DEVELOPMENT AND QUALITY EVALUATION OF A READY-TO-EAT BANANA COMPOSITE FOOD FOR OLDER INFANTS AND YOUNG CHILDREN

By

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ABSTRACT

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Among low-income families in developing countries, foods fed to infants and young children are rich in carbohydrates but limiting in protein, and important micronutrients. Inadequate protein levels in the diet of children can lead to protein energy malnutrition (PEM). The objective of this study was to develop a high-protein weaning food, with enhanced nutritional composition and sensory properties. Light red kidney beans, brown rice and semi-ripe Cavendish bananas were used for the development of banana-rice-bean (BRB) porridge. These raw materials were air-dried at 60 °C for 8-16 h, and milled into flours, which were used to formulate seven BRB composite flour treatments. The treatments and individual flours were analyzed for nutritional composition and physicochemical properties. Four out of seven treatments were selected for sensory evaluation of porridge. All BRB composite flour contained significant levels of protein, ranging from 5.70 to 8.52 g/100g. Ash and crude fat content ranged from 2.25 to 3.05 g/100g and 1.23 to 1.73, g/100g respectively. The resistant starch and dietary fiber contents were 6.35 to 9.21 and 10.1 to 11.82 g/100g, respectively. The raffinose and stachyose levels ranged from 0.19 to 0.46 mg/g and 3.49 to 6.27 mg/g, respectively. The prepared porridges were shown to be of acceptable quality by 31 African and Asian mothers. Twenty-nine of the panelists indicated that they would feed at least one of the porridges to a child below five years of age. Based on the results of this study, BRB porridge could be used as a nutritious weaning food.

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KEY TO ABBREVIATIONS

CATA: check all that apply

FAO: Food and Agriculture Organization

GHS Ghana Health Service

GSS: Ghana Statistical Service

MOH: Ministry of Health

NDC: Non-digestible carbohydrates

OAC: oil absorption capacity

RS: Resistant starch

TDF: Total dietary fiber

UNICEF: United Nation Children's Fund.

WAC: Water absorption capacity

WAI: Water activity index

WCARO: West and Central Africa Regional Office

WHO: World Health Organization

WSI: Water solubility index

CHAPTER 1

INTRODUCTION

Stunting and wasting are the most common conditions in children below five years of age from low and middle-income countries, particularly children from low socioeconomic status families (Vollmer and others 2014). Stunting occurs when a child's height is too low for their age, specifically, "whose heights are less than two standard deviations below the median height for the age of the standard reference population" (UNICEF/WHO 2015). The most common cause of stunting is lack of essential macro and micronutrients such as protein, iron and zinc in the diet of children. Stunting typically leads to negative growth consequences such as cognitive impairment in children, which can be irreversible (Dewey and Adu-Afarwuah 2008).

Globally, "5.9 million children under the age of 5 died in 2015 and about 45% of all child deaths are linked to malnutrition" (UNICEF 2015). Children below the age of 5 in some developing countries such as Malawi often suffer from severe malnutrition. This malnutrition is evident in the high rate (42%) of stunting in this demographic (UNICEF 2015). UNICEF/WHO (2015) reported a decline in stunting rate globally in the year 2015 but ironically, number of stunted children is increasing in Africa and the continent has not experienced significant improvement in stunting rate (UNICEF/WHO 2015). In Ghana for instance, 28% stunting in children less than 5 years of age was recorded in 2011 of which 35% were from low-income families and only 14% were from the richer quintile (WCARO 2011). As of 2014, Ghana is still listed as one of the countries that suffer from malnutrition: 19% of children are stunted, 5% wasted, and 11% suffer from underweight (GSS/GHS/ICF 2015).

The growth rates of breast-fed infants (mostly below 6 months) in most developing countries are similar to those of infants in developed countries (GSS/GHS/ICF, 2015). However, during the weaning period, infants in developed countries continue to grow normally while stunting and wasting are observed in most infants in developing countries due to undernutrition (Lartey and others 1999). This underdevelopment is mostly due to the poor nutritional quality of complementary foods that are fed to infants and to other factors such as infections and inadequate feeding (Amagloh and others 2012). WHO defines complementary feeding as “the process starting when breast milk alone is no longer sufficient to meet the nutritional requirements of infants, and therefore other foods and liquids are needed, along with breast milk.”

Cereal-legume porridges are the most common traditional foods given to infants during the weaning period and has received much interest over the years. Cowpea, soybean, maize, and groundnuts are the most popular ingredients used in formulation. The high starch content (amylose) in maize leads to high viscosity of porridge during cooking due to swelling and requires dilution with large amounts of water leading to consequent thinning of nutrients (Amagloh and others 2013). The addition of locally produced food crops is being explored as an alternative to fortification and to address the challenges of malnutrition. The right selection and combimation of indigenious food crops could help meet macronutrient needs of older infants and young children (Twum and others 2015).

In Ghana, approximately 20 to 50% losses of food crops including fruits and vegetables are lost annually (Twum and others 2015). The addition of fruits and vegetables to infant food is recommended by Codex Alimentarius (CODEX 1991). Dessert banana is rich in minerals, vitamins, potassium, phosphorous and magnesium. It also and enhances the flavor and taste of most foods (Da mota and others 2000; Bello-Perez and others 2012). Dessert banana is underutilized and is subjected to high post-harvest losses in Ghana because it is mostly consumed fresh and rarely incorporated into food products (Twum and others 2015).

Rice is the second most consumed cereal after maize in Ghana. Locally produced rice is usually crowded out by imported rice because of consumer preference for imported rice. Some of the reasons for this are the poor quality of local rice produced, and a general inclination to imported goods (Boakye and Egyir 2014). Processing and adding rice, as an ingredient to other products will, therefore, increase its value. Brown rice is a good source of B-carotene, thiamine, niacin and magnesium (Babu and others 2009; Boakye and Egyir 2014). Beans contain appreciable levels of carbohydrates, protein, and fiber. In most tropical countries, however, substantial postharvest losses of beans occur due to high temperatures and humidity and also spoilage caused by weevils due to lack of storage facilities (Nyombaire and others 2011; Rui and Boye 2013). Finding ways to process and incorporate these food crops into ready-to-eat shelf stable products, would not only mitigate the problem of undernutrition among children under five years of age, but it will also contribute to adding value to these food crops with consequent reduction in post harvest losses.

The overall goal of this study therefore, was to develop a ready-to-eat complementary food, with improved protein content and sensory attributes using rice, banana and bean, for use in Ghana and other developing nations. This is to help mitigate protein-energy malnutrition (PEM) and also to help diversify the number of traditional complementary foods available for children. The objective is to analyze the level of selected nutrients and non-digestible carbohydrates. Nutritional composition covered in this study included: proximate and mineral composition, raffinose, stachyose and resistant starch and some physicochemical properties.

CHAPTER 2

LITERATURE REVIEW

The purpose this section is to review nutritional requirements for infants and young children and also to describe available methods for processing and producing infant food.

2.1 Standards and Nutritional Guidelines for young children

Guidelines for preparing complementary foods are usually established by World Health Organization (WHO) and Codex Alimentarius. These standard procedures and guidelines are highly recommended during processing and formulation of foods given to infants. This is to ensure optimum growth, development, and good health. Dietary guidelines cover daily nutritional requirements, which provides nutrients in the right amount without causing excess or deficit (WHO/FAO 2004). The WHO hopes to achieve 45% rate in stunting by 2025. The development of nutritionally adequate complementary foods is one of the interventions that are employed to help achieve this goal. With regard to the 2025 goal, government agencies, which regulate such as the Food and Drug Authority in various nations, are required to enforce strict regulations on the development and marketing of inappropriate complementary foods to children. They should endorse and allow commercialization of food products that meet standard requirements and national dietary guidelines for infants (WHO 2015).

The requirements of a healthy diet for children are similar to that for adults. Components of a healthy diet include legumes, nuts, fruits and vegetables, low sodium, low sugar and high potassium levels. Recommendations for children include exclusively breastfeeding of infants for at least 6 months and continually for 2 years accompanied with complementary foods (WHO 2015).

2.1.1 WHO nutritional guidelines

Nutritional requirements for children vary with the current stage of growth and development. Recommended nutrient intake (RNI) is the daily nutrient requirement that meets the daily nutritional need of a healthy individual. The RNI set by WHO for children from 6 months up to 23 months are represented in table 2.1. The recommended levels (table 2.1) were adapted from the WHO guidelines from 1998. There are not many recommendations for older children from age 2 to 5 years. There is, however, work underway for the development of dietary guidelines specific for children of this age group (WHO HQ/AFRO 2013).

Table 2.1: WHO recommended nutrient intake for children age 6 to 23 months

Nutrient	Recommended Intake		
	6 to 8 months	9 to 11 months	12 to 23 months
Protein (g/day)	9.1	9.6	10.9
Vitamin A (μg RE/day)	400	400	400
Folate (μg/day)	80	80	160
Niacin (mg/day)	4	4	6
Pantothenic acid (mg/day)	1.8	1.8	2.0
Riboflavin (mg/day)	0.4	0.4	0.5
Thiamine (mg/day)	0.3	0.3	0.5
Vitamin B6 (mg/day)	0.3	0.3	0.5
Vitamin B12 (μg/day)	0.5	0.5	0.9
Vitamin C (mg/day)	30	30	30
Vitamin D (μg/day)	5	5	5
Vitamin K (μg/day)	10	10	15
Calcium (mg/day)	400	400	500
Chloride (mg/day)	500	500	800
Copper (mg/day)	0.3	0.3	0.4
Fluoride (μg/day)	0.05	0.05	0.05
Iodine (μg/day)	90	90	90
Iron (mg/day)	9.3	9.3	5.8
Magnesium (mg/day)	54	54	60
Manganese (mg/day)	0.02	0.02	0.02
Phosphorous (mg/day)	400	400	270
Potassium (mg/day)	700	700	800
Selenium (μg/day)	10	10	17
Sodium (mg/day)	320	350	500
Zinc (mg/day)	4.1	4.1	4.1

RE: Retinol equivalent

(Dewey and Brown 2003)

2.1.2 Codex Alimentarius recommendations

The choice of raw materials for preparation and formulation of infant foods should be based on availability, affordability, diets that are usually given to children as well as feeding habits of infants. Raw materials should be sorted and cleaned where applicable. Also, raw materials are to be treated in a way so as to reduce antinutritient levels. Soaking, moist heat treatment, fermentation, cooking for prolonged hours are common processing methods that can help in minimizing lecthins, phytate, trypsin inhibitors and other antinutrients. Fiber levels must be reduced to a minimum of 5 g/ 100 g on dry basis. Energy coming from protein shall not be less than 6% or more than 15% of the total energy coming from the complementary foods (CODEX 1991).

2.2 Traditional diets for young children

Most African mothers in the low or middle socio-economic class resort to traditional foods for feeding their children due their inability to afford complementary foods that are commercially available. Another reason is mothers' preference to familiar ingredients that are used in the preparation of these traditional foods hence making mothers trust those foods that are traditionally prepared (Ejigui and others 2007).

2.2.1 Africa

African diets are heavily plant-based and so are diets for infants and children younger than five years of age. Porridge prepared from cereals and legume blends is the most popular porridge given to infants and children on the continent of Africa (Achi 2015; Achidi and others

2016; Gabaza 2016). Maize, millet, cowpeas, soybean, and groundnuts are often used during preparation. The use of these types of blends helped in the reduction of protein energy malnutrition over the years in countries like Ghana. Mashed bananas are also given to infants in countries like Uganda (Gibson and others 2010; Achidi and others 2016). When legumes and cereals are used, they are usually processed by roasting or fermentation method. Regardless of the use of these blends, some parts of the African continent and other developing countries still suffer from protein-energy malnutrition (UNICEF/WHO 2015).

2.2.2 Ghana

Porridges prepared from locally produced legume and cereal blends are the most common weaning foods. Additional foods that are introduced after six months up to two years are banku and stew, tea, fried eggs, sausage, yam, mashed kenkey, jollof rice, bread, and 'mpotompoto', etc. (Pelto and Klemesu 2011). These foods range from semi-solid to solid foods; the age of a child is a determinant of food choice and extent of solidity. These foods are given to children at least twice a day; frequency is again determined by a child's age and demands for food. That is, the degree of solidity of food increases with age (GSS/GHS/ICF 2015).

2.3 Recent Developments and Recommendation for feeding young children

Several interventions have been put in place to help address the challenge of malnutrition. This includes educating mothers on the importance of adequate and healthy feeding practices for infants and young children. The most common approach is the development and formulation nutritious food products that would help meet the nutritional requirements of this demographic

2.3.1 Value-added food products

These types of food products involve the application of different processing methods such as dehydration, milling, extrusion, juicing, etc. to improve and preserve foods (USDA 2016). The growing need for key nutrients, particularly micronutrients led to the addition of processed fruits and vegetables to already existing cereal-legume blends that are traditionally produced. Recent developments include addition of powdered fish, sweet potato flour, fruits, vegetables and milk solids to enhance the nutrient density of complementary foods for infants and young children (Achidi and Ukwuru 2015; Murthy and others 2016). A recent study by Oyeyinka and Oyeyinka (2016) suggested that addition of *Moringa oleifeira* powder improves the nutritional quality of food products targeted towards children.

2.3.2 Fortified food products

Fortification of food products for infants and young children becomes important when a child is fed the right amount of food but his/her nutritional requirements are not met. Infants between the ages of 6 to 8 months, for instance, require high levels of nutrients in their foods due to the rapid growth rate. Food Fortification involves the addition of certain micronutrients (this is mostly the case for traditional complementary foods prepared for infants) in their pure form or by adding food ingredients that are considered to be rich sources of some micronutrients, mostly vitamins and minerals. The food fortificant should assimilate well into the food product that is being fortified while maintaining sensory properties of the food product (Oyenyinka and Oyenyinka 2016).

Vitamin A, zinc and iron are the most common micronutrients that are fortified in complementary foods in developing countries. Iron and zinc are not fully absorbed in the infant's gut; the presence of high levels of certain antinutritional factors such as phytic acid in complementary foods inhibits complete absorption and makes these minerals less bioavailable (Gabaza and others 2016).

2.3.3 Dietary supplements

Dietary supplements are products that may come in the form of tablets, syrups or powder mostly containing essential minerals, vitamins, and amino acids that are ingested by mouth for nutritional purposes (WHO, 2016). They are mostly recommended based on special needs. Over 300 million children worldwide died from anemia in 2011, which led to the development of recent guidelines by the WHO for infants and children on daily iron supplementation, especially for children in areas of high malaria prevalence (WHO 2016).

2.4 Nutrient rich raw materials choices used in infant Food Formulation

The choice of raw materials for formulating infant diets is determined by different such as nutrient density of traditional diets, complementary feeding practices, socioeconomic factors and availability of ingredients (CODEX 1991). Some examples of commonly utilized legumes and cereals for traditional infant diets in Africa and other developing countries are millets, sorghum, maize, soybean, rice, etc. Cereals are typically rich in sulfur-containing amino acids (cysteine and methionine) but limiting in the essential amino acid lysine while legumes are generally high in lysine but have only low levels of cysteine and methionine. Therefore cereals and legumes are complementary in terms of protein and essential amino acid needs (Bazaz and others 2016; Temba and others 2016). Fruits, in general, contain a substantial amount of micronutrients and antioxidants and their incorporation increases the nutritional quality of complementary foods. Most fruits are recognized for their vitamin C, fiber, antioxidant and mineral contents.

2.4.1 Banana

Banana (*Musa* spp.) is widely cultivated in tropical and subtropical regions of developing countries, usually by small-scale farmers as a staple food. Bananas are also grown on a large scale for export. They are ranked as one of the largest grown food crops worldwide following rice, maize, and wheat. Bananas are classified into two groups based on their culinary characteristics (dessert and sweet bananas) and cooking bananas. Cooking bananas include plantains and are usually cooked before consumption (Aurore and others 2009).

Compared to fruits like apples and oranges, processed banana products are less common on the market (Aurore and others 2009). At the end of the year 2000, only 0.1 % of the bananas that were produced globally were used industrially (Aurore and others 2009). According to the second annual report of the United States International Trade Commission in 2011, banana is one of the least processed fruits in Africa, and undergoes high post-harvest losses. To add value to banana and avoid post-harvest losses, the fruit is incorporated into other food products such as cake and pie (Aurore and others 2009; Karthiayan and others 2013).

2.4.1.1 Nutritional significance of banana

Dessert bananas are easily digestible (Mohapatra and others 2010) and can be incorporated into food products that are made for individuals who may have the need for digestibility, oil and fat-free foods and higher mineral content diets. People with these special needs include; infants, the elderly and individuals with stomach ulcers and some gastrointestinal disorders (Aurore and others 2009).

The pulp contains significant levels of potassium, phosphorous and magnesium (Table 2.1) Dehydrated bananas contain relatively high energy and sugar levels (Table 2.1). The proximate, mineral and vitamin composition of fresh and dehydrated bananas are represented in table 2.2.

There is much interest growing in banana due to its potential use as a food source for diabetes management because it has a low glycemic index and it is also used to treat diarrhea (Mohapatra others 2010; Pillay and Fungo 2016). Banana also contains important phenolics and flavonoids which, act as antioxidants. The nutritional value of banana flour makes it a great product for use in baby foods, particularly when accompanied by legumes (Mohapatra and others 2010).

Table 2.2: Nutritional composition of raw and dehydrated banana per 100g

Nutrient	Unit	Raw banana	Dehydrated banana
Proximate			
Water	g	74.91	3
Energy	Kcal	89	346
Protein	g	1.09	3.89
Total lipids		0.33	1.81
Carbohydrate	g	22.84	88.28
Total dietary fiber	g	2.6	9.9
Total sugars		12.23	47.3
Minerals			
Calcium	mg	5	22
Iron	mg	0.26	1.15
Magnesium	mg	27	108
Phosphorous	mg	22	74
Potassium	mg	358	1491
Sodium	mg	1	3
Selenium	µg	1	3.9
Vitamins			
Vitamin C	mg	8.7	7
Thiamin	mg	0.031	0.18
Riboflavin	mg	0.073	0.24
Niacin	mg	0.665	2.8
Vitamin B-6	mg	0.367	0.44
Folate	mg	20	14
Choline, total	mg	9.8	19.6
Beta Carotene	µg	26	101
Alpha carotene	µg	25	96
Vitamin A, IU	IU	64	248
Vitamin K	µg	0.5	2

(USDA 2016).

2.4.2 Beans

Common beans (*Phaseolus vulgaris L.)* are legumes, which thrive well in Eastern Africa and some parts of southern Africa. A substantial amount of dry beans are lost after harvest due to lack of appropriate storage facilities and preservation methods. (Nyombaire and others 2011)

2.4.2.1 Nutritional significance of beans

Dry beans are generally low in fat but high in protein and dietary fiber (Table 2.3). The protein present in beans is about two times the amount present in cereals. Due to the expensive nature of animal proteins, bean meal is a preferable source of protein in developing countries particularly among families with low socioeconomic status. This preference is due to the rich protein and calorie content of beans. In developing countries, beans are boiled and eaten as a cuisine and served with other delicacies (Nyombaire and others 2011). Known for its high dietary fiber content (Table 2.3), beans serve as a good source of roughage, which enhances bowel movement. The proximate compositions of a variety of kidney beans are shown in Table 2.3.

Table 2.3: Nutritional composition of different cultivars of dry beans flour

Bean cultivar	Fat (%)	Protein (%)	Ash (%)	Crude /dietary fiber %)
Cranberry	1.28-1.4	22.36-24.3	4.25	20.9
Dark red kidney	1.1-1.16	27.09-28.5	4.84	21.9
Kidney (wet basis)	1.6	20.9	3.8	26.3(d)
Light red kidney	1.28	24.15	4.40	-
Kidney*wb	1.7	24.5	3.3	-
Pinto	1.0-1.34	23.19-23.7	4.53	21.8
Navy	1.5-1.8	25.1-30.4	3.85-4.6	7.6, 23.3
Navy*	1.74	23.1-28.3	3.73-4.1	1.95

* = dehulled
Wb = wet basis
(Rui and Boye 2013)

2.4.3 Rice

Rice (*Oryza sativa* L) is an important cereal, largely produced in Asian countries, is a staple food some countries and is consumed in more than half of the globe. Rice consumption is increasing in most sub-Saharan African countries and is taking over from traditional staple foods such as yam and cassava (Tomlins and others 2005). Irrespective of the variety, rice is a good source of carbohydrates, particularly starch and is high in calories, 232Kcal (Table 2.4). It also contains fiber, some micronutrients such as phosphorous and magnesium (Table 2.4).

2.4.3.1 Nutritional composition of rice

Nutritional composition of rice varies with rice type; that is, white rice (milled rice) or brown rice. Brown rice is the type of rice in which the husk has not been removed and is generally considered more nutrient dense compared to its white rice counterparts (Table 2.4). Rice is remarkably high in carbohydrates and contains relatively low levels of protein. When not consumed together with protein-rich ingredients diets, rice-based diets could, lead to protein-energy malnutrition (Babu and others 2009). Phytic acid, an antinutritional factor is present in the rice bran and can be reduced by soaking or more significantly by fermentation and germination (Kaur and Kapooȓ 1990). Rice bran also contains other antinutrients such as tannins, oxalates, trypsin inhibitors and polyphenols (Kaur and Kapooȓ 1990).

Table 2.4: Nutritional profile (per 100g) of white and brown rice

Parameters	Brown rice	White rice
Calories	232	232
Protein (g)	4.88	4.1
Carbohydrate (g)	49.7	49.6
Fat (g)	1.17	0.205
Dietary fiber (g)	3.32	0.74
Thiamin, B1 (mg)	0.223	0.176
Riboflavin, B2 (mg)	0.039	0.021
Niacin, B3 (mg)	2.73	2.050
Viatamin, B6 (mg)	0.294	0.103
Follacin (μg)	10	4.1
Vitamin E (mg)	1.4	0.462
Magnesium (mg)	72.2	22.6
Phosphorous (mg)	142	57.4
Potassium (mg)	137	57.4
Selenium (mg)	26	19
Zinc (mg)	1.05	0.141

(Babu and others 2009)

2.5 Processing and Preparation of raw materials for formulation of diets for infants

To ensure a safe and healthy diet for infants and young children, certain processesing meethods and methods are recommended by Codex Alimentarius during formulation of complementary foods.

2.5.1 Sorting and cleaning

Sorting and cleaning are carried out to remove debris, foreign materials, and damaged seeds. It also involves treatment of the raw material with water to remove unwanted materials. Sorting and cleaning are almost always the initial stages of raw material preparation before proceeding to the next stage of treatment. This stage applies to all types of raw materials used in formulation of infant foods (CODEX 1991).

2.5.2 Soaking

Where applicable, legumes, cereals and pulses are soaked by covering with enough water, at least 4x water (Afify and others 2011; Achi and Ukwuru 2016). The positive effect of soaking on reducing oligosaccharides such as raffinose and stachyose and other antinutritional factors is well documented (Egaunlenty and Aworh 2003; Siddiq and others 2006).

2.5.3 Dehulling

Dehulling is the removal of the seed coats of lentils, legumes, pulses, or oil seeds to minimize the amount of dietary fiber to an acceptable level for infants and young children (CODEX 1991). There is evidence of disruption in zinc and iron absorption in infants who consume diets high in dietary fiber (CODEX, 1991; Gabaza and others 2016). Dietary fiber also reduces intake of food in infants and children, induces satiety at a minimum intake and leads to bulkiness of stool. Dehulling can reduce concentrations of phenolic compounds, antinutritional factors: phytates, chymotrypsin and trypsin inhibitors and tannins, which have the ability to drastically, reduce protein absorption and amino acid digestibility (CODEX 1991; Egaunlenty and Aworh 2003).

2.5.4 Fermentation

Fermentation is an age-old process employed in food preservation. Fermentation is a biochemical process in which, a substrate is transformed by the action of microorganisms into other compounds such as ethanol, which, may enhance nutritional and sensory properties of food products (Adenike 2016; Gabaza and others 2016). This method is mostly applicable to cereals and grains such as maize, millet, and sorghum during the preparation of infant foods (Egaunlenty and others 2002; Galati and others 2014). In Ghana, a typical fermentation process involves soaking maize in water for 3 days to a week to allow the seeds to sprout. The sprouted seeds are later milled and turned into a gruel known as 'Koko' for infants (Nagai and others 2012).

The fermentation process can be either controlled or uncontrolled; the uncontrolled process does not employ specific microorganisms and is a random spontaneous process, induced by microorganisms present in the environment (Adeninke 2016). The latter method is used in homes in Africa and other developing countries during the preparation of traditional gruels for both adults and infants. The challenge, however, is the possibility of contamination of cereals and grains with mycotoxins during the fermentation period (Watson and others 2015). Fermentation helps in the reduction of phytate activity by hydrolyzing them; this could enhance mineral absorption and improve B-vitamin content (CODEX 1991).

2.5.5 Roasting

Roasting or toasting involves dry heating of legumes, cereals, grains, pulses and oil seeds at very high temperatures (80°C) before or after soaking coupled with dehydration (CODEX 1991; Twum and others 2015). This process significantly improves taste and flavor of legume and cereal blends, which is attributed to pre-digestion of starches. Digestibility of the toasted product also improves (CODEX 1991). Roasting also decreases bulkiness (density) and also results in high quality end product because insects, microorganisms and enzyme activity are destroyed at high temperatures (CODEX 1991). Loss of protein could, however, occur during roasting due to the browning reaction that occurs between amino acids and reducing carbohydrates at high temperatures; a good control of the process is needed to avoid protein loss (CODEX 1991). Roasting is the major method employed at the household and small-scale level to prepare weanimix, a popular weaning food in Ghana. It is difficult to optimize temperatures at household and small-scale levels so process control are not adequate (CODEX 1991).

2.5.6 Milling

Dry raw materials after pretreatment can be combined and milled together or milled separately and mixed afterward depending on technological feasibility. Preserving the nutritional quality ingredients during milling is very important. While milling reduces the particle size of ingredients and makes their incorporation into product easier, it could also lead to bulkiness of the flour samples (CODEX 1991; Nagai and others 2012). Bulkiness can, however, be reduced by addition of alpha-amylases to allow pre-digestion of starch and help reduce the amount of water required during cooking. Excess dilution of formulated product during preparation could cause reduction in food to water ratio leading to low nutrient density (Amagloh and others 2013).

2.5.7 Extrusion cooking

Extrusion cooking is a technique used to cook food under high pressure and controlled temperature (Obatolu and others 2000; Nyombaire and others 2011). The product is allowed to pass through different sizes of die(s) -determined by desired attributes. The extrudate exhibits different physical and sensory attributes than the original ingredients (Alonso and others, 2000). Extrusion cooking is used for the production of snacks, breakfast cereals, and instant powders. The process can be employed for further cooking of composite ingredients of intended infant formula after milling (Ojokoh and Fagbemi 2016).

Extrusion cooking has an advantage of lowering the amount of water required to reach gelatinization temperature. It also inactivates phytic acid and trypsin inhibitors (Camire and others 1990; CODEX 1991). The amino acids L-lysine, L-arginine, L-tryptophan and sulfur-containing amino acids cysteine and methionine and vitamins may, however, be lost if processing parameters such as temperature are not well controlled (CODEX 1991).

2.5.8 Food dehydration

Food dehydration is a method of food preservation that has been in existence for several centuries (Vega-Mercado and others 2001; Aguilera and others 2003). This method entails removal of moisture from food products to a level that minimizes microbial activity and chemical reactions which otherwise could lead to food product deterioration (Aguilera and others 2003).

2.5.8.1 Air-drying

This method is relatively less expensive than most drying methods (freeze drying, vacuum drying, and microwave dehydration) and is used to dehydrate food products in an enclosed vacuum or chamber. Materials to be dehydrated are often placed on open trays and hot air is passed over the products and moisture is removed by convection. The air-drying method is referred to as the traditional or conventional drying method because it is often operated at relatively higher temperature. It is able to provide appreciable shelf stability but may compromise the nutritional, sensory, chemical and physical qualities of food products. Commonly altered qualities include: loss of flavor, altered taste, texture and rehydration ability, and reduced vitamin C (Cohen and Yang 1995; Vega-Mercado and others 2001).

2.5.8.2 Vacuum drying

This is similar to air-drying but it makes use of lower temperatures and higher pressures to remove water. It is relatively less expensive compared to freeze-drying and the product characteristics and attributes (flavor, taste, and aroma) are better preserved during this process compared to air-drying (Chen and others 2006; Thipayarat, 2007). Vacuum belt drying is a subtype of vacuum drying except the process is continuous (Chen and others 2006; Wang and others 2007).

2.5.8.3 Spray drying

Liquid samples or free flowing products are dehydrated using this method. Spray drying consists of droplet formation that is pumped through a nozzle into a hot drying medium, which utilizes atomization to evaporate moisture and to form fine particles. The end product particles are mostly uniform and even spherical shapes but may vary depending on whether the temperature at which the products are dried is below or above droplet temperature. Powdered milk and instant coffee are commonly produced by this method. Spray drying has the advantage of producing uniform and specified product characteristics under constant conditions. It is also a continuous process and easy to operate (Vega-Mercado and others 2001).

A huge shortfall of this method, however, is that it is not suitable for drying a wide range or types of products. For instance, raw materials that are high in fat cannot be dehydrated using spray drying unless the fat content is removed to a minimal level. Also, materials high in sugar content may have to be diluted or spray dried with a carrier such as maltodextrins (Cohen and Yang 1995).

2.5.8.4 Drum drying

Drum drying is employed for dairy products, cereals, gelatin beverages and bakery goods. It can be used to dehydrate slurries, purees, and pastes by conduction. The product to be dehydrated is uniformly poured over a heated drum to evaporate moisture; the drum blades scrape dried product. The uniformity of slurry and full attachment of products to the drum is important for obtaining a high quality and fully dehydrated product. Occasionally, the product may need some modification by addition of other ingredients to ensure the above conditions are met. The commercially available drum may be a single or double drum. High rates of drying are obtained during drum drying and are very heat economical. The disadvantage, however, is the high temperature of the drums that causes severe damage to the end product. This has led to a decline in the use of drum drying (Cohen and Yang 1995; Vega-Mercado and others 2001).

2.5.8.5 Freeze-drying

Freeze drying is utilized for any product type as long as it can be frozen. Freeze-drying also known as lyophilization, operates on the principle of sublimation. Frozen samples are dried at room temperatures under high vacuum (Vega-Mercado and others 2001). The temperatures lead to little or no losses in sensory attributes or structure. Also, the porous nature of the end product attained as result of sublimation of ice crystals from the product's surface causes the product to rehydrate at a fast rate (Vega-Mercado and others 2001; Prothon 2002).

The process is very expensive for commercial use because of extensive periods of drying, which leads to higher compressor energy requirements. Longer drying periods required during freeze-drying is due to the formation of a thick layer whiles the drying process progresses, making removal of remaining ice crystals difficult (Cohen and Yang 1995; Vega-Mercado and others 2001).

2.6 Quality Evaluation

Quality evaluation includes but is not limited to nutritional analysis, microbial analysis, as well as physicochemical properties, functional properties and also sensory attributes. Quality evaluation is essential as it influences consumer preferences, packaging decisions, and shelf stability. Nutritional composition analysis is the priority when it comes to foods given to infants and children (Achidi and others 2016).

Nutritional quality also includes antinutritional factors. Proteins and micronutrients are the most important nutrients for infants and young children. The average human requires at least 49 different nutrients to maintain a normal and healthy development. A lack or insufficient intake of one of the 49 nutrients could lead to adverse health effects or even death (Welch and Graham 2004). Most childhood stunting, infections and morbidity are linked to inadequate intake of one or more micronutrients (UNICEF/WHO 2015).

2.6.1 Protein

Normal growth and development of infants and young children are determined by the amount and quality of protein consumed. Quality of protein is entails bioavailability and also the presence and amount of essential amino acids. A combination of legumes and cereals provides the right amount and quality of protein. However, it may become necessary to improve the protein quality (bioavailability and amount of essential and limiting amino acids) for children by the addition of fish, meat or dairy products to allow for amino acid complementarity (Dewey and Adu-Afarwuah 2008).

2.6.2 Carbohydrates

Carbohydrates are one of the sources of energy in the diet and are found primarily in starchy foods. To provide the right amount of energy, easily digestible starchy foods should be selected for children. Other higher energy sources such as fat and oils can also be added to increase energy levels. Incorporation of certain carbohydrates for other purposes, such as sweetness, should be added sparingly (CODEX 1991).

2.6.3 Dietary fiber

Dietary fibers are non-digestible parts of carbohydrates that escape digestion and may be fermented in the human gut to produce short chain fatty acids that are nutritionally beneficial. Excess gas production could, however, result from fermentation. Dietary fiber is comprised of complex mixture of indigestible polysaccharides (cellulose, hemicelluloses, oligosaccharides, pectins, gums), and lignin found mostly in plant cell wall material (Tosh and Yada 2010; Brownlee 2011).

Dietary fiber is associated with easy bowel movement and stool bulkiness (Agget, 2003). The antinutritional effect of dietary fiber is still unclear and not concretely documented. The positive effects seem to exceed the suspected anti-nutritional factors: “Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation” (Tosh and Yada 2010).

Some studies showed that dietary fiber can decrease absorption of zinc, iron and micronutrients that are present only in minute concentrations (Gabaza and others 2016). Codex Alimentarius recommendation of dietary fiber in formulated complementary food is at most 5 g per 100 g on a dry basis (CODEX 1991).

2.6.4 Resistant starch

The polymer chains of starches are made of mostly straight-chain amylose and branched chain amylopectin molecules. The branched-chain amylopectin has glucose molecules connected by, linearα (1→4) and branched chain α (1→6) glycosidic linkages. The linear chain is packed more closely compared to the branched chains, which are packed more loosely contributing to instability in the latter. Starches exist in the native form but they can be chemically or enzymatically modified to produce a specific or desired type of starch. Native starch can be classified based on a crystalline pattern exhibited under x-ray crystallography, digestibility by enzymes and also by nutritional properties (Sajilata and others 2006).

2.6.4.1 Starch classification

X-ray crystalline structure is composed of types A, B and C. These types are determined by the chain lengths of polymers making up the core of the loosely packed amylopectin network, by the compactness and density of starch granules and also by the availability of water in the system (Sajilata and others 2006; Sharma and others 2008).

The incubation of starch in vitro with digestible enzymes without prior treatment, results in rapidly digestible, slowly digestible, and resistant starch. This classification is determined by ease and rate of conversion into its monomer glucose units. Rapidly digestible starches (RDS) are entirely hydrolyzed to glucose units after 20 minutes of incubation. This is attributed to its irregularly shaped and loosely packed nature, which make them easily accessible to digestive enzymes such as alpha amylase. RDS types are common is foods that are cooked by application of moist heat. Common examples are potatoes and bread (Sajilata and others 2006; Sharma and others 2008).

Slowly digestible starch (SDS) undergoes digestion slower in the small intestine (about 100 minutes). This type of starch, are also amorphous in nature, except it is not physically accessible to digestive enzymes. Slowly digestible starches are found in food products with uncooked starch such as green bananas. Resistant starch (RS) does not digest in the small intestine and may be fermented once it reaches the large intestines. During chemical assays, RS is calculated by subtracting the sum of RDS and SDS from total starch (TS). (Woo and Seib 2002; Agett and others 2003; Sajilata and others, 2006).

Classification according to nutritional properties produces two main categories-digestible and resistant starches. The digestible group consists of RDS and SDS whilst resistant group consists of 4 subcategories: resistant starch type 1, 2, 3 and 4 (RS1, RS2, RS3, RS4 respectively) (Sajilata and others 2006). RS type 1 is common in fully or partially milled grains, cereals, legumes and certain bulky starches. Their resistance to digestion can be reduced by through milling and chewing (Sajilata and others 2006). RS type 2 has a special granular structure that makes them inaccessible. This type is predominant in raw starch due to relatively dehydrated starch content and compact lattice structure. RS type 2 comes from ungelatinized starch, which is common in bananas. Cooking and other methods of food processing minimize the resistance and amount of RS type 2.

RS type 3 is formed upon cooling. Gelatinized starch containing amylose molecules have the tendency to retrograde to form RS type 3. They are totally inaccessible and escape digestion in the small intestine, particularly by pancreatic amylases. They can be distributed in solution by addition of potassium hydroxide (Sajilata and others 2006). RS type 4 if formed during cross-linking of chemically modified starches and are the least susceptible to digestibility (Sajilata and others 2006).

2.6.4.2 Functional properties of resistant starch

Commercially, resistant starches are often incorporated into other food products, especially to prepare low-moisture food products. The wide usage of resistant starches in the food industry is due to their low water-holding capacity, smooth texture, bland taste and white color, which allow less interference with the integrity of products they are added to (Sajilita and others 2006). The health benefits of resistant starches include hypoglycemic effects, hypocholesterolemic effect, minimal gallstone formation and its capacity to curb colon cancer

(Topping and Clifton 2001). Research also showed that RS provides a prebiotic effect by serving as a substrate for the growth of beneficial bacteria such as *Bifidobacterium* (Bird and others 2010). Additionally, absorption of calcium, zinc, phosphorous and iron are enhanced in the presence of approximately 16.4% RS compared with diets made exclusively of digestible starch (Topping and Clifton 2001; Sajilata and others 2006). T

he figure below explains the effect of RS on blood glucose concentration compared to a control diet (granola bars). Generally, there was a steady increase in blood glucose (90 to 92 mg/dl) for the first 30 minutes after consumption of resistant starch. The consumption of the control diet (granola bars) led to a drastic increase in blood glucose from approximately 93 to 102 mg/dl after 30 minutes.

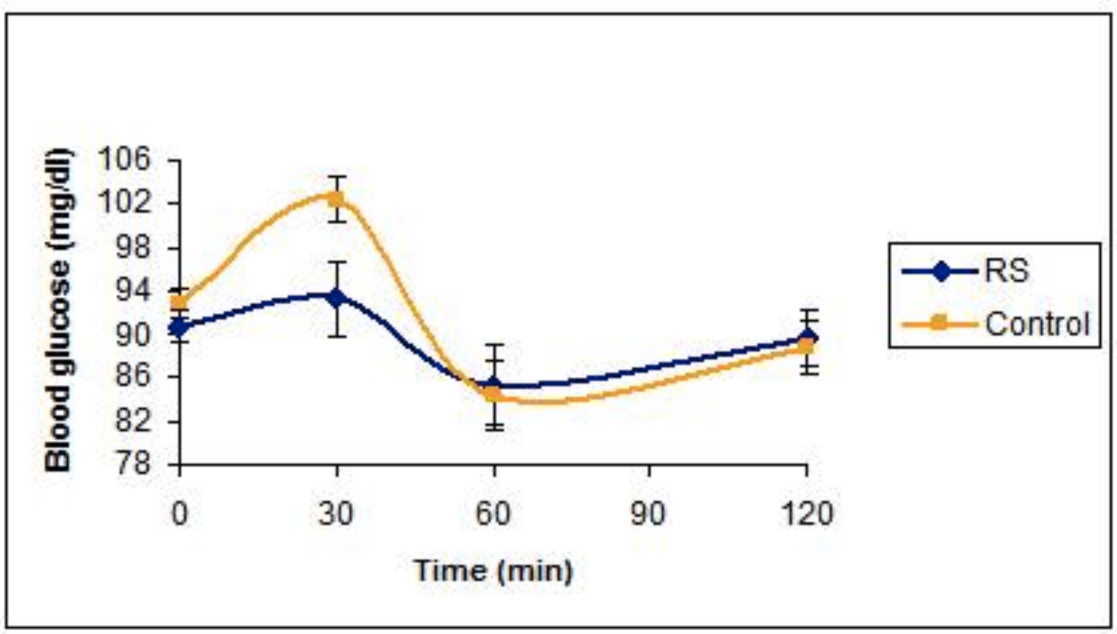


Figure 2.1: Resistant starch and its effect on blood glucose level (Duncan and others 2009).

2.6.5 Oligosaccharides

Oligosaccharides such as raffinose and stachyose are not digestible and are classified under non-digestible group of carbohydrates. Non-digestible carbohydrates produce low to zero energy in foods. Oligosaccharides mostly fall into one of the following categories: inulin, fructooligosaccharides, galactooligosaccharides or trans-galactooligosaccharides (Roberfroid and Slavin 2000). Fructooligosaccharides are found in certain fruits like bananas; inulin in artichoke and galactooligosaccharides in legumes, pulses, and some vegetables. Galactooligosaccharides include raffinose and stachyose. The inability of monogastric mammals to completely digest and absorb these oligosaccharides is due to the lack of the alpha-galactosidase enzyme (Agostoni and others 2004).

During the breakdown and fermentation of oligosaccharides in the colon, other products (Figure 2.3) or excess gas production could result (Mussatto and Mancilha 2007). Stachyose, a tetrose, and raffinose are the main culprits associated with gastrointestinal discomfort due to excessive gas production. Their levels are reduced during soaking and cooking which leads to a consequent reduction in gas production (Mulimani 1995; Rui and Boye 2013). The functional and health benefits linked to oligosaccharides are a prebiotic effect, hypocholesterolemia, hypoglycemia, colonic health, etc. These health effects are greatly connected to fructooligosaccharides and, to a lesser extent, to galactooligosaccharides (Aggett and others 2003).

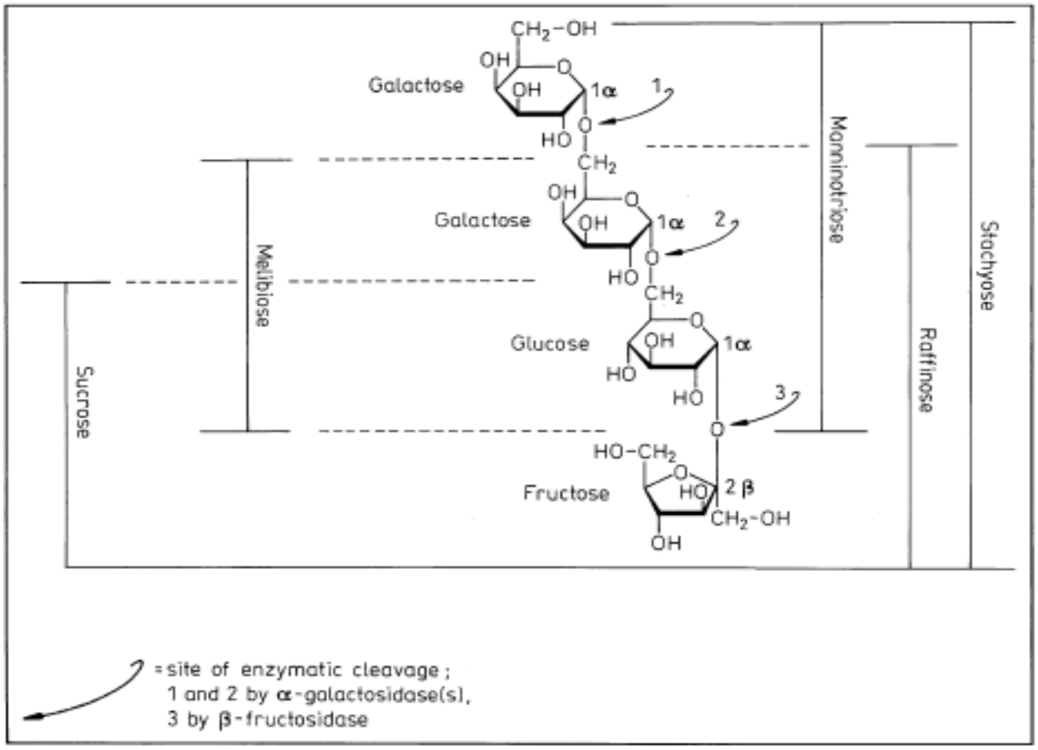


Figure 2.2: Structure of some galactooligosaccharides

2.6.6 Lipids

Fats and lipids are important in complementary foods and they boost the bulk energy content of foods. Essential fatty acids, linoleic and alpha-linolenic acid are necessary for cognitive development in infants and children. They are also necessary for the absorption of fat-soluble vitamins (WHO/FAO 2004). The addition of oils sources containing omega 3 fatty acids such as Docosahexaenoic acid (DHA) at recommended levels should also be considered when preparing food for infants and older children (CODEX 1991).

2.6.7 Vitamins and Minerals

Vitamin and mineral deficiencies among children in developing countries are commonly reported for calcium, iron, zinc and vitamin A. Other important vitamins and minerals include: vitamin B complex, vitamin C, vitamin D, vitamin E, folate, and selenium. All vitamins and minerals provided in a child's diet should meet daily nutritional requirements as recommended in table 1. Each vitamin or mineral plays a special role and ensures the healthy development of infants and children (WHO/FAO 2004).

Vitamin A is essential for good vision and deficiency of vitamin A can cause night blindness, xerophthalmia or cause susceptibility to other infections like anemia and diarrhea. Efficient absorption of vitamin A is also dependent on the presence of fat or fatty acids. Fish, liver, egg yolk, whole milk, green leafy vegetables, yellow and orange non-citrus vegetables are food sources rich in vitamin A (WHO/FAO 2004).

Vitamin D is required for healthy skin growth and optimum absorption of calcium and phosphate which in turn lead to strong bone development, muscle contraction and nerve development. Sunlight is required to make vitamin D in humans is the sun. Only a minimum amount is provided through the diet. Latitudinal differences, seasonal changes, and cultural disparity can have a significant effect on the vitamin D supply in both children and adults. Babies born in autumn are at a higher risk of vitamin D deficiency (WHO/FAO 2004).

Vitamin C also known as ascorbic acid is synthesized in the liver of some mammals mostly from glucose. Humans are unable to synthesize vitamin C and is therefore requires from the diet. Vitamin C is an electron donor, the basis of its antioxidant, biochemical and molecular functions. Its antioxidant role enables it to stabilize folate in food. Vitamin C is also needed for repair of damaged tissues. The deficiency of vitamin C in the diet can lead to scurvy. Vitamin C also increases the absorption of soluble non-heme iron at levels at approximately 25 mg by chelation or by maintaining iron in the reduced form. Citrus fruits, kiwi, papaya, and vegetables are good sources of vitamin C (WHO/FAO 2004).

B-Complex Vitamins refers to all B vitamins excluding vitamin B12. The main function in addition to other physiological roles is acting as a coenzyme or co factor in many biochemical pathways required in metabolism of certain nutrients such as carbohydrates, branched-chain amino acids, fatty acids, etc (Table 2.5). Rice and wheat are the main sources of B-vitamins; the amount of these vitamins can be significantly compromised when cereals are excessively polished. Beriberi (cardiac and dry), peripheral neuropathies, pellagra, and oral and genital lesions related to riboflavin deficiency used to be a global health challenge in some parts of the world but has experienced a huge decline (WHO/FAO 2004).

Table 2.5: Physiologic roles and deficiency signs of B-complex vitamins

Vitamin	Physiologic roles	Clinical signs of deficiency
Thiamin (B1)	Coenzyme functions in metabolism of carbohydrates and branched-chain amino acids syndrome	Beriberi, polyneuritis, Wernicke Korsakoff syndrome
Riboflavin (B2)	Coenzyme functions in numerous oxidation and reduction reactions	cheilosis, angular and dermatitis
Niacin (nicotinic acid and nicotinamide)	Cosubstrate/coenzyme for hydrogen transfer with numerous dehydrogenases	Pellagra with diarrhoea, dermatitis, and dementia
Vitamin B6 (pyridoxine, pyridoxamine, and pyridoxal)	Coenzyme functions in metabolism of amino acids, glycogen, and sphingoid bases	Nasolateral seborrhoea, glossitis, and peripheral neuropathy (epileptiform convulsions in infants)
Pantothenic acid	Constituent of coenzyme A and Fatigue, sleep disturbances, phosphopantetheine involved in impaired coordination, and fatty acid metabolism	Fatigue, sleep disturbances, nausea
Biotin	Coenzyme functions in bicarbonate-dependent and carboxylations	Fatigue, depression, nausea, dermatitis, and muscular pains

(WHO/FAO 2004)

The main role of calcium in humans is to maintain strong teeth and bones. About 99% of calcium stores are in the skeleton. Other functions of calcium include certain enzyme- mediated reactions and healthy nervous and muscle functioning. Only 25 to 30% of calcium from the diet is absorbed. A large amount of calcium must be included in the diet to ensure optimal absorption to meet daily nutritional requirements. Calcium absorption is also regulated by the amount of sodium, vitamin D, and protein that are part of the diet. Increased intake of sodium leads to an increase in calcium excretion in the urine. Vitamin D helps in efficient absorption of calcium, a lack or decreased vitamin D in the body could increase susceptibility to calcium deficiency (WHO/FAO 2004). Major sources of calcium are dairy products and certain plant sources such as legumes and some fruits and vegetables. The daily requirements of infants and children ranged from 200 to 800 mg/day (WHO/FAO 2004).

Selenium is a trace mineral, which performs complex biochemical functions and is linked to the antioxidant activity of glutathione. A decrease in selenium intake is associated with consequent decrease in glutathione capacity. A daily selenium intake in complementary foods and infant formula is recommended at a level of 10 μg (WHO/FAO 2004).

Magnesium acts as a cofactor for several biochemical enzymes involved in protein synthesis, RNA and DNA synthesis (Hurley and Doane 1989). Magnesium is widely distributed in most foods and commonly found in green leafy vegetables, legumes, nuts, spices, soy flour, and some shellfish. Magnesium deficiency is rare but severe deficiencies can lead to symptoms such as muscular weakness, nausea, anorexia, weight loss, tetany, muscular spasm and hyperirritability (WHO/FAO 2004).

Iron is responsible for heme synthesis, which is essential for oxygen transport in the human body (Hurley and Doane 1989). Infants solely depend on iron from the diet and an increase in iron requirement is needed during the weaning period to sustain normal growth and development. Foods containing appreciable levels of lean red meat and ascorbic acid usually are sufficient to provide daily iron needs during this period (WHO/FAO 2004). "Iron deficiency is possibly one of the most common nutritional deficiencies" (WHO/FAO 2004). The most common symptoms of iron deficiency are anemia. Studies also suggest a link between iron deficiency and brain impairment in children, which makes increasing iron content in the diet for children very important (WHO/FAO, 2004).

Zinc helps in motor coordination and the entire neuron system is dependent on the adequate availability of zinc. Lean meat, red meat, whole grains, cereals, and legumes are a good source of zinc (WHO/FAO 2004). No known clinical symptoms have been documented for mild to low level of zinc deficiency, but severe deficiencies could lead to delayed sexual and bone development, diarrhea, alopecia, skin lesions and susceptibility to infections (Hurley and Doane 1989).

In summary, several important factors are considered during the development of an infant food containing sufficient nutrients for developing countries. Additionally, processing methods must be chosen carefully to produce a tasty value added-product that is marketable in low-income areas of the developing world. The next chapter outlines the methods used to produce and analyze such a product.

CHAPTER 3

MATERIALS and METHODS

Canvendish bananas, brown rice and light red kidney beans were purchased from a local source. Chemicals and reagents used were of analytical grade. Resistant starch and dietary fiber assay kits were purchased from Megazyme international (Wicklow, Ireland). All other chemicals and reagents to were purchase from Sigma Aldrich (St. Louis, Missouri, USA). All treatments were prepared in duplicates and the entire procedure was completely repeated from raw material treatment to physicochemical analysis.

3.1 Flour processing

3.1.1 Red kidney bean flour

Red kidney beans were sorted, cleaned and washed in cold water. The beans were soaked in 4x water at 70°C for 8 h. The water was drained and the beans were cooked in boiling water for 30 min. Cooked beans were cooled under cold running water and air dried using a food dehydrator, model SD-P9000 (Tribest Sedona, Anaheim, C.A., U.S.A.) at 60±1 °C for 8-10 h. (ambient air entered the dryer at a temperature of 23 ± 2°C and warm air exited the dryer at 60 ± 2°C; humidity in the room was recorded at 17 ± 2%). Dehydrated beans were dehulled in a hammer mill, model W series (Schutte-Buffalo, N.Y., U.S.A.) followed by manual removal of remaining seed coats. Samples were then milled using a UDY sample cyclone mill, Belt-Drive model 3010-019 (UDY Corp. Rome, Italy) to a particle size of 0.5 mm. The flour was packaged in 1-mil polyethylene bags and stored 23±1 °C until used.

3.1.2 Rice flour

Brown rice was cleaned and washed and cooked for 30 minutes in boiling water. The rice was then cooled and dried at 60±1 °C for 8-10 h. Conditions were the same as those used during dehydration of kidney beans.

3.1.3 Banana flour

Cavendish bananas (Dole™ brand) ranging from "more green than yellow" to "more yellow than green" banana was purchased. CIE color of fresh bananas with peels was also determined; the b color value, which is an indicator of the degree of yellowness ranged from 33.83 to 52.75. Bananas were peeled, and sliced using a knife into about 4 mm thickness and treated with ascorbic and citric acid. The pretreated banana slices were uniformly arranged on trays and dried at 60°C in a Sedona dehydrator for 12-16 h. Dehydrated slices were milled into flour (0.5 mm).

3.2 Product formulation

Bean, rice, and banana (BRB) composite flours treatments are presented in Table 3.1. The ratios were selected based on Codex Alimentarius recommendation of amount of energy required from protein, from 6 to 15 % of total energy contained in the complementary food (CODEX 1991) and also based on consumer perception. Individual flours were also analyzed for nutritional and physicochemical properties.

Table 3.1: BRB composite flours (%)

Treatment	Banana	Rice	Beans
Trt-1	80	10	10
Trt-2	70	10	20
Trt-3	70	20	10
Trt-4	60	25	15
Trt-5	55	20	25
Trt-6	50	30	20
Trt-7	45	40	15

3.3 Proximate Analysis

Moisture, total lipids and ash contents were determined based on AOAC 2005 methods with a slight modification during determination of total lipids by the use of microwave-hexane extraction.

3.3.1 Moisture content

About 2 g of samples were weighed into dry aluminum pans. Samples were placed in a forced-air oven overnight at 105^{o}C, and then cooled in desiccators. Dry weight was recorded and percentage moisture determined.

3.3.2 Ash composition

Empty crucibles plus covers were weighed and 2-3 g of samples were added and placed in a muffle furnace overnight at 550°C. They were allowed to cool in a muffle furnace and transferred to desiccators to finish cooling. Crucibles plus ash were weighed and percentage ash content was calculated.

3.3.3 Crude Fat

Sample tube liners, specific for a microwave reaction unit, Multiwave model 3000 (Anton Paar, Ashland, N.C, U.S.A.) were placed in the tube holder of an analytical scale. Using a Approximately 1 g of BRB composite flour samples were transferred to the bottom of the tube liners. Tube liners were placed in ceramic vessels and 10 mL each of acetone and hexane was added. Vessels were assembled, placed on a carousel and then into a microwave extractor.

The extractor was operated under the following conditions: temperature ramp increased 5^{o}C/min, 110°C final temperature; held for 10 min at 110°C; cooled to 40 (about 20 min) and disassembled. Sample extracts were filtered through glass wool into pre-weighed round bottom flask and solvent was evaporated using a rotary evaporator. Flasks containing crude fat were dried at 100^{o}C for ~10 min, cooled in a desiccator and weighed. Total crude fat was determined.

3.3.4 Protein

Protein content was determined using Kjeldahl method for sample digestion and neutralization followed by indophenol method of nitrogen determination.

3.3.4.1 Digestion

Approximately 0.5 g samples were placed into microwave digestion tubes and 4 mL of hydrogen peroxide was added followed by 6 mL of sulfuric acid. The tubes were assembled into a carousel for and heated for a total of 1 h. The tubes were held for 45 minutes at a pressure rate of 0.5 bar/S and 800W and cooled for 20 minutes in the microwave digestion unit, Multiwave model 3000 (Anton Paar, Ashland, V.A., U.S.A.). After complete digestion, samples were transferred to a 100 mL volumetric flask followed by addition of water to bring the final volume to 100 mL.

3.3.4.2 Neutralization and dilution of digested samples

Two Milliliter digested sample was added to approximately of 25 mL of water in a 100 mL beaker. Digested sample was neutralized with 1M Na_2CO_3 to obtain a pH of 6.5 - 7.5 and transferred to a 50 mL volumetric flask. Volume was brought to 50mL with water and mixed thoroughly.

3.3.4.3 Nitrogen determination

Ammonium chloride was used as a nitrogen source for preparation of a standard curve. Five standards were prepared and sample dilutions prepared when necessary.

Table 3.2: Standard solutions for nitrogen determination.

Preparation of Standards					
	0 μg N	1.25 μg N	2.5 μg N	3.75 μg N	5 μg N
mL of standard (5 μg of N/mL)	0	0.25	0.5	0.75	1
mL of nanopure H_2O	1	0.75	0.5	0.25	0

Two milliliters each of reagent 1 (10 g Phenol, 50 mg sodium pentacyanonitrosyl ferrate dehydrate per L) and reagent 2 (15 g sodium hydroxide, 10 mL sodium hypochlorite per L) were added to each tube and mixed well. Tubes were placed in a water bath at 50°C for 40 min. Samples and standards were blue color after 10 – 15 min. After the 40 min incubation, the absorbance of samples and standards were measured at 640nm using a microplate reader, model, synergy HTX Multi-Mode (BioTek, Winooski, VT, U.S.A) and nitrogen concentration was quantified using standard curves and protein content was calculated using a conversion factor of 6.25.

3.4 Raffinose and stachyose determination

3.4.1 Extraction

Raffinose and stachyose contents were determined according to the method of Kuo and others (1988). Flour samples (75 mg to 100 mg) were suspended in approximately 80% ethanol in a 5 mL fluted cap, (Note: volume of ethanol added was calculated for each sample based on their respective weights from a standard concentration of 25 mg/mL), placed horizontally on an orbital shaker (50 rpm) at 40C for 16 h, and the suspension was centrifuged at 3000 g for 10 min to obtain clarified ethanol sugar extract. Ethanol was evaporated overnight using a CentriVap concentrator.

3.4.2 HPLC analysis

The pellet was re-suspended in 1 mL of mobile phase and the solution passed through a 0.2um filter (Puradisc 25 TF, Whatman) through a centrifugation process using a Microcentrifuge, model 5424, (Eppendorf, Hauppauge, NY). An aliquot (1.2 mL) of re-suspended mobile phase was used for HPLC analysis in a 6.5 x 300 mm steel cartridge Waters Sugar-Pak carbohydrate column (WAT085188, Waters Co., Milford, M.A., U.S.A.).

The mobile phase contained 134 uM Na_2Ca EDTA set at constant flow at 0.5mL/min, 90°C, 13 min run time per sample. Quantification was done with Waters 410 differential refractometer held at 35°C using Infrared (IR) detector. Standards for sucrose (2.92-46.74 mM), glucose and fructose (0.22 to 4.44 mM), raffinose (0.13-1.34 mM) and stachyose (0.12-1.20 mM) were used to generate standard spectra.

3.5 Total dietary fiber

Total dietary fiber content of composite flour was determined based on AACC method 32-05.01 and AOAC method 985.29 (AOAC 1987) using the Megazyme assay kit (Megazyme Int'l., Wicklow, Ireland). Duplicates g samples were weighed into 400 mL beakers ensuring that weights of duplicates only differed by less than 20 mg from each other. Fifty milliliter of sodium phosphate buffer (pH 6.0) was added to samples and the pH adjusted when necessary to a range of 6.0±0.1. The samples were incubated with 50 µL heat-stable α-amylase solution at 98-

100°C for 15 min in a water bath with intermittent shaking at 5 min intervals. The beakers were covered with aluminum foil before incubation. The solutions were allowed to cool to room temperature and pH adjusted to 7.5±0.1 with 0.275 N NaOH solution.

The samples were then incubated at 60°C with 100 µL of protease solution for 30 minutes with continuous agitation. The solutions were to cooled to room temperature, pH adjusted with 0.325 N HCl solution to 4.5±0.2, 200 µL amyloglucosidase was added and incubated at 60°C with continuous agitation for 30 minutes.

10. Pre-heated 95% ethanol (280 mL) was added to samples and left at room temperature for 1 h to allow the formation of precipitate.

The precipitated enzyme digests were filtered through pre-weighed celite contained in a fritted glass crucible. The celite was moistened and redistributed with 78% ethanol and drawn onto the fritted glass of crucible to form an even mat by applying suction using a vacuum pump. Sample residues obtained during filtration were successively washed with three 20 mL portions of 78% ethanol, two 10 mL portions of 95% EtOH, and two 10 mL portions of acetone.

Crucibles containing residue were dried at 105°C in an air oven overnight, cooled in a dessicator and weighed to determine residue weight. The residues were then corrected for ash and protein. One duplicate was ashed in a muffle furnace at 525°C for 5 hours, cooled in desiccator and weighed to determine ash content. Protein weight was determined for the second residue, using the Kjeldahl method (with colorimetric determination of nitrogen) and by using 6.25 factor. Blanks were run along samples to measure contributions from reagents used.

Calculations

Uncorrected average blank residue (UABR) = Average blank residue of duplicate blanks (mg)

Blank protein residue (BPR) = UABR x % protein in blank

Blank ash residue (BAR) = UABR x % ash in blank

Corrected blank (CB) = UABR-BPR-BAR

Uncorrected average sample residue (USAR) = Av sample residue of duplicate samples

Sample protein residue (SPR) = USAR x % protein in sample

Sample ash residue (SAR) = USAR x % ash in sample

Corrected sample residue (CSR) = USAR-SPR-SAR-CB

% TDF = 100 x CSR/mg sample

3.6 Resistant starch determination

3.6.1 Hydrolysis and solubilisation of non-resistant starch

For resistant starch measurement, AOAC Method 2002.02 (AOAC 2000) method was used, following the Megazyme assay kit (Megazyme Int'l., Wicklow, Ireland). Flour samples (100 ± 5 mg) were directly weighed into 15mL Falcon tubes. Tubes were gently tapped to ensure that samples reached the bottom of tubes. Four milliliters of pancreatic α-amylase (10 mg/mL) containing amyloglucosidase (AMG) was added to each tube. Tubes were tightly capped, content of tubes were mixed using a vortex mixer, and incubated in a 37°C water bath with continuous shaking. The tubes were removed after 16 h and excess water on tube surface wiped; they were then uncapped and treated with 4.0 mL of ethanol (99% v/v) with vigorous stirring on a vortex mixer. The tubes were centrifuged at 1,500 g for 10 min and supernatants decanted. The pellets were re-suspended in 2 mL of 50% ethanol with vigorous mixing. Samples were again centrifuged after further addition of 6 mL of 50% ethanol, stirred, decanted, re-suspended and centrifuged one last time. Any liquid remaining after decantation was removed by inverting the tubes on absorbent paper.

3.6.2 Measurement of Resistant Starch

Pellets were re-suspended in 2 mL of 2 M KOH and dissolved by stirring with magnetic bars followed by stirring in ice/water bath for 20 min. In order to prevent enzyme hydrolysis, 8 mL of 1.2 M sodium acetate buffer (pH 3.8) was added to each tube with stirring and 0.1 mL of amyloglucosidase (AMG) was added and mixed. Tubes were incubated in a water bath at 50°C for 30 min with intermittent mixing. Samples containing greater than 10% RS were transferred into 100 mL volumetric flask, topped up with distilled water, and mixed well. External magnets were used to remove the stirrer bar in while washing the solution from the tube into the volumetric flask. An aliquot of the solution was taken and centrifuged at 1,500 g for 10 min. No dilution step was required for samples containing less than 10% RS; tubes were directly centrifuged for 10 min. Aliquots (0.1 mL) in duplicates of supernatants for both diluted and undiluted step were transferred to glass tubes (16x 100 mm) and 3 mL of GOPOD reagent was added. The solution was then incubated at 50°C for 20 min.

3.6.3 Non-Resistant (Solubilized) Starch

Supernatant solutions obtained by centrifugation of the initial incubation were combined with the supernatants obtained from the subsequent two 50% ethanol washings. Volume was adjusted to 100 mL with 100 mM sodium acetate buffer (pH 4.5) in a volumetric flask and mixed thoroughly. In duplicates, 0.1 mL of the resulting solution was incubated with

10 μL of dilute AMG solution (300 U/mL) in 100 mM sodium maleate buffer (pH 6.0) for 20 min at 50°C. The solution was mixed with 3.0 mL of GOPOD reagent and the tubes were incubated at 50°C for a further 20 min.

3.6.4 Measurement of Absorbance

Absorbance of all samples and standards were measured at 510 nm against a reagent blank for both resistant and non-resistant starch. The content of resistant and non-resistant (solubilised) starch were determined by further computation:

Resistant Starch (g/100 g sample)(samples containing > 10% RS):

$= \Delta E \times F \times 100/0.1 \times 1/1000 \times 100/W \times 162/180$

$= \Delta E \times F/W \times 90.$

Resistant Starch (g/100 g sample)(samples containing < 10% RS):

$= \Delta E \times F \times 10.3/0.1 \times 1/1000 \times 100/W \times 162/180$

$= \Delta E \times F/W \times 9.27.$

Non-Resistant (Solubilized) Starch (g/100 g sample):

$= \Delta E \times F \times 100/0.1 \times 1/1000 \times 100/W \times 162/180$

$= \Delta E \times F/W \times 90.$

ΔE = absorbance (reaction) read against the reagent blank.

F = conversion from absorbance to micrograms (the absorbance obtained for 100 μg of D-glucose in the GOPOD reaction is determined, and F = 100 (μg of D-glucose) divided by the GOPOD absorbance for this 100 μg of D-glucose.

100/0.1 = volume correction (0.1 mL taken from 100 mL).

1/1000 = conversion from micrograms to milligrams.

W = dry weight of sample analyzed = “as is” weight x [(100-moisture content)/100].

100/W = factor to present RS as a percentage of sample weight.

162/180 = factor to convert from free D-glucose, as determined, to anhydro-D-glucose as occurs in starch.

10.3/0.1 = volume correction (0.1 mL taken from 10.3 mL) for samples containing 0-10% RS

3.7 Mineral Analysis

Calcium, iron, magnesium, and zinc were analyzed in this study following AOAC Official Method 999.11 (AOAC 2005) for sample and standard preparation. Atomic absorption spectrometer model, SpectrAA 55 series (Agilent Technologies, Santa Clara, CA, U.S.A.) was used to analyze Ca, Fe, Mg, and Zn. Approximately 0.5g of porridge samples were digested for 90 min with 2 mL of H_2O_2 and 8 mL of nitric acid in a Microwave extraction unit. Digested samples were diluted to 25 mL with deionize water. For Ca and Mg, 5 mL of diluted digests were further diluted to 20 mL for final absorbance readings. Ca, Fe, Mg, and Zn standards were prepared from calcium carbonate, iron metal, magnesium wire, and zinc metal strips, respectively. For each mineral, working standards (Appendix B) were prepared from the 1000 µg/mL stock solutions. Lanthanum standard solution was added to calcium and magnesium standards, to minimize matrix interferences. The working conditions for each mineral are represented in Table 3.3. Pressure was provided in the atomic absorption spectrophotometer using air acetylene.

Table 3.3: Variable and fixed working conditions for calcium, iron, magnesium and zinc

	Wavelength (nm)	Slit Width (nm)	Lamp current (mA)	Optimum Working range (µg/mL)
Calcium	422.7	0.5	10	0.01–3
Iron	248.3	0.2	5	0.06–15
Magnesium	202.6	1.0	4	0.15–20
Zinc	213.9	1.0	5	0.01–2

3.8 Physical properties

3.8.1 Color

Color parameters were measured for banana, rice, bean and BRB composite flours using a Minolta color meter, model CR-400 (Konica Minolta Sensing, Inc., Osaka, Japan). The CIE L*, a*, and b* were read using a D75 light source and the observer angle at 10°. About 25g of flours was placed in a sample cup and color values were recorded as: L* (0, black; 100, white), a* (–a, greenness; +a, redness), and b* (–b, blueness; +b, yellowness). Color values a* and b* values were used to calculate the Chroma and Hue angle according to method of Little (1975):

Chroma = $\sqrt{a^2 + b^2}$

Hue angle (h°) = $\tan^{-1}\left(\frac{b}{a}\right)$

3.8.2 Bulk density

Bulk density (loose) was determined according to the method of Okaka and Potter (1977). A 50-g sample was filled into a 100-mL graduated measuring cylinder. The cylinder was tapped gently several times on a laboratory bench to a constant volume. The results for bulk density were reported as g/mL.

3.8.3 Water absorption and oil absorption capacities (WAC/OAC)

Water and oil absorption capacities were determined by the method of Mason and Hoseney, (1969). Two grams of flour were mixed with 20 mL distilled water and refined corn oil (for oil absorption capacity) at 30C and centrifuged using Sorval RT 6000B Refrigerated centrifuge, for 15 min. The supernatants were dried in an oven at 130°C for 2 hours. Water and oil absorption was calculated as the increase in weight of the pellet or sediment.

$$\text{WAC or OAC} = \frac{(\text{wt of sediment + centrifuge tube}) - (\text{wt of centrifuge tube})}{\text{wt of original sample}} \text{X } 100$$

3.8.4 Water solubility index

Dried supernatants obtained from the determination of WAI step were weighed to determine the water solubility index of flour using this formula:

$$\text{WSI} = \frac{\text{wt of supernatant + wt of dried supernatant}}{\text{wt of original sample}} \text{X } 100$$

3.9 Sensory evaluation of BRB composite porridge

Out of the 7 BRB composite flour treatments, 4 were selected for porridge preparation and = sensory evaluation. This choice of four flours was to prevent tasting and evaluation fatigue. Sensory evaluation of porridge was carried out at Michigan State University, Department of Food Science and Human Nutrition, Sensory Laboratory.

Thirty-one mothers from 17 countries on the African and Asian continent (DR Congo, Ghana, Kenya, Malawi, Uganda, Tanzania, South Africa, India, Zambia, Zimbabwe, China, Taiwan, Vietnam, Namibia, Pakistan and Sierra Leone) participated in the sensory evaluation. Participants were allowed to read and sign a consent form confirming their acceptance to participate in the sensory evaluation. Only mothers who consented were allowed to evaluate the porridge. Evaluators were compensated with $15 for participation. The Institutional Review Board (IRB) at the Michigan State University approved this study.

An instant porridge was prepared from the banana composite flour in a ratio of 1:3 (1 part of flour to 3 parts of water). Water at 60 °C was mixed with approximately 5 g of flour to form porridges that were served to panelist. Samples were served in transparent plastic cups labeled with random 3-digit numbers- 241, 871, 463 and 973. Panelists were asked to evaluate the porridge for its consistency, flavor, appearance, mouthfeel, sweetness and overall acceptability on a 9-point Hedonic scale (Meilgaard and others 1999): 9=like extremely, 8=like very much, 7 =like moderately, 6 = like slightly, 5 = neither like nor dislike, 4= dislike slightly, 3=moderately, 2= dislike very much and 1= dislike extremely. “Check all that apply” (CATA) technique, containing a list of five attributes and ingredients were utilized to gain more insight into consumer perception of the weaning porridge. Participants were also asked if they would feed any of the porridges to a child less than 5 years. The sensory evaluation questionnaire was prepared using SIMS (vs. 6.0) sensory software (SIMS, Berkely Heights NJ, US).

3.10 Statistical Analysis

One-way analysis of variance (ANOVA) was used to analyze the data, using Statistical Package for Social Sciences (SPSS version 22, International Business Machines, New York, U.S.A.). The sensory data were analyzed by ANOVA using SAS software, version 9.3 (SAS Institute, Inc., Cary, North Carolina, U.S.A.). The separation of means or significant difference comparisons were made by Tukey's HSD and the statistical significance was defined as $p < 0.05$.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Nutritional composition of ingredients

Proximate composition, dietary fiber, raffinose and stachyose content of rice, bean and banana flour are represented in Table 4.1. No significance differences (P>0.05) were observed between the three samples for moisture content. Banana flour recorded the highest ash content. All samples differed significantly (P<0.05) in ash content. Protein content was highest for bean flour and least for banana flour as expected. Banana flour contained relatively high levels of resistant starch, which differed (P<0.05) from amount present in rice and bean flour. Rice and bean flour contain some stachyose and raffinose. Stachyose and raffinose were not detected in banana flour. Bean flour contained highest amounts of the dietary fiber.

Table 4.1: Nutritional composition of Banana, rice and bean flour.

	Banana flour	Rice flour	Bean flour
Moisture (%)	4.59 ± 1.19^{a}	3.65 ± 0.59^{a}	3.76 ± 0.61^{a}
Ash (%)	3.07 ± 0.026^{c}	1.23 ± 0.01^{a}	2.88 ± 0.11^{b}
Fat (%)	1.00 ± 0.01^{c}	2.42 ± 0.17^{a}	1.82 ± 0.96^{b}
Protein (%)	3.76 ± 0.13^{c}	7.87 ± 0.45^{a}	20.15 ± 0.44^{b}
Resistant starch (g/100g)	6.27 ± 0.49^{b}	2.81 ± 1.96^{a}	3.70 ± 0.20^{a}
Raffinose (mg/g)	ND	0.26 ± 0.09^{a}	1.64 ± 0.08^{b}
Stachyose (mg/g)	ND	1.06 ± 0.007^{a}	13.17 ± 0.61^{b}
Dietary fiber (g/100g)	9.54 ± 0.56^{c}	6.60 ± 0.56^{a}	22.82 ± 0.69^{b}

Means ± SD in the same column with same letters are not significantly different (Tukey's HSD test, P>0.05)

ND = Not detected

Apart from water activity, moisture content is one of the important determinants of shelf stability of food products. Lower moisture contents of food are associated with longer shelf life relative to food products containing high levels of moisture. This is because High moisture content support microbial growth especially yeasts and moulds. The moisture contents observed in the present study were significantly lower than values, 8.4 to 13.7, g/100g reported by Asare and others (2004) for rice-cowpea blend and also the maximum CODEX recommendations (15.5 g/100 g) for wheat flour (CODEX, 1985).

Ash is the total amount of inorganic content remaining after the organic carbon components are oxidized upon exposure to high heat treatment in a furnace (550°C). The inorganic material (ash) is referred to as the total mineral composition of a particular sample. Fresh bananas contain high levels of minerals, particularly, potassium, magnesium and phosphorous. This explains the relatively high total ash material in banana flour ($P<0.05$) (Table 4.1).

Lipids are important in children's diet for efficient absorption of fat-soluble vitamins such as vitamin A, which is important for good sight development in infants. Also, essential fatty acids assist in cognitive development in infants, curbing their susceptibility to cognitive impairment in adulthood. Crude fat components of the individual ingredients were generally low as expected for fruits, cereals, and legumes (Table 4.1).

Protein is by far one of the most important nutrients that are required for normal growth and development in children. Legumes are naturally rich in protein, containing about 3 times the protein level in cereals. Proteins reported in literature for red kidney beans flour are generally from 23 to 30 % (Rui and Boye, 2013). The amounts recorded in this study are slightly lower than reported (Table 4.1). The amount of protein reported here for banana (3.76%) and brown rice flour (7.87%) are consistent with those listed by USDA food composition database (USDA, 2016).

Unripe bananas contain resistant starch type 2 (RS2), which decreases significantly with ripening (Akerberg and others 1998). Akerberg and others (1998) reported a resistant starch (RS type 2) content between 31% to 72% total starch. Langkilde and others (2002) and Menezes and others (2011) reported 54% and 48.99% respectively of RS type 2 in raw green banana flour. Semi-ripe bananas were used in this study hence a lower value, 6.27% (Table 4.1) was obtained. This could present potential benefits if this banana flour is used in the formulation of food products for infants; infants and young children require only moderate amount of resistant starch in their diets. This is because diets consisting of high non-digestible starches content leads to low digestible energy density of food products (CODEX 1991). Children consume foods in relatively smaller quantities compared to adults and may require higher energy from a particular meal. Sajilata and others (2002) reported that meals containing about 16.4% resistant starch were associated with higher calcium and iron absorption rates in the gut compared to starches that are completely digested.

Resistant starch levels obtained in this study are similar to results reported by Tovar and others (1990) and Wang and others (2010). They reported a decreasing resistant starch content with cooking. Wang and others (2010) recorded a decrease of RS from 29.37 to 3.59% for cooked red kidney bean whiles Tovar and others (1990) reported 3.3% resistant starch in cooked, freeze-dried and milled red kidney bean flour. This is consistent with 3.70% obtained in this study (Table 4.1), considering that the beans in this study were cooked for 30 minutes and that of Tovar and others (1990) were cooked for 60 to 70 minutes. The resistant starch content of brown rice flour (2.85%) is similar to those obtained by De la Hera and others, (2013) (2.3% to 3.8%) and by Eggum and others (1993) (2% to 3.4%). Egum and others (1993) reported an increased in resistant starch with cooking.

Raffinose and stachyose are naturally abundant in legumes and pulses but lower in cereals and absent in fruits. The general trend obtained for raffinose and stachyose for bean flour in this study, is in congruence with the results obtained by Shimelis and Rakshit (2007). They reported a decrease in raffinose content during soaking and cooking but a relatively high level of stachyose even after cooking. Raffinose content (1.64mg/g) is closer to the value reported by Shimelis and Rakshit (2007) (1.8 mg/g). They, however, showed lower amount of stachyose (4.7 mg/g) compared to 13.17mg/g (Table 4.1). Jangchud and Bunnag (2001) used a synonymous method to the one employed in this study except the beans were boiled for 15 minutes and they obtained raffinose and stachyose values of 5.6mg/g and 17.9mg/g respectively. Compared to values reported in this study, it is apparent a relatively longer cooking time (30 minutes) played a role in lower content of raffinose and stachyose.

Shanmugavelan and others (2013) reported an average raffinose content of 0.29 g/100g for cereals in general and 0.16 g/100g for brown-black rice. Overall, no values have been reported in literature for raw or processed brown rice and bananas. The current study presents 0.26mg/g and 1.06 mg/g of raffinose and stachyose, respectively, for rice flour. The predominant type of oligosaccharide in bananas is fructooligosaccharides; they have not been shown to contain galactooligosaccharides including raffinose and stachyose (Mussatto and Mancilha 2007). No raffinose and stachyose was detected in bananas for this study. However, we observed pseudo peaks for banana flour. The chromatograms for raffinose and stachyose for the three flours are listed in appendix C.

Bean flour contained the highest total dietary fiber (TDF) content (22.82g/100g). Tosh and Yada (2010) documented TDF levels from 23 g/100g to 32 g/100g for all types of raw kidney beans seeds. Wang and others (2010) reported that cooking increases dietary fiber content; they showed an increase in dietary fiber from 19.97 g/100g to 24.56 g/100g for 80% cooked dark red kidney beans flour. The TDF content in this study is consistent with values stated in the two studies above. The slightly lower levels could also be linked to the fact that kidney beans used were dehulled to some extent; dehulling reduces fiber content (CODEX 1991). The amount of TDF in brown rice flour was 6.6g/100g. The USDA Food database composition indicated a 4.6g/100g TDF content for raw brown rice flour. Additionally, Lee and others (1988) reported 4.91 g/100g to 7.34 g/100g for different varieties of brown rice. The TDF for banana flour was 9.54 g/100g, which is similar to those stated by USDA food composition database (9.9g/100g). TDF values of 7.6 g/100g for fully ripe bananas and 6 g/100g to 15.5 g/100g for varieties of green bananas are also well documented in literature (Da Mota and others 2000; Aurore and others 2009)

4.2 Proximate composition of BRB composite flours

Proximate composition of the seven different composite flours prepared from rice, bean, and banana flours is represented in Table 4.2. Significant differences ($P<0.05$) existed between most BRB (banana-rice-bean) composite flours for all proximate composition except for moisture content ($P>0.05$). Essentially, all nutrients seem to be a direct reflection of the amount shown by the various ingredients (rice, beans, and banana flour) in Table 4.1. This could be an indication of minimal interaction effect between the three flours at the levels used in the present study.

For instance, Trt-1 containing the most banana flour (80%) showed percentage ash of 3.05% (Table 4.2) Similarly, sample Trt-5 made of highest bean flour percentage (25%) gave protein content of (8.53%). The highest MC (4.42%) is about two times less than codex standard for flour (8%). This could be a good indicator of potential shelf stability of all composites. Protein composition of composite flours (5.70% to 8.52%) is identical to the ones shown by similar composite flour produced by Twum and others (2015) using soybean flour "5.46% to 8.95%" (Table 4.2). It must, however, be acknowledged that the composite ratios and ingredients used in formulation of products in the two study are totally different. No significance difference existed between Trt-1 and Trt-3; both flours had bean flour content maintained at 10% and different rice and banana flour percentages. Trt-5 and Trt-6 showed no significance difference ($p > 0.05$) for protein and ash (Table 4.2).

Nutritionally, all flours contained recommended levels of protein since the total amount of protein needed from complementary foods to meet daily protein needs per day for older infants and young children, ranged from 2g for 6-8months old infants and 5 to 6g for infants who are 12-23 months old (Dewey and Adu-Afarwuah 2008). Percentage lipids at levels reported in this study seem too low (Table 4.2) to meet daily lipid needs for infants and older infants. However, it is noted that porridge or similar foods are not considered a typical source of fat in the diets of young children. The amount of lipid required from complementary foods is approximate "3 g day-1 at 9–11 months and 9–13 g day-1 at 12–23 months" (Dewey and Adu-

Afarwuah 2008). It may be necessary to accompany food prepared from these flours with other foods containing lipids particularly those with essential fatty acids. Such sources include fish, egg, liver, nut pastes and vegetable oils (Dewey and Adu-Afarwuah 2008).

Table 4.2: Proximate composition of BRB composite flours.

Treatments	Moisture (%)	Ash (%)	Fat (%)	Protein (%)
Trt-1	4.41 ± 0.94^{a}	3.05 ± 0.31^{c}	1.23 ± 0.07^{a}	5.70 ± 0.10^{a}
Trt-2	4.42 ± 0.96^{a}	2.77 ± 0.07^{bc}	1.35 ± 0.05^{ab}	7.29 ± 0.16^{bc}
Trt-3	4.16 ± 0.97^{a}	2.81 ± 0.32^{bc}	1.42 ± 0.07^{bc}	6.15 ± 0.17^{a}
Trt-4	4.17 ± 0.99^{a}	2.49 ± 0.15^{ab}	1.52 ± 0.07^{cd}	5.83 ± 1.28^{ab}
Trt-5	4.12 ± 1.10^{a}	2.59 ± 0.18^{ab}	1.52 ± 0.06^{cd}	8.52 ± 0.21^{d}
Trt-6	4.04 ± 0.85^{a}	2.29 ± 0.02^{a}	1.62 ± 0.08^{de}	8.13 ± 0.22^{cd}
Trt-7	4.18 ± 1.15^{a}	2.25 ± 0.16^{a}	1.73 ± 0.09^{e}	7.77 ± 0.24^{cd}

Treatments had banana, rice and bean ratios, respectively, as follows: Trt-1=80:10:10, Trt-2=70:10:20, Trt-3=70:20:10, Trt-4= 0:25:15, Trt-5=55:20:25, Trt-6=50:30:20, and Trt-7=45:40:15.
Means ± SD in the same column with same letters are not significantly different (Tukey's HSD test, $P>0.05$)

4.3 Non-digestible carbohydrates of BRB composite flours

Data for resistant starch (RS), total dietary fiber (TDF), raffinose and stachyose for BRB treatments are presented in Table 4.3. Numerically, values of all nutritional components represented the original amount present in rice, bean and banana flour with respect to the percentage used in the BRB (banana-rice-bean) composite flours. Statistically, however, RS, and TDF components were not different for all BRB composite flour treatments ($P> 0.05$). Some differences ($P<0.05$) were observed in Stachyose and raffinose levels. Trt-5 containing the most beans content showed the highest raffinose and stachyose.

There are no specific dietary guidelines for the amount of non-digestible carbohydrates (NDC), such as raffinose, stachyose and resistant starch that should be present in the diet of children in The lack of solid regulations of NDCs (encompasses components represented in table 3) is probably due to the well-established physiological roles of NDCs in the human gut. NDCs provide prebiotic effects in children (Vandenplas 2002; Agget and others 2003). Some oligosaccharides including galactooligosaccharides are occasionally added to commercial complementary foods as prebiotics (Agget and others 2003; Vandenplas 2002). Some studies also suggest a link between absorption of certain micronutrients with diets high in NDCs (Agget and others 2003).

Regardless, only moderate amounts of NDCs are needed in young children because the lack or over consumption of NDCs can cause certain adverse effects such as diarrhea and difficulty emptying the bowel in young children (Agget and others 2003). The use of rice and rice products in infant food were associated with reduction in regurgitation.

The American Academy of Pediatrics recommends 0.5 g/kg dietary fiber per body weight (Agget and others 2003) and CODEX recommends 5% TDF on dry basis in complementary foods. Total dietary fiber content of BRB composite flours exceeds Codex standards for complementary foods (CODEX 1991). It may be very important to use fully dehulled beans in flour formulation to help reduce the dietary fiber content (CODEX 1991).

RS content suggested that approximately 90.9 to 93.6 g/100g of starch present in BRB composite flour is digestible. This was evident in the high sucrose, fructose and glucose levels recorded for banana, rice and bean flour (Appendix C).

Table 4.3: Resistant starch, total dietary fiber, raffinose and stachyose content of BRB composite flours

Treatments	Resistant starch (g/100g)	Total dietary fiber (g/100g)	Raffinose (mg/g)	Stachyose (mg/g)
Trt-1	9.21 ± 2.2[a]	10.35 ± 0.87[a]	0.19 ± 0.08[a]	3.53± 0.17[a]
Trt-2	8.17 ± 1.18[a]	11.60 ± 0.79[a]	0.35 ± 0.07[b]	4.62± 0.71[ab]
Trt-3	8.13 ± 3.35[a]	10.1 ± 0.73[a]	0.22 ± 0.06[ab]	3.49± 0.24[a]
Trt-4	7.17 ± 1.84[a]	10.64 ± 0.65[a]	0.31 ± 0.10[b]	3.99± 1.03[ab]
Trt-5	6.71 ± 1.30[a]	11.82 ± 0.42[a]	0.46 ± 0.09[c]	6.27± 0.40[c]
Trt-6	6.99 ± 1.63[a]	11.11 ± 0.33[a]	0.41 ± 0.07[c]	4.92± 0.43[b]
Trt-7	6.38 ± 1.40[a]	10.63 ± 0.01[a]	0.35 ± 0.09[b]	3.95± 0.37[ab]

Treatments had banana, rice and bean ratios, respectively, as follows: Trt-1=80:10:10, Trt-2=70:10:20, Trt-3=70:20:10, Trt-4= 0:25:15, Trt-5=55:20:25, Trt-6=50:30:20, and Trt-7=45:40:15.
Means ± SD in the same column with same letters are not significantly different (Tukey's HSD test, P>0.05)

4.4 Mineral Composition

The amount of calcium, iron, magnesium and zinc in banana, rice and bean flour, and banana flour are shown in Table 4.4. Bean flour showed high levels of calcium, iron, magnesium and zinc. All three flours differed significantly (P<0.05) in mineral contents. The calcium, iron, magnesium and zinc contents for bean flour were closer to the values reported by Wang and others (2010) and Barampama and Simard (1995) for kidney beans. Wang and others (2010) reported 78 Ca, 5.37 Fe, 153 Mg and 3.04 Zn mg/100g dry basis. Barampama and Simard (1995) obtained 145 mg/100g for iron, 2.76 mg/100g for zinc and 145 mg/100g for magnesium.

Mineral content obtained were similar to the amounts found by Gregorio and others (2000); Heinemann and others (2005) for different varieties of brown rice.

Amounts of calcium, iron, magnesium found in banana flour (20.61, 1.11, 101.95 and 0.66, mg/100g respectively) are comparable to results acquired by Haslinda and others (2009). They obtained 28.9 Ca, 1.73 Fe, 105.34 Mg and 0.74 Zn, mg/100g respectively on a dry basis for green banana flour.

Table 4.4: Calcium, iron, magnesium and zinc levels (mg/100g) of banana, rice and bean flour

	Banana flour	Rice flour	Bean flour
Calcium	20.61 ± 0.8[a]	10.61 ±0.41[b]	69.71 ± 0.78[c]
Iron	1.11 ± 0.08[a]	1.19 ± 0.13[b]	7.27 ± 0.27[c]
Magnesium	101.95 ± 0.98[a]	109.12 ±2.73[b]	131.23 ± 1.18[c]
Zinc	0.66 ± 0.03[a]	2.04 ± 0.05[b]	2.29 ± 0.04[c]

Means ± SD in the same row with same superscripts are not significantly different (Tukey's HSD test, P>0.05)

The amount of calcium, iron, magnesium and zinc in BRB composite flours treatments are presented in Table 4.5. Mineral content differed significantly (P<0.05) among treatments. The highest iron and magnesium levels (2.83 and 111.61, mg/100g) respectively obtained in this study were generally higher than the largest (0.59 Fe and 12.6 Mg, mg/100g) value recorded by Twum and others (2015) for maize-soybean composite flour. However, they reported 2.34 mg/100g of zinc, whereas the present study recorded 1.44 mg/100g (Table 4.5).

Recommended daily nutrient intake (RDI) for infants and children aged 6 months to 23 months by the WHO (2002) standards for calcium, iron, magnesium and zinc are 400mg to 500mg, 5.8 mg to 9.3mg, 54mg to 60 mg and 2.8 mg to 4.1mg per day respectively. CODEX also recommends that 50 to 75% of RDI of individual nutrients come from complementary foods (CODEX 1991; Dewey 2008). Based on bioavailability, RDI for iron and zinc are recommended as follows; iron (mg): 11.6, 5.8 and 3.9 for 5%, 10 % and 15% dietary iron bioavailability respectively. Zinc (mg): 8.3, 4.1 and 2.4 for low, medium and high dietary zinc bioavailability respectively (CODEX 1991).

Considering these standards and other factors such as portion size consumed, the frequency of feeding, and other diets that are consumed by infants, all composites could minimally meet most of the daily nutritional requirements for this demographic except for calcium requirements. It would therefore be necessary to incorporate dairy-based diets as part of foods given to infants to help meet their daily needs of calcium.

Table 4.5: Calcium, iron, magnesium and zinc levels in BRB composite flour

Treatments	Calcium (mg/100g)	Iron (mg/100g)	Magnesium (mg/100g)	Zinc (mg/100g)
Trt-1	24.56± 0.68a^{b}	1.78± 0.08^{a}	105.82± 0.97^{a}	0.95± 0.03^{a}
Trt-2	29.34± 0.42^{d}	2.45± 0.08^{bc}	108.48± 1.00^{abc}	1.14± 0.03^{b}
Trt-3	23.72± 1.19^{a}	2.24± 0.19^{b}	105.40± 3.24^{a}	1.10± 0.06^{b}
Trt-4	25.82± 0.48^{bc}	2.28± 0.08^{b}	108.38± 0.60^{abc}	1.26± 0.03^{c}
Trt-5	30.81± 0.49^{d}	2.83± 0.10^{d}	111.61± 0.38^{c}	1.33± 0.05^{cd}
Trt-6	26.63± 1.08^{c}	2.58± 0.14^{cd}	110.23± 0.96^{b}	1.41± 0.03^{de}
Trt-7	24.14± 0.48$_{ab}$	2.33± 0.10^{bc}	108.12± 1.10^{ab}	1.44± 0.17^{e}

Treatments had banana, rice and bean ratios, respectively, as follows: Trt-1=80:10:10, Trt-2=70:10:20, Trt-3=70:20:10, Trt-4= 0:25:15, Trt-5=55:20:25, Trt-6=50:30:20, and Trt-7=45:40:15.
Means ± SD in the same column with same letters are not significantly different (Tukey's HSD test, P>0.05)

4.5 Physical properties

Table 4.6 represents data for color parameters, L*, a* and b* values. Color is an important parameter in food products, particularly pertaining to aesthetics attributes of food products and consumer preference. L* value indicates the degree of lightness (whiteness), a* values represents green to red and b* value, blue to yellow. The highest L value was expressed in rice flour followed by bean flour and then banana flour. Banana flour differed significantly ($P<0.05$) from rice and bean flour, which did not differ from each other ($P>0.05$); this same trend was shown for a* values. All fours differed significantly ($P< 0.05$) in b* parameter. Banana flour had the highest a value (3.05) followed by bean flour (1.67) and lastly rice flour (0.36). Bean flour showed the least degree of yellowness (b*= 8.51). Banana flour showed the highest b* value.

Table 4.6: Color parameters L*, a*, b*, values and Chroma and Hue angle of banana, rice and bean flour

	L	a	b	Chroma	Hue angle
Banana flour	76.89 ± 2.49^{b}	3.05 ± 0.47^{c}	15.19 ± 1.61^{b}	15.5 ± 1.66^{b}	1.37 ± 0.00^{b}
Rice flour	82.77 ± 0.2^{a}	0.36 ± 0.19^{a}	9.82 ± 0.63^{a}	9.82 ± 0.62^{a}	1.53 ± 0.02^{a}
Bean flour	82.63 ± 0.17^{a}	1.67 ± 0.06^{b}	8.51 ± 0.27^{a}	8.67 ± 0.25^{a}	1.38 ± 0.01^{b}

Means ± SD in the same row with same superscripts are not significantly different (Tukey's HSD test, $P>0.05$)

The light red kidney beans used in this research lost most of its color after soaking. The high degree of lightness could also be attributed to the fact that about 70% of the seed coats were removed before milling. Wani and others (2013) reported an L* value of 81.6, a* = 1.3 and b *=7.9 for raw red kidney bean flour. Lambert and others (2006) showed an L* value of 85, a* = 1 and b value of 13 for raw brown rice flour. L* a* and b* values are lower than reported above (82.77, 0.36 and 9.82 respectively). Differences in physical attributes between cooked and uncooked rice could be a major factor. L* parameters reported here were slightly higher whiles b values are lower (L* =76.89 and b =15.19) than those presented by Rakshit (2011) for fully ripe banana flour (L*= 68.29 and b =21.6). The difference is apparently due to the use of more green than ripe bananas in formulating the flour. Chroma color parameter is an indicator of the richness of color or degree of color intensity. Banana flour seems richer in color than rice and bean flours ($P<0.05$). Hue angle which basically indicates how a sample appear to the human eye suggest that rice flour appeared differently ($P<0.05$) from bean and banana flour.

Data for density, water absorption index (WAI), water solubility index (WSI), and oil absorption capacity (OAC) are represented in table 4.7. Bulk density is the mass per unit volume of occupied by a sample. Bulk density influences packaging and transportation decisions in the food industry. Bulk density differed for all three flours ($P<0.05$). Moongngarm and others (2014) showed 0.6 to 0.67 g/mL for varieties of brown rice flour, Wani and others (2013) reported 0.88mg/mL for raw kidney bean flour; Zakpa and others (2010) reported 0.76 g/mL for ripe plantain.

Table 4.7: Density, water solubility, and water and oil absorption properties rice, beans and banana flour.

	Bulk density (g/mL)	WAC (g/g)	WSI (%)	OAC (g/g)
Banana flour	0.85 ± 0.02^{a}	3.03 ± 0.64^{a}	24.65 ± 0.11^{a}	1.82 ± 0.04^{a}
Rice flour	0.708 ± 0.03^{b}	4.75 ± 0.22^{b}	1.1 ± 0.0^{b}	1.67 ± 0.04^{b}
Bean flour	0.76 ± 0.002^{c}	3.80 ± 0.01^{c}	10.22 ± 0.01^{b}	1.65 ± 0.03^{b}

Means ± SD in the same row with same superscripts are not significantly different (Tukey's HSD test, $P>0.05$)

Water absorption index or water absorption capacity and oil absorption capacity is the amount of water or oil respectively, that is held per gram of flour or protein. Rice flour, with least moisture content exhibited the highest water holding capacity followed by bean flour and for banana flour (Table 4.7). This trend is contrary to the linear relationship between protein concentration and water absorption capacity (Rui and Boye 2013).

For oil absorption capacity (OAC), banana flour showed the highest value and differed significantly to OAC of beans and rice flour did not differ from each other (P>0.05) (Table 4.7). Siddiq and others (2010) obtained WAI and OAC of 2.25 and 1.52 respectively for red kidney bean flour, which is similar to values obtain in the current study. WAI and OAC reported by Becker and others (2014) for varieties of brown rice flour were 2.85 g/g to and 1.81 to 2.03 g/g respectively. Gamlath (2008) indicated WAI for extruded banana flour at 5.68 g/g. Even though the above values we obtained for rice and banana flour differed from what is reported here, the disparities are not extreme.

Water solubility index is linked to degree of dextrinization and gelatinization and consequent starch solubility. It is a reflection of the amount of starch granules that underwent disruption during processing (Nyombaire and others 2011). Rice is a relatively rich source of starch compared to beans and semi-ripe bananas. The WSI value for rice flour is an indication of high degree of intact starch granules hence least water solubility (Table 4.7). Banana flour was relatively more soluble (24.65%) but slightly higher than those found (23.35%) by Gamlath (2008) for extruded banana flour.

L*, a*, b* Chroma, and Hue color parameters for composite flours are presented in Table 4.8. L* values ranged from 76.74 obtained for Trt-1 to 79.85 for Trt-6. Lower L* values would be a negative indicator of quality due to enzymatic browning of bananas. Values for a* parameter ranged from 1.99 for Trt-6 to 2.91 for Trt-1. b* values ranged from 12.92 to 14.72.

No differences in b* values (p>0.05) were observed among treatments. Significant differences existed for among treatments for L* and a* values. Asare and others (2004) showed L* values ranging from 79.07 to 91.21 for extruded rice-cowpea-groundnut blend. All BRB composite flours showed the same (P>0.05) degree of intensity indicated by chroma values (Table 4.1). Results obtained for Hue angle showed that, with the exception of Trt-6 and Trt-7, the other porridge samples did not differ in appearance.

Table 4.8: Color parameters L*, a*, b*, values and Chroma and Hue angle of BRB composite flour

Treatments	L*	a*	b*	Chroma	Hue angle
Trt-1	76.74 ± 1.69^{a}	2.91 ± 0.06^{c}	14.72± 1.03^{a}	15.02 ±0.99^{a}	1.375 ± 0.02^{a}
Trt-2	77.31 ± 1.05^{ab}	2.72 ± 0.05^{c}	13.89 ±0.67^{a}	14.15 ± 0.64^{a}	1.377 ± 0.01^{a}
Trt-3	77.13 ± 1.04^{ab}	2.66 ± 0.11^{c}	13.81 ± 0.86^{a}	14.07 ± 0.82^{a}	1.379 ± 0.02^{a}
Trt-4	78.94 ± 0.75^{bc}	2.30 ± 0.08^{b}	13.83 ±1.67^{a}	14.02 ± 1.66^{a}	1.404 ± 0.01^{ab}
Trt-5	77.67 ± 0.46^{ab}	2.65 ± 0.25^{c}	13.28 ±0.32^{a}	13.54 ± 0.26^{a}	1.373 ± 0.02^{a}
Trt-6	79.85 ± 0.75^{c}	1.99 ± 0.25^{a}	13.12 ±1.77^{a}	13.27 ± 1.78^{a}	1.420 ± 0.00^{b}
Trt-7	78.97 ± 0.40^{bc}	2.00 ±0.06^{a}	12.92 ± 0.88^{a}	13.07 ±0.87^{a}	1.417 ± 0.00^{b}

Treatments had banana, rice and bean ratios, respectively, as follows: Trt-1=80:10:10, Trt-2=70:10:20, Trt-3=70:20:10, Trt-4= 0:25:15, Trt-5=55:20:25, Trt-6=50:30:20, and Trt-7=45:40:15.
Means ± SD in the same column with same letters are not significantly different (Tukey's HSD test, P>0.05)

Results for density, Water absorption index (WAI), oil absorption capacity (OAC) and water solubility index (WSI) are presented in table 4.9. The highest WSI was obtained for Trt-1 (28.41%) and the least (17%) for Trt-7. The WSI obtained for composite flours appear to be affected by amount of banana and rice flour used in formulation. Trt-1 formulated with the highest banana content was the most soluble whiles Trt-7 containing highest amount of rice flour showed the least degree of solubility (Table 4.9). In exception of WSI, there were no differences (P>0.05) between all BRB composite flours with regards to density, WAC and OAC.

The densities (0.78 to 0.82, mg/mL) obtained for BRB porridges fell within the range (0.295 to 1.541, g/mL) reported by Asare and others, (2004) for extruded rice-cowpea-groundnut. It is expected that extruded flours would be lighter in terms of density, compared to those processed by other methods (CODEX 1991).

Table 4.9: Density, water and oil absorption and water solubility properties of BRB composite flours

Treatments	Density	WAI	OAC	WSI (%)
Trt-1	0.82 ± 0.009^{a}	2.79 ±0.23^{a}	1.76 ± 0.04^{a}	28.41 ± 0.06^{b}
Trt-2	0.82 ± 0.014^{a}	2.87 ± 0.16^{a}	1.71 ± 0.06^{a}	26.12 ± 0.02^{ab}
Trt-3	0.81 ±0.034^{a}	3.02 ± 0.19^{a}	1.77 ± 0.05^{a}	24.01 ± 0.05^{ab}
Trt-4	0.78 ± 0.035^{a}	3.03 ± 0.21^{a}	1.75 ± 0.01^{a}	23.29 ± 0.04^{ab}
Trt-5	0.80± 0.007^{a}	2.98 ± 0.21^{a}	1.76 ± 0.03^{a}	22.66 ± 0.05a^{b}
Trt-6	0.81 ± 0.001^{a}	3.10 ± 0.32^{a}	1.75 ± 0.02^{a}	19.84 ± 0.37^{ab}
Trt-7	0.78 ± 0.037^{a}	3.03 ± 0.77^{a}	1.74 ± 0.03^{a}	17.00 ± 0.03^{a}

Treatments had banana, rice and bean ratios, respectively, as follows: Trt-1=80:10:10, Trt-2=70:10:20, Trt-3=70:20:10, Trt-4= 0:25:15, Trt-5=55:20:25, Trt-6=50:30:20, and Trt-7=45:40:15.
Means ± SD of treatments in the same column with same superscripts letters are not significantly different (P>0.05).

4.6 Sensory Evaluation and consumer acceptability

The results of sensory attributes (appearance, consistency, mouthfeel, sweetness and overall acceptability) of four BRB porridges are shown in Figure 4.1. Apart from sweetness attribute, no differences were observed in panelist ratings between porridge samples for all attributes and overall acceptability. Sweetness scores suggested a higher liking of samples with increasing banana content; Trt-1 & Trt-2 differed from Trt-5 (P< 0.05). All porridges were acceptable based sensory scores of 6.5 to 7.1 on a 9-point Hedonic scale. Out of 31 panelists 29 of them agreed they would feed any of the porridges to a child below 5 years.

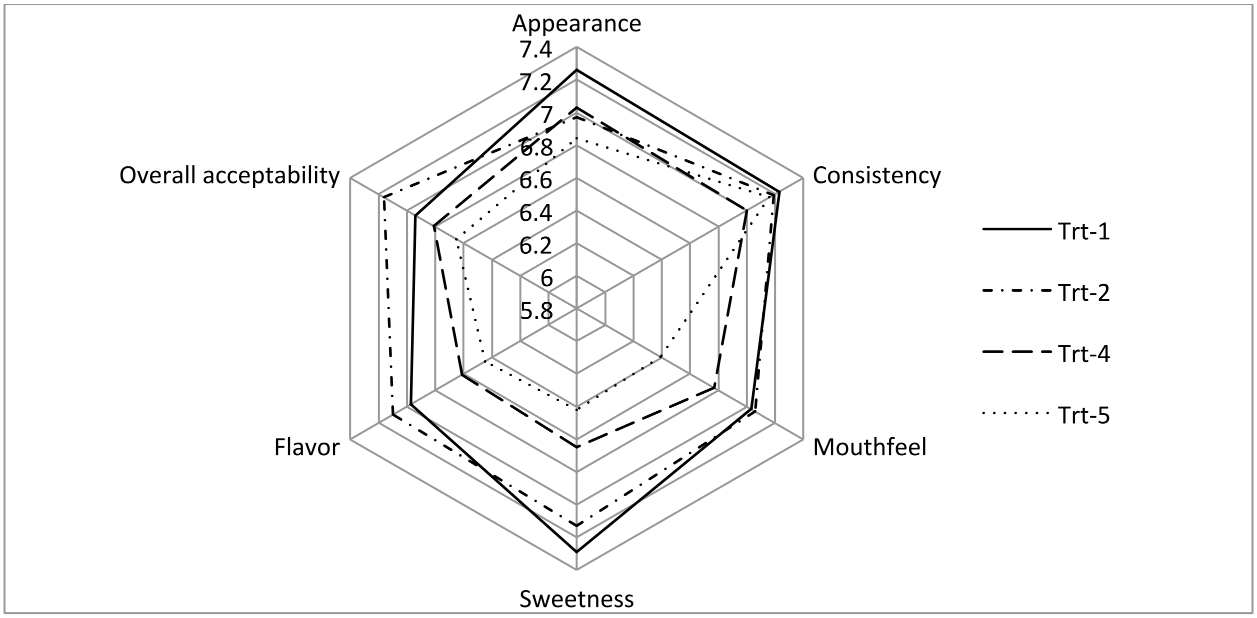


Figure 4.1: Sensory attributes and overall acceptability of BRB porridge

Treatments had banana, rice and bean ratios, respectively, as follows: Trt-1=80:10:10, Trt-2=70:10:20, Trt-4= 0:25:15, Trt-5=55:20:25.

The percentage of mothers on the hedonic scale regarding overall acceptability is presented in figure 4.2. Consumer taste preferences are one of the most complicated aspects of sensory chemistry, due to great disparities in taste preferences. It is however well noted that the demographic used for the sensory evaluation are from 17 different countries. The wide range of taste preferences was evident in the overall liking for each of the porridges. Most mothers, 41.9% liked Trt-1 very much, but Trt-1 also seemed to be the highest on "dislike slightly" and "dislike moderately" scale (6.5%). Surprisingly, the second highest porridge on the "like very much" scale (liked by 32.3% panelists) was Trt-5. This confirmed the complexity and unpredictability of consumer preferences. Regardless, there was a decent overall acceptability of all porridges.

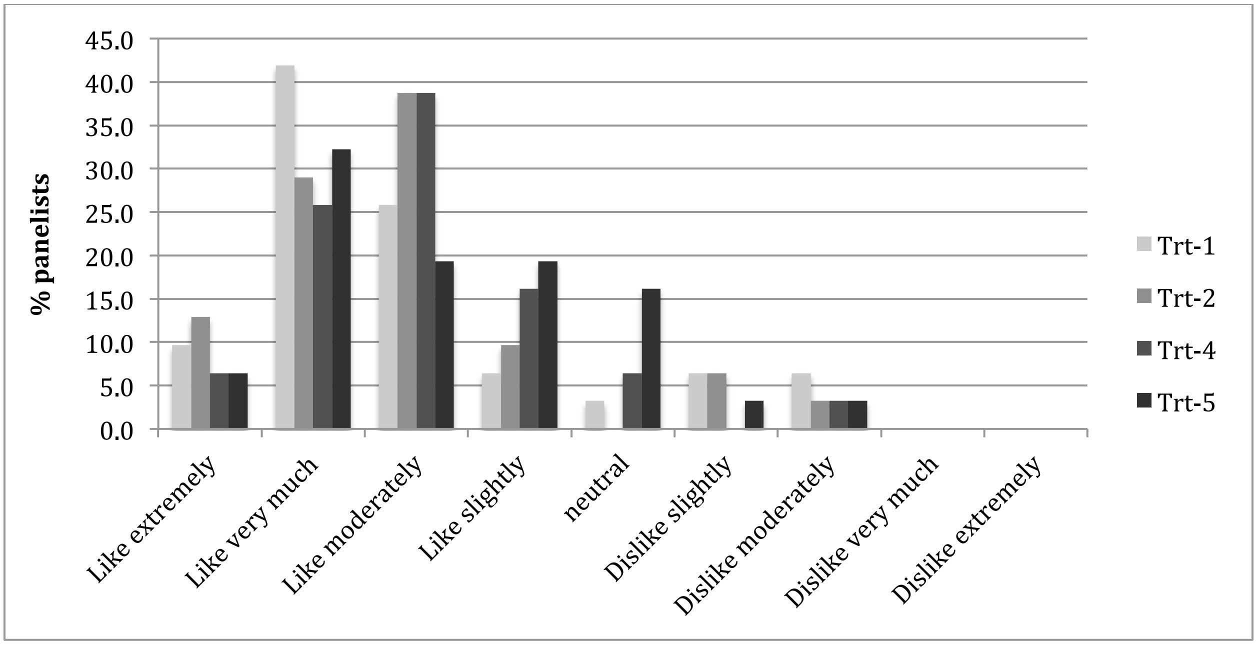


Figure 4.2: Percent panelist distribution of overall acceptability of BRB porridge

Treatments had banana, rice and bean ratios, respectively, as follows: Trt-1=80:10:10, Trt-2=70:10:20, Trt-4= 0:25:15, Trt-5=55:20:25.

Figure 4.3 represent percentage distribution of description of attributes by panelist for BRB composite porridge samples; Panelists were asked to "check all that apply" (CATA). There were distinctions and some trends between samples for some attributes such as flavorful, bland, beany and raw. The percentage of panelists, who selected flavorful, decreased with decreasing banana flour content; this same trend in reverse was recorded for "bland" attribute. "Traditional" description of samples was higher for higher rice plus bean flour content combined (Figure 4.3). There were differences (P<0.05) between porridge samples for: "flavorful", "sweet" and traditional attributes.

Approximately 15% of the mothers perceived beany flavor in Trt-2 and Trt-5. Most of the mothers who selected beany and "raw" attributes chose the composite flours with the highest percentage of bean flour (20% and 25%). This suggests a feeling of "rawness" with increasing bean flour content. However, no differences were observed between samples for panelists who described the porridge samples as "beany" and "raw". At 10% bean flour, it appears panelists' perception of "beany" flavor and rawness of porridge, only one panelist perceived beany "flavor" and "rawness".

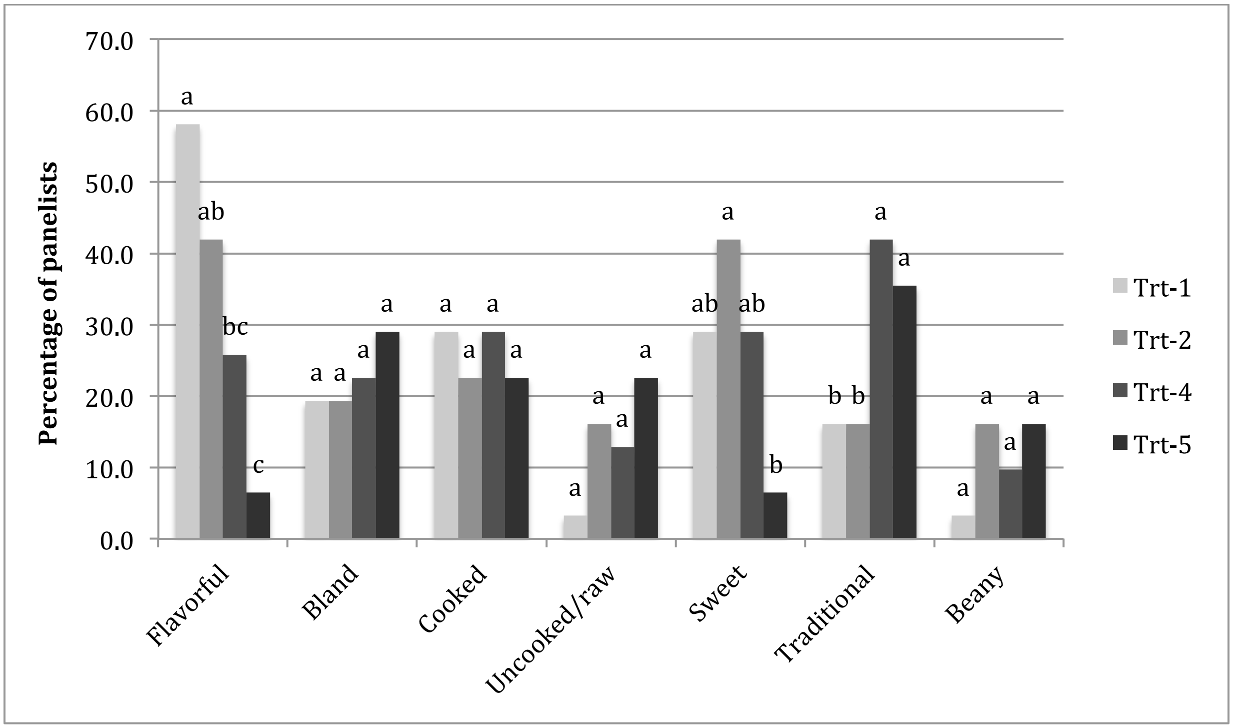


Figure 4.3: Check all that apply (CATA) attributes of BRB porridge

Treatments had banana, rice and bean ratios, respectively, as follows: Trt-1=80:10:10, Trt-2=70:10:20, Trt-4= 0:25:15, Trt-5=55:20:25.
The same letters on bars are not significantly different (P>0.05)

Result for "Check All That Apply" (CATA) ingredients is shown in Figure 4.4. Banana was the most perceived ingredient. Banana has a naturally strong and overwhelming flavor, which increases with the degree of ripeness. The perception and distinction of banana flavor as dehydrated flour in composites could suggest minimal flavor loss during the air-drying process. Mothers also perceived bean and rice; these ingredients including banana were listed in the consent forms that were signed by participants. Differences existed between samples for banana, bean and corn perception by panelists.

Other ingredients and flavors indicated were corn, carrot, wheat and citrus. The number of panelists who perceived corn and wheat were relatively higher compared to the number who perceived carrot and citrus; only one person perceived carrot. The percentage of panelists perception of citrus decreased with decreasing banana component, which could be due to the presence of about 7 mg ascorbic acid in banana flour (USDA 2016). Recognition of wheat, corn and carrot could be linked to flavor and ingredient interaction, producing a different sensory effect or it could be just as a result of misperception by some panelists.

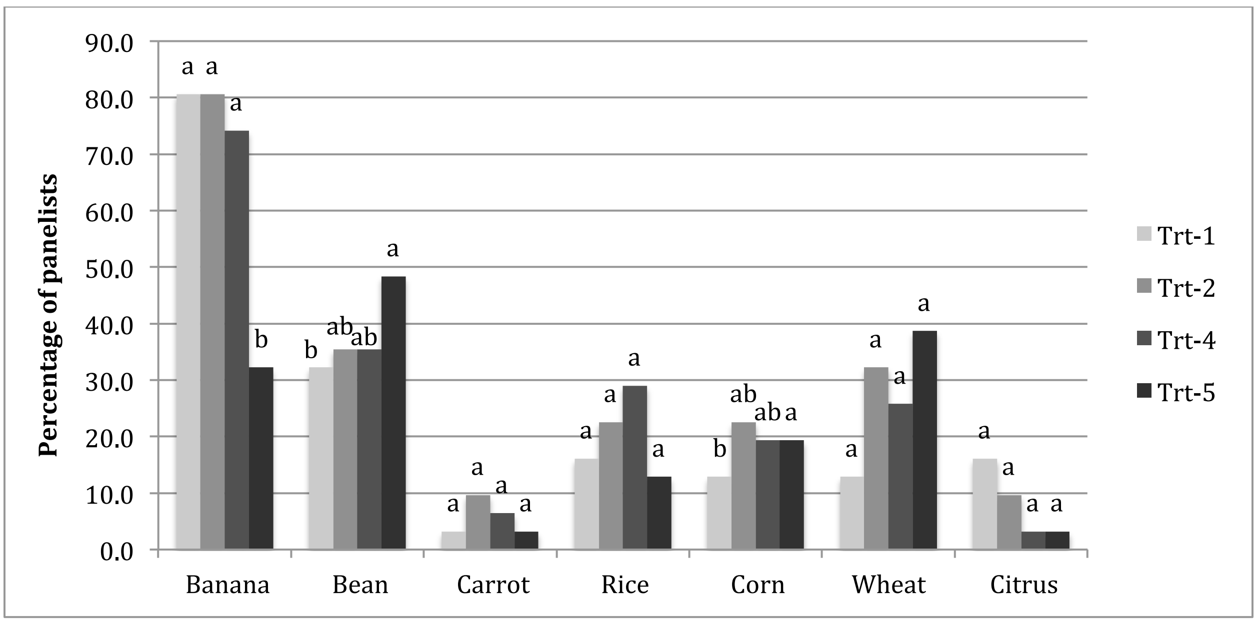


Figure 4.4: Check all that apply (CATA) ingredients of BRB porridge

Treatments had banana, rice and bean ratios, respectively, as follows: Trt-1=80:10:10, Trt-2=70:10:20, Trt-4= 0:25:15, Trt-5=55:20:25.
Bars sharing the same letter within attributes are not significantly different (p>0.05)

CHAPTER 5

OUTCOMES and RECOMMENDATIONS

5.1 Conclusion

All BRB composite flour contained significant levels of protein. Flatulence-causing oligosaccharides were lower in BRB flour than in cooked bean flour and the amounts of non-energy contributing resistant starch was less than 10%. Dietary fiber levels exceeded Codex Alimentarius recommendations for complementary foods. Banana flour had a positive impact on Sweetness and "flavorful" attribute of BRB porridge and could be added to traditional cereal-legume blends to improve flavor and sweetness, which could ultimately lead to avoidance of added sugars to traditional infant foods. Instant porridges prepared from selected BRB composite flours were all of acceptable quality by 31 mothers of Africa and Asia origin. Twenty-nine mothers indicated that they would feed at least one of the porridges to a child below 5 years of age. BRB porridge could be incorporated as part of children's diet to help alleviate protein energy malnutrition.

5.2 Recommendations

It is important to accompany diets containing cereal-legume blends with foods coming from animal sources in order to improve zinc and iron contents to ensure adequacy of these nutrients for infants. Additionally, fortification of cereal-legume blends with limiting but essential minerals is important to meet daily nutritional requirements. Also, fruits and vegetables containing high levels of vitamin C could be added to diets given to infants to help improve absorption of soluble non-heme iron, which is the main component in most traditional infant diets. Antinutritional factors should be determined to know the extent of bioavailability of zinc and iron in cereal-legume blends made for children, such as BRB infant food.

APPENDICES

Appendix A: Recommended new dietary reference intake

Table 6.1: Recommended new dietary reference intake (DRI) for children age 6 to 23 months

Nutrient	Recommended Intake		
	6 to 8months	9 to 11 months	12 to 23 months
Protein (g/day)	9.1	9.6	10.9
Vitamin A (µg RE/day)	500	500	300
Folate (µg/day)	80	80	150
Niacin (mg/day)	4	4	6
Pantothenic acid (mg/day)	1.8	1.8	2.0
Riboflavin (mg/day)	0.4	0.4	0.5
Thiamine (mg/day)	0.3	0.3	0.5
Vitamin B6 (mg/day)	0.3	0.3	0.5
Vitamin B12 (µg/day)	0.5	0.5	0.9
Vitamin C (mg/day)	50	50	15
Vitamin D (µg/day)	5	5	5
Vitamin K (µg/day)	2.5	2.5	30
Calcium (mg/day)	270	270	500
Chloride (mg/day)	500	500	800
Copper (mg/day)	0.2	0.2	0.3
Fluoride (µg/day)	0.5	0.5	0.7
Iodine (µg/day)	130	130	90
Iron (mg/day)	11	11	7
Magnesium (mg/day)	75	75	80
Manganese (mg/day)	0.6	0.6	1.2
Phosphorous (mg/day)	275	275	460
Potassium (mg/day)	700	700	800
Selenium (µg/day)	20	20	20
Sodium (mg/day)	320	350	500
Zinc (mg/day)	3	3	3

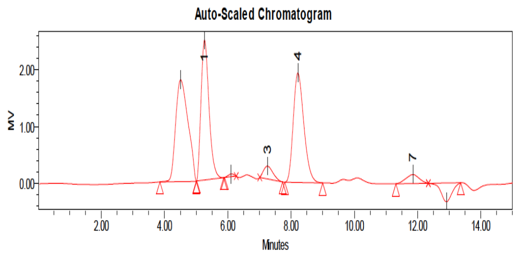
(Adebeyi and others 2016).

Appendix B: Working standard solutions for mineral analysis

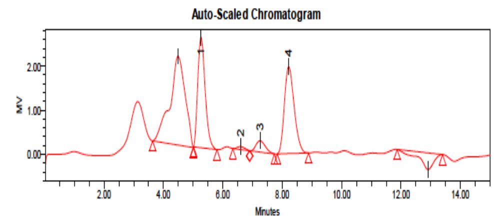
Table 6.2: Concentrations of working standards solutions for calcium, magnesium, iron and zinc

ppm	Stock Vol (mL)	Water (mL)	La (mL)
Calcium			
0	2 mL HNO3	47.5	0.5
1	0.05	49.45	0.5
2	0.1	49.4	0.5
2.5	0.15	49.375	0.5
3	0.2	49.35	0.5
4	0.25	49.3	0.5
Magnesium			
0	2 mL HNO3	47	1
1	0.05	48.95	1
5	0.25	48.75	1
10	0.5	48.5	1
15	0.75	48.25	1
20	1	48	1
Iron			
0	2 mL HCl	48	0
3	0.15	49.85	0
5	0.25	49.75	0
8	0.4	49.6	0
10	0.5	49.5	0
12	0.6	49.4	0
Zinc			
0	2 mL HCl	48	0
0.5	0.025	49.975	0
1	0.05	49.95	0
1.5	0.075	49.925	0
2	0.1	49.9	0
2.5	0.125	49.875	0

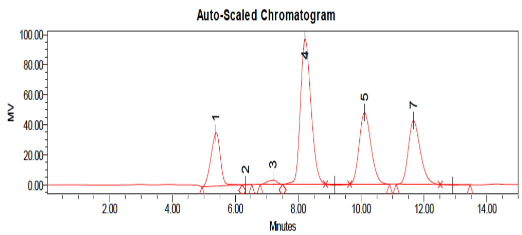
Appendix C: Chromatogram output for sugar analysis



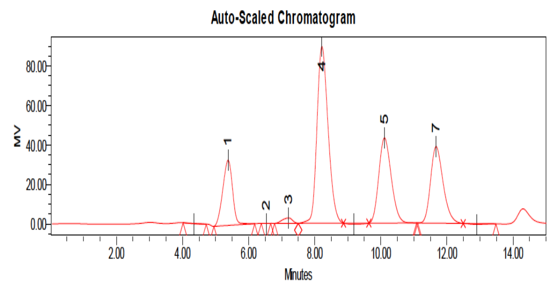
Rice flour



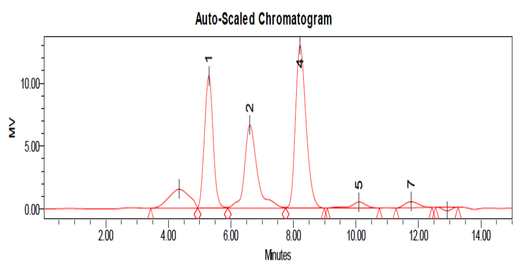
Rice flour



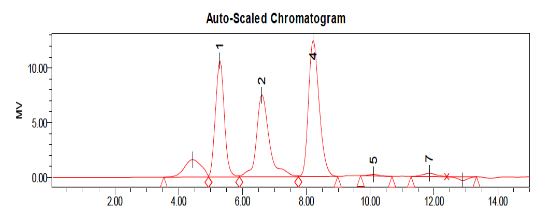
Banana flour



Banana flour



Bean flour



Bean flour

Figure 6.1: Chromatograms for rice, banana and bean flour in replicates

Peak 1 = glucose-6 phosphate, peak 2 = stachyose, peak 3 =raffinose, peak 4 = sucrose, peak 5 = glucose, peak 7 = fructose

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