b}
S2-2	0.6	0.0	0.4	0.0	6.7^{b}	7.5^{a}	7.3^{a}	6.7^{ab}	7.7^{a}
S2-3	0.5	0.0	0.5	0.0	6.3^{b}	6.3^{b}	6.7^{a}	6.6^{b}	6.6^{b}
S2-4	0.5	0.0	0.0	0.5	6.1^{b}	6.4^{b}	6.9^{a}	6.5^{b}	6.7^{b}
Target	0.6	0.4	0.0	0.0	8.0^{a}	7.3^{a}	6.9^{a}	7.6^{a}	7.5^{a}

^{ab} Different superscripts within each column indicate significant difference ($p < 0.05$).
PP = Peanut paste; BMMP = Barley malted milk powder; SMMP-1 = Sorghum malted milk powder type 1 (Malted sorghum powder: Non-fat dry milk powder = 1:20); SMMP-2 = Sorghum malted milk powder type 2 (Malted sorghum powder: Non-fat dry milk powder = 1:30).

Therefore, S2-2 was considered to be the best peanut beverage formulation containing SMMP. Just like the *Target*, the proportions of peanut paste and malted milk powder, in the two component mixture, were also 0.6 and 0.4, respectively.

Product matching is a well-known sensory technique used to compare sensory characteristics of a product, especially after reformulation [31]. The need for reformulation could be necessitated by the change of ingredient suppliers, change of ingredients to meet emerging consumer preferences or part of a product improvement strategy among others. In this study, product matching was an effective shortcut for developing an acceptable peanut-based beverage that had SMMP in its formulation. Unlike barley, sorghum is commonly grown in Sub-Saharan Africa, and it is already used for the production of both alcoholic and non-alcoholic beverages among others [20]. Therefore, use of sorghum in the formulation may have some competitive advantages. Most bitter sorghum varieties have tannins which interfere with nutrient absorption. However, the sorghum variety (ICSV 112) used in this study was chosen because its grains have a sweet taste and do not contain tannins [32]. Therefore, no effect on nutritional quality is expected.

3.3. Sensory characteristics of the samples

Out of the 18 terms included in the CATA question, significant differences were found in the citation frequencies of 7 terms (Table 7.4). Therefore, the CATA question revealed differences in the consumer perceptions on the sensory characteristics of the evaluated samples. Among the significant 7 CATA terms, 6 of them (*thick, smooth, creamy, whitish color, grainy, and watery*) had a significant impact ($p < 0.05$) on the overall mean score. When the terms *thick,* *smooth,* and *creamy* were used to describe a sample, there was an increase in the overall liking mean score of the sample compared to when the terms had not been used.

Table 7.4. Cochran's Q test based on citation frequency of the CATA terms used to describe the samples.

		Frequency (%)				
Descriptor	*p*-value	S2-1	S2-2	S2-3	S2-4	*Target*
Tasty	0.490	50^{a}	53^{a}	63^{a}	61^{a}	61^{a}
Tasteless	0.483	5^{a}	3^{a}	8^{a}	0^{a}	5^{a}
Sweet	0.690	74^{a}	76^{a}	84^{a}	76^{a}	74^{a}
Bitter	0.406	13^{a}	5^{a}	11^{a}	5^{a}	5^{a}
Salty	0.105	13^{a}	16^{a}	11^{a}	24^{a}	5^{a}
Sour	0.255	0^{a}	5^{a}	0^{a}	3^{a}	0^{a}
Aromatic	0.092	40^{a}	43^{a}	47^{a}	40^{a}	55^{a}
Roasted peanut flavor	0.377	66^{a}	63^{a}	71^{a}	58^{a}	74^{a}
Smooth	0.000***	50^{b}	58^{ab}	58^{ab}	40^{b}	84^{a}
Grainy	0.001**	18^{ab}	24^{ab}	21^{ab}	37^{a}	3^{b}
Creamy	0.096	55^{a}	68^{a}	63^{a}	74^{a}	79^{a}
Stable	0.000***	45^{b}	45^{b}	37^{b}	53^{ab}	79^{a}
Brown color	0.000***	50^{b}	68^{ab}	58^{b}	53^{b}	90^{a}
Whitish color	0.000***	42^{a}	24^{ab}	40^{a}	37^{a}	3^{b}
Thick	0.000***	18^{b}	45^{ab}	21^{b}	40^{ab}	58^{a}
Watery	0.000***	61^{a}	26^{bc}	58^{ab}	37^{abc}	21^{c}

***Indicates significant difference at $p < 0.001$.
**Indicates significant difference at $p < 0.01$.
[abc] Values followed by different superscripts within each row are significantly different ($p < 0.05$).

As shown in Figure 7.3, the term *thick* had the highest positive mean impact (0.71) followed by *smooth* (0.54), and *creamy* (0.52). On the other hand, when the term *watery*, *grainy, and whitish color* were cited, there was an overall liking mean drop of 0.98, 0.95, and 0.48, respectively (Figure 7.3). Therefore, samples perceived to be watery, grainy, and whitish in color were not liked by the consumers.

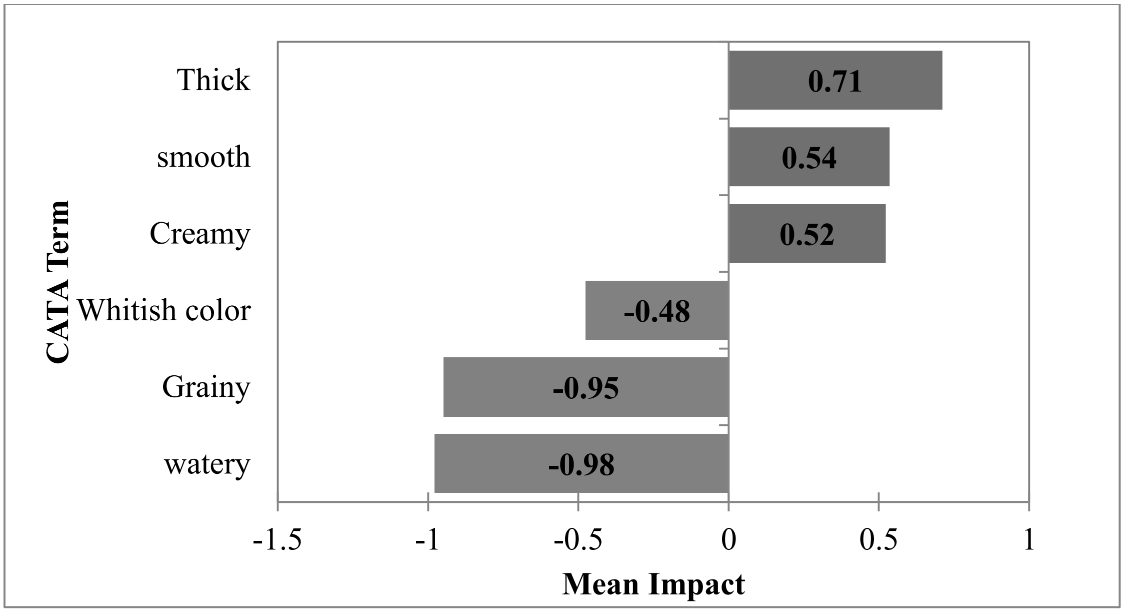

Figure 7.3. Mean impact analysis based on citation frequency of the significant CATA terms.

A check-all-that-apply (CATA) question is one of the most novel, simple, reproducible and valid option for sensory characterization of a wide range of products using consumers although it does not give attribute intensities [22]. Unlike JAR, CATA can offer insights on the impact of attributes whose intensities are rarely described as "too much" like smoothness and homegeinity among others [22,33]. Several studies have reported the use of CATA as being equally good as the other sensory descriptive tests when profiling or characterizing products [34,22,35]. Irrespective of the sensory characterization technique (JAR or CATA) used in this study, samples that were percieved not to have the right level of thickness were not liked. Just as expected, samples that were percieved to be waterly were not liked in this study. A study by Gama et al. [6] found that Malawian consumers like foods that are more filling. However, as previously noted with JAR responses, consumers have their own perceptions regarding the right level of an attribute in a food product even if it is generally desirable. Therefore, it was not suprising that samples that were percieved to be too thick were also not liked. Non-deffatted peanuts were used in this study and based on CATA results, the samples were stable. Therefore, with proper designing, is possible to have an acceptable peanut-based beverage even if non-deffated peanuts are used in the formulation.

4. Conclusion

In the current study, the development of peanut-based beverages with desirable sensory properties was achieved using a two-component mixture design and product matching approaches. Levels of the two key components (peanut paste and malted milk powder), constituting 16% of the total peanut beverage by weight, were optimized to maximize consumer acceptability. The optimal concentrations of the peanut paste and malted milk powder (BMMP or SMMP), in the two-component mixture, were 60% and 40%, respectively. No differences were found between the model predicted overall liking scores and experimental score. The model equation predicted the actual overall liking scores with 96% accuracy. Therefore, maintaining all other factors constant, the model can be used to predict overall liking of various formulations of the peanut-based beverages based on peanut paste and malted milk powder mixture composition.

References

1. WHO (2016) The Double Burden of Malnutrition. http://apps.who.int/iris/bitstream/10665/255413/1/WHO-NMH-NHD-17.3-eng.pdf?ua=1. Accessed 14 July 2017
2. WHO (2018) Malnutrition. https://www.who.int/news-room/fact-sheets/detail/malnutrition. Accessed 2 January 2019
3. Foyer CH, Lam H-M, Nguyen HT, Siddique KH, Varshney RK, Colmer TD, Cowling W, Bramley H, Mori TA, Hodgson JM (2016) Neglecting legumes has compromised human health and sustainable food production. Nature plants 2 (8):16112
4. Davis JP, Dean LL (2016) Peanut composition, flavor and nutrition. In: Peanuts. Elsevier, pp 289-345
5. Eertmans A, Victoir A, Notelaers G, Vansant G, Van den Bergh O (2006) The Food Choice Questionnaire: Factorial invariant over western urban populations? Food quality and preference 17 (5):344-352
6. Gama AP, Adhikari K, Hoisington DA (2018) Factors influencing food choices of Malawian consumers: A food choice questionnaire approach. Journal of Sensory Studies 33 (5):e12442
7. Jáuregui-Lobera I, Ríos PB (2011) What motivates the consumer's food choice? Nutricion Hosppitalaria 26 (6):1313-1321
8. Prescott J, Young O, O'neill L, Yau N, Stevens R (2002) Motives for food choice: a comparison of consumers from Japan, Taiwan, Malaysia and New Zealand. Food quality and preference 13 (7):489-495

9. Henry C, Whiting SJ, Phillips T, Finch SL, Zello GA, Vatanparast H (2015) Impact of the removal of chocolate milk from school milk programs for children in Saskatoon, Canada. Applied Physiology, Nutrition, and Metabolism 40 (3):245-250

10. NPB (2015) History of Peanuts and Peanut Butter. National Peanut Board. http://nationalpeanutboard.org/peanut-info/history-peanuts-peanut-butter.htm. Accessed 16 March 2017

11. Van Kleef E, van Trijp HC, Luning P (2005) Consumer research in the early stages of new product development: a critical review of methods and techniques. Food quality and preference 16 (3):181-201

12. Slater SF, Narver JC (2000) Intelligence generation and superior customer value. Journal of the academy of marketing science 28 (1):120-127

13. Rubico S, Phillips R, Resurreccion A, Beuchat L (1989) Nutritional, microbiological, and sensory qualities of a peanut beverage prepared using various processes. Journal of food science 54 (6):1540-1543

14. Chompreeda P, Haruthaithanasan V, Oupadissakoon C, Suknak K (1989) Development of a chocolate flavored peanut beverage. Journal of Food Science 54 (5):1359-1360

15. Galvez FCF, Resurreccion AV, Koehler PE (1990) Optimization of processing of peanut beverage. Journal of Sensory Studies 5 (1):1-17

16. Rustom I, López-Leiva M, Nair BM (1996) UHT-Sterilized Peanut Beverages: Kinetics of Physicochemical Changes during Storage and Shelf-Life Prediction Modeling. Journal of food science 61 (1):198-203

17. Hinds MJ, Beuchat LR, Chinnan MS (1997) Properties of a thermal-processed beverage prepared from roasted partially defatted peanuts. International journal of food science & technology 32 (3):203-211

18. Deshpande R, Chinnan M, McWatters K (2008) Optimization of a chocolate-flavored, peanut–soy beverage using response surface methodology (RSM) as applied to consumer acceptability data. LWT-Food Science and Technology 41 (8):1485-1492

19. Howard BM, Hung YC, McWatters SK (2010) Analysis of ingredient functionality and formulation optimization of an instant peanut beverage mix. J Food Sci 75 (1):S8-19. doi:10.1111/j.1750-3841.2009.01380.x

20. Taylor J Overview: Importance of sorghum in Africa. In: Afripro: Workshop on the Proteins of Sorghum and Millets: Enhancing Nutritional and Functional Properties for Africa, Pretoria, 2003. vol 4.

21. Meullenet J-F, Xiong R, Findlay CJ (2008) Multivariate and probabilistic analyses of sensory science problems, vol 25. John Wiley & Sons,

22. Varela P, Ares G (2012) Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterization. Food Research International 48 (2):893-908

23. Myers RH, Montgomery DC, Anderson-Cook CM (2016) Response surface methodology: process and product optimization using designed experiments. John Wiley & Sons,

24. Cornell JA (2011) Experiments with mixtures: designs, models, and the analysis of mixture data, vol 403. John Wiley & Sons,

25. Clark JE (1998) Taste and flavour: their importance in food choice and acceptance. Proceedings of the nutrition society 57 (4):639-643

26. Fotopoulos C, Krystallis A, Vassallo M, Pagiaslis A (2009) Food Choice Questionnaire (FCQ) revisited. Suggestions for the development of an enhanced general food motivation model. Appetite 52 (1):199-208

27. Januszewska R, Pieniak Z, Verbeke W (2011) Food choice questionnaire revisited in four countries. Does it still measure the same? Appetite 57 (1):94-98

28. Pollard J, Kirk SL, Cade J (2002) Factors affecting food choice in relation to fruit and vegetable intake: a review. Nutrition research reviews 15 (2):373-387

29. Krølner R, Rasmussen M, Brug J, Klepp K-I, Wind M, Due P (2011) Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part II: qualitative studies. International Journal of Behavioral nutrition and physical activity 8 (1):112

30. WHO (2003) Promoting fruit and vegetable consumption around the world. Dostupno na adresi: http://www who int/dietphysicalactivity/fruit/en/ Datum pristupa 10

31. Carpenter RP, Lyon DH, Hasdell TA (2012) Guidelines for sensory analysis in food product development and quality control. Springer Science & Business Media,

32. ICRISAT (1995) Sorghum variety Pirira 2 (ICSV 112). http://oar.icrisat.org/607/1/PMD_61.pdf. Accessed January 12 2018

33. Ares G (2015) Methodological challenges in sensory characterization. Current Opinion in Food Science 3:1-5

34. Ares G, Antúnez L, Bruzzone F, Vidal L, Giménez A, Pineau B, Beresford MK, Jin D, Paisley AG, Chheang SL (2015) Comparison of sensory product profiles generated by

trained assessors and consumers using CATA questions: Four case studies with complex and/or similar samples. Food Quality and Preference 45:75-86

35. Bruzzone F, Vidal L, Antúnez L, Giménez A, Deliza R, Ares G (2015) Comparison of intensity scales and CATA questions in new product development: Sensory characterisation and directions for product reformulation of milk desserts. Food Quality and Preference 44:183-193

CHAPTER 8

SENSORY AND NUTRITIONAL PROPERTIES OF PEANUT-BASED BEVERAGES: A PROMISING SOLUTION FOR UNDERNUTRITION IN MALAWI[1]

[1] Gama, A.P., Mwangwela, A.M., Wainaina W.G., and K. Adhikari. To be submitted to *Journal of the Science of Food and Agriculture*.

Abstract

Undernutrition remains a challenge in countries like Malawi. To address this challenge, the search for effective nutrition interventions and nutritious foods especially from sustainable and resilient food sources, like peanuts, is on-going. In this study, sensory profiles of six peanut-based beverage prototypes were determined. Two highly acceptable beverages were identified. Then, their nutrient profiles were determined using official standard analytical methods. One of the beverages had barley malted milk powder (S3-2) while the other had sorghum malted milk powder (S3-5) in its formulation. The S3-5 had a better nutrient profile than S3-2, "peanut milk," and F100 (WHO-recognized reference diet), respectively, in terms of protein, potassium, and calcium. The S3-5 also had a better nutrient composition than whole milk, in terms of protein, fat, potassium and iron. A 237-mL (8 oz.) serving of the S3-5 was an excellent source (% DV ≥ 20) of high-quality protein, total dietary fiber, phosphorus, calcium, molybdenum, and manganese and also, a good source (10 ≤ % DV < 20) of potassium and magnesium. Based on acceptability results, both S3-2 and S3-5 can potentially increase peanut consumption in Malawi. In the long term, the S3-5 may help in the management of undernutrition given its nutritional quality. Beside Malawi, the peanut-based beverage may also be valuable in other countries where undernutrition is also a challenge.

1. Introduction

Malnutrition, as a result of deficient or excess intake of energy, macronutrients, and micronutrients remains a global challenge [1]. Unlike excess intake, a deficient intake of nutrients (undernutrition) is more prevalent in developing countries especially among children [2]. Worldwide, 52 million under-five children are wasted (low weight for height), 17 million are severely wasted, and 155 million are stunted (low height for age) [1]. Approximately, 45% of deaths among children aged below five years are related to undernutrition especially in developing countries [1]. Given the malnutrition challenge, WHO is working with UN member States and other partners to achieve "universal access to effective nutrition interventions and healthy diets from sustainable and resilient food systems" [1]. Among the sustainable, resilient, and nutritious food sources are legumes like peanuts [3]. Unfortunately, in countries like Malawi, despite the adequate supply, peanut consumption is low (4.98kg/capita/yr.) [4].

Among other factors, the limited diversity of peanut products that meet consumer preferences contributes to the low peanut consumption in Malawi [5]. Food is not just eaten for its nutritional value. More often, eating is a source of pleasure and comfort [6]. Therefore, the development of acceptable food products plays a key role in promoting consumption. For instance, global soy consumption has increased following the introduction of more soy products like tofu, soy "milk," energy bars, and other extruded products [7,8]. As a way of increasing peanut consumption and reducing undernutrition, prototypes of peanut-based beverages were developed. A beverage was chosen because compared to solid or semi-solid foods, beverages are convenient, easy to digest, appeal to all age groups, and can be delivered in multiple flavor options. Considering that the sensory appeal of food is one of the dominant food choice motives even in developing countries like Malawi [9], both the sensory and nutritional properties of the peanut-based beverages were determined in this study.

Based on WHO [10] guidelines for managing severe malnutrition, a liquid product known as F100 is currently used to promote rapid weight gain. F100 is an energy and protein-dense milk-based product fortified with vitamins and minerals. However, the search for other acceptable and sustainable alternatives is still on-going. In the present study, the nutrient profiles of the peanut-based beverages were compared to that of the F100, full fat cow milk (whole milk), Elmhurst "milked peanuts" (Steuben Foods Inc., Elma, NY, USA), and the Food and Drug Administration (FDA) Daily Reference Values (DRVs) or Reference Daily Intakes (RDIs), respectively. The findings of this study are valuable not only for Malawi but other countries too where undernutrition is equally a big challenge.

2. Materials and methods

2.1. Sensory analysis

Consumer acceptability of six peanut-based beverage samples (Table 8.1) was done at a central location by Malawian consumers (n = 177) aged 18 and above. The adults were targeted since they are the ones mostly making food choices on behalf of children as well. Aroma, appearance, flavor, texture and overall liking were scored using a 9-point hedonic scale (1 – dislike extremely; 5 – neither like nor dislike; 9 – like extremely) (Appendix E). The consumers were also asked to describe each sample through a check-all-that-apply (CATA) question. Coded samples at 7 ^{o}C (~ 30 mL each) were served monadically following a completely randomized balanced block design. The sensory test protocol was approved by the University of Georgia's Institutional Review Board (IRB Approval Number: STUDY00004112).

Table 8.1. Key properties of the evaluated peanut-based beverages.

Property	PBV-BMMP[1]			PBV-SMMP[2]		
	S3-1	**S3-2**	**S3-3**	**S3-4**	**S3-5**	**S3-6**
Flavor	Natural	Caramel	Vanilla	Natural	Caramel	Vanilla
Total soluble solids (°Brix)	19.01	19.01	19.01	20.30	20.30	20.30
pH	6.55	6.55	6.55	6.55	6.55	6.55
Viscosity (mPa-s)	64.00	64.00	64.00	66.40	66.40	66.40
Color						
Lightness (L)	55.39	55.39	55.39	58.07	58.07	58.07
Redness (a)	5.91	5.91	5.91	7.22	7.22	7.22
Yellowness (b)	17.59	17.59	17.59	16.25	16.25	16.25
Total plate count (CFU/g)	< 1	< 1	< 1	5	5	5
Yeasts (CFU/g)	< 1	< 1	< 1	< 1	< 1	< 1
Molds (CFU/g)	< 1	< 1	< 1	< 1	< 1	< 1
Aflatoxins						
B_1 *(ppb)*	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
B_2 *(ppb)*	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
G_1 *(ppb)*	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
G_2 *(ppb)*	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

[1]PBV-BMMP is a peanut-based beverage incorporation barley malted milk powder (BMMP) and [2]PBV-SMMP is a peanut-based beverage incorporating sorghum malted milk powder (SMMP) in addition to the other ingredients (water, peanut paste, sugar, salt, and xanthan gum).

2.2. Nutrient analysis

Based on the sensory evaluation results, two highly acceptable peanut-based beverages were identified. Official standard methods were used to determine the concentrations of crude protein, amino acids, crude fat, fatty acids, sugars, total dietary fiber, and minerals, in the peanut-based beverages.

2.2.1. Protein and amino acid analysis

Crude protein was determined using an improved Kjeldahl method (AOAC 950.48) [11]. Considering that peanuts, milk, barley, and sorghum are the likely sources of protein in the product mixture, a general conversion factor of 6.25 was used to calculate protein concentration from the measured nitrogen [12]. To quantify the amino acids, protein hydrolysates were prepared and analyzed using Ion Exchange Chromatographic method [13]. Methionine and cysteine were determined separately after performic acid oxidation according to AOAC 985.28 method [11]. Tryptophan was determined after alkali hydrolysis with NaOH (AOAC 988.15) [11]. Then, protein quality was estimated by comparing the concentrations of the indispensable amino acids with the FAO/WHO reference amino acid pattern [14].

2.2.2. Fat and fatty acid analysis

Crude fat was determined gravimetrically after Soxhlet extraction following AOAC 948.22 method [11]. Cis and trans fatty acids were determined by capillary gas-liquid chromatography according to AOCS Ce 1f-96 method [15]. Fatty acid methyl esters (FAMEs) were separated on a DB-23 capillary column (15 m x 0.25 mm i.d. with a 0.25 µm film) from Agilent Technologies, Santa Clara, CA, USA. One microliter of the sample was injected at a 60:1 split ratio onto the column. A thermal gradient of 180 °C for 1 min., 180 °C to 195 °C at 5 °C/min, then 195 °C to 240 °C at 10° C/min, for a total run time of 8.5 min, was used. Fatty acid peaks were identified by comparing the retention times with a FAME standard mix RM-3 (Sigma Aldrich Co., St. Louis, MO, USA). The fatty acids concentrations were determined from the calibration curve.

2.2.3. Carbohydrate analysis

Glucose, fructose, lactose, maltose, and sucrose were determined using an Ion Chromatographic method according to AOAC 996.04 [11]. The total concentration of sugars was reported as total carbohydrates. Total dietary fiber was determined using an enzymaticgravimetric method (AOAC 991.43) [11]. Dried defatted sample (1g) was digested using enzymes. The digest was precipitated with ethanol and filtered to obtain the residue. The residue, considered as the total dietary fiber, was washed with ethanol and acetone before drying and weighing.

2.2.4. Mineral analysis

All minerals (Boron, calcium, copper, iron, magnesium, manganese, molybdenum, nickel, potassium, sodium, and zinc), except phosphorus, were determined using Inductively Coupled Plasma Mass Spectrometry (ICP/MS) according to ASTM E 1613 method [16]. Phosphorous was determined calorimetrically following the AOAC 995.11 method [11].

2.2.5. Nutritional value estimation

Calculations were done to determine the adequacy of the peanut-based beverages in meeting the daily nutrient requirements. The calculations were based on the Food and Drug Administration (FDA) Daily Reference Values (DRVs) and Reference Daily Intakes (RDIs) for adults and children aged 4 and above [17]. The DRVs and RDIs are herein generally referred to as Daily Values (DVs). Furthermore, the nutrient densities of the peanut-based beverages were compared with that of the reference product (F100) (Nutriset, 76770 Malaunay, France), full fat cow milk (whole milk), and a "peanut milk" product branded as Elmhurst "milked peanuts" (Steuben Foods Inc., Elma, NY, USA). The nutrient concentrations of the F100 and the Elmhurst "milked peanuts" were based on the manufacturer's declared values while those of the whole milk were obtained from the United States Department of Agriculture (USDA) database [18].

The energy values of the peanut-based beverages were calculated using the conversion factors of 4 kcal/g (17 kJ/g) for carbohydrate and protein, and 9 kcal/g (37 kJ/g) for fat [19].

2.2. Statistical analysis

Differences in mean hedonic scores were assessed by one-way analysis of variance (ANOVA). Tukey's honestly significant difference test (HSD) was used for means separation. Consumer segmentation, based on overall liking scores, was done using Hierarchical Cluster Analysis (HCA) by Ward's method. CATA data were analyzed using Cochran's Q test followed by McNemar (Bonferroni) method for pairwise comparisons [20]. Mean impact analysis was done to assess the effect of the CATA responses on overall liking mean scores of the samples. For the construction of sensory maps, only the significant CATA attributes were included. Sensory maps were obtained through Correspondence Analysis (CA). Mean values for the evaluated nutrients were based on two replications and were compared using an independent two-sample t-test. All statistical analyses were done using XLSTAT (ver 19.01; Addinsoft, New York).

3. Results and discussion

3.1. Consumer acceptability

Significant differences ($p < 0.05$) among the samples were found in all the evaluated parameters except texture (Table 8.2). The mean overall liking scores of the samples ranged from 7.0 to 7.6. Samples S3-2 (barley malt, caramel flavor) and S3-5 (sorghum malt, caramel flavor) had the highest mean overall liking scores of 7.5 and 7.6, respectively. By just considering the responses of all the consumers (n =177), one may conclude that all the consumers well liked all the samples since no sample had a mean score below 7.0 in any of the evaluated parameters (Table 8.2). However, cluster analysis results showed otherwise. Three significant consumer clusters were found (Figure 8.1). Cluster 2 was the largest cluster comprising 49.7% of the consumers followed by cluster 1 (28.8%) and then, cluster 3 (21.5%).

Table 8.2. Consumer acceptability of peanut-based beverages.

	Mean				
Product	**Appearance**	**Aroma**	**Flavor**	**Texture**	**Overall Liking**
S3-1	7.5^{a}	7.1^{ab}	7.0^{c}	7.0^{a}	7.0^{b}
S3-2	7.5^{a}	7.5^{a}	7.5^{ab}	7.3^{a}	7.5^{a}
S3-3	7.2^{ab}	7.1^{ab}	7.3^{abc}	7.1^{a}	7.2^{ab}
S3-4	7.0^{b}	7.1^{ab}	7.3^{abc}	7.1^{a}	7.2^{ab}
S3-5	7.3^{ab}	7.5^{a}	7.6^{a}	7.4^{a}	7.6^{a}
S3-6	7.1^{b}	7.0^{b}	7.2^{bc}	7.2^{a}	7.2^{ab}

^{abc} Different superscripts within each column indicate significant difference ($p < 0.05$).

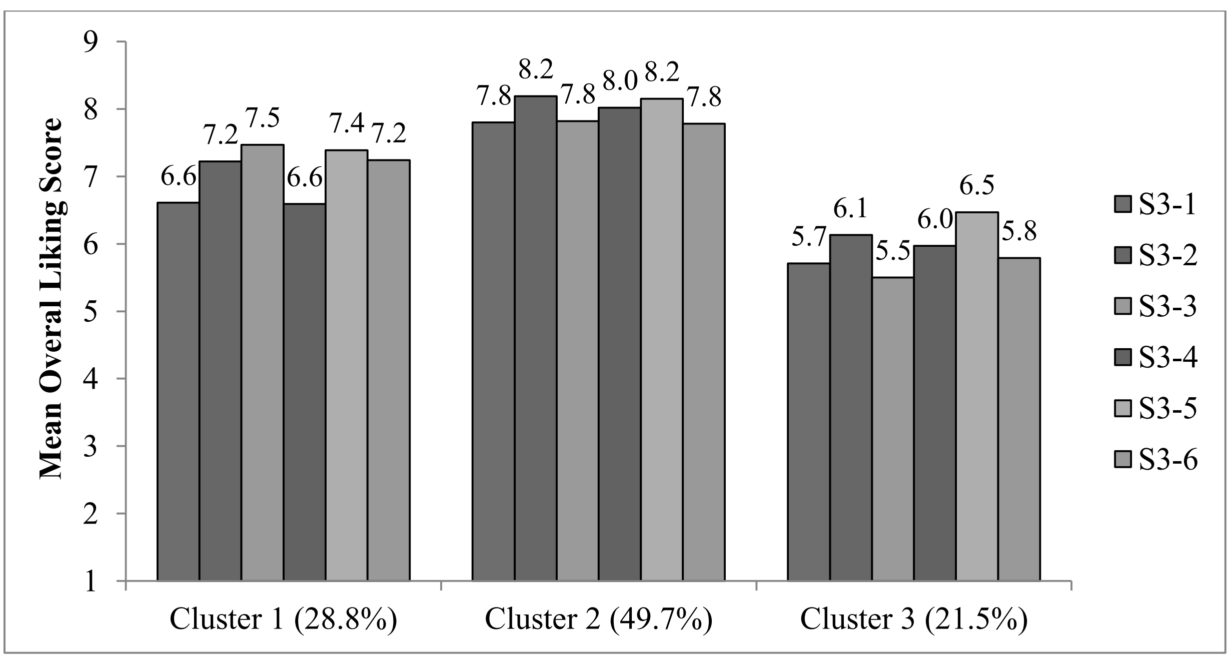

Figure 8.1. Consumer acceptability of the peanut-based beverages by the cluster.

The mean overall liking scores for the samples in clusters 1, 2, and 3 ranged from 6.6 to 7.5, 7.8 to 8.2, and 5.5 to 6.5, respectively. Therefore, Clusters 1, 2, and 3 were described as clusters for moderate likers, exceptional likers, and slight likers, respectively. There were no significant differences ($p > 0.05$) in cluster composition based on gender or age of the consumers. The three distinct consumer clusters found in this study confirms the diversity in consumer preferences, even within the same population. This is the reason why marketers just target a specific consumer segment within a population unlike trying to please everyone [21]. Since the cluster of slight likers was the smallest (21.5%), the success prospects of the peanut-based beverages are high. Irrespective of the cluster, samples S3-2 (barley malt, caramel flavor) and S3-5 (sorghum malt, caramel flavor) had relatively higher mean overall liking scores just like before clustering. Coincidentally, the two most liked samples had a caramel flavor.

The importance of flavor in foods cannot be overemphasized. For instance, a study in Canada found that when chocolate flavored milk was not an option, many children were not drinking milk [22]. The flavor of food could be natural or artificial. Artificial flavorings are mostly used in beverages to impart a flavor of choice, to modify an already existing flavor, or as a way of masking some undesirable flavor [23]. The ultimate goal is to increase the acceptability of the end product. However, this study confirmed that the type of flavor also matters. Unlike the caramel-flavored samples, samples with natural or vanilla flavor had relatively lower overall liking scores.

3.1.1. Drivers of consumer acceptability

Out of the 18 terms included in the CATA question, significant differences ($p < 0.05$) were found in the citation frequency of 10 of the terms (Table 8.3). Among the significant 10

CATA terms, 7 of them (*tasty, sweet, caramel flavor, creamy, brown color, thick, and watery*) had a significant impact ($p < 0.05$) on the overall liking mean score. Except for the term watery, when the other terms were used to describe a sample, there was an increase in the overall mean score of the sample compared to when the terms had not been used. The term *tasty* had the highest positive mean impact (0.60) followed by *creamy* (0.58), *thick* (0.47), *sweet* (0.41), *caramel flavor* (0.38), and lastly *brown color* (0.18). On the other hand, when the term *watery* was cited, the mean overall liking score dropped by 0.42 (mean impact = - 0.42). Therefore, samples perceived to be watery were not liked by the consumers. A study by Gama et al. [9] found that the Malawian consumers want foods that are more filling. Therefore, their disliking of the samples that were perceived to be watery is not surprising.

Table 8.3. Cochran's Q test results based on CATA responses.

	Citation Frequency (%)						
Descriptor	**S3-1**	**S3-2**	**S3-3**	**S3-4**	**S3-5**	**S3-6**	***p*-value**
Tasty	49^{b}	54^{ab}	54^{ab}	55^{ab}	64^{a}	57^{ab}	0.009
Tasteless	7^{a}	3^{a}	5^{a}	5^{a}	1^{a}	4^{a}	0.112
Sweet	51^{ab}	54^{a}	53^{a}	42^{c}	49^{b}	42^{c}	0.006
Bitter	3^{a}	0^{b}	1^{b}	2^{b}	3^{a}	4^{a}	0.027
Salty	2^{a}	3^{a}	3^{a}	3^{a}	3^{a}	2^{a}	0.541
Sour	1^{a}	2^{a}	1^{a}	1^{a}	2^{a}	0^{a}	0.127
Aromatic	19^{a}	24^{a}	22^{a}	23^{a}	25^{a}	19^{a}	0.246
Roasted peanut flavor	45^{a}	41^{a}	49^{a}	53^{a}	45^{a}	46^{a}	0.154
Caramel flavor	22^{b}	38^{a}	22^{b}	27^{b}	33^{a}	26^{b}	0.000
Vanilla flavor	14^{b}	7^{c}	16^{ab}	14^{b}	9^{c}	20^{a}	0.001
Smooth	44^{a}	41^{a}	40^{a}	37^{a}	44^{a}	38^{a}	0.360
Grainy	7^{a}	6^{a}	9^{a}	10^{a}	8^{a}	8^{a}	0.772
Creamy	34^{c}	41^{bc}	39^{bc}	49^{ab}	57^{a}	46^{ab}	0.000
Stable	20^{a}	24^{a}	24^{a}	22^{a}	23^{a}	22^{a}	0.725
Brown color	59^{a}	56^{ab}	58^{ab}	38^{c}	41^{c}	45^{bc}	0.000
Whitish color	5^{c}	9^{bc}	5^{c}	20^{a}	20^{a}	17^{ab}	0.000
Thick	20^{c}	25^{b}	26^{b}	40^{a}	38^{a}	38^{a}	0.000
Watery	42^{a}	37^{b}	32^{b}	22^{c}	23^{c}	25^{c}	0.000

^{abc} Different superscripts within each row indicate a significant difference ($p < 0.05$).

Based on the correspondence analysis (CA) sensory profile map, the first two dimensions explained 83.5% of the variability in the data (Figure 8.2a). Samples were sorted along the first dimension according to their malted milk powder type. Samples containing SMMP (S3-4, S3-5, and S3-6) were located on the negative side of the first dimension and mostly described as tasty, creamy, thick, and whitish. Samples containing BMMP (S3-1, S3-2, and S3-3) were located on the positive side of the first dimension and were mainly characterized as sweet, watery, and brown. Similar to the results of mean impact analysis, the CA showed that overall liking was mainly associated with terms *tasty*, *creamy*, *thick*, *caramel flavor*, *sweet* and *brown color* descriptors (Figure 8.2b).

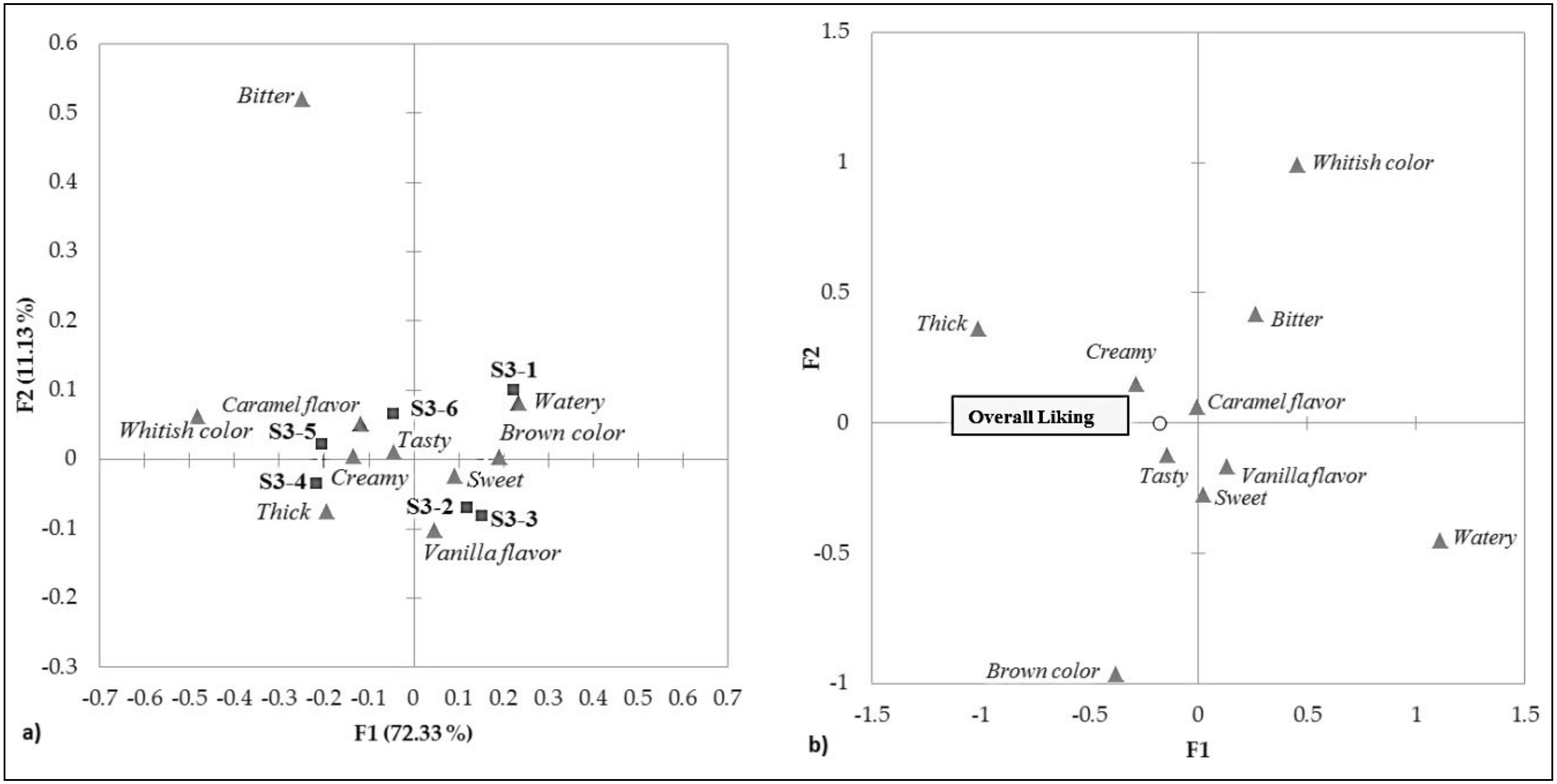

Figure 8.2. a) Correspondence analysis plot for the products and the significant CATA attributes**. b)** Correlation map of the significant CATA attributes with overall liking.

3.2. Nutrient composition

The nutrient compositions of the two samples with relatively higher overall liking scores, S3-2 (barley malt, caramel flavor) and S3-5 (sorghum malt, caramel flavor) were determined.

3.2.1. Carbohydrates

S3-2 (barley malt, caramel flavor) had a significantly higher concentration ($p < 0.05$) of total sugar than S3-5 (sorghum malt, caramel flavor) (Table 8.4). Considering the sugar profiles, there was significantly ($p < 0.05$) more glucose, fructose, sucrose, and maltose in S3-2 than in the S3-5. Lactose and total dietary fiber were the only carbohydrate components whose concentrations were significantly higher ($p < 0.05$) in the S3-5 compared to the S3-2.

Table 8.4. Carbohydrate composition of the peanut-based beverages.

	Mean ± SD (g/100g beverage)	
Component	**S3-2**	**S3-5**
Glucose	1.00 ± 0.01^{a}	$<0.10^{b}$
Fructose	0.50 ± 0.03^{a}	0.20 ± 0.01^{b}
Lactose	0.30 ± 0.01^{b}	2.10 ± 0.03^{a}
Sucrose	6.80 ± 0.14^{a}	5.90 ± 0.17^{b}
Maltose	2.20 ± 0.06^{a}	$<0.10^{b}$
Total Sugar	10.80 ± 0.25^{a}	8.20 ± 0.21^{b}
Total Dietary Fiber	2.00 ± 0.03^{b}	2.40 ± 0.07^{a}

^{ab} Different superscripts in each row indicate a significant difference ($p < 0.05$); SD = Standard deviation.

Carbohydrates are the primary source of energy for the body. The preferred source of energy for most body cells is glucose, and through homeostasis, the blood glucose level is regulated to support optimal functioning of the body [24]. When there is an insufficient supply of glucose, the body breaks down muscle tissue to synthesize glucose from amino acids. Therefore, a sufficient supply of glucose from carbohydrates prevents the destruction of proteins. However, just like with any essential nutrient, too much carbohydrate intake in the diet may worsen some health conditions like diabetes and obesity [24] unless the carbohydrate is rich in dietary fiber. Dietary fiber helps in lowering the glycemic index of foods and therefore, may help in reducing the risk of obesity and diabetes[25]. Except for sucrose which was deliberately added, the rest of the sugars (glucose, maltose, fructose, and lactose) were components of the raw materials (malted barley powder, malted sorghum powder, non-fat dry milk powder, and peanut paste) that were used in processing the beverages. The dietary fiber was most likely from the malted sorghum and barley powder. The total dietary fiber concentrations in the peanut-based beverages (2.0 – 2.4 g/100g) were within a suitable range (< 5 g/100 g). According to the Codex Alimentarius Commission, the 5g/100g of food is the maximum limit of fiber in supplementary foods for infants and young children [26]. The limit is set because too much fiber (≥ 5g/100 g) may also affect the absorption efficiency of various essential nutrients [26].

3.2.2. Fat

S3-2 (barley malt, caramel flavor) and S3-5 (sorghum malt, caramel flavor) had statistically similar concentrations of total fat (Table 8.5). Considering the fatty acid composition of the fat, both beverages had palmitic, stearic, oleic, linoleic, arachidic, gondoic, behenic, and lignoceric acids. The dominant fatty acids were oleic, linoleic, and palmitic acids with concentrations ranging from 50.5 - 51.8%, 28.0 - 30.3%, and 9.2 - 11.3% of the total fat, respectively. Just like the total fat, there were no significant differences ($p > 0.05$) in the concentrations of all the fatty acids in the beverages except for stearic and lignoceric acids (Table 8.5). Likewise, there were no significant differences ($p > 0.05$) in the respective concentrations of total saturated, monounsaturated, and polyunsaturated fats in the two peanut-based beverages. Trans-fatty acids were not detected in any of the evaluated peanut-based beverages. The main source of the fat in the beverages was the peanuts, and as expected, the fatty acid profiles found in this study were typical of ordinary (low-oleic) peanut oil [27,28].

Table 8.5. Fatty acid composition of the peanut-based beverages.

	Mean ± SD (g/100g beverage)		g/100g fat	
Component	**S3-2**	**S3-5**	**S3-2**	**S3-5**
Palmitic acid (16:0)	0.63 ± 0.05^a	0.46 ± 0.04^a	11.30	9.20
Stearic acid (18:0)	0.19 ± 0.01^a	0.14 ± 0.01^b	3.40	2.70
Oleic acid (18:1*n*-9)	2.83 ± 0.10^a	2.59 ± 0.13^a	50.50	51.80
Linoleic acid (18:2*n*-6)	1.57 ± 0.10^a	1.52 ± 0.06^a	28.00	30.30
Arachidic acid (20:0)	0.09 ± 0.01^a	0.08 ± 0.01^a	1.60	1.60
Gondoic acid (20:1*n*-9)	0.06 ± 0.01^a	0.05 ± 0.00^a	1.10	1.00
Behenic acid (22:0)	0.13 ± 0.01^a	0.11 ± 0.00^a	2.40	2.20
Lignoceric acid (24:0)	0.10 ± 0.01^a	0.06 ± 0.00^b	1.80	1.20
Total Saturated Fat	1.15 ± 0.08^a	0.90 ± 0.08^a	20.40	16.90
Total Monounsaturated Fat	2.89 ± 0.10^a	2.64 ± 0.13^a	51.60	52.80
Total Polyunsaturated Fat	1.57 ± 0.10^a	1.52 ± 0.06^a	28.00	30.30
Total Trans Fat	0.00	0.00	0.00	0.00

[ab] Different superscripts in each sub-row indicate a significant difference ($p < 0.05$).

Over the past years, high-fat intake has been identified as one of the risk factors for some non-communicable diseases like coronary heart disease [29]. Nevertheless, not all fat is bad. The body needs essential fatty acids to support critical biological functions. Fats provide energy, are a medium for the absorption of fat-soluble vitamins, and are crucial for proper development and survival during the early stages of life: embryonic development and early growth after birth to infancy and childhood [30]. Consideration of the type of fat and not just the quantity being consumed is important [29]. High intake of saturated fats and trans-fatty acids are more detrimental to health than a high intake of unsaturated fats [29,31,32]. High saturated fat and trans-fatty acids intake are associated with increased serum cholesterol and low-density lipoprotein (LDL) cholesterol which are risk factors for coronary heart disease (CHD) [29]. Children with high saturated fat intake are more likely to have atherosclerosis and CDH later in life [33]. Therefore, the absence of trans-fatty acids and the relatively high concentration of total unsaturated fatty acids in the fat of S3-2 (79.6%) and S3-5 (83.1%) are good (Table 8.5). Furthermore, the linoleic acid concentration in S3-2 (1.52g/100g of beverage) and S3-5 (1.57g/100g of beverage) were all adequate as they exceeded the linoleic acid minimum limit (1.4 g/100g of product) for supplementary foods for infants and young children [26]. Linoleic acid cannot be synthesized by the body and therefore is an essential fatty acid that must be provided in the diet. In infants, linoleic acid deficiency results in poor growth and development, a flaking skin (dermatitis), and an impaired immune response while in adults, the obvious sign is dermatitis [34]. Based on the fatty acid profiles, consumption of the peanut-based beverages could be beneficial to children now and even in their later life.

3.2.3. Protein

As shown in Table 8.6, S3-5 had a significantly higher ($p < 0.05$) protein content (4.98%) compared to the S3-2 (3.65%). Considering the amino acid compositions of the protein in the two beverage samples, glutamic acid (glutamic acid + glutamine) was the most dominant amino acid ranging from 19.65 to 19.91% of the total protein followed by aspartic acid (aspartic acid + asparagine) (9.77 to 10.90%), and arginine (7.72 to 10.21%). The beverages had statistically similar ($p > 0.05$) concentrations of cysteine, glycine, and arginine. The concentrations of the rest of the amino acids were significantly higher ($p < 0.05$) in the S3-5 compared to S3-2 (Table 8.6).

Table 8.6. Protein and amino acid composition of the peanut-based beverages.

	Mean ± SD (g/100g beverage)		% of Total Protein	
Component	**S3-2**	**S3-5**	**S3-2**	**S3-5**
Crude protein	3.65 ± 0.07^{b}	4.98 ± 0.25^{a}	-	-
Alanine	0.14 ± 0.01^{b}	0.18 ± 0.01^{a}	3.92	3.62
Arginine	0.37 ± 0.01^{a}	0.38 ± 0.01^{a}	10.21	7.72
Asparagine + Aspartic acid	0.40 ± 0.01^{b}	0.49 ± 0.01^{a}	10.90	9.77
Cysteine	0.04 ± 0.00^{a}	0.05 ± 0.00^{a}	1.19	0.99
Glutamine + Glutamic acid	0.72 ± 0.03^{b}	0.99 ± 0.04^{a}	19.65	19.91
Glycine	0.18 ± 0.01^{a}	0.19 ± 0.01^{a}	5.03	3.73
Histidine	0.08 ± 0.00^{b}	0.12 ± 0.01^{a}	2.23	2.40
Isoleucine	0.13 ± 0.01^{b}	0.21 ± 0.01^{a}	3.61	4.18
Leucine	0.26 ± 0.01^{b}	0.40 ± 0.01^{a}	6.99	8.04
Lysine	0.22 ± 0.00^{b}	0.31 ± 0.01^{a}	5.91	6.23
Methionine	0.10 ± 0.01^{b}	0.16 ± 0.01^{a}	2.84	3.12
Phenylalanine	0.18 ± 0.01^{b}	0.25 ± 0.01^{a}	5.07	5.03
Proline	0.19 ± 0.01^{b}	0.33 ± 0.01^{a}	5.22	6.63
Serine	0.16 ± 0.00^{b}	0.23 ± 0.00^{a}	4.49	4.55
Threonine	0.12 ± 0.00^{b}	0.18 ± 0.01^{a}	3.26	3.51
Tryptophan	0.04 ± 0.00^{b}	0.05 ± 0.00^{a}	0.96	1.06
Tyrosine	0.15 ± 0.01^{b}	0.22 ± 0.01^{a}	4.11	4.50
Valine	0.16 ± 0.01^{b}	0.25 ± 0.01^{a}	4.41	5.01

^{ab} Different superscripts in each row indicate a significant difference ($p < 0.05$); SD = Standard deviation.

Despite the differences in the concentrations of the amino acids in S3-2 (barley malt, caramel flavor) and S3-5 (sorghum malt, caramel flavor), both beverages had complete proteins. As shown in Figure 8.3, all the indispensable amino acid concentrations in proteins from S3-2 and S3-5 were adequate (exceeding the reference pattern). Proteins from peanuts are known to be deficient in some indispensable amino acids especially lysine, methionine, and threonine [35-37]. Isoleucine and valine have also been reported to be among the limiting amino acids in some peanut varieties [38]. Therefore, the complete proteins found in the peanut-based beverages are likely due to the incorporation of non-fat dry milk powder. One other main concern about plant-based proteins is on their poor digestibility compared to proteins from animal sources. However, proteins from peanuts are highly digestible by humans with protein digestibility values similar to those of animal sources [36,39]. Therefore, the evaluated peanut-based beverages are sources of high-quality protein. Protein quality is critical when assessing the adequacy of diets especially for children that are otherwise consuming enough quantities of macro and micronutrients [40,41]. Adequate amounts of the indispensable amino acids must be supplied in the diet to sustain protein synthesis. If protein synthesis stops, almost every function of cellular life is affected. Proteins support growth and maintenance of body tissues, function as enzymes, maintain fluid and electrolyte balance, regulate acid-base balance, serve as antibodies, acts like carriers (transporters), function as hormones, and are secondary sources of energy [42]. Therefore, based on the amino acid profiles, consumption of the peanut-based beverages will effectively support these important functions and promote good health.

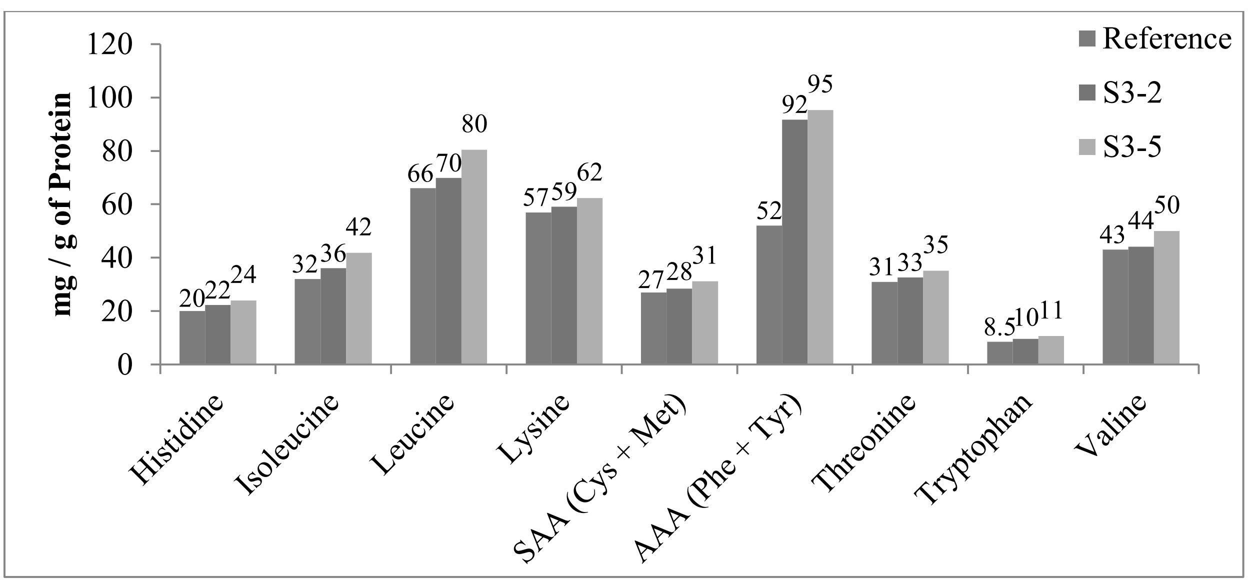

Figure 8.3. Indispensable amino acid concentrations in the peanut-based beverages in comparison to the recommended reference pattern for all other foods and population groups except infants [14]. SAA = sulfur-containing amino acids; Cys = cysteine; Met = methionine; AAA = aromatic amino acids; Phe = phenylalanine; Tyr = Tyrosine.

3.2.4. Minerals

In this study, concentrations of twelve minerals were determined (Table 8.7). S3-5 had significantly higher ($p < 0.05$) concentrations of calcium, iron, phosphorus, potassium, and zinc than the S3-2. Only the concentrations of copper and sodium were significantly higher ($p < 0.05$) in the S3-2. The concentrations of boron, manganese, molybdenum, and nickel, in the two beverages, were similar ($p > 0.05$). Peanuts are a significant source of most essential minerals except calcium, iron, and zinc [43,44]. Therefore, the high concentrations of calcium in the peanut-based beverages was due to the incorporation of non-fat dry milk powder in the formulation.

Table 8.7. Mineral composition of the peanut-based beverages.

	Mean ± SD (Per 100g)	
Component	**S3-2**	**S3-5**
Boron (µg)	143.00 ± 0.99^a	140.00 ± 1.56^a
Calcium (mg)	25.20 ± 0.42^b	92.40 ± 0.57^a
Copper (µg)	102.00 ± 0.85^a	84.40 ± 0.42^b
Iron (µg)	241.00 ± 1.13^b	265.00 ± 0.28^a
Magnesium (mg)	28.20 ± 0.28^b	31.20 ± 0.42^a
Manganese (µg)	210.00 ± 1.41^a	206.00 ± 0.85^a
Molybdenum (µg)	12.00 ± 0.28^a	12.10 ± 0.28^a
Nickel (µg)	23.30 ± 0.28^a	23.10 ± 0.14^a
Phosphorus (mg)	82.00 ± 1.41^b	116.00 ± 0.71^a
Potassium (mg)	154.00 ± 1.41^b	224.00 ± 1.84^a
Sodium (mg)	40.00 ± 0.57^a	36.90 ± 0.42^b
Zinc (µg)	298.00 ± 1.41^b	511.0 ± 2.26^a

^{ab} Different superscripts in each row indicate a significant difference ($p < 0.05$); SD = Standard deviation.

3.2.5. Nutritional value

Considering a serving size of 237 mL (8 oz.), the S3-5 was an excellent source (% DV ≥ 20) of protein, total dietary fiber, phosphorus, calcium, molybdenum, and manganese while the S3-2 was an excellent source of fat, molybdenum, and manganese only (Table 8.8). However, both S3-2 and S3-5 were good sources (10 ≤ % DV < 20) of potassium and magnesium.

Table 8.8. Nutrient density of the peanut-based beverages.

		Mean ± SD (per 100g)		Mean per 8 Oz. (237 mL) serving			
Food Component	**DV**	**S3-2**	**S3-5**	**S3-2**	**% DV**	**S3-5**	**% DV**
Energy (kcal)		108.80	97.30	257.86	-	230.60	-
Protein (g)	50	3.65 ± 0.07^b	4.98 ± 0.25^a	8.65	17	11.80	24
Fat (g)	65	5.60 ± 0.14^a	5.00 ± 0.28^a	13.27	20	11.85	18
Carbohydrate (g)	300	10.80 ± 0.25^a	8.20 ± 0.21^b	25.60	9	19.43	6
Dietary Fiber (g)	25	2.00 ± 0.03^b	2.40 ± 0.07^a	4.74	19	5.69	23
Potassium (mg)	3500	154.00 ± 1.41^b	224.00 ± 1.84^a	364.98	10	530.88	15
Sodium (mg)	2400	40.00 ± 0.57^a	36.90 ± 0.42^b	94.80	4	87.45	4
Phosphorus (mg)	1000	82.00 ± 1.41^b	116.00 ± 0.71^a	194.34	19	274.92	27
Calcium (mg)	1000	25.20 ± 0.42^b	92.40 ± 0.57^a	59.72	6	218.99	22
Magnesium (mg)	400	28.20 ± 0.28^b	31.20 ± 0.42^a	66.83	17	73.94	18
Molybdenum (μg)	75	12.00 ± 0.28^a	12.10 ± 0.28^a	28.44	38	28.68	38
Iron (mg)	18	0.24 ± 0.00^b	0.27 ± 0.00^a	0.57	3	0.64	4
Zinc (mg)	15	0.30 ± 0.00^b	0.51 ± 0.00^a	0.71	5	1.21	8
Manganese (mg)	2	0.21 ± 0.00^a	0.21 ± 0.00^a	0.50	25	0.50	25
Copper (mg)	2	0.10 ± 0.00^a	0.08 ± 0.00^b	0.24	12	0.19	9

^{ab}Different superscripts in each sub-row indicates a significant difference ($p < 0.05$); DV is Daily Value (DRV or RDI) based on a 2000 calorie diet; SD = Standard deviation.

Compared to the F100, the S3-2 (barley malt, caramel flavor) had higher concentrations of protein and fat while S3-5 (sorghum malt, caramel flavor) had higher concentrations of protein, potassium, and calcium (Table 8.9). The concentrations of fat and iron in the F100 were similar to those of the S3-5 (sorghum malt, caramel flavor). Compared to "peanut milk," both S3-2 (barley malt, caramel flavor) and S3-5 (sorghum malt, caramel flavor) had higher concentrations of protein, fat, potassium, and calcium (Table 8.9). A comparison with whole milk showed that the S3-2 (barley malt, caramel flavor) had higher concentrations of protein, fat, and iron while S3-5 (sorghum malt, caramel flavor) had higher concentrations of protein, fat, potassium and iron (Table 8.9). The energy density of S3-5 (97 kcal/100g) was slightly lower than that of F100 (100 kcal/100g) and S3-2 (109 kcal/100g) but higher than the energy density of "peanut milk" (63 kcal/100g) and whole milk (67 kcal/100g), respectively. Fat contribution to the total energy was highest in "peanut milk" (66%) followed by S3-2 (47%), S3-5 and whole milk (46%), and F100 (45%). However, protein contribution to the total energy content was highest in the S3-5 (21%) followed by whole milk (20%), "peanut milk" (16%), S3-2 (14%) and F100 (10%).

Table 8.9. Comparison of nutrient densities of the peanut-based beverages with other products.

	Per 100g				
	F100	**"Peanut milk"[1]**	**Whole milk**	**S3-2**	**S3-5**
Energy (kcal)	100.0	63	67	109	97
Protein (g)	2.5	2.5	3.3	3.7	5.0
Fat (g)	5.0	4.6	3.3	5.6	5.0
Potassium (mg)	212.0	58	167	154.0	224.0
Calcium (mg)	58.0	10	125	25.0	92.0
Iron (mg)	0.4	0.4	0.0	0.2	0.3

[1] Commercial product marketed as Elmhurst milked peanuts (Steuben Foods Inc., Elma, NY, USA).

The percentage contribution of fat to total energy for S3-2 (47%) and S3-5 (46%) were within the recommended range (45–60%) for ready-to-use therapeutic foods [45]. The beverages had a much higher protein to energy ratio. The percentage contribution of protein to total energy for S3-5 (21%) and S3-2 (14%) exceeded the 10 to 12% WHO [45] set range of protein contribution to the total energy in ready-to-use therapeutic foods and were higher than that of

F100 (10%). Nutrient density determines the type of tissue to be synthesized during catch-up and normal linear growth. A high energy intake results in adipose tissue deposition while a high nutrient intake results in lean tissue synthesis [46]. However, the dietary protein requirement needed to enable satisfactory normal linear growth in children is greater than the protein requirements for maintenance and tissue deposition [47]. Therefore, intake of high-protein foods like the peanut-based beverages can potentially lead to sufficient deposition of lean tissues and normal linear growth in malnourished children. Although a protein-rich diet is desirable, a proper balance between protein and energy supply is crucial especially when one is severely malnourished [47]. In the absence of sufficient energy and normal liver functionality, a high protein diet can result in an acid load as a result of failure to break down and excrete the excess protein [46].

In most developing countries like Malawi where corn is the main staple food, porridge from blended flours of protein-rich legumes and cereals such as corn–soy blend (CSB) is also commonly used for prevention and treatment of acute malnutrition and growth retardation [48]. However, the sensory appeal of the porridge is questionable. Therefore, based on the sensory and nutritional properties, the peanut-based beverage containing sorghum malt (S3-5) has a more competitive advantage.

4. Conclusion

Both peanut-beverage formulations containing sorghum malt and barley malt were liked by the consumers. Irrespective of the formulation type, caramel-flavored samples S3-2 (barley malt) and S3-5 (sorghum malt) had relatively higher overall liking scores than the other samples. Therefore, they both have a potential of promoting and increasing peanut consumption in Malawi and any country where they may be equally acceptable. The S3-5 had a better nutrient composition than S3-2 in terms of protein, total dietary fiber, potassium, phosphorus, calcium, magnesium, iron, and zinc. The S3-5 also had a better nutrient composition than F100 and "peanut milk," respectively, in terms of protein, potassium, and calcium. Likewise, the S3-5 had better nutrient composition than whole milk, in terms of protein, fat, potassium and iron. A 237-mL (8 oz.) serving of the S3-5 was an excellent source of high-quality protein, total dietary fiber, phosphorus, calcium, molybdenum, and manganese and also, a good source of potassium and magnesium. Therefore, the formulation incorporating sorghum malted milk powder (S3-5) has the potential for use in preventing and managing malnutrition. However, further studies on the efficacy of the S3-5, using clinical trials, are required to provide further evidence on the in vivo nutritional quality. .

References

1. WHO (2018) Malnutrition. https://www.who.int/news-room/fact-sheets/detail/malnutrition. Accessed 2 January 2019

2. WHO (2011) WHO, nutrition experts take action on malnutrition. https://www.who.int/nutrition/pressnote_action_on_malnutrition/en/. Accessed 2 January 2019

3. Foyer CH, Lam H-M, Nguyen HT, Siddique KH, Varshney RK, Colmer TD, Cowling W, Bramley H, Mori TA, Hodgson JM (2016) Neglecting legumes has compromised human health and sustainable food production. Nature plants 2 (8):16112

4. FAOSTAT (2014) Malawi Food Balance Sheet. http://www.fao.org/faostat/en/#data. Accessed 13 December 2015

5. Gama AP, Adhikari K, Hoisington DA (2018) Peanut Consumption in Malawi: An Opportunity for Innovation. Foods 7 (7). doi:10.3390/foods7070112

6. Clark JE (1998) Taste and flavour: their importance in food choice and acceptance. Proceedings of the nutrition society 57 (4):639-643

7. Rimal A, Moon W, Balasubramanian SK (2008) Soyfood consumption patterns: effects of product attributes and household characteristics. Journal of Food Distribution Research 39 (3):67-78

8. Hartman GL, West ED, Herman TK (2011) Crops that feed the World 2. Soybean—worldwide production, use, and constraints caused by pathogens and pests. Food Security 3 (1):5-17

9. Gama AP, Adhikari K, Hoisington DA (2018) Factors influencing food choices of Malawian consumers: A food choice questionnaire approach. Journal of Sensory Studies 33 (5):e12442

10. WHO (1999) Management of severe malnutrition: a manual for physicians and other senior health workers. http://apps.who.int/iris/bitstream/handle/10665/41999/?sequence=1. Accessed 16 January 2019

11. AOAC (2016) Official Methods of Analysis, vol 2. 20th edn. AOAC International, Maryland, USA

12. Greenfield H, Southgate DA (2003) Food composition data: production, management, and use. Food & Agriculture Organization,

13. Hamilton PB (1963) Ion Exchange Chromatography of Amino Acids. A Single Column, High Resolving, Fully Automatic Procedure. Analytical Chemistry 35 (13):2055-2064

14. FAO (2011) Report of an FAO expert consultation on dietary protein quality evaluation in human nutrition. http://www.fao.org/ag/humannutrition/35978-02317b979a686a57aa4593304ffc17f06.pdf. Accessed 10 November 2017

15. Firestone D (2013) Official methods and recommended practices of the AOCS. AOCS,

16. ASTM E 1613 (1999) Standard Test Method for Determination of Lead by Inductivety Coupled Plasma Atomic Emission Spectrometry (ICP-AES). Flame Atomic Absorption Spectrometry (FAAS), or Graphite Furnace Atomic Absortion (GFAAS) Techniques

17. FDA (2013) A Food labeling guide - Guidance for industry. https://www.fda.gov/downloads/food/guidanceregulation/guidancedocumentregulatoryinformation/UCM265446.pdf.

18. USDA (2018) National Nutrient Database for Standard Reference Legacy Release. https://ndb.nal.usda.gov/ndb/search/list. Accessed 3 February 2019

19. FAO (2003) Food energy – methods of analysis and conversion factors. http://www.fao.org/uploads/media/FAO_2003_Food_Energy_02.pdf. Accessed 14 March 2016

20. Varela P, Ares G (2012) Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterization. Food Research International 48 (2):893-908

21. Wedel M, Kamakura WA (2002) Introduction to the special issue on market segmentation. International Journal of Research in Marketing 19 (2002):181 - 183

22. Henry C, Whiting SJ, Phillips T, Finch SL, Zello GA, Vatanparast H (2015) Impact of the removal of chocolate milk from school milk programs for children in Saskatoon, Canada. Applied Physiology, Nutrition, and Metabolism 40 (3):245-250

23. Reineccius G (2013) Source book of flavors. Springer Science & Business Media,

24. Gibney MJ, Vorster HH, Kok FJ (2002) Introduction to human nutrition. Blackwell Science Oxford,

25. Veronese N, Solmi M, Caruso MG, Giannelli G, Osella AR, Evangelou E, Maggi S, Fontana L, Stubbs B, Tzoulaki I (2018) Dietary fiber and health outcomes: an umbrella review of systematic reviews and meta-analyses. The American journal of clinical nutrition 107 (3):436-444

26. Codex (1991) Guidelines on formulated supplementary foods for older infants and young

children, CAC/GL 08. http://1srw4m1ahzc2feqoq2gwbbhk.wpengine.netdna-cdn.com/wp-content/uploads/2016/01/PRES-3b_FKA__2009__GUIDELINES-ON-FORMULATED-SUPPLEMENTARY-FOODS.pdf. Accessed 23 January 2019

27. Shin EC, Pegg RB, Phillips RD, Eitenmiller RR (2010) Commercial runner peanut cultivars in the USA: Fatty acid composition. European journal of lipid science and technology 112 (2):195-207

28. Mora-Escobedo R, Hernández-Luna P, Joaquín-Torres IC, Ortiz-Moreno A, Robles-Ramírez MdC (2015) Physicochemical properties and fatty acid profile of eight peanut varieties grown in Mexico. CyTA-Journal of Food 13 (2):300-304

29. Hu FB, Manson JE, Willett WC (2001) Types of dietary fat and risk of coronary heart disease: a critical review. Journal of the American College of Nutrition 20 (1):5-19

30. Uauy R (2009) Dietary fat quality for optimal health and well-being: overview of recommendations. Annals of Nutrition and Metabolism 54 (Suppl. 1):2-7

31. Mozaffarian D, Aro A, Willett WC (2009) Health effects of trans-fatty acids: experimental and observational evidence. European journal of clinical nutrition 63 (S2):S5

32. Mozaffarian D, Micha R, Wallace S (2010) Effects on coronary heart disease of increasing polyunsaturated fat in place of saturated fat: a systematic review and meta-analysis of randomized controlled trials. PLoS medicine 7 (3):e1000252

33. Berenson GS, Srinivasan SR, Bao W, Newman WP, Tracy RE, Wattigney WA (1998) Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. New England journal of medicine 338 (23):1650-1656

34. Sanders TA (2016) Introduction: the role of fats in human diet. In: Functional Dietary Lipids. Elsevier, pp 1-20

35. Andersen PC, Hill K, Gorbet DW, Brodbeck BV (1998) Fatty acid and amino acid profiles of selected peanut cultivars and breeding lines. Journal of Food Composition and Analysis 11 (2):100-111

36. Singh B, Singh U (1991) Peanut as a source of protein for human foods. Plant Foods for Human Nutrition 41 (2):165-177

37. Young C (1979) Amino acid composition of peanut (Arachis hypogaea L.) samples from the 1973 and 1974 uniform peanut performance tests. Proceedings American Peanut Research and Education Association American Peanut Research and Education Association

38. Young C, Waller G, Hammons R (1973) Variations in total amino acid content of peanut meal. Journal of the American Oil Chemists' Society 50 (12):521-523

39. Gilani GS, Cockell KA, Sepehr E (2005) Effects of antinutritional factors on protein digestibility and amino acid availability in foods. Journal of AOAC International 88 (3):967-987

40. Semba RD (2016) The rise and fall of protein malnutrition in global health. Annals of Nutrition and Metabolism 69 (2):79-88

41. Schönfeldt HC, Hall NG (2012) Dietary protein quality and malnutrition in Africa. British Journal of Nutrition 108 (S2):S69-S76

42. Widmaier EP, Raff H, Strang KT, Vander AJ (2008) Vander's human physiology: the mechanisms of body function. Boston: McGraw-Hill Higher Education,

43. Stalker T, Wilson RF (2015) Peanuts: genetics, processing, and utilization. Elsevier,

44. Ronzio RA (2003) The encyclopedia of nutrition and good health. Infobase Publishing,

45. WHO (2007) Community-based management of severe acute malnutrition. Fact sheet. Geneva, Switzerland: WHO, WFP, UNSSCN, UNICEF. https://www.unicef.org/publications/files/Community_Based_Management_of_Sever_Acute__Malnutirtion.pdf. Accessed 21 January 2019

46. Golden MH (2009) Proposed recommended nutrient densities for moderately malnourished children. Food and nutrition bulletin 30 (3_suppl3):S267-S342

47. WHO (2007) Protein and amino acid requirements in human nutrition. World health organization technical report series (935):1

48. Matilsky DK, Maleta K, Castleman T, Manary MJ (2009) Supplementary feeding with fortified spreads results in higher recovery rates than with a corn/soy blend in moderately wasted children. The Journal of nutrition 139 (4):773-778

CHAPTER 9

CONCLUSIONS

Development of a peanut-based beverage was achieved through careful consideration of the factors that influence food choices and peanut consumption in Malawi, identifying a Malawi peanut variety with better sensory properties and optimizing the formulation to achieve the best sensory and nutritional properties.

Results of a consumer survey (n = 489) showed that mood, health, price, preparation convenience, sensory appeal, and familiarity are influencing food choices in Malawi. In general, the factor structure and factor ranking were different from those found in Britain as hypothesized. Among the food choice motives, only health, price, preparation convenience, and sensory appeal influenced peanut consumption. Demographic variables had significant effects ($p < 0.05$) on the food choice motives, peanut products preferences and readiness to try new foods, respectively. For instance, women were mostly influenced by familiarity when making food choices, preferred more traditional peanut products like peanut flour, and were more food neophobic compared to men. However, the sensory appeal was the food choice motive that was not affected by gender, age, education level, occupation, and monthly income of the consumers. Therefore, the sensory appeal was considered as the universal food choice motive, and its maximization was given much attention in this study. Considering that food ingredients can affect the sensory properties of the end-products, six dominant Malawi peanut varieties were evaluated to determine their suitability for use in formulating a peanut-based beverage. As hypothesized, different Malawi peanut varieties had different sensory properties. Nsinjiro and

Baka varieties had better sensory properties than the other varieties. Nsinjiro was eventually chosen for use in formulating the peanut-based beverage after also considering the adoption rates of the peanut varieties in Malawi.

Colloidal stability is one of the critical determinants of sensory quality of beverages. Therefore, the effects of lecithin, xanthan gum, propylene glycol alginate, and their combinations on the colloidal stability of a peanut-based beverage were evaluated. At a usage level of 0.5% by weight of the beverage, the optimum stabilizer and emulsifier combination was 66% xanthan gum and 34% lecithin. Then, levels of the two key components (peanut paste and malted milk powder), constituting 16% of the total peanut beverage by weight, were also optimized to maximize consumer acceptability. As hypothesized, through product optimization techniques, it was possible to develop an acceptable and stable peanut-based beverage even when non-defatted peanuts were used. The optimal combination of the peanut paste and malted milk powder, in the two-component mixture, were 60% and 40%, respectively. A further increase in the proportion of the peanut paste in the mixture had a negative effect on sensory properties, and ultimately on consumer acceptability.

The final beverage formulation had water, peanut paste, sorghum malted milk powder, sugar, salt, xanthan gum, and flavorings. The beverage was generally liked by the consumers (n = 177) for being tasty, thick, creamy, sweet, caramel-flavored, and with the desired brownish color. The overall liking scores of the peanut-based beverage were 6.5, 7.4, and 8.2 for clusters of slight likers, moderate likers, and exceptional likers, respectively. Since the cluster of slight likers was the smallest (21.5%), the peanut-based beverage has the potential of promoting peanut consumption in Malawi and in any country where it may be equally acceptable. In the long term, the beverage can be useful in the management of undernutrition given its nutrient composition. A

237-mL (8 oz.) serving of the peanut-beverage was an excellent source (% DV ≥ 20) of high-quality protein, total dietary fiber, phosphorus, calcium, molybdenum, and manganese and also, a good source ($10 \leq$ % DV < 20) of potassium and magnesium.

Based on the findings, development of a nutritious and acceptable peanut-based beverage was achieved and can be scaled up. However, further studies are required before commercialization. The further studies should focus on market research and impact pathways, packaging and best processing technology, the effect of changing peanut variety, and a shelf life study when all the variables have been fixed.

APPENDIX A

QUESTIONNAIRE FOR A CONSUMER SURVEY ON FACTORS INFLUENCING FOOD CHOICES

A. General food choice motives

It is important to me that the food I eat on a normal day

1. Is easy to prepare

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

2. Contains no additives

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

3. Is low in calories

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

4. Tastes good

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

5. Contains natural ingredients

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

6. Is not expensive

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

7. Is low in fat

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

8. Is familiar

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

9. Is high in fiber and roughage

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

10. Is nutritious

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

11. Is easily available in shops and supermarkets

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

12. Is good value for money

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

13. Cheers me up

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

14. Smells nice

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

15. Can be cooked very simply

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

16. Helps me cope with stress

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

17. Helps me control my weight

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

18. Has a pleasant texture

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

19. Is packaged in an environmentally friendly way

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

20. Comes from countries I approve of politically

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

21. Is like the food I ate when I was a child

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

22. Contains a lot of vitamins and minerals

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

23. Contains no artificial ingredients

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

24. Keeps me awake/alert

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

25. Looks nice

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

26. Helps me relax

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

27. Is high in protein

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

28. Takes no time to prepare

Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important
☐	☐	☐	☐	☐	☐	☐

29. Keeps me healthy

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

30. Is good for my skin/teeth/hair/nails etc.

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

31. Makes me feel good

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

32. Has the country of origin clearly marked

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

33. Is what I usually eat

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

34. Helps me to cope with life

☐	☐	☐	☐	☐	☐	☐
Extremely unimportant	Unimportant	Slightly unimportant	Neither important nor unimportant	Slightly important	Important	Extremely important

35. Can be bought in shops close to where I live or work

☐ Extremely unimportant	☐ Unimportant	☐ Slightly unimportant	☐ Neither important nor unimportant	☐ Slightly important	☐ Important	☐ Extremely important

36. Is cheap

☐ Extremely unimportant	☐ Unimportant	☐ Slightly unimportant	☐ Neither important nor unimportant	☐ Slightly important	☐ Important	☐ Extremely important

B. Additional food choice motives

Is there anything else you consider to be important apart from the items listed above?

Yes ☐ No ☐

If **yes**, please write the item(s) below

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

C. Demographic Information

C1 Gender: ☐ Male ☐ Female

C2 Age: ☐ 18 – 20 ☐ 21 – 29 ☐ 30 – 39 ☐ 40 – 49 ☐ 50 and above

C3 Highest level of formal education

☐ None

☐ Primary

☐ Secondary

☐ Tertiary

C4 Occupation

- ☐ Formal Employment
- ☐ Self Employed
- ☐ Menial jobs
- ☐ Student
- ☐ None

C5 Monthly income

- ☐ Less than MK 50, 000
- ☐ MK 50, 000 – MK 99, 000
- ☐ MK 100, 000 – MK 299, 000
- ☐ MK 300, 000 – MK 499, 000
- ☐ MK 500, 000 and above

APPENDIX B

QUESTIONNAIRE FOR A CONSUMER SURVEY ON PEANUT (GROUNDNUTS)

CONSUMPTION

A	**Consumption of groundnuts**
A1	Do you eat groundnuts? ☐ Yes ☐ No Give reason(s) if your answer is **No** and proceed to C1. ………………………………………………………………………………………… …………………………………………………………………………………………
A2	In what form do you eat groundnuts? (Choose all that apply) ☐ Peanut butter ☐ Roasted groundnuts ☐ Boiled groundnuts ☐ Raw groundnuts ☐ Cooking oil ☐ Groundnut flour in relish/porridge ☐ Other (specify)……………………………………….…………………………… ……………..………………………………………………………………………
A3	Which groundnut form/product do you like most? …………………………..……………………………………………………...................... Give reason(s) for your choice …………………………………..………………………………………………........... ……………..…………………………………………………………………………

A4	Are you satisfied with the diversity of groundnut products on the Malawian market? ☐ Yes ☐ No If your answer is **No,** what other products would you want to see on the market? …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………
A5	How often do you eat groundnuts / groundnut products? ☐ Every day ☐ At least thrice a week ☐ At least once a week ☐ Occasionally
B	**Food Neophobia**
B1	Would you try a new food/ beverage that you have never seen before? ☐ Yes ☐ No If your answer is **No,** give reason (s)? …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………
B2	What would make you to try a new food/ beverage that you have never seen before? …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………

C	**Demographic Information**
C1	Gender: ☐ Male ☐ Female
C2	Age: ☐ 18 – 20 ☐ 21 – 29 ☐ 30 – 39 ☐ 40 – 49 ☐ 50 and above
C3	Highest level of formal education ☐ None ☐ Primary ☐ Secondary ☐ Tertiary
C4	Occupation ☐ Formal Employment ☐ Self Employed ☐ Menial jobs ☐ Student ☐ None
C5	Monthly income ☐ Less than MK 50, 000 ☐ MK 50, 000 – MK 99, 000 ☐ MK 100, 000 – MK 299, 000 ☐ MK 300, 000 – MK 499, 000 ☐ MK 500, 000 and above

APPENDIX C

SAMPLE OF SCREENER FOR SENSORY TESTS

Name: __________________

Phone number: ________________________ Email address: __________________

The sensory lab at University of Georgia, in conjunction with the department of Food Science and Technology of LUANAR, Bunda Campus, is conducting a study on peanut-based beverages. For this project, we will run a sensory test. The test will last approximately 1 hour and you will be compensated with (Monetary amount) after the test. To participate, you are required to come to (Place) on (Date)

Would you be interested? Yes ☐ No ☐

If yes, please answer the following questions:

1. What is your gender? Male ☐ Female ☐

2. What is your age group? Below 18 ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐
46-55 ☐ 56-65 ☐ Above 65 ☐

3. Do you have any food allergies like groundnuts, cow milk, soy or wheat allergies?
Yes ☐ No ☐

4. How often do you eat groundnuts and groundnuts-based products?
   - Daily ☐
   - 2-3 times/ week ☐
   - 2-3 times/ month ☐
   - Once /month ☐
   - Less than once /month ☐

5. We have the following times for the tests; please choose one.

9am - 10am ☐ 11am - 12pm ☐ 1pm - 2pm ☐ 3pm – 4pm ☐

You will be notified (through the contact details you have provided above) if you have qualified to participate in this study. Your contact details will be used only for the purposes of this study and will be kept confidential.

Note: Any response in red font resulted in disqualification. Potential participants completed the screening questionnaire with no prior knowledge of the exclusion criteria.

APPENDIX D

BALLOT FOR OPTIMIZATION SENSORY TESTS

Panelist Code:_______ Sample Code:

Please rinse your mouth with water before starting. You can rinse at any time during the test if you need to. Thank you!

Please LOOK at this sample and then, answer the following questions:

1. Mark the box that best describes your opinion about the **BROWN COLOR** of this sample.

☐	☐	☐	☐	☐
Not enough at all	Not enough	Just About Right	Too much	Far too much

Please SNIFF this sample and then, answer the following question:

2. Mark the box that best describes your opinion about of the **ROASTED PEANUT AROMA** of this sample.

☐	☐	☐	☐	☐
Not enough at all	Not enough	Just About Right	Too much	Far too much

Please TASTE this sample and then, answer the following questions:

3. Mark the box that best describes your opinion about the **ROASTED PEANUT FLAVOR** of this sample.

☐	☐	☐	☐	☐
Not enough at all	Not enough	Just About Right	Too much	Far too much

4. Mark the box that best describes your opinion about **SWEETNESS** of this sample.

☐	☐	☐	☐	☐
Not enough at all	Not enough	Just About Right	Too much	Far too much

5. Mark the box that best describes your opinion about **SALTINESS** of this sample.

☐	☐	☐	☐	☐
Not enough at all	Not enough	Just About Right	Too much	Far too much

6. Mark the box that best describes your opinion about the **THICKNESS** of this sample.

☐	☐	☐	☐	☐
Not enough at all	Not enough	Just About Right	Too much	Far too much

7. Mark the box that best describes your **OVERALL LIKING** of this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

APPENDIX E

BALLOT FOR CONSUMER ACCEPTABILITY TEST

Panelist Code:_______ Sample Code:

Please rinse your mouth with water before starting. You can rinse at any time during the test if you need to. Thank you!

Please LOOK at this sample and then, answer the following question:

1. Mark the box that best describes your liking of the **APPEARANCE** of this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please SNIFF this sample and then, answer the following question:

2. Mark the box that best describes your liking of the **AROMA** of this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Please TASTE this sample and then, answer the following questions:

3. Mark the box that best describes your liking of the **TASTE** of this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

4. Mark the box that best describes your liking of the **TEXTURE** of this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

5. Mark the box that best describes your **OVERALL LIKING** for this sample.

☐	☐	☐	☐	☐	☐	☐	☐	☐
Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

6. How would you describe this sample? **CHECK ALL THAT APPLY**

☐ Tasty	☐ Aromatic	☐ Creamy
☐ Tasteless	☐ Roasted peanut Flavor	☐ Stable (No visible separation)
☐ Sweet	☐ Caramel Flavor	☐ Brown color
☐ Bitter	☐ Vanilla Flavor	☐ Whitish color
☐ Salty	☐ Smooth	☐ Thick
☐ Sour	☐ Grainy	☐ Watery

APPENDIX F

PICTURES OF SENSORY TESTS ENVIRONMENT