FORMULATION AND EXTRUSION OF SNACK PRODUCTS

FOR SCHOOL CHILDREN

by

NEHA P. JAIN

(Under the Direction of Dr. R. D. Phillips)

ABSTRACT

The goal of this research is to use the major crops of the West Africa and to formulate a least cost product which meets the nutritional requirement of the 9-13 yr old school children**.** The project involved development of a prototype and process that will increase the income of the small scale industries.

Six formulations were optimized with least cost formulation software using FAO/WHO snack food recommendations. The formulations were further extruded using Twin screw extruder (APV Baker). The moisture and fat content were varied to see its physical and chemical effect on the final product. Later the sensory analysis was carried out to check its acceptability by customers. Each formulation contained about 13-17% protein, 400kcal/100g and sufficient amount of essential amino acid. The formulation with 37% Corn, 50 % Cowpea, 10% Banana and 1% Peanut was ranked equivalent to the commercial product. This project represents a focal point for nutrition, food science, economics, and consumer acceptance.

INDEX WORDS: Snack, Formulation, Extrusion, and School going children

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DEDICATION

TO

This thesis is dedicated to **God “KESHULALJI MARASABH**. It is also dedicated to my maternal grandparents, parents, my aunt Ms. Preeti Bhandari and my younger sister Ms. Prochi Jain for their support, encouragement and unfailing love.

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CHAPTER 1

Introduction

Children are the future of all nations, and childhood malnutrition, whether over- or under- may lead to irreversible problems in adulthood. Changing demographics in both developed and developing countries is leading to increased consumption of snack and convenience foods, most of which contain excess fat and calories and are deficient in other nutrients. The snack food consumption has increased over the last few decades and its still increasing. The emphasis on human nutrition in developing countries has traditionally been on under-nutrition and the struggle of the population to acquire sufficient calories, protein, essential amino acids and other nutrients.

Conversely, in developed countries, such as the US, we are faced with the challenge of over nutrition and an epidemic of obesity. Even in developing regions of the world, affluent populations are encountering the problems of over-nutrition while many continue to be undernourished. Snack foods are generally perceived, with some justification, to contain excess fat, refined carbohydrates, and calories and to be deficient in other nutrients. Nevertheless, they remain extremely popular with consumers and have great potential for nutrient delivery.

American snack food industry has come to realize that consumer demand for healthier products is requiring that they too design and produce healthier snack foods. Consumption of convenience foods will only increase as more women in both industrialized and developing countries work outside the home, leaving less time for food preparation. The product developed in this research is appropriate for both regions. Taking Ghana for example, street food forms a 100 million dollar market, employing 60,000 people and forming 40% of total food budget of family. With growing urban poverty, childhood malnourishment has reached 18 %. In developing countries, food and nutrition programs have come to emphasize food production instead of food relief. The purpose of this research is to design, produce, and evaluate nutritious, low-cost, convenient food/snack products.

In initial part of study Linear programming software was used to formulate optimum formulations from cowpea, peanut, corn, banana and palm oil. The formulations were designed to be nutritionally adequate for 9-13 yr old children. These mixtures were selected based on the price of the product. The second part of the study involved the extrusion of the six different formulations by extrusion cooking. These mixtures were made at different moisture levels from 18% to 22% and fat content from 2.5% to 7.5%. Nutritional analyses was performed to compare the actual nutrient profile after extrusion to the predicted values derived by the formulation software. Finally, the formulations produced were evaluated to determine if they were of acceptable sensory quality with respect to appearance, color, flavor, aroma, texture and likeness.

CHAPTER 2

Literature Review

I. Malnutrition

a. Undernutrition

Malnutrition refers to deviations from adequate and optimal nutritional status in infants, children and in adults. In children, under nutrition manifests as underweight and stunting (short stature), while severely undernourished children present with the symptoms and signs that characterize conditions known as kwashiorkor, marasmus or marasmic (Grantham-McGregor et al. 2000)

Undernutrition is caused primarily by an inadequate intake of dietary energy and protein. Some common factors affecting undernourishment are:

- Starvation or semi-starvation caused by inadequate availability and or access to food as a result of war, poverty, famine or conflict.
- Voluntary reduction of food intake for various reasons, including psychological e.g. anorexia nervosa.
- Intestinal disorders and infections or parasitic infestations may cause mal absorption of nutrients and may be associated with anorexia, which can contribute to undernutrition.
- Severe pathology not confined to or associated with gut function e.g. infections, inflammatory disorders, neoplasm, and organ failure which results in enhanced tissue catabolism (this may be associated with anorexia) (Shetty 2006).

Consequences of undernutrition include loss of body fat, wasting of skeletal muscle and atrophy of the visceral organs (except the brain and nervous tissue). The degree of wasting varies with the type and duration of the disease and is also influenced by factors such as age, gender, physical activity, adequacy of intake of other nutrients, presence of infection and endocrine status. Loss of tissues coupled with specific micronutrient deficiencies compromises the ability to mount an immune response, thereby predisposing individuals to periodic infections. Impairment of physiological function may reduce capacity for work.

Assessment of undernutrition

Nutritional intakes, estimates of the amount of food eaten, are used to assess the adequacy of dietary energy and protein. High mortality associated with severe malnutrition in children has been reduced dramatically in recent years following the development of internationally accepted guidelines for the management of this condition. The recommended two-stage process, stabilization followed by nutritional rehabilitation, forms the basis of the clinical management. Immediate treatment during the stabilization stage includes attention to fluid, electrolyte balance, hypothermia and antibiotic cover for infections recognizing that severely malnourished children do not exhibit classical features of infectious disease. Nutritional rehabilitation is a much slower process that follows. Undernutrition remains a devastating problem in many developing countries—affecting over 815 million people and causing more than one-half of all child deaths.

It is recognized at times that protein mal- nutrition in vulnerable groups, and especially in infants and in young children, is a worldwide problem. Efforts to find solutions, that are suitable to prevent malnutrition like use of protein-rich foods (or combination) besides milk to prevent (and cure) protein malnutrition are of a relatively recent date; they often lack scientific background that would be desirable (Autret & Van Veen 1955) for older infants and young children. In economically underdeveloped countries, those protein-rich foods have to be very cheap, and nutritious.

b. Obesity/Overnutrition

In addition to the problem of underprivileged children facing mal-nutrition in developing countries, children from elite classes in developing and developed countries also face the challenge of obesity. Studies show that 17% of US youngsters are obese and million are overweight (Cook 2007). In the US alone in the age group of 9-12 year olds, obesity has increased from 5% during 1976-1980 to 16% during 1999--2002. This leads to an increased risk of cardiovascular consequences and other serious physical and psychosocial health problems (Dietz 1998). In the US a lot of data is gathered and provided by National Health and Nutrition Examination Surveys. Surveys provide representative data on nutritional intake of the whole population since 1960, whereas in European countries, not much representative information is available, and the information is limited by considerable heterogeneity regarding age, way of sampling, and assessment methods (Malecka-Tendera et al. 2005). Most of the data shows that over time there has been an increase in eating frequency and that this pattern of eating is associated with an increase in the energy consumed on each eating occasion. This presumably reflects larger portion sizes, and an increase in the energy density of items consumed, reflecting the change in diet quality (Zizza et al. 2001). For example, analysis of dietary data from the British National Diet and Nutrition Survey (4–18 years) has shown that the most-sedentary individuals have higher intakes of savory snacks (Rennie et al. 2005). This rise in consumption and frequency of snacking suggests potential cause for concern in relation to body weight.

One of the most noticeable changes in the diet in recent years has been the increase in portion size, especially in relation to soft drinks and energy-dense foods such as savory snacks and confectionery (Nielsen & Popkin 2003; French 2005). Studies in young children have shown that while appetite control is initially good and 3-year-old children appear insensitive to the effects of portion size, this innate regulation is rapidly lost and for children 5 years of age energy intake tends to increase when presented with larger portions (Rolls et al. 2000). A longitudinal study in 12-year-old children has suggested that each serving of soft drinks increases the risk of becoming obese by 1.6-fold over a 19-month period (Ludwig & Gortmaker 2001)

A desirable snack is high in nutritional value and low in energy (HNLE) such as vegetables, fruits and low-fat dairy foods. Whereas, less desirable choices are low in nutritional value and high in energy (LNHE) such as candy, chips, cookies, crackers and snacks; these are often called “junk foods (Heddley et al. 2004; Anderson & Patterson 2005).

Increase in meal frequency, and also in energy density, are a very effective method for increasing energy intake during-feeding programs (Brown et al. 1995) in malnourished children in developing countries. It seems ironic that this strategy developed to feed the world’s most malnourished children has become the norm in many households in the developed world. The threat this poses to body weight needs to be seriously evaluated (Jebb 2005).

c. Recommended Dietary Intakes/DRI to address malnutrition

i. Overview

The Food and Nutrition Board of the Institute of Medicine was established in 1940 and provides recommendations for nutrient intake for various age groups. This guideline is called Dietary Reference Intake (DRI). It is a new approach adopted by “The Food and Nutrition Board” which provides quantitative estimates of nutrient intakes for use in a variety of settings. DRI activity includes role food and nutrient components in long term health, going beyond deficiency diseases. DRI considers the bioavailability of foods (Institute of Medicine (U.S.).

Panel on Macronutrients. & Institute of Medicine (U.S.). Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. 2005).

The 4 primary uses of DRI are as follows:

1. Assessing intake of groups
2. Assessing intake of individuals
3. Planning diets for individual
4. Planning diets for groups

The DRI consist of 4 reference intake:

1. Recommended Dietary allowance: Defined as "An average daily dietary intake that is sufficient to meet the nutrient requirement for almost 97-98% of the total healthy persons in a particular life stage and gender group".

2. Estimated average intake: Defined as "A nutrient intake value that is estimated to meet the requirement of half the healthy individuals in a group". It is based on various parameters like disease risk and other health parameters are considered along with knowledge of the distribution of requirements, to develop RDAs prior to setting EAR. The RDA for a nutrient is to be used only as a goal for dietary intake by healthy individuals(Yates et al. 1998).

3. Adequate Intake: Defined as "is the observed or experimentally obtained estimates of nutrients intake by a group of healthy individuals". When one is unable to calculate the EAR, AI will be calculated (Murphy & Poos 2002).

4. Total Upper limit Intake: Defined as "The highest level of daily nutrient intake which will not pose any risk to the health of an individual in general population. It refers to the amount of nutrient that a body can tolerate biologically." However, risk of adverse effect can increase if one goes beyond UL. UL should not be considered as recommended levels of nutrient. UL is mostly used for the purpose of fortification of foods and diet supplements with nutrients.

The nutrients can be classified a macronutrients and micronutrients. Calories, fat and protein are categorized as macronutrients. Protein plays a very important role in development of growing child. There is need to focus on protein intake of children. As children might be given a diet limited to single protein food or limited number of protein source. The major difference between plant protein and animal protein is its concentration of protein and indispensable amino acids. The concentration of some plant source of protein may be too low to make then adequate by themselves basically if consumed in their traditional form (Young & Pellett 1994). However children can overcome malnutrition if they are given well-formulated diets based entirely on the plant food sources. These mixtures of plant protein have a potentially of high value (Oxford, UK: Pergamon Press)

ii. Proteins/Amino acids

The term proteins means "to take first place", was introduced by Dutch chemist Mulder in 1838. Proteins form the major elements of cellular structure, biochemical catalysts and are important in regulating genes (Pencharz & Ball 2003). They are essential in the diet as carriers of essential amino acids and reduced nitrogen. Adequate amount of proteins are important for growth and recovery from disease. Proteins are also the most functionally diverse chemicals of life. All enzymes are proteins and without their catalyst effect there would not be any chemistry of life. There is significant quantity of proteins in each cell of the body. It forms about one fifth of the total weight of an adult. Muscle contain about half of that proteins, one fifth in bone and cartilage, one tenth in skin, and rest distributed throughout the other tissues and fluids of the body. Proteins are made up of 20 different amino acids. All these are made up of carbon, hydrogen, oxygen and nitrogen atoms. However, cysteine and methionine also contain a sulfur atom. All amino acids contain an amino group (NH2), carboxyl group (COOH), and hydrogen atom (H), which are attached to a central carbon atom. This atom is also bound to side chain or side group. The carboxylic group is acidic and usually exits in its ionized form as -COO-, having released a hydrogen (H+) ion, and the amino group, being basic in nature, also exists in the ionized form as –NH3+ at physiological pH. The side chain of amino acid can be divided into 8 categories: Aliphatic amino acids, Hydroxyl containing amino acid, Sulfur containing amino acid, aromatic amino acid, acidic amino acid, basic amino acid, amide amino acid and imino acid praline (Ziegler et al. 1996).

Nutritional Classification of amino acids: Amino acids are divided into 2 groups namely: Essential (indispensable) and Nonessential (dispensable) amino acids. Essential amino acids are the ones that cannot be synthesized by our body to meet growth and maintenance requirements. Therefore it is important to provide them in human diet. Non essential amino acids are the one that can be synthesized by human body(Pencharz & Ball 2003). There are 9 essential amino acids. They are namely, valine, leucine, isoleucine, threonine, methionine, phenylaline, tryptophan, lysine and histidine. Proteins are required for growth and maintenance of tissues, formulation of essential body components, transportation of nutrients, regulation in water balance, maintenance of appropriate pH, defense mechanism and detoxication. The amino acids are linked by peptide bond to form protein. Dipeptides are formed by joining two amino acids, and tripeptides, three. Proteins are polypeptide in nature as it contains many amino acids. All dietary proteins need to be broken down in intestinal digestive tract into individual amino acid, dipeptides and tripeptides by enzyme called proteases. Nutritionally, proteins are judged on the basis of amino acid content, human amino acid requirements, and protein digestibility (Young & Pellett 1994). Protein digestibility will vary from food to food, ranging from 78% for legumes to 97% for eggs. Digestibility also differs for foods containing substance that modify digestive process and are called enzyme inhibitors (Ziegler et al. 1996). Protein can be either plant protein or animal protein. Plant protein form 65% of the per capita supply of protein around the world (Young & Pellett 1994). There are about 20 major plant crops, which are generally divided into cereals, vegetables (including legumes), fruits and nuts. Forms that are most important groups for human protein nutrition are: cereal grains and food legumes, including oil-seed legumes. Mixtures of plant proteins can serve as a complete and well balanced source of amino acids for meeting human physiological requirements. Cereal grains form a substantial portion of the world's food protein and energy. The Second International Congress on Vegetarian Nutrition recommended significant reduction in the amounts of cereals and legumes used as feed and to increase their direct use in food for humans.

Specific plant proteins may be low in specific amino acids, however mixtures of plant protein are capable enough to provide equivalent of high quality animal protein. Digestibility of plant protein varies according to food sources and the processing method used.

Efforts need to be made to find other suitable, protein-rich foods (or combinations) to prevent (and cure) protein malnutrition (Autret & Van Veen 1955) for older infants and young children, protein foods besides milk are needed. A lot of studies have been conducted on improvement of weaning foods. However, there needs to be more focus on school children of different age groups. In economically underdeveloped countries, snack food needs to be affordable and convenient to help meet protein requirement of the children.

iii. Fat

Fat is an essential component of diet along with protein and carbohydrate. Fats have benefits like treating eczema in infants. They are also required for intravenous feeding with hypercaloric solutions like glucose and amino acid. Also, dietary sources of n-3 fatty acids are required for the optimum tissue function. Mammalian cells are able to synthesize saturated and n-9 and n-7 series unsaturated fatty acids from acetyl Co-A, but lack delta 12 and 15 desaturating enzymes necessary for insertion of double bond at the n-6 and n-3 positions respectively, of the fatty acid carbon chain(Ziegler et al. 1996). The dietary essential acids are linoleic acid and linolenic acid. Long chain and more unsaturated n-6 and n-3 fatty acids, including archidonic acid (20:4n-6), eicosapentaenoic acid and (20:5n-3), and docosahexaenoic acid (22:6n-3), which are synthesized from 18:2n-6 and 18:3n-3 by alternating desaturation and elongation. The fat requirements of children can be judged according to 4 criteria:

1) The possible obligate needs of fat as a metabolic fuel,

2) The provision of a sufficiently energy-dense diet to meet energy needs,

3) The adequate supply of essential fatty acids, and

4) The supply of sufficient fat to allow adequate absorption of fat-soluble vitamins.

iv. Carbohydrate

Carbohydrates constitute the majority of biomolecules on our planet. Depending on the cultural and dietary choices, the dietary carbohydrates can vary, but generally includes starch, simple sugars, complex polymers known as “dietary fibers,” and minor components. A number of other carbohydrates are added to human diets in quantity: hydrolyzed corn starch, fructose syrups made from corn starch, modified starches, gums, mucilages, sugar alcohols and other industrial products. These are added to change texture, mouth feel, shelf life, color, viscosity and taste. Deficiency of carbohydrates can lead to disturbances in metabolism and intestinal functions and in long run can lead to serious health risk such as diverticulities in aged ad increased chances of cancer. Keeping blood glucose constant and increasing glucose production at times is the most important biological imperatives of carbohydrate disposition in humans. A majority of complex carbohydrates other than starches are digested in large intestine. Some of the ingested starch like limit dextrin can escape the digestion in small intestine and end up in the large intestine. The bacterial flora of these intestines then metabolizes these compounds and produces short chain fatty acids: Butyric, Isobutyric, Propionic and Acetic acids. Butyric and Isobutyric are important source of gut cell and reduce risk if carcinogenic changes in these cells. The large intestine also produces bacterial masses which help to prevent diverticulitis and entrapment of pieces of hard fecal matter.

v. Vitamins

Apart from the macronutrients required for proper functioning of body, one also requires vitamins. Vitamins are, or are the precursors of co-factors necessary for the activity of many enzymes. Vitamins are classified as A, B, D, E and K. In nutritional sense the Vitamin A family includes all naturally occurring compounds with biological activity of retinol. As provitamain A, carotenoids are nutritionally active and are included in vitamin A family. Vitamin A in food is present mainly in retinyl ester. During proteolytic digestion in the stomach, retinyl ester and provitamin A carotenoids are released from foods and aggregate together with other lipids. The absorption efficiency of dietary vitamin A in healthy person who ingest significant amount of fat (>10) is >80%. Dietary carotenoids are absorbed in range on 1-3g/day i.e. approximately half as well as vitamin A. Vitamin is mostly stored in liver and it's depletion from liver is around 0.5%/day. The average daily requirement in healthy individual varies according to age, body mass, metabolic activity etc. Common dietary source of Vitamin A is dairy products, marine fish e.g. cod, marine mammals e.g. polar bear. While for provitamin A, carotenoids are carrot, yellow squash, papayas, oranges, corn, tomatoes etc. In US 75% of the RE from performed vitamin A and 25% from provitamin A carotenoids.

Vitamin D is important for regulation of calcium metabolism in higher animals. Vitamin D contains 2 hormones parathyroid hormone and calcitonic hormone that are responsible for daily maintenance of calcium and mineral homestatics. The vitamin D affects the cell differentiation and proliferates including the cancer cells and also helps in formation of insulin. Deficiency of Vitamin D leads to rickets. The active form of Vitamin D is steroid hormone. Vitamin D3 is formed in the presence of sunlight and is relatively a prohormone and is not known to have any intrinsic biological activity itself. It is only after Vitamin D3 is metabolized by the kidney that they are biologically active. Also, as the D3 is produced in skin, humans don't require Vit D if sufficient sunlight is provided. However, in absence of sunlight it can be required to supplement with Vit D. In US during winter month's substantial proportion of population require regular dietary Vit D supplement because of suboptimal level of sunlight. This is however not required in Africa as of sufficient sunlight even during winters.

The third fat soluble vitamin is Vitamin E. The dietary vitamin E is primarily composed of alpha- and gamma tocopherol, of which 20-50% is normally absorbed. Because of being hydrophobic in nature, it has to absorbed in bile acid secreted by liver. Any diseases that affect the total surface area of cell or length of intestine can lead to malabsorption of Vit E. The rich sources of Vitamin E in US diet are vegetable oils, wheat germ, nuts and other grains.

Finally, Vitamin K is the last vitamin of fat soluble vitamins group. It is extracted from plant and animal tissue with non polar solvents. Natural compound with vitamin K activity are 2- methyl-1, 4-naphthoquinones. Phylloquinone, the form isolated from green plants, has a phytyl group, whereas the bacterially synthesized forms of the vitamins have an unsaturated multiprenyl group at this position. Adsorption of phylloquinone from the gut is via the lymphatic system, and conditions that result in a generally impairment of lipid adsorption also adversely influences vitamin K absorption. The deficiency of vitamin K leads to increase in one stage prothombic time brought about by the failure to produce normal amounts of essential clotting factors. The most common condition known to result in Vitamin –K responsive hemorrhagic event in adults occur in the patients who has low dietary intake of Vitamin K and also in some patients receiving antibiotics.

Vitamin C and Vitamin B are considered to be water soluble vitamins. Vitamin C is also known as ascorbic acid, ascorbate or ascorbate monoanion. It is excellent antioxidant. Most mammals synthesise ascorbate from glucose. Humans and other primates lack the terminal enzyme, gluconolactone oxidase, in the ascorbate bisynthesis pathway, so humans need to ingest ascorbate to survive. Acorbate is found in many fruits and vegetables e.g. foods are papaya, mango, kiwi, plantain, sprouts, etc. The deficiency of vitamin C can lead to scurvy.

Other water-soluble vitamins include the Vitamin B group which has several members, B-1, B-2, B-6, B-12, B-3, B-5 and B-9. Vitamin B-1 is important for carbohydrate metabolism and energy production and important for healthy nervous system. Its deficiency can cause Frank deficiency causes beri-beri (muscle wasting, nervous system interruption), less severe deficiency can cause a number of illnesses including depression, loss of appetite and the diseases associated with appetite suppression. Deficiency has also been associated with dementia. Sources of vitamin B1 are brewer's yeast, brown rice, cereals, bread, beans, pork, liver etc. Vitamin B-2 has similar function and it's required for to healthy mucous membranes. Its deficiency leads to a host of symptoms associated with defective membrane integrity, such as sore tongue, mouth and lips, flaky skin, dry eyes, Anemia and implicated in nervous system disorders including depression. Vit B-2 rich foods are dark green vegetables (spinach), nuts, cheese, brewer's yeast, grains, milk, bread etc. Vitamin B3 is required for proper fat and carbohydrate metabolism, protein synthesis, including the neurotransmitter serotonin, maintaining healthy nervous system, promotes healthy skin, hair and digestive system and known to lower cholesterol and triglyceride levels. It's deficiency lead to pellagra. Food rich in B-3 are grains, Beef, Liver, peanuts, brown rice kidney, grains, sunflower seeds, peanuts, brown rice sunflower seeds, etc. Vitamin-B5 is widely found and is produced in intestine tract by bacteria. Its deficiency is rarely observed. Vitamin B-6 is important for neurotransmitter synthesis, maintaining healthy nervous system, protein synthesis, normal growth and essential for linolenic acid metabolism and conversion to prostaglandin E1. Its deficiency causes dwarfism, dementia, depression and osteoporosis. Its present in salmon, whole grain, cereals, sunflower seeds, tomato juice, trout, beans, brown rice, brown or enriched bread etc. Vitamin B-12 is essential for DNA synthesis, formation of red blood cells, necessary to maintain health nervous system, protein synthesis, fat and carbohydrate metabolism and helps in calcium absorption. Sources of this vitamin are cereals, meat, liver, dairy products egg, kidney etc.

vi. Minerals

In addition to vitamins, our body also needs 15 minerals that help regulate cell function and provide structure for cells. Amounts needed for most of these minerals are quite small and excessive amounts can be toxic to your body. Major minerals, in terms of amount present are as follows:

Calcium: Required for strong teeth, bones, nerve function and muscle. Few sources are milk and milk products, fish, turnip, mustard greens, almonds, tofu and broccoli.

Chloride: Regulates body fluid volume, concentration and acid-base balance. Few sources are milk and milk products, fish, turnip, mustard greens etc.

Chromium: Regulates blood glucose. Few sources are whole grains, brewer's yeast, and meats

Copper: Required for growth, bone maintenance, blood formation and for nerve function. Found in sea foods, nuts, seeds etc.

Fluoride: Required for dental and bone health. A mineral which is important for dental and bone health. Tea, foods cooked in fluorinated water and fluorinated water.

Iodine: Important for production of thyroid hormones. Present in sea foods, iodized salt and food made in iodized salt.

Iron: Essential constituent of blood and muscle and important for the transport of oxygen. Found in legumes, egg yolk, red meat, liver etc.

Magnesium: It functions in many enzyme processes. Present in nuts, legumes, Green leafy vegetables and whole grains.

Manganese: important for formation of bone, growth, reproduction, and carbohydrate metabolism. Found in fruits, whole grains, vegetables and tea.

Molybdenum: Required for many enzyme processes, nerve function and protein metabolism. Present in milk, breads and cereals.

Phosphorus: A mineral essential to bone formation and maintenance, energy metabolism, nerve function and acid balance. Present in dairy products, fish, eggs, etc.

Potassium: Required for muscle contraction, nerve function and maintenance of normal blood pressure. Found in fruits and vegetables.

Selenium: It is associated with antioxidant properties and fat metabolism. Excessive amounts of selenium may cause hair and nail loss. Found in meat etc.

Sodium: A mineral that regulates body fluid volume, concentration and acid-base. Present in table salt, milk and milk products, eggs etc.

Zinc: It is important for taste sensation, wound healing, and growth. Found in liver, seafood's, eggs etc.

II. Role of foods in providing proper nutrition

a. Traditional foods and processes and eating patterns

The traditional foods of West Africa require one form of processing or the other before final cooking, especially the cereals. Although the consumption of local cereals (millet, sorghum, fonio and maize) is relatively widespread, the technology for their processing is far from adequate. Traditional processing methods are time consuming and tedious, while several traditional meals involve lengthy pre-preparation and final cooking time. The processing and cooking of sorghum, millet or fonio for example take more time than rice and so more and more African women who in their bid to increase family income take employment outside the home, have less time available for food processing and cooking, they thus often resort to the easy to cook rice. (National Research Council (U.S.). Board on Science and Technology for International Development. 1996). Consumer survey results suggest that the increase in rice consumption in the sub region in relation to total cereal consumption is not so much the low price of rice and its easy availability but the effect of urbanization. With urbanization comes a change in employment patterns particularly of women, increasing the opportunity cost of women's time due to increasing involvement in hired Labor or self employment away from home. This increasing absence of women (homemakers) away from homes for a large proportion of the day leads to substitution towards "convenience" foods - the most popular being easy-to-prepare cereals like rice and wheat products. Easy availability all year round of local foods in their fresh and socially acceptable processed forms, and at affordable prices seems to be the key to overcoming the major constraints towards consumer utilization of locally available foods. In order to achieve this objective, the active participation of the food industries in the sub region in establishing viable rural and urban markets for local food products is imperative (Levin et al. 1999).

In spite of the recent moderate advances in food technology in the sub region, enough research efforts have not being directed to change the current perception of these cereals as low status grains in order to increase and expand their uses in the rural areas as well as to develop new products for urban markets and the increasing number of food industries. Nutritional Costs of ensuring all-year round availability of Local Foods.

There are thus obvious losses using traditional and even mechanized methods of dehulling, and so the nutrient content of the final ready-to-eat product depends on the processing technique be it traditional or mechanized, and the rate of extraction of the cereal grain. Significant fractions of the water soluble vitamins and some minerals are removed during both traditional and mechanized processing. Available data on sorghum show that 9% of total protein, 18% of calcium, 3% of iron, 39% of thiamine and 16% of niacin are lost during traditional processing, although some nutrients particularly iron was found more available after dehulling. Nutritional losses are perhaps inevitable if these local cereals and other foods are to be available in the market all year round. It is however known that such processing losses in food nutrients can be compensated by consumption of diets containing a mixture of cereals, legumes, tubers and vegetables. In the urban centers, cereals take around 40-86.7 of the food budget. This statistics is disheartening knowing that millet, sorghum, maize and fonio which in the past were very important sources of food energy in the sub region have lost their positions of importance to rice and wheat since the 1960s. This suggests that today, the best part of the family's food budgets go to the purchase of rice and wheat products. Because these foods are imported, particularly the wheat products, they are much more expensive than the local foodstuffs (Lfeyironwa 1995).

Food technological institutes and food industries have roles to play in ensuring easy availability of our local foods in nutritionally adequate and culturally acceptable forms. Their roles must not end with the production of such foods; there is need for continuous research aimed at evolving better, versatile and more acceptable products. These new products should in turn be subjected to intense recipe development, be aggressively popularized through their use in the preparation of locally acceptable and nutritionally adequate meals. Finally, there is a need for continued research into newer and better ways of utilizing the partly processed foods and popularizing new recipes evolved (Pencharz & Ball 2003). For the consumer, food is meant to allay hunger, and sustain health, Foodstuffs contain and supply the body the food nutrients required by the body-carbohydrates, proteins, fats, minerals and vitamins. Consuming the right type of food nutrients in optimum amounts depends on food availability and individual food choices.

Throughout Africa and the West African subregion in particular, grow and are cultivated food crops that:

Supply energy

- roots and tubers:
  - starchy fruits
  - fats and oils
  - cereals

Supply protein

- legumes
- cereals
- leafy vegetables

Supply minerals

- cereals
- legumes
- leafy vegetables

Supply vitamins

- vegetables
- legumes
- cereals
- tubers.

The prices of most locally grown in Dakar, Senegal and available foodstuffs, compared to those of the imported food items (including imports from within West Africa), does show, even if in a small degree, that it makes economic sense to consume local food products. However, the known nutrient losses incurred by processing and the use of additives to preserve color and texture of foods during long storage further confounds the decision by individuals to consume imported processed foods as against locally grown, fresh and nutritionally more adequate alternatives.

It is indeed an economic waste to consume imported processed foods in place of local alternatives but the reality of the situation is that countries in the sub region spend each year, millions of their respective foreign exchange equivalents in subsidizing rice and wheat imports in order to sustain the increasing tastes for rice, bread and other wheat products (Lfeyironwa 1995).

b. Snacks and their increasing importance in developed and developing countries

Snack consumption has increased over the last few decades and it is still increasing (Jahns 2001). Snacks mostly consist of the food that it consumed outside the meal. The "meal" usually refers to the three main eating moments of the day, including breakfast, lunch and Dinner. The term "snack" refers to other eating episodes, and includes all foods and drinks consumed outside the context of the three main meals (Graaf 2006). It has been observed that most snacks in the industrialized world have a high energy density. On an average, energy content is about 1500-200 KJ/100 g (400-500 Kcal/100g) (Voedingscentrum 2004). Potato chips are also high- energy density products with about 550 kcal/100g and even 'low-fat' (so called 'diet' or 'light') chips contain about 500 kcal/100g. Beverages do not contain a large amount of energy per 100gms, however their quantity of consumption increases the energy intake. For example, sugar containing soft drinks contains 170 KJ/100g, but a 250 ml portion contains almost around 400kcal (Cordain et al. 2005). The high energy density of current snacks stand in strong contrast to the low- energy density of most foods in Paleolithic diets, which predominantly consist of minimally processed plant-based foods and foods from animal origin e.g. most fruits and vegetable contain less than 100kj/100g (Voedingscentrum 2004). The serving size in the market is quite misleading.

From a large number of recent studies we know that humans easily overeat on high-energy dense foods (Blundell et al. 1996). In addition, it has been demonstrated that already in infancy individuals learn to like tastes and flavors that are associated with a high-energy density e.g. (Birch et al. 1989). We like energy-dense foods and we easily consume considerable amounts from them. This tendency for passive (unconscious) over consumption of energy/fat makes sense from an evolutionary point of view: being able to ingest more energy than you expend is beneficial because it allows for energy (fat) storage that may be required in times of food scarcity (Graaf 2006). People mostly eat in episodes especially insofar meals are consumed. After the consumption of a meal hunger gradually builds up again, until the next eating moment (Blundell et al. 1996). This pattern seems different for snack consumption, many snacks are consumed when people are not hungry (Castonguay et al. 1983). The rhythm of appetite responses across the day has been observed in many studies, and coincides with the meal pattern that is maintained (de Graaf et al. 1993).

The factors that affect the excessive eating are the food supply, pervasive food advertising and marketing, and the increased consumption of food away from home (Lin 1999; French et al. 2001b). The school food environment can have a significant effect on adolescents' food choices because a large proportion of total daily energy is consumed at school (French

2004). Foods sold outside the national School Lunch Program (i.e., “competitive foods”) make up an increasing share of students’ purchases at school, especially at the secondary level (French 2004). Away- from home foods are defined as foods obtained from restaurant, fast-food outlet, vending machine and street foods (Lin 1999).

These foods are ready to eat foods and consumer has no control over the serving size and nutritional quality. Not only have portion sizes for foods purchased at fast-food places and restaurants increased sharply, but prepackaged foods purchased in grocery and convenience stores are also being marketed in larger sizes (Young & Nestle 1995; French et al. 2001b).

Whereas in the 1950s, soft drinks were marketed in 6.5-oz single serving bottles, by the 1970s the standard serving size was 12 oz. In 2000 the 20-oz bottle was the typical single serving size, a 250% increase from the 1950s. Fast food restaurants have been marketing super sized hamburgers (216 g; 570 kcal), super sized fries (198 g; 610 kcal), and 42-oz soft drinks (Corporation 2002). Candy bars and potato chips that used to be sold in 1 oz servings are now being marketed in 2–3 oz packages (Young & Nestle 1995). Larger portions encourage increased consumption through a variety of physiological or cognitive mechanisms(Wansink 1996). Larger-sized packages are priced less per unit weight as compared with smaller-sized packages, so this perception is, in fact, correct. For example, the cost per ounce for soft drinks purchased at a convenience store is 5¢ per ounce for a 12 oz serving, but only 2.3¢ per ounce for a 42 oz serving. This research suggests that people will consume a greater quantity of food or beverage from a “supersize” serving size compared to a small size, especially if the unit price is lower (Wansink 1996; French et al. 2001b).

c. Street foods in developing countries

An individual's food choice depends on three main factors taste, value of the snack and nutrition quality (Glanz et al. 1998; French et al. 1999). It will change from person to person. People from lower socioeconomic group will emphasize more the cost of the product while those from elite socioeconomic group who are health conscious will emphasize more nutritional labeling of the product (Solheim et al. 1996; Glanz et al. 1998). It has also been observed that when people buy foods they tend to buy tastier and cheaper selections, rather than considering the nutritional value. This is true also for children. This raises an important question, "Can people be influenced to purchase and consume more healthful food if the foods are increased in attractiveness through lowering prices?" Study done by CHIPS (Changing Individuals' Purchase of Snacks) showed that when price of the low-fat food was decreased by 10%, 25%and 50%, the percentage of low-fat snack sales increased by 9%, 39% and 93% respectively (French et al. 2001a). This show by reducing price in vending machines one can encourage the selection of lower-fat snacks by the consumer. However, there was still concern that whether these findings were applicable to adolescent population (Krebs-Smith et al. 1996; Nicklas 1997). A study was conducted to see the effect of consumption of fruits and vegetable which are mostly considered to be the least desirable product. The results showed that by reducing the price the sales of health foods increased 4- folds. The effect of strategy to raise the price of 3 high –fat food and reducing the price of 4 low-fat foods like low-fat chips was studied. The study showed that by raising the price of high-fat food by 10% and reducing price of low-fat food by 25% it showed that revenues generated from 7 foods was within the 5% of revenues generated from the usual-price conditions (Hannan 2000). However, in developing countries like Ghana, the source of snack foods in school for children is "Street foods" not vending machines.

Buy modifying the nutritional profile of the street foods sold and still keeping the price in mind, one can help children to make a healthy choice.

An FAO report indicates that these street foods can provide cheap nutrition that can benefit the urban population. According to the study done by Webb and Hyatt (Webb & Hyatt 1988) found that street foods provide 15% of the recommended dietary intake for energy and 18% for protein in the diet of secondary school students. In another study it was found that street foods contribute 25% of the energy and 52% of the protein intake of a group of urban adolescents in Nigeria (Oguntona & Kanye 1995). It was observed that there was a significant relationship between the socioeconomic status and street food consumption(Reit et al. 2001).

III. Improved approach to nutritious convenience foods

a. Formulation

i. Software

Least costing software was first developed in 1947 by G.B. Dantzig for US airforce. This program is based on "Linear programming" method. Diets can be formulated using Pearson's Square or simultaneous equation method. A standard linear programming model used for this purpose is as follows (Winfeed 2007):

$$\text{Minimise } \sum_{j=1}^{n} c_j x_j \quad \rightarrow \quad (j = 1, 2, 3, \ldots\ldots n)$$

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

$$\sum_{j=1}^{n} a_{ij} x_j \geq b_i$$

$$\sum_{j=1}^{n} x_j = 1$$

$$x_j \geq 0$$

where

c_j = Cost per unit for jth ingredient

x_j = Quantity of jth ingredient

a_{ij} = Quantity of ith nutrient per unit of jth ingredient

b_i = Requirement for ith nutrient in the diet

There is lot of choice for feed formulation software in the market. The software range from simple spreadsheet to complex packages designed for large feed manufacturers. The software package may also contain an accounting system and inventory management feature. Also, there are software's available in the market which is designed for specific animals. This software also requires nutritionist knowledge so as to take into consideration loss of nutrient (Winfeed 2007).

Another popular method of feed formulation is stochastic programming. Its name comes from a Greek word meaning skilful at aiming. The purpose of the software is to meet the nutritional requirement as targeted at least cost.

The standard formula for this programming is: (Winfeed 2007)

$$\text{Minimise } \sum_{j=1}^{n} c_j x_j \quad \rightarrow \quad (j = 1, 2, 3, \ldots\ldots n)$$

subject to

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

$$\sum_{j=1}^{n} a_{ij} x_j \geq b_i$$

The first method provides a diet which is not 100% accurate and need to keep a margin of around 5-10% to meet the desired requirement. However, this is not an economical approach. The second software has higher accuracy.

For any formulation to work, one need to input the information required for the formulation. The formulation runs on data entered by the user and accuracy of result will be only as accurate as the initial information that was input by the user.

Basic feature of the software include: (Winfeed 2007)

1. Ingredient list
2. Nutrient composition
3. Formulation specification.

Ingredient List:

The user inputs ingredients available for inclusion in formulation. The list of ingredients should contain unit price

1. Nutrient composition:

   Each ingredient user inputs should have a nutrient profile available for that particular product.

2. Formulation specifications:

   The formulation specifications are set like nutrient desired or ingredients quantity etc, so at to keep these constrain and formulate a product.

   One of the main use of using this software is to choose the best possible ingredient/ingredients to meet the desired nutritional requirement at least cost (Rossi 2004).

Formulation Analysis Tools:

1. Marginal price changes (MPC)-This is cost change which shows by how much the price of ingredients need to decrease to be able to be accepted in formulation.

2. Shadow price cost (SPC)-Marginal cost of change when subtracted from current price of the ingredient we get SPC. SPC of ingredient included in formulation is always zero. Similarly, change in formula cost with change in nutrient constrain is called to shadow price of nutrient.

3. Parametric price change- The software shows the impact of varying prices on the ingredient and some software also plot the summary graphs called price maps. This allows the user to understand how much ingredient can be used if the price of ingredient changed (Rossi 2004).

Some advanced features:

1. Nutrient factoring-This feature allows the capability to provide the ratio between different nutrients.

2. Optimum density-This allows the user to make a formulation with specific nutrient proportion relaxing the weight constrains.

3. Multi-blending-This allows more than one formulation to be made at once, taking into consideration the ingredient that they are available in limited quantities.

ii. Local Commodities

1. Cereals

a. Corn

Corn (Zea mays L.) is an important cereal crop. It originated in Mexico. It is tall plant belonging to grass family. It has erect stalk and fibrous root system with single leaf at each node. It is a self pollinating species and is monoecious. It has a male (tassel) and female (ear) flower located on the same plant. The ear contains around 300-1000 developed kernels arranged in row (Cob). It is a warm seasonal crop (Watson & Ramstad 1994). The maize mainly consists of carbohydrates. It is used in food and feed industry as a source of energy as it contains high source of starch and also as source of enzyme for biosynthesis. The base of the kernel consists of pedicle, placento-chalazal tissue and the basal endosperm transfer cells. The carbohydrate play an essential play an essential role in intermediary metabolism in all tissues. Corn kernels contains around 72-73% of carbohydrate. Sugars like fructose, sucrose and glucose form around 1-3% of the kernel. The corn kernel is a rich source of phosphorous and sulphur. It is present in form of phytic acid-the hexaphosphate ester of inositol. While sulphur is present in the form of organic form as constituent of methionine and cystine (Watson & Ramstad 1994). The pericarp and tip of corn constitute around 80% of the total fiber by provided by corn. The beneficial effects of fiber for the human body make it very popular among food items. Many millers are offering neutral dietary fiber (NDF) from around 50-65% to 88-92%. Fiber helps in proper bowling system and also prevents carious diseases (Kies 1982).

b. Sorghum & Millet

Sorghum, *sorghum bicolor, (L) Moench*, is a grain for areas of low rainfall. The sorghum bran is low in protein and ash and rich in fiber components. The germ fraction in sorghum is rich in ash, protein and oil but very poor in starch. Over 68 percent of the total mineral matter and 75 percent of the oil of the whole kernel is located in the germ fraction. Its contribution to the kernel protein is only 15 percent. Sorghum germ is also rich in B-complex vitamins. Endosperm, the largest part of the kernel, is relatively poor in mineral matter, ash and oil content.

It is, however, a major contributor to the kernel's protein (80 percent), starch (94 percent) and B-complex vitamins (50 to 75 percent).

Pearl millet bran is low in mineral matter like that of sorghum, but it is remarkably rich in protein (17.1 percent). The germ fraction in pearl millet is relatively large, 16 percent as against 10 percent in sorghum. It is also rich in oil (32 percent), protein (19 percent) and ash (10.4 percent). Practically all the oil (87 percent) of the whole kernel is in the germ fraction, which also accounts for over 72 percent of the total mineral matter. Greater concentration of minerals in the germ and the bran layers than in endosperm is typical of cereal grains (MacMasters et al 1971). The total fat content of pearl millet is higher than that of other millets and sorghum because of the size of the germ and its high oil content and because of somewhat higher levels of fat in the bran fraction. Sorghum along with millet represents approximately 70% of total cereal production in West Africa. Four countries in West Africa (Niger, Burkina Faso, Mali and Sudan) with combined population of about 40 million, depend on sorghum and millet for 1000 calories per head on daily basis (Food and Agriculture Organization of the United Nations. 1995). Many household may brew their opaque beer (chibuku) from sorghum or millet malt. Breads and porridges are also made from sorghum and millet.

c. Rice

Rice *(Oryza sativa,Linn.)* is dehusked rice. The caryopsis, contains: embryo (germ) 2% to 3%; pericarp 1% to 2%; seed coat plus aluerone layer 4 to 6%; endosperm 89%to 93%. Rice varieties are available with protein content of 6-14% (dry weight basis). Rice is deficient in lysine and threonine, but contain high digestibility compared to cereals of 98%. The fiber content varies from 0.3% for white rice to 1% for brown rice. White rice consumption for long time can cause vitamin disease called beriberi. This is because 40% of the thiamine and niacin are removed during washing and 20% further during cooking. By par boiling the paddy before dehulling, vitamins penetrate the kernel and 80% is saved and makes polished parboiled rice more nutritious. Over half of the rice eaten in South Asia and West Africa is parboiled, totaling more than 20% of the world consumption. Some of the products made from rice are: Chinese noodles, Indian Idli is made by soaking white rice and a pulse, Japenese Miso is ferementеd paste made to season other foods, Japenese Koji, Chinese red rice etc. (American Association of Cereal Chemists. 1947; Johnson & University of Georgia. 1986; McCance et al. 1988; Dendy & Dobraszczyk 2001)

d. Wheat

Wheat belongs to *Triticum spp*. Wheat contains around 6% to 20% protein, most of which is in the form of gluten. Both the quality and quantity of gluten are key indicators of the wheat quality. Gluten protein is responsible for the gas-retention property of the bread dough during baking. Loaf volume increases as protein content in the dough increases. Moisture content in wheat is around 14% to 30%. It is one of the most important characteristic of protein as it affects the specific weight and values of the wheat as miller do not want to pay for water. Wheat constitutes about 28.5% of the total cereal production in the world, with rice and maize at 27.4% and 28.1% respectively. Approximately 70% of the world wheat production is used as foods, mainly as bread and other baked productions such as cakes and cookies, and also as a source of animal feed.

2. Legumes

a. Cowpeas

Cowpea seed (Vigna unguiculata L. Walp.) is a legume. Legumes compliment the amino acid profile of most cereals, they contain twice as much protein as cereals and, except for the sulphur containing amino-acids (methionine and cystine) which are adequate in cereals (Fashakin and Ojo,1988; Nielsen, 1991).

Cowpea originated in Africa, 5-6 thousand years ago and is very important local crop of West Africa. It is used for animal fodder, as a vegetable, and as a grain legume (Davis & Putnam 2003). In last 25 years the production of cowpea has increased tremendously. Cowpea is a warm-season, herbaceous legume. It grows over a wide range of soil types and moisture regimes and prefers temperatures between 20° and 35°C.

The cowpea seed is globular or kidney shaped depending upon the restriction in the pod (Kabas et al. 2007) of various colors including white, cream, green, buff, red, brown, and black and it can be smooth or wrinkled. Seeds may also be speckled, blotchy or mottled. The seed weight averages between 5 and 30 g/100 seeds (Ige 1977). Many are also referred to as 'eyed' where the white colored hilumis surrounded by another color. The protein contents of cowpea are in the range of 15–35% (Arora 1976; Clemente 1998). In a study cowpea starch was isolated and found to be most abundant component, (Arora 1976; Oluwatosin 1998). It is rather difficult to obtain pure starches from legumes, due to their high protein contents (Moorthy 2004). Lipid content of cowpea starches is low and is similar to tuber starches and much lower than in cereal starches 1%, (Eliasson 2004). Legume starches contain high amylose content (Singh 2004). The amylose range of cowpea is around 20.9%–48.7%. When measured in water, the starches had a shift toward larger granule sizes, indicating slight swelling of the granules in cold water (range, 3–64 lm; mean, 19 lm) (Huang et al. 2007). Because of the higher amount of amylopectin in the cowpea is compared to other peas like chickpea and yellow pea, cowpea starch has higher gelatinization temperature, slight difference in crystalline structure and higher peak viscosity (Huang et al. 2007). Studies show that bean products rich in water-soluble dietary fiber and puridfied forms of water-soluble dietary fiber can reduce blood cholesterol (Anderson 1982; Anderson 1985). Bean products can lower the serum cholesterol levels. Beans are also rich source of inexpensive fiber. They are good source of complex carbohydrate (50–60%) and a low source of fat (1–3%) and high in complex carbohydrates. These characteristics make beans ideally suited to helping consumers meet the dietary goals of reducing fat intake and increasing the intake of starch and other complex carbohydrates (Huges 1991). Cowpea is an important food for children and is consumed in a variety of ways. They are consumed in form of thick soup made by cooking cowpea with spices and palm oil which is eaten alone or with yam, maize or rice. They are also consumed as akara balls) or steamed (moin-moin) (Phillips & McWatters 1991). Legume proteins are of poor nutritional value unless subjected to heat treatment (Nielsen, 1991). Cowpea needs to be rehydrated and cooked to be able to make it edible. It needs more cooking time and use of more fuel and loss of nutrients, constraining the use of dry beans as food in developing countries. According to the study conduced by Shehata et al. (Shehata et al. 1984) it was found that cowpea stored under nitrogen required a shorter cooking time than those stored in jute bags or and metal containers.(Taiwo 1998)

3. Oilseeds

a. Peanut

Peanut (Arachis hypogaea L.) is an annual crop grown predominantly in the Mediterranean region. Peanuts are classified as nuts for dietary studies, but they are actually not nuts. They have characteristic of both nuts and pulses. Peanuts are legumes which grow underground also in many countries popularly known as groundnut (Higgs & Higgs 2002). Peanut of the pea family, has thin brown skin and develops into an underground pod. Such pod usually contains two of these seeds. Its seeds are a rich source of edible oil (43–55%) and protein (25–28%) (Akcali et al. 2006). It is widely cultivated in warm climates. The crop is an important source of protein in human nutrition and livestock feeds (Aydin 2007). Peanut consist of shell (Spanish about 20% and Runner 26) % and Kernel (80% Spanish and 74% Runner). The kernel is made up of about 72.4% cotyledons (halves), 4.1% skins, and 3.3%germs (hearts). It contains of equal weights of both fatty and non fatty constituents. The importance of unsaturated fats have been described (Willett 1998). Studies show that by consuming peanuts 5 times a day one can reduce the chances of cardiovascular disease (CVD), type two diabetes and gallbladder disease (Hu et al. 1998; Jiang et al. 2002; Tsai et al. 2004). According to the US Government food survey data from 1994 nut eaters especially peanuts eaters had lower BMIs than non nut and peanut eaters (Sabate 2003; Griel et al. 2004). It was also found that regular peanut consumer have better overall quality of diet, having higher intakes of vitamin E and folate, zinc, magnesium, iron, monounsaturated fat and dietary fiber, and lower intakes of cholesterol (Griel et al. 2004). Forty eight percent of the total fat in peanut is monounsaturated, oleic acid and it contains no cholesterol. Peanuts are as rich in antioxidants as many fruits, in particular vitamin E and the polyphenol, p-coumaric acid, which has been shown to block lipid peroxidation and reduce cholesterol levels. The peanut mainly contains four tocopherols (Woodroof 1983) among which alpha t ,which has higher biological activity compared to other tocopherol, was recognized as most abundant homolog (Talcott et al. 2005). Thus, making use of a moderate fat diet with peanut can improve diet quality both directly and indirectly (Higgs 2005). The crude protein of peanut seed ranges from 22-30% (Altschul 1964). Total protein of the peanut can be classified as albumin, globulin, arachin, nonarachin and conarachin (Cherry et al. 1973). Archinin forms 63% of the total protein while conarachin forms around 33%. However, peanut is deficient in lysine and methionine (Woodroof 1983). The starch content of peanut varies from around 5-5%.

The cotyledons contain round 18% carbohydrate and skin contains around 1%. It also contains about 4-7% sucrose. The peanut flavor, nuttiness, sweetness and bitterness can be controlled by harvesting, storing and processing conditions.

4. Starchy tubers, banana, plantain, and others

Roots and Tubers provide energy to our body in form of carbohydrate. The energy provided is one-third of that of an equivalent weight of grain, such as rice or wheat, as tubers have high water content. The nutritive composition of roots and tubers varies place to place depending on the climate, the soil, the crop variety and other factors. Protein content in most root crops is low, and sulphur containing amino acids are the limiting amino acids. Cassava, sweet potato, potato and yam contain some Vitamin C and yellow varieties of potato, potato, yam and cassave contain beta-carotene. The root crops, banana and plantain are mainly made up of 60-90% carbohydrate. Plant carbohydrate is made up of cellulose, gum and starches, but starches are the main source of nutrient energy as cellulose is also not digested.

Starches are made up of two main polymers, a straight chain glucose polymer called amylose, which usually constitute about 10-30 percent of the total, and the branched chain glucose polymer, amylopectin, which makes up the rest. The physical properties of starch affect the digestibility and processing qualities of root crops. The rheological properties of starch grain becomes important in preparation of some foods like fufu. Cassava has special characteristic for food processing. It is readily geletanized by cooking with water and the solution after cooling remains comparatively fluid. Banana is known to have beneficial effect in intestinal disorders. Yam and Cassava in Africa is high in protein. However, most roots and tubers are limiting in sulphur amino acids, which can be supplemented by combining them with wide variety of foods like cereals.

5. Isolated Fats

a. Palm oil and others

Palm oil is the highest source of provitamin A carotenoids, and it is highly bio-available because of the fat milieu and the absence of a plant matrix (Choo Y 1993). It also provides fat, which is often in short supply and affects the bio-efficacy of dietary provitamin A carotenoids. It is also a source of several antioxidants including vitamin E and non-VA carotenoids which are involved in the prevention of cancer and other chronic diseases (Ng et al. 2000). RPO has been shown, contrary to common belief, to have a protective role in cardiovascular disease through increasing HDL-cholesterol (Edem 2002). It is a staple fat in several countries of West, Central, and Southern Africa. However, the levels of consumption by nutritionally vulnerable groups and the extent of oil blanching, which destroys the VA activity, are by and large unknown. Palm oil helps women and children to overcome deficiency of VA (Zeba et al. 2006)

b. Processing

i. Extrusion and its advantages

The cereals and legumes are cooked or proceed before human consumption to increase their palatability and acceptability. Methods such as thermal processes that use high temperature, short time proceeding conditions like extrusion, microwave heating and spray drying are widely used in industries. The utilization of such treatments can either enhance or reduce the nutritive value of protein as a result of factors such as temperature. Many plant components contain numerous components that can prove to be toxic to the health. The processing or cooking process results in destruction, inactivation or lessening of toxic components (Anti nutritional factors). For example, Lema bean contains amylase inhibitors which may interfere with the starch digestion and cyanogens which may lead to respiratory failure. Tannins which are found in most legumes can form a less digestible complex with proteins. The extrusion process helps to inactivate the anti nutritional factors like protease inhibitors and other proteinaceous anti nutritional factors. This is important especially when processing the leguminous seed (Asp et al. 1987).

Extrusion cooking is a high temperature, short time (HTST) process that is commonly used in the food industry. The process combines the use of unit operations such as feed transport, mixing, working and forming conditions of high pressures and shear forces at relatively low moisture contents (Camire et al.1990). It is a continuous process in which there is minimal nutrient destruction. The feed material is cooked, stabilized, homogenized, and dehydrated. There is change observed in physical, molecular, sensory and microbial properties of the product (Kollengode and Hanna, 1997). Also in comparison to the traditional pressure cooking rendering operations, extrusion is an energy efficient process with no waste effluents (Harper, 1981). Extrusion cooking also has beneficial effect on the protein nutritional value by inhibiting the antinutritional factors and is of significant importance for leguminous seeds. Food Extrusion has been practiced for almost 40 yrs and is relatively a new technology. Its first application was in formation of pasta for its kneading and formation. During 1940's extruders were used for precooking of cereal and oil seed blends and later for production of animal feed. This method increases the palatability and digestibility of the food (Richard Jansen and Judson M Harper). For developing countries, extrusion process can provide an intermediate food processing technology for local manufactures to develop a nutritious and acceptable product (Harper 1989). Extrusion cooking is a rapid and economical way to manufacture food products such as expanded snacks, macroni, ready-to-eat, breakfast cereals, breadings, croutons, soup bases, drink bases, and pregelatinized starch (Harper 1986a). Its versatile and low cost processing properties make it popular in food and feed technology application industries (Harper 1986a).

Effects of extrusion cooking

1. Starch:

Starch is present in plants in form of granules. Starch consist of two polysaccharides namely amylose and amylopectin. Both polysaccharides are based on chains of 1→4 linked α-D-glucose, but whereas amylose is essentially linear, amylopectin is highly branched containing on average one 1→6 branch point for every 20-25 straight chain residues (Hoseney 1994). A large variety of plants such as cereals, legumes and tubers contain starch respectively cereals (which are 50-60% db starch), legumes (25-50% db), and tubers (60-95% db). The extrusion process does not affect the starch content of the product as there is no new linkage formed (Colonna & Merciet 1983).

Functionality has been defined as any property (besides nutrition) of a food ingredient that affects its utilization (Pour-El 1981) and most of the physical and sensory properties of extrudes depend on the extent of starch degradation (Gomez and Aguilera 1983). During extrusion the starch by action of heat, shear action and moisture undergoes gelatinization and melting which leads to depolymeration of amylose and amylopectin (Colona et al 1984; Camire et al.1990). Extrusion plays a very important role in the in the processing of starch containing foods as it provides desired shape, expansion, crispness and pleasing characteristic to the product.

Effect of starch on extruded product are as follows (Feldberg and Smith):

Density control-----A starch high is amylose tends to produce a highly expanded snack product.

Strength-----Strength can be increased and breakage reduces by certain modified starches and is often associated with hard texture.

Shelf life improvement-----The crispiness of the product can be maintained by pregelatinization waxy starch.

Moisture intake-----Extruded product have low moisture content in them which gives product with harder flinty texture. This helps to avoid pet foods and cereals from being soggy in bowl.

Flavor-------Flavor of choice can be added to the finished product. As the product is high in amyl pectin starches which gives a expanded product of bland taste.

Water-holding capacity-----The water activity of the semi moist food is reduced due to highly modified starches and dextrin.

Fat binding---In extruded meat product modified starches “trap” or bind. There by reducing shrinkage.

The textural properties of finished starch product depend on the ratio of amylose to amylopectin in starch (Murray et al). A high amylopectin product promotes puffing giving a very light and fragile product. However, if the product is high in amylase it will give less puffed and harder variety of product. Also, 205 amylose in starch is considered minimum requirement for puffing and amylase contents greater that 50% give an exceeding dense product lacks puff.

Extruders machine are capable of processing dry granular cereal ingredients (up to moisture 20%). During the transport the mechanical energy required to turn screw is converted to heat, raising the temperature of the mixture to over 150°C. The resulting plasticized feed materials are then forced through die. The pressure drop across the die causes puffing to occur when the high-temperature water in the product rapidly converts to steam (Linko and Harper 1998).

2. Protein

The protein structural changes can occur due to heat and shear and cause denaturation, association and bond scission. In case of high temperature the formation of a concentrated solution, possible formation of some covalent bonds in the melted phase occurs. While at cold and transition amorphous regions at sufficiently low moisture non-covalent and disulfide bonding into a vitreous state is possible. The digestibility of the plant extrusion can be increased at Mild Extrusion (Srihara and Alexander, 1984, Hakanssonet et al., 1987).

The millard reaction that occurs during storage or processing of the free-amino group of lysine reacts with the carbonyl group of other compounds present, such as reducing sugars. However the product of this reaction cannot be utilized by humans after digestion and absorption. The formed complex product when digested (Hurrell and Carpenter, 1981; Rutherfurd & Moughan, 1997; Larsen et al., 2002). In vitro amino acid analysis under acid hydrolysis conditions some of these Millard compounds revert back to lysine. During metabolic process this results in overestimation of lysine. Millard reaction is generally promoted by extrusion (Bj¨orck & Asp, 1983; Berset, 1989). It is generally believed that Millard reactions involving lysine occur during manufacturing of pet foods (Morris et al. 1994). Scientific data, however, indicate that lysine damage due to the thermal processing employed in the manufacture of pet foods appears to be minimal.(Hendriks et al. 1999). According to a study heat sterilization process employed in the production of a moist feline diet did not significantly damage lysine. In addition, one study reported only a 3% difference between total and reactive lysine for a dry extruded feline diet indicating that 97% of the lysine contained a free -amino group and as such

Millard reactions involving lysine were minimal during processing and storage (Rutherfurd et al. 1997).

The plant protein source legumes are also rich and inexpensive sources of carbohydrates, dietary fibers, vitamins and some minerals including trace elements (Gatel & Grosjean 1990). The presence of antinutritional factors such as phytates, polyphenols, enzymeinhibitors (trypsin, chymotrypsin, and a-amylase) and hemagglutinins limit the consumption of legumes (Fernandez et al. 1997). But there are also results obtained where low concentration of antinutritional exert beneficial health effect (Shahidi & Shahidi 1997). Therefore one can remove or reduce the unwanted antinutritional components by modifying the processing conditions. One of the methods utilized for increasing the utilization of legume is extrusion cooking (Van der Poel 1990). There is rapid increase in the application of extrusion cooking to legume processing and can now be considered as a technology of its own right.

3. Fats

In extrusion process fats and oils have 2 functions is to lubricant and modify quality of final product.

Types of extruders:

Extrusion cooking is done by Extruders. Extrusion machine has given food manufactures to offer a wide range of textured and shaped product. The extruders can be classified into various ways, one of them is based on their thermodynamic characteristic of the extrusion process (Harper 1986a). They can be classified as piston extruders, roller extruders, and screw extruders:

Piston extruder—It is a simplest form of extruder. It consist of single piston or battery of piston which force the material through the nozzle onto a wide conveyor e.g. used in confectionary industry.

Roller Piston- In roller extruder two counter rotating drums are placed together. The product characteristic is controlled using the rotation speed b of the drums and the distance between them e.g. used for sticky material.

Screw extruders-They are categorized into three types, - Single, twin and multi screw.

Twin Screw Extruders-The twin screw extruder is used in industry since 1970's and are extensively used in food production.

- Advantages of Twin screw:
- Better process control
- Versatility of product obtained
- Flexible design making cleaning easy
- Rapid product changeover.

A profiling barrel hosing holds screws which are placed adjacent to each other and making a horizontal figure of eight. It may have intermeshing where flight of one screw engages other or non intermeshing screw where flight of one screw does not engage the other. The screw arrangement can be both counter rotating and co-rotating. For processing of low viscosity material like chewing gum, jelly etc, intermeshing counter rotation machines are utilized. Such material requires low screw speed and low resistance time.

For the product of expanded snack intermeshing co-rotating screw are used where high degree of heat transfer is required. Here the flow is combination of both drag and positive flow. These extruders are mostly self wiping which gives it high capacity and enhances mixing ability.

The radical force generated is easily and evenly generated than intermeshing counter rotating machine. The pressure profile within the barrel is controlled by foreword and reverse conveying disk. By pushing the material towards the barrel the forward conveying disc increases the pressure and similarly the reverse conveying disc delay the passage of material through the extruder.

IV. Research Objective

The primary objective of this study was to apply existing knowledge to the development of snack foods that would meet the nutritional needs of 9-13 year old child. The product concept was generated by previous studies done by many researchers. The decision to use appropriate technology was also motivated by the principal conditions relevant to design and employing an intervention that cold be sustained by the local community and help in economic growth.

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CHAPTER 3

Application of Least Cost Formulation Software in Snack Food Formulations [1]

[1]N. P. Jain and R. D. Phillips. To be submitted to Food Research International

Abstract

In developing countries malnourishment is major concern in school children. Low cost snack foods, suitable as supplements which satisfies 9-13 yr old nutritional requirement were designed for the West African market. The projected vector for these snack foods were street vendors in West Africa. The local crops of Ghana were used for formulation. The least cost formulations were mainly made of cowpea, corn, peanut, banana, palm oil and water. The constraints placed during formulation were on fat content ranging from 2.5 to 7.5% and moisture content 15% and 18%. The prices of ingredient were adjusted for inflation using the Ghana consumer price index. A total six formulations were selected such that 100g serving size met ¼ DRI requirement and the ingredient price of the product ranged from $0.17 to $0.20 per kg. Each formulation contained a minimum 11g of protein, 400 kcal/100g of energy and met amino acid requirements.

Keywords: Street foods; Dietary Reference Index; Snacks; Consumer Price Index; Least cost formulation

1. Introduction

In developing countries, malnourishment is still a major concern (Von Braun et al. 2005). According to Food and Agriculture Organization of the United Nations, "850 million people worldwide were undernourished in 1999 to 2005" and the number of malnourished people has recently been increasing (FAO 2007).

Unlike developing countries, in developed countries the major nutritional challenge is that of obesity. Studies show that 17% of USA youngsters are obese and million are overweight (Cook 2007). This leads to an increased risk for cardiovascular consequences and other serious physical and psychosocial health problems (Dietz 1998). The obesity concern has become so strong in US that many states have banned snack foods in vending machines e.g. in New Jersey.

As snack foods are sold in vending machines in developed countries, in developing countries like those in Africa they are often available in form of street foods which form a major source of food for an individual. Street foods are often derived from the traditional foods that are the most popular meals in these countries (Edwards 1985). For example in Ghana street foods are a million dollar market and form about 40% of the total food budget (Ekanem et al. 1994) with a combined annual turnover of US $100 million (WHO 2006). In Accra alone there are 60,000 street food vendors. These street foods are developed from the traditional foods and are mostly energy dense and consumed by children (Levin et al. 1999). Studies show that almost two-thirds of students normally had breakfast at home; it consisted usually of tea, "sometimes with milk added". Only a small proportion of the children bring packed lunches for their mid-morning meal and mostly purchased street foods brought from street vendors during school recess (FAO 2007). Some popular street foods include akara (fried cowpea paste), roasted and fried yam and plantain, foo-foo, moin-moin (steamed cowpea paste) and buru-kutu (a fermented sorghum drink) (Owhe-Ureghe 1993).

The nutritional environment in most schools throughout the world has two components: Meal plan program and sales of competitive foods. According to USDA those foods are called competitive foods which are sold at school other than the meal plan program provided by government or school authority (Kann et al. 2005). Street foods sold by vendors at school are also categorized as competitive foods.

Snack foods, such as candy, chips, cookies, crackers and snacks, are mostly low in nutritional value and high in energy; these are often called “junk foods” (Heddley et al. 2004; Anderson & Patterson 2005). Most snacks are also unable to meet the Dietary Reference Intake. The Dietary Reference Intakes (DRIs) are a comprehensive set of nutrient reference values for healthy populations that can be used for assessing and planning diets (Institute of Medicine (U.S.). Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. 1997). They are being determined by the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes of the Food and Nutrition Board, Institute of Medicine (IOM), National Academy of Sciences, with help from Health Canada.

Although snack foods are filling and help meet daily energy needs, they generally lack a variety of other nutrients essential for active, growing children (Bhat & Waghray 2000; Mensah et al. 2002). Unfortunately, energy-dense, but nutrient-poor, snacks are the only foods many of the children can afford in West Africa. FAO's Nutrition and Consumer Protection Division (AGN) is focusing on enhancing the safety and nutritional quality of school street foods. According to the study done by AGN it was found that these foods provide about two thirds of children’s daily food intake comes and form a significant part of the dietary intake of child (FAO

2007) By introducing better nutrition and more variety of street foods for street vendors to sell at affordable price, street foods could become a major part of the solution to problems of poor nutrition among school children (Oguntona et al. 1998). These street food vendors obtain this snack food ingredient from whole sale market or retail sector and are mostly governed by children's preference and cost. Vendors, when contacted for the survey, agreed that they are unable to provide vegetables and fruits because of the cost factor (Kinabo 2004).

According to same-price elasticity, if a price of commodity increases then the consumption of that commodity decreases (Epstein et al. 2006). In this complementary relationship as price of the first commodity increases then purchase of second commodity decreases (e.g. as price of hotdog increases then purchase of mustard will decrease). Also, in case of cross price elasticity, if the price of the first commodity increases, then there is also an increase in consumption of substitute commodity. The tendency to substitute may be affected by income. A study showed that when the income available to purchase a given brand of cigarette is reduced, smokers are more likely to substitute an alternative brand that is lower in price than to stay with their preferred brand (DeGrandpre et al. 1993). Extended to food purchases, this research suggests that relative to other children, those who have less available money to spend may choose healthier foods when the price of less healthy foods increases, despite having a greater preference for unhealthy foods (Epstein et al. 2006).

The objective of this research was to formulate affordable snack products which can be a supplement to meal plan programs and also contribute significantly to the nutrient requirements of 9-13 yr old children. A least cost formulation software was selected to develop nutritionally optimized mixtures for subsequent conversion to snacks. The crops selected for this research were local crops of Ghana taking into consideration the preference of children and affordability of final product.

In this study, fat and moisture contents were constrained to produce formulas that could be successfully processed by extrusion. Further, banana was forced into some formulations in an attempt to provide its desirable flavor to some products. High and low prices for each commodity were specified, based on price variations over a five year period and within year price variations.

Materials and Methods

I. Formulation Approach

A. Software

Least cost formulation software are used to choose the best possible ingredient/ingredients to meet the desired nutritional requirement at least cost (Rossi 2004). It is based on "Linear programming. In this study we used Version 6.01.Concept4-S (Creative formulation concept LLC, Annapolis, MD)

To formulate a product using this software, one needs to input the following information.

1. Ingredient list:

   The user inputs ingredients available for inclusion in formulation. The list of ingredients should contain unit price

2. Nutrient composition:

   Each ingredient user inputs should have a nutrient profile available for that particular ingredient.

3. Formulation specifications:

The formulation specifications are set to desired nutrient levels or ingredients quantity etc.

B. Inputs into software

(i) Ingredients selected

The ingredients were selected among the common commodities available in West Africa. Commodities chosen for possible inclusion into products were

Cereals: Maize, sorghum, millet.

Oilseeds: Peanut.

Starchy legumes: Cowpea.

Roots: Yam, cassava, starchy fruits (banana).

Vegetable oil: Palm.

ii) Ingredient nutrient profiles

The possible ingredients's nutrient profiles were obtained from the USDA data base (USDA-ARS 2006). Banana puree and peanut flour nutritional profiles were given by the suppliers. Nutritional profile of 28% fat-light peanut flour profile was obtained from Golden Peanut Company, Alpharetta, GA, and aseptic banana puree nutrition profile was obtained from Borj ITI Tropical's, Inc. Philadelphia, PA.

Table 3.1 Nutritional composition of ingredients used in formulation

Nutrient	Corn flour	Peanut flour	Cowpea flour	Banana	Palm oil
Proximates /100g					
Moisture(g)	10.91	1.05	11.95	74.91	
Fat(g)	3.86	28.18	1.26	0.33	100
Protein(g)	6.93	41.32	23.52	1.09	
CHO(g)	76.85	20.18	60.03	22.84	
Energy(Kcal)	272	523	336	89	884
Leucine(g)	0.85	0.35	1.81	0.07	
Phenylalanine(g)	0.29	2.68	1.37	0.05	
Lysine(g)	0.19	1.48	1.59	0.05	
Valine(g)	0.35	1.73	1.12	0.05	
Isoleucine(g)	0.25	1.42	0.96	0.03	
Threonine(g)	0.26	1.42	0.89	0.03	
Methionine+cystine(g)	0.15	0.51	0.33	0.01	
Histidine(g)	0.21	1.45	0.73	0.08	
Tryptophan(g)	0.05	0.40	0.29	0.05	

iii) Ingredient prices

The prices of the ingredients were obtained from wholesale market of Ghana (Amedo 2006). The 30 yrs prices were obtained through the preceding given source. However, five years of data from 2001 to 2005 was used for Consumer Price Index (CPI) calculations. The prices were converted to US dollars. The minimum and maximum prices for the ingredient were used for the formulation.

The CPI was used to compare dollar amounts between years using "constant dollars". Constant dollars are dollars which are adjusted for inflation.

Adjusting for inflation, the following formula was used:

$Pb=Pn*(CPIn/CPIb)$

Where, Pb = Price in base year dollars (i.e. price in “constant dollars”)

Pn= Price in year n

CPIn= CPI of the year n

CPIb= CPI of base year

Once Pb is determined the next step was to convert the price in $US using the exchange rate

i.e. Pus=Pb/E

Pus= Price in US dollars

Pb= CPI corrected price

E= Exchange rate

The Pus obtained for monthly five years data was grouped according to seasons namely, Dec to March and July to Oct. This was done to take into consideration the general trend in price rise and fall according to growing season and availability. From this data minimum and maximum price was selected to get a range of data to see the variation in prices of various commodities and to make least cost product using this data.

The minimum price was from December to March for all commodities while the maximum price was obtained between months of July to October.

The calculation for corn is shown Table 3.2, 3.3, 3.4.

Table 3.2 Corn price in cedis/kg

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	1290.32	1324.24	1468.51	1777.04	1871.55	1814.84	1894.89	1820.00	978.45	1027.00	1245.80	1506.90
2002	1444.88	1405.20	1415.75	1460.83	1537.36	1620.75	1514.94	1270.34	1029.85	1025.40	1128.37	1246.46
2003	1397.59	1419.10	1469.31	1416.50	1544.32	1763.14	1722.07	1543.61	1297.46	1317.77	1495.93	1577.04
2004	1814.31	1737.31	1808.37	1910.08	2039.33	2165.54	2472.58	2359.42	2088.44	2030.00	2370.00	2630.00
2005	2496.50	2738.30	3067.80	3662.00	4325.30	4503.10	4191.80	3354.45	2852.50	2850.20	3067.90	2787.30

Table 3.3 Corn price adjusted for CPI (Cedis/kg)

Year	CPI	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	32.90	560.84	575.58	638.29	772.39	813.47	788.82	823.61	791.06	425.28	446.39	541.49	654.98
2002	14.80	628.02	610.77	615.36	634.95	668.21	704.46	658.47	552.15	447.62	445.69	490.45	541.77
2003	26.70	607.46	616.81	638.63	615.68	671.24	766.35	748.50	670.93	563.94	572.77	650.21	685.46
2004	12.60	788.58	755.12	786.01	830.22	886.39	941.25	1074.71	1025.52	907.74	882.34	1030.12	1143.13
2005	14.30	1085.10	1190.20	1333.42	1591.70	1880.00	1957.27	1821.97	1458.01	1239.80	1238.80	1333.46	1211.50

Table 3.4 Corn price in US dollars

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	0.27	0.28	0.31	0.38	0.40	0.38	0.40	0.39	0.21	0.22	0.26	0.32
2002	0.23	0.23	0.23	0.24	0.25	0.26	0.25	0.21	0.17	0.17	0.18	0.20
2003	**0.10**	0.11	0.12	0.11	0.12	0.14	0.14	0.12	0.10	0.10	0.12	0.13
2004	0.11	0.10	0.11	0.12	0.12	0.13	0.15	0.14	0.13	0.12	0.14	0.16
2005	0.15	0.16	0.18	0.22	0.26	0.27	**0.58**	0.20	0.17	0.17	0.18	0.17

The values in bold are highest and lowest prices

Looking at price cycles establish lowest and highest prices for each ingredient as follows:

Table 3.5 The lowest and highest value of the ingredient price in US dollar.

Ingredient	Lowest ($/kg)	Highest ($/kg)
Corn	0.14	0.58
Cowpea	0.25	1.00
Peanut	0.36	1.29
Banana	0.09	0.49
Palm oil	0.62	2.06
Millet	0.22	0.90
Cassava	0.10	0.24
Yam	0.18	0.60
Sorghum	0.24	0.95
Rice	0.28	1.05
Garri	0.20	0.80

iv) Nutrient target

The nutritional targets were set to formulate a product which is able to meet requirement of 9-13 yrs old children, as shown in Table 3.6

Table 3.6 DRI requirement of school going children.

Nutrient	9-13 year
Protein(g)	34
Iron(mg)	8
Total fat(g)	62-85
Calcium (mg)	325
Calories	Girls 1600-2000 Boys 1800-2400
Vit A (IU)	2000
Vit C (mg)	45
Sodium(mg)	1500-2200
Cholestrol(mg)	<300
Methionine(g)	0.748
Cystine(g)	0.748
Lysine (g)	1.496
Tryptophan(g)	0.306
Threonine (g)	0.952
Isoleucine(g)	0.952
Leucine(g)	1.496
Leucine(g)	1.496

Source: USDA/ARS Children's Nutrition Research Center at Baylor College of Medicine (March 8, 2006)

v) Impose constraints

Based on the nutritional requirement to be targeted and changes to make in formulation for extrusion conditions various constraints were imposed. Fat levels expected to allow puffing while examining the effect of these levels of fat on product quality were levels 2.5, 5 and 7.5%. Some of the fat was required for spicing coating, so we decided to use rest of the fat to meet our desired level by spicing. Moisture levels in the range expected to produce acceptable product 15% and 18% to increase the shelf life and to make product crisp and acceptable. Banana was incorporated as one of the ingredient when formulations were made at 18% moisture, while at 15% moisture it was not included. No constraint was placed on vitamin and minerals level as minimum levels can be met by adding a supplement to the snack food after extrusion. Minimum constraints were placed for amino acids.

4. Results & Discussion

When the nutritional and local commodity constraint was introduced in software, six major formulations satisfying the requirement of nutrition, price and ingredient was obtained. The software mostly selected corn, cowpea, peanut, banana and oil for its formulation. The different formulations were obtained by constraining fat and moisture levels. At 15 % moisture formulation A, B and C were obtained with no banana. While when moisture constrains was increased to 18% Banana was automatically included in the ingredient list. It was also observed that cost of the product was minimum when the amount of corn in mixture was maximum, as its inexpensive source of nutrients. Also, using this software it is possible to generate a very large number of formulations from a given list of ingredients by adjusting nutritional constraints, by forcing the software to include or exclude certain ingredients, and by specifying ingredient prices as they vary due to changes in availability due to harvest cycle, demand, and many other factors. From the formulations generated by this process the six shown in Table 3.7 were chosen for processing and further study.

Table 3.7 Ingredient composition (%) of optimized formulation and their cost.

Formulation #	Cost $/Kg	Corn Flour	Peanut flour	Cowpea flour	Banana	Palm oil	Water
A	0.20	38.13	1.11	56.70	NA	NA	4.05
B	0.18	55.68	8.76	30.36	NA	NA	5.21
C	0.17	72.61	16.46	4.57	NA	NA	6.36
D	0.19	37.35	1.36	50.83	10.46	NA	NA
E	0.18	54.25	9.07	24.61	12.07	NA	NA
F	0.17	69.68	16.57	NA	13.65	0.09	NA

NA-Ingredient not selected in formulation

The ingredients selected for formulations were mainly Cowpea, Corn, Peanut, Banana and Palm Oil. The ingredient composition of the six snack formulations were optimized to meet the nutritional requirement of the snack food are provide in Table 3.7. The Table 3.8 shows a comparison of minimum and obtained composition of formulations.

Table 3.8 Constrains placed on snack food formulations and comparison of minimum levels set for protein and amino acid to the formulations obtained

Formulation	15% Moisture						18% Moisture					
	2.5 % Fat		5 % Fat		7.5 % Fat		2.5 % Fat		5 % Fat		7.5 % Fat	
	A		B		C		D		E		F	
	Minimum	Obtained	Minimum	Obtained	Minimum	Obtained	Minimum	Obtained	Minimum	Obtained	Minimum	Obtained
Fibre, Total Dietary (g)	*	9.84	*	9.96	*	10.08	*	9.46	*	9.58	*	9.69
Sugar (g)	*	4.15	*	2.45	*	0.78	*	5.03	*	3.52	*	2.12
Carbohydrates (g)	*	63.57	*	62.78	*	61.87	*	61.88	*	61.05	*	60.01
Protein (g)	9.13	16.44	8.87	14.62	8.62	12.91	8.49	15.22	8.25	13.43	8.02	11.83
Leucine (g)	1.38	1.38	0.39	1.26	0.38	1.14	0.37	1.28	0.36	1.16	0.35	1.05
Lysine (g)	0.40	0.99	0.39	0.72	0.38	0.46	0.37	0.91	0.36	0.64	0.35	0.39
Valine (g)	0.23	0.79	0.22	0.69	0.22	0.59	0.21	0.73	0.21	0.63	0.20	0.54
Isoleucine (g)	0.26	0.65	0.25	0.54	0.24	0.46	0.24	0.60	0.23	0.51	0.22	0.42
Threonine (g)	0.26	0.62	0.25	0.54	0.24	0.46	0.24	0.58	0.23	0.49	0.22	0.42
Methionine +cystine (g)	0.20	0.25	0.20	0.23	0.19	0.20	0.19	0.23	0.18	0.21	0.18	0.19
Tryptophan (g)	0.08	0.19	0.08	0.15	0.08	0.12	0.08	0.17	0.07	0.14	0.07	0.10

* Minimum values were not set for this nutrient

Among various ingredients used for different formulations the peanut and cowpea represent sources with high protein (Table 3.1). Peanut flour contains 41.32% protein and 28.18% fat: whereas, the cowpea flour contains 23% protein. Comparison of the six primary ingredient sources of amino acid used showed that they varied widely in amino acid composition, thus providing the individual impact to the formulated blend. The richest source of limiting amino acid lysine was cowpea with 1.591 g of protein. While closely followed by peanut at 1.483 g, lysine was least in banana puree. Tryptophan was highest in peanut 0.40% while lowest in corn around 0.049g.

The methionine and lysine requirement is met in these snacks by blends of cereal and legume. As increasing levels of fat in the formulations were specified, increasing levels of peanut were incorporated at the expense of cowpea with corn providing most of the remaining protein. It was also necessary to incorporate small amounts of water and oil into these formulations to meet the processing target levels. The inclusion of banana was limited by the high water content of banana puree. When cowpea flour was included in the snack food formulation, addition of peanut flour in high quantity was not required to reach adequate protein and amino acid levels. This helped to control the fat levels in the snack food to desired levels as cowpea is very low in protein content.

The software generated many formulations meeting the nutrition requirement of 9-13 yr old children, using different combination of ingredients, in addition to those shown in Table 3.8. However, these formulations were selected on basis of their minimum pricing. Surprisingly, when the higher price range was inserted, the resulting formulations had similar ingredients in similar proportions. Formulations A, B and C were made at a constraint of 15% moisture and didn’t contain banana puree. Formulations D, E and F were made at 18% moisture constraint and contained banana puree. Table 3.7 shows all formulations selected to be extruded into puffed snack. Formulation A was highest source of protein compared to all other products with 16.44 g of protein. This formulation contained highest amount of cowpea 56.70 g compared to other ingredients in the same formulation while negligible amount of peanut. It also contained 38.13 g of corn. This formulation contained 2.5% fat and 15g of moisture. It also contains the maximum amount of limiting amino acids compared to all other products. Other formulations from formulation B to formulation F were also able to meet the minimum nutritional requirement. The ingredient corn was present in each mixture and is major contributor to starch content of the formulation. Formulations which are a blend of legume and cereal contains an acceptable amount of starch, which undergoes gelatinization during extrusion to produce puffed snacks (De Cindio et al. 2002). Formulation D contains the maximum amount of lysine. As per the nutrient database for meal planning developed by Wheeler. There is 7.14 g to 9.00 g of protein in the snacks provided to children. However, the formulations made using least cost formulation software have protein range from 11.83 g to 16.44 g of protein. It also meets the limiting amino acid requirements which other snacks are unable to meet.

The ingredients price information used for the calculation of the least cost formulations are provided in Table 3.5. Although, earlier work has been done showing the price of the formulation, it was based on a single current price and did not take into account the price fluctuation due to inflation, nor within-year price fluctuations (El-Habashy et al. 1997). The price of the product selected here was corrected for inflation considering the data for 5 yrs which five years. The formulation C and F were least cost formations with cost of the product was $0.17/Kg. Formula C had least cost because of the maximum percentage of corn about 72% which cost about $0.14/Kg. It was observed that formulations with the same fat constraint but different moisture level that is 15% and at 18%, showed that the cost at 15% was always higher than cost at 18% moisture. This is, of course, due to the fact that water was assigned a cost of zero. Also, formulation E had least cost because of the 54% corn and 13.65 % of banana which provide a cheap source of nutrients.

5. Conclusions

In conclusion, the study shows that Least Cost Formulation Software can be applied to the development of snack foods. The study shows that selected legume/cereal formulations have the potential of producing nutritionally adequate formulations. However, it is necessary to process these formulations by extrusion to demonstrate that they can transformed into actual products. It is also necessary to perform chemical analysis on the resulting products to compare their final nutrient composition with computed/predicted values.

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CHAPTER 4

Convenient, Nutritious, and Affordable Snack Production by Extrusion Process for School Children[1]

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ABSTRACT:

Snacks designed to meet, in a one hundred gram serving, one fourth of the DRI for protein, essential amino acids, and fat for 9-12 year old children were made by twin screw extrusion. Least cost formulations of commodities commonly available in Ghana were extruded at moisture contents of 18%, 20% and 22%, fat contents of 2.5%, 5% and 7.5%, a screw speed of 400 rpm and a barrel temperature of 135ºC. The effects of composition and extrusion conditions on physical and nutritional properties of different snacks were studied. It was observed that as fat and moisture level increased, the expansion of the product decreased. During extrusion the different moisture and fat levels affected the density, protein, fat, moisture, amino acid, expansion ration and shear stress. The product was tested for aroma, color, texture, flavor and overall liking. There was no significant difference in ratings for all the sensory attributes except one sample made at 20% moisture and 7.5% fat.

Keywords: density, extruded snack, cereal/legume blend, consumer acceptance, sensory attributes

Introduction

Snack foods are characterized by their unique textural attributes that make them popular among consumers throughout the world. Several sensory terms, such as crispy, crunchy and crumbly, are often used to describe the specific textural characteristics of snack foods (Ravi et al., 2007). Demand for snacks has been growing over the past several years. The first generation snacks are considered conventional baked crackers and potato chips. Second generation snacks encompass the puffed collets produced by a low moisture extrusion processing, where the major sources used to produce highly expanded collets are degerminated corn grits, other cereals, and/or starch (Choi and University of Georgia., 2002). Once extruded, the collets are dried (or baked in the industrial vernacular) to lower than 4% moisture, and can be coated with flavors and oil (Harper, 1989). Third-generation snacks are indirectly expanded snacks, referred to as half-, semi-, or intermediate products.

Extrusion cooking is popular way of making second and third generation snack. Extrusion machines have given food manufactures a way to offer a wide range of textured and shaped product (Suknark et al., 1999). Extrusion cooking has various advantages over the conventional methods like high productivity, versatility, low operating costs, energy efficiency and shorter cooking time. (Ding et al., 2005). The extrusion machine makes variety of product like breakfast cereal, puffed snack etc, (Anderson, et al 1996: Meuser, et al, 1969). During extrusion there are various changes that occur in raw material such as gelatinization and sometimes dextrinization of starch, denaturation of protein, and destruction of vitamins (Ilo, et al., 1999). The factor which largely determines this is the moisture content of the product. Low-moisture extrusion of starch-rich ingredients leads to breakdown of amylose and amylopectin. Starch dextrinization(Gomez et al., 1983) and amylopectin breakdown due to mechanical shear

(Davidson et al., 1984) have been observed during low-moisture, high-shear single-screw extrusion. Starch solubilization (Mercier et al., 1975), macromolecular degradation of amylose and amylopectin (Colonna et al., 1984), and reduction of high molecular weight polysaccharide (Wen et al., 1990) were reported during twin-screw extrusion.

Snack extruders uses low moisture levels of 10-20%. In extrusion cooking, the puffed snack is formed by the vaporization of the water vapor at or near the exit (Sacchetti et al., 2004),where the dough is subjected to sudden transformation due to lower pressure. In the extruder shear, die geometry and rate of heating are the principle factors responsible for controlling product expansion (Bhattacharya et al., 1986) According to studies done earlier, it was found that as moisture increases the density, and hardness increase, while expansion and crispiness decrease.(Ding et al., 2005). Second generation snack are cooked in extrusion barrel and expand upon exiting the die (Suknark et al., 1998).

Although popular with consumers, snack product are generally unable to contribute to dietary requirements other than those for energy since they are often made of cereals and fat. To increase the protein content and the nutritive value of snack products ,one can make use of more nutritious ingredients such as peanuts and cowpea in the formulation of snack prior to extrusion (Suknark et al., 2001).

Hence, this research was carried out with following objectives:

1) Extrude different snack formulations previously generated by nutrient optimizing/least costing software at varying moisture and fat levels.

2) Study the physical and chemical properties of the resulting products.

3) Determine consumer acceptance using preference test.

Materials and Methods

Materials

Material source

The white, degerminated corn flour used in this study was purchased from ConAgra (Omaha, Neb., U.S.A.); partially defatted (28%), lightly roasted peanut flour was obtained from Golden Peanut, Alpharetta, GA; whole cowpea (California Blackeye 47) was obtained from Tarke (Warehousem Meridian, CA)., banana puree was obtained from ITI Tropicals, Lawrenceville, NJ; vegetable oil cinnamon, salt, and sugar were purchased from local grocery store. All were used without further processing.

Cowpea flour

Whole cowpea obtained from California grown beans (Tarke warehouse meridian, CA) was made to flour for extrusion formulation. The cowpea was soaked in water for 2 sec, drained, dried in an oven at 60oC for 12 hr, was and decorticated by coarsely breaking the seeds in a plate mill followed by passing through a seed cleaner to remove seed coats and eyes. Decorticated cotyledons were ground in a hammer mill (Model 6_14, Champion Products, Inc., Eden Prairie, MN) equipped with a 1.6mm screen. Other all flours and banana puree were obtained commercially. The formulations of ingredients have been reported (Jain et al., 2007). The ingredient were mixed to the desired ration using a ribbon blender (Model HD 1°- 3SS, Munson Machinery Co., Utica, NY)

I. Feed Materials for Extrusion

A 22.5 kg lot of feed materials were made based of the formulations developed in Chapter 3. Ingredients were weighed into a ribbon mixer (model HD 1 ½ - 3SS, Munson Machinery Co., Utica, NY) and blended for 30 minutes, following which they were transferred to heavy polyethylene bags and stored at 10C until use in a few days. Formulations are given in Table 4.1.

II Extrusion

Extrusion cooking was done to make a variety of different puffed snack as per the formulations. A co-rotating twin-screw APV Baker extruder (Model MPF 1700-30, APV Baker Ltd., Peterborough, England) with a length (750 mm) to diameter (30 mm) ratio of 25:1 and a tapered die with 2mm round orifice were used. The extruder consisted of the 4 independent heating or cooling zones and temperature controlled clam- shell barrel and die holder. The tapered die had an orifice of 2mm. Cooling water was delivered such that its exit temperature was maintained at 25-30 °C. Thermocouples were used to measure the dough temperature in the barrel. Torque (% full power) and pressure at the die (Dynisco transducer) were recorded. In this process, the materials were first fed into the volumetric feeder up to ½ filled, so as to maintain pressure and flow rate. The feeder was a K-Tron volumetric feeder (ModelK2VT20, K-Tron Corp., Pitman, NJ). Water was delivered to the extruder by a piston pump (Bran & Lubbe, Type N-P 31 Buffalo Grove, IL). Before starting the experiment the output rates of the feeder and pump were first calibrated. A screw configuration with combination of forward and reverse paddle was used to provide optimal performance in preliminary experiments. The extrusion condition varied according to the product formulation. The parameters were: screw speed = 400 rpm, Temperature -Zone1 to 5 -100,125,135,135,135 °C, Feed rate- 10kg/hr (Dry mater basis), Feeder Rate-125-205 rpm, Moisture content 18, 20, 22%. The extruded product was packed in polyethylene bags and stored at -18ºC and the later dried so as to lower the moisture and seasoned.

III Drying

After the product was extruded and stored next they were cut manually into size of 2 cm and dried in a Mechanical Convention oven (Model-91 and 91e PID Lindberg/Blue,A General Signal Compay,Ashevills,NC) at 70°C for 24hr to remove surface moisture and also to avoid cooking. Next they were sealed in Ziploc® freezer bags and stored at - 18°C prior to seasoning.

IV Analytical determination

These puffed snacks were studied to determine the effect of formulation and extrusion variables on physical, chemical/nutritional, and sensory characteristics.

1. **Nutritional Analysis.**

Composition (moisture and protein) were determined by procedures described in Official Methods of Analysis of AOAC International, 15th Ed. (AOAC 1990), no 925.09and 990.22 (using LECO (Model-Fp,Warrendale,PA.). respectively. Protein was calculated from the Nitrogen using a Kjedahl factor of 6.25. Moisture was determined using the Isotemp Vacuum Oven (Model 281 A, Fisher Scientific Co., Suwannee, GA). Fat analysis was done using an acid hydrolysis method to free lipids from complexes with amylose formed during extrusion and an ANKOM ^{XT15} (ANKOM Technology, Macedon, NY) extraction system.

Amino acid samples were first hydrolyzed using a method similar to Tuan and Phillips(1995). About forty milligrams of dried sample, containing approximately 10mg of protein were added to 5ml of a 12 N HCL solution containing 2.5%phenol in heavy walled hydrolysis tub; and 3ml of 2% DTDPA (dithiodiprpprionic acid) solution in 0.2 NaOH was then added. Next, 0.5 ml of an internal standard solutions, norleucine was added to the mixture. Then 1.5 ml of double deionised water was added to adjust the acid strength to 6N. These tubes were then sealed and subjected to alternate vaccum and flushing with argon for three times to remove air (oxygen) from the tubes. The tubes were placed in a heating block at 145°C and hydrolysed for 75 minutes.

After the cooling of tubes they were subjected to the AccQ Tag Derivatization method for amino acids (Water's Corporation 1996). One milliliters of hydrolysate was diluted to 25 ml in a volumetric flask and .a portion filtered through a 0.2 micron Millipore Teflon filter. HPLC samples were prepared by mixing 10ul of filtrate with 70 ul of AccQ fluor derivitization reagent in borate buffer. Next it was vortexed in low-volume vial. Samples were then heated at 55°C for 10 minutes and cooled. The reverese phase AccQ Tag Colum(C-18)(3.6x150 mm) used a binary solvent A (5.1 pH acetate buffer) and solvent B (60% acetonitrile, 40%water solution with a 50 – minute flow at 1ml/min).

2. Physical Analysis

A) Bulk density. A glass beaker was taken and the weight of the glass beads was recorded. Next the beaker was filled half with beads and the extrudase were added to it. The container was tapped on a wooden table 15 times and then tapped 10 times more while simultaneously adding glass beads to fill and overflow the beaker. The excess glass beads on the top of the container were removed by using a flat edge of a stainless steel scraper. The weight of the container was measured with and without the glass beads to get the weight of the sample. Next, the volume of the beads was taken and bulk density of beads was determined by weight of beads divided by volume occupied by beads. Finally, bulk density was calculated.

B) Expansion ratio. Expansion ratio was defined as the ratio of the diameter of the extrudates and the diameter of the die (Balandran-Quintana and others 1998). A digital vernier caliper was used to measure the diameter of the extrudate. Measurements were taken on 10 randomly selected pieces of extrudate, and ER was calculated as: E = D/D2, where D and D2 were the diameters of the extrudate and the die nozzle, respectively.

C) Shear stress.

To measure the shear strength of starch extrudates, dry strands (<2% db) of 2g of extrudates was placed across the width of an Instron Universal Testing Machine(Model 1122, Instron Corp., Canton, MA)equipped with a 5 load cell and Kramer. The force required to shear the product was recorded with an Instron universal testing machine (model TM) at a crosshead speed of 1 cm/ min. Shear stress was calculated by dividing the shear force by the crosssectional area of the extrudate sheared (Bhattacharya and Hanna 1987a). By dividing the maximum shear force by sample weight one obtained apparent shear strength (N/g). The reported values were averages of three determinations. Mechanical force to shear the product was represented in terms of apparent shear strength. Each value is an average of three readings.

V Spicing

A preliminary study was conducted with spice mixture containing 0.5 g cinnamon, 0.5 g salt and 0.5 g sugar. This mixture was unable to provide desired taste and the mixture formulation was modified to 4 g of cinnamon, 10 g of sugar and 1g of salt to coat 50 gm of the extruded product. In preparation for sensory analysis, samples of dry extrudate were placed in a rotating pan coating drum and sprayed with vegetable oil using a pre-weighed aerosol sprayer. The fat was added on each extruder according to the amount required to meet the DRI requirement. Spraying was stopped intermittently and amount of oil dispensed determined by re-weighing the sprayer. The mixture was sprayed using a salt dispenser between oil applications.

VI Sensory evaluation

Consumer preference test

Thirty two panelists were recruited from University of Georgia, Griffin Campus, consisting of staff and students, to evaluate snack samples. The consumers were asked to sign a consent form and provide demographic details of their age, gender, race, level of education, and household income, prior to sensory evaluation. The participants were not allergic to any of the ingredients contained in the any of the formulations. In a plastic cup the panelist were provided three pieces of each sample coded with 3-digit random numbers. A control sample consisting of a commercial puffed, cinnamon flavored cereal product, and five experimental samples were simultaneously presented to panelists in random order. The samples were provided with water and paper ballots on a stainless steel tray. Consumers evaluated the samples in individual booths under fluorescent light at room temperature. Drinking water and unsalted soda crackers were provided to cleanse the mouth between samples to minimize any residual effect of previous samples. Evaluation was conducted in individual booth at room temperature (23°C). A 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) was used to evaluate product attributes (color, appearance, aroma, flavor, texture) and overall acceptance. Product acceptance (yes or no) and willingness to buy (yes or no) were asked for each sample. Consumers were also asked to write comments freely about the samples.

Statistical analysis

The statistical analyses of data were performed by using the Statistical Analysis System (SAS Institute, Inc., 1988). Least Significant Difference (LSD) test was performed for comparisons. ANOVA was done on the samples, so as to see effect of moisture, fat and incorporation of banana on the physical properties of product.

Results & Discussion

I Formulations

Six different formulations which met the 1/4th of the DRI requirement for protein essential amino acids and fat at least cost were extruded. Table 4.1 shows the composition of each formulation that was extruded.

Table 4.1 Extruded snacks formulations (% ingredient)

Formulation #	Corn (g/100g)	Cowpea (g/100g)	Banana (g/100g)	Peanut (g/100g)	Palm oil (g/100g)	Water
A	38.13	56.7	NA	1.11	NA	4.05
B	55.67	30.37	NA	8.75	NA	5.2
C	72.6	4.57	NA	16.46	NA	6.35
D	37.35	50.82	10.46	1.36	NA	NA
E	54.24	24.6	12.07	9.07	NA	NA
F	69.68	Na	13.65	16.57	0.09	NA

NA Formulation could not be extruded

II Chemical and Physical Analysis

1. Protein, fat and moisture
   The different moisture content in the products varied from 18%,20%and 22%. Table 4.2 shows the actual moisture, fat and protein contents of the formulations obtained after extrusion in comparison to the predicted values. It was observed that there is a loss of about 10% moisture during extrusion and final products moisture content varied from 9-11%. The formulation also had fat constraint of 2.5%, 5% and 7.5%. The fat content obtained after extrusion was lower than predicted values this could be due to the use of degerminated corn flour. Also, the nutritional values used for formulation were obtained from the USDA Food Composition database, and these values may have differed from those of the actual samples used in this research. All analysis (except for moisture) were conducted on dry matter basis

Table 4.2 Moisture content, Fat content and Protein content of different snacks

Formulation #	Corn	Cowpea	Banana	Peanut	Palm oil	Water	CFS Formulations Moisture %	Fat %	Protein %	Actual Results Fat%	Protein%
A	38.13	56.7	-	1.11	-	4.05	18	2.5	15.21	1.72±0.47	17.18±0.59
							20	2.5	15.21	1.55±0.27	17.22±0.44
							22	2.5	15.21	1.58±0.13	14.55±0.24
B	55.67	30.37	-	8.75	-	5.2	18	5	14.62	4±0.86	16.68±0.02
							20	5	14.62	4.21±0.01	16.47±0.25
							22	5	14.62	3.28±0.85	16.21±.035
C	72.6	4.57	-	16.46	-	6.35	18	7.5	12.91	5.27±0.14	17.66±0.38
							20	7.5	12.91	4.32±0.14	17.21±0.05
							22	7.5	12.91	4.42±0.41	15.32±0.5
D	37.35	50.82	10.46	1.36	-	-	18	2.5	NA	NA	NA
							20	2.5	16.44	1.72±0.76	15.87±0.13
							22	2.5	16.44	1.35±0.35	15.97±0.49
E	54.24	24.6	12.07	9.07	-	-	18	5	13.43	3.8±0.78	15.37±0.57
							20	5	13.43	2.9±0.60	15.26±0.27
							22	5	13.43	3.43±0.16	14.25±0.23
F	69.68	-	13.65	16.57	0.09	-	18	7.5	NA	NA	NA
							20	7.5	11.83	4.54±0.14	15.91±00
							22	7.5	11.83	4.03±0.01	15.41±0.01

- Ingredient not selected in the formulation

NA Formulation could not be extruded

Table 4.3 Amino acid composition of the extruded Snacks (g/100g of protein)

Amino Acids	A			B			C			D		E			F	
	18[a]	20	22	18	20	22	18	20	22	20	22	18	20	22	20	22
asp	2.32	1.55	1.91	1.83	1.80	1.30	1.60	1.65	1.56	1.80	1.51	3.63	1.70	1.29	1.69	1.57
ser	1.25	0.78	1.02	1.03	0.98	0.70	0.86	0.89	0.85	0.96	0.82	1.98	0.90	0.71	0.90	0.90
glu	3.81	2.44	3.16	2.98	3.02	2.20	2.57	2.86	2.71	2.96	2.43	6.25	2.90	2.23	2.71	2.84
gly	1.12	0.61	0.93	0.93	0.89	0.70	0.71	0.92	0.87	0.87	0.64	1.80	0.80	0.66	0.77	1.06
his	0.95	0.54	0.82	0.76	0.68	0.50	0.61	0.75	0.76	0.68	0.56	1.26	0.60	0.42	0.67	0.71
arg	1.51	0.94	1.38	1.26	1.20	0.90	1.01	1.33	1.37	1.17	0.90	2.36	1.20	0.89	1.11	1.34
thr	0.89	0.55	0.71	0.67	0.65	0.40	0.57	0.65	0.67	0.60	0.53	1.16	0.60	0.41	0.61	0.58
ala	1.12	0.70	0.94	0.96	0.90	0.70	0.77	0.85	0.83	0.91	0.72	1.86	0.80	0.67	0.83	0.86
pro	1.01	0.72	0.85	0.92	0.88	0.80	0.77	0.87	0.88	0.96	0.72	2.04	0.90	0.75	0.82	0.82
cysx	0.32	0.15	0.31	0.38	0.39	0.50	0.29	0.29	0.22	0.50	0.31	1.15	0.20	0.46	0.27	0.29
tyr	0.99	0.57	0.93	0.93	0.78	0.60	0.66	0.87	0.86	0.80	0.58	1.54	0.70	0.57	0.75	0.90
val	0.91	0.60	0.80	0.71	0.66	0.40	0.61	0.63	0.70	0.61	0.56	1.18	0.60	0.41	0.66	0.62
met	0.25	0.17	0.25	0.34	0.27	0.30	0.23	0.25	0.25	0.33	0.21	0.57	0.20	0.29	0.26	0.24
lys	1.22	0.81	0.61	0.81	0.86	0.60	0.78	0.63	0.68	0.78	0.75	1.28	0.60	0.51	0.81	0.54
Ile	0.88	0.57	0.71	0.66	0.62	0.40	0.56	0.59	0.65	0.58	0.50	0.99	0.60	0.36	0.61	0.57
leu	1.66	1.11	1.39	1.38	1.30	0.90	1.16	1.27	1.29	1.27	1.08	2.65	1.20	0.93	1.25	1.22
phe	1.30	0.79	1.03	1.04	0.97	0.70	0.84	0.94	0.94	0.91	0.77	1.83	0.80	0.63	0.91	0.88
Total	21.52	13.59	17.75	17.64	16.85	12.31	14.61	16.26	16.07	16.68	13.60	33.53	15.22	12.18	15.62	15.94

[a] Moisture %

In Table 4.3 one observes sample C at 18 to 22% moisture showed similar results of amino acids composition. While amino acids for E at 20 & 22% moisture were different than 18% moisture. This difference could be due the error during conducting the experiment. As, it should be noted that during extrusion amino acid losses are minimal (Phillips and Finley, 1989).

In some cases when comparing the obtained results with the predicted values one find that though these formulations are able to meet the nutritional requirement, of 0.38g, they have lower values than the predicted values. However sample C gives a good replica in case of limiting amino acid lysine around 0.69 which meets the DRI requirement of 0.38g and also meets the predicted value of 0.49g.

2. Shear strength

The shear strength of extrudates made from Corn, Cowpea, Peanut, Banana and Oil are presented in Table 4.4. The shear strength was highest for formulation B at 18% moisture which did not contain banana in its formulation and was lowest for C at 18% moisture.

Table 4.4 Apparent shear strength of the extruded Snacks (N/g)

Formulation #	Moisture %	Shear Strength (N/g)
A	18	153.40 A
	20	67.65 BC
	22	46.33 BC
B	18	151.22 A
	20	153.60 BC
	22	152.45 A
C	18	42.70 C
	20	42.99 C
	22	51.72 BC
D	18	NA
	20	85.93 BC
	22	49.82 BC
E	18	33.26 A
	20	45.49 C
	22	51.50 BC
F	18	NA
	20	67.64 BC
	22	60.60 BC

Means followed by the same letter in each column are not significantly
NA Formulation could not be extruded

Corn Puffed Snack Control- 157.18A
Cinnamon cereal Control-145.98 A

The sample C at 20% moisture was very low compared to F at 20% moisuture. The shear strength was high in sample B at 18% moisture, as in this sample the starch content was low due to lower amount of corn compared to cowpea and peanut which contributed to protein content. In addition shear stress experienced during extrusion contributes to denaturation (Phillips, 1989) and the texturization of protein during extrusion is due to cross linking. Therefore, in starchy products as protein content is increased product becomes tougher (Colonna et al 1989).

2. Bulk density

The bulk density of extrudates made from Corn, Cowpea, Peanut, Banana and Palm Oil are presented at different constituents are presented in Table 4.5. In the present study the minimum bulk density occurred at sample C at 18% moisture without banana .as ingredient. And maximum bulk density occurred at sample F at 20% moisture. Studies show that if expansion increased it would be logical to assume that BD would decrease, under similar conditions; but BD increased abruptly at 22%feed moisture when temperature increased, this could be due to the effect of high temperatures on viscosity and starch degradation resulting in less expansion (Camire et al., 1990).

Table 4.5 Bulk Density of the extruded Snack

Formulation #	Moisture %	Bulk Density g/cm^3
A	18	0.2010 B
	20	0.4341B
	22	0.1031 B
B	18	0.0647 B
	20	0.0763 B
	22	0.1017 B
C	18	0.0587 B
	20	0.0700 B
	22	0.1173 B
D	18	NA
	20	0.2137 B
	22	0.1210 B
E	18	0.3217 B
	20	0.4393 B
	22	0.4900 B
F	18	NA
	20	0.9727 A
	22	0.4383 B

NA Formulation could not be extruded
Means followed by the same letter in each column are not significantly.

3. Expansion ratio

Table 4.6 shows the result of expansion ratio. Volume expansion ratio of sample B at 5% fat and 20% moisture, Sample Cat 7.5% fat and 20% moisture was maximum. This was because of high starch content delivered by high corn content. The starch undergoes gelatinization and results in expansion of the product As snack products are expanded, expansion results in textures that make them appetizing and crisp(Mercier et al., 1989). Most studies recognize that starch—as the dominant polymer in most cereal systems—plays a major role in expansion, while other ingredients such as proteins, sugars, fats, and fiber act as diluents. Starch is made of linear amylose and branched amylopectin,which impact expansion differently.(Mercier et al., 1975) reported that a high amylopectin content leads to light, elastic, and homogeneous expanded textures, while a high amylose content leads to hard, less expanded extrudates. According to several authors, maximum expansion of starch is reached at 50% amylosecontent (Launay et al., 1983, Mercier et al., 1975) . While least expansion was of sample F at 7.5%fat and 20% moisture. As this although contain high amount of corn, it also contained banana as one of its ingredient which acts as lubricant and reduces the shear though which product goes and thereby reducing the expansion ratio.

Table 4.6 Expansion ratio of the extruded Snack

Formulation #	Moisture %	Expansion Ratio
A	18	4.0490 E
	20	5.5555 C
	22	5.1510C
B	18	6.0650 B
	20	6.4780 A
	22	6.4140 AB
C	18	5.5940 C
	20	6.4560A
	22	5.6370 C
D	18	NA
	20	4.4465 B
	22	4.7970 D
E	18	3.2040 F
	20	3.5380 F
	22	3.1810 F
F	18	NA
	20	2.5770 G
	22	2.6250 G

Means followed by the same letter in each column are not significantly different

NA Formulation could not be extruded

Table 4.7 Effect of Banana on physical properties

Formulation	Bulk density (g/cm^3)	Expansion ratio	Shear Strength (N/g)
With banana	0.04 a	3.49 b	56.32 b
Without banana	0.14 b	5.17 a	84.67 a

Means followed by the same letter in each column are not significantly different

Table 4.8 Effect of Moisture on physical properties

Formulation with moisture %	Bulk density (g/cm^3)	Expansion ratio	Shear Strength (N/g)
18	0.16 a	4.73 a	70.15 a
20	0.36 a	4.85 a	77.22 a
22	0.23 a	4.63 a	68.74 a

Means followed by the same letter in each column are not significantly different

Table 4.9 Effect of Fat on physical properties

Formulation with Fat %	Bulk density (g/cm^3)	Expansion ratio	Shear Strength (N/g)
2.5	0.16 a	5.41 a	50.80 c
5.0	0.25 a	4.82 ab	97.92 a
7.5	0.42 a	3.61 b	66.00 b

Means followed by the same letter in each column are not significantly different

One observes a significant difference between formulations with and without banana as ingredient affecting physical properties as shown in Table 4.7. The incorporation of banana in formulation decreased expansion ratio and bulk density while increased shear strength. Variation in moisture levels didn't play any role in affecting the bulk density, expansion ration and shear strength of the product. Also, fat didn't affect the bulk density of the products. Results indicate that the bulk density was affected by the incorporation of banana as an ingredient. It was found that bulk density of banana formulation was lower than that of non banana formulations. In case of expansion ration the formulation without banana were significantly different from banana formulation. Also, expansion ration was affected by the fat content. The expansion was higher at 2.5 % fat and lowest at 7.5%fat.

Table 4.10 Sensory Analysis of the extruded snack

Samples	Appearance	Color	Aroma	Flavor	Texture	Liking
A	6.75 a	6.94 a	6.06 b	6.50 ab	6.78 ab	6.47 a
B	6.25 ab	6.53 ab	6.38 ba	6.37 ab	6.31 bc	6.31 a
C	6.06 b	6.50 ab	6.50 ab	6.28 b	5.84 c	6.32 a
D	6.72 a	6.94 a	6.47 ba	7.00 a	7.09 a	6.87 a
E	5.69 b	5.94 c	6.06 b	5.09 c	4.69 d	4.78 b
Control	6.25 ab	6.31 bc	6.91 a	7.00 a	7.09 a	6.72 a

Means followed by the same letter in each column are not significantly different.

19-commercial product

III SENSORY RESULTS

1. Preference test

The consumers had the opportunity to taste the samples and rate them in terms of their liking or dislikes for the following attributes; Appearance, flavor, color, aroma, texture and liking. The formulations were brownish in color with cinnamon seasoning. There were 5 experiment samples and one commercial cinnamon cereal as control. During preliminary studies five samples at 20% moisture levels were found to be acceptable for preference and were chosen for preference test. The preference test using hedonic scale was performed on the samples. The rating for each sample was given ranging from like extremely (9) to dislike extremely (1). Analysis of variance was performed on the ranked data for 32 panelists. The panelists were also asked to complete a questionnaire on demographics during the session (Appendix B). More than half (70%) of the respondents were female between 25-34 years of age and rest were males. There were 15% respondents of Asian descent and 80% were Americans and 5% were African this food was said to be taste by a large number of respondents (55%).

The results for appearance indicate that appearance score ranged from 5.6 to 6.7 Table 4.10. The sample A, B, D and control were not significantly different from each other while sample B, C, E and Control were also not significantly different from each other Table 4.10. The color of the formulation was also acceptable and ranked above commercial sample. The commercial product (Control) was ranked best in terms of overall liking and also was preferred in terms of flavor. Sample D formulation was also ranked high in terms of liking, aroma and flavor Table 4.10. Sample A was preferred best in terms of appearance and color. Except sample E all other samples were equally acceptable.

Color is important to attract consumers before they taste the product (Fransis, 1991) and from visual observation. The products were of different shades of brown depending upon their volume. There was no significant difference found between sample Control and D, which were most preferred sample. While sample E was least preferred sample. This difference was seen between the products because of the similar quantity of spicing for 50 g of product but because the volume of each extruded was different. It was observed that as expansion ration increased for 50 g of sample, the color was lighter shade of brown and vice versa. Therefore one can easily control the amount of spicing in 100 g of product to get the desired color on each sample.

In case of aroma, no significant difference was found between any products, however Control was preferred the most. The spicing was of cinnamon and may be during storage one lost some aroma or the amount added was not enough for the aroma. While, texture of control and D were preferred the most and there was no significant difference between the two, while sample E was least preferred and there was statistical difference found between this sample and other samples. Also, E was least preferred and had statistical difference in case of appearance. Sample A was the most appealing product.

Means of hedonic rating for overall likeness of sample A, B, C, D and Control were not significantly different. But sample E was least preferred with significant difference. Consumers rated the flavor of D and Control as most preferred while sample E was rated as least preferred sample.

The physical properties of the snack affected the consumer preference. Sample D and Control were most acceptable because of the flavor, high expansion, low bulk density and shear stress. Szczesniak (1987) stated that texture is sensory property that people can perceive, describe and quantify. Texture is also influenced by time, temperature, force and effect of saliva as physical properties are affected by mouth feel (Guinard and Mazzucchelli,1996). The E was least expanded product with high bulk density and shear strength which affected the flavor, texture and overall likeness. The bulk density and cellularity is extrudates affects the strength and fracture properties. Also as expansion was low and so it had less volume for spicing and it affected the flavor, appearance and color of the product.

Conclusions

In conclusion, the study shows that it is possible to produce a nutritious and affordable snack using extruder. The addition of banana and fat content significantly affect the acceptability of similar formulation. Moisture has no effect on the physical changes of the product. The best product was obtained with fat content of 2.5% and moisture content of 20%. Further modification can be made in spicing to enhance the acceptability of the product. Further, studies need to be done to modify composition and spicing according to results shown in this study, so as to improve the existing products.

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CHAPTER 5

Summary and Conclusions

In conclusion, the study shows that Least Cost Formulation Software can be applied to the development of snack foods. The selected legume/cereal formulations have the potential of producing nutritionally adequate formulations. The formulations incorporated Banana as ingredient at moisture level 18% while they were not accepted at moisture level 15%. Apart from that the mixtures were also able to meet the amino acid requirement for school children in age group of 9-13 yr. These formulations were then extruded using twin screw extruder. The formulations with high fat content and high moisture content were difficult to extrude. However, there were several acceptable products extruded. The moisture and fat content significantly affected the acceptability of extruded product. The best product was obtained with fat content of 2.5% and moisture content of 20%. The extruded product was spiced with cinnamon and spicing was kept constant for each product. All the extruded samples were compared with the commercial sample of cinnamon cereal. It was found that the product with fat content of 2.5% and moisture content of 20% was most acceptable product while product with fat content of 7.5% and moisture content 20% was least acceptable product. Further studies need to be done to modify composition and spicing according to results shown in this study, so as to improve the existing products.

APPENDIX A

Demographic Questionnaire

Panelist Code:________   Date: ______________

Please answer all questions. All information is confidential and will not be identified with your name.

1. What is your age group? (Please check **ONE**)
   1. ____18-24 years old   2. ____25-34 years old   3. ____35-44 years old
   4. ____45-54 years old   5. ____55-64 years old   6. ____65-74 years old
   7. ____75 yrs or older

2. What is your gender? (Please check **ONE**)
   _____Male   _____Female

3. To what ethnic group do you belong? (Please check **ONE**)
   1. ____White   2. ____Black   3. ____Spanish/Hispanic   4. ____Asian
   5. ______________________Other (please specify)

4. What is your marital status? (Please check **ONE**)
   1. ____Never married   2. ____Married   3. ____Separated, Divorced
   4. ____Widowed

5. Level of education? (Please check the **one** which best applies to you)
   ____ 1. Less than 8 years of school
   ____ 2. 9-12 years of school
   ____ 3. Graduated high school or equivalent
   ____ 4. Vocational school or some college (<4yrs)
   ____ 5. Completed college (B.S.)
   ____ 6. Graduate or professional school (masters, Ph.D., law, medicine, etc.)

6. Please check the **one** which best applies to you:
   ____ 1. Employed full-time
   ____ 2. Employed part-time
   ____ 3. Unemployed
   _____ 4. Retired

7. What was the approximate level of your household income before taxes last year?
   (Please check **ONE**)
   ___ 1. under $10,000   ___ 5. $40,000 to $49,999

___ 2. $10,000 to $19,999
___ 3. $20,000 to $29,999
___ 4. $30,000 to $39,999
___ 6. $50,000 to $59,999
___ 7. $60,000 to $69,999
___ 8. $70,000 and over

Thank you

APPENDIX B

Panelist Code: _______ Sample Code: _____ Date: _________

Please evaluate this product and check the space that best reflects your feeling about the product for all 6 questions. Please write comments in the space provided below.

1. How would you rate the "**OVERALL APPEARANCE**" of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1	2	3	4	5	6	7	8	9

Comments ____

2. How would you rate the "**OVERALL COLOR**" of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1	2	3	4	5	6	7	8	9

Comments ____

3. How would you rate the "**OVERALL AROMA**" of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1	2	3	4	5	6	7	8	9

Comments ____

4. How would you rate the "**OVERALL FLAVOR**" of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1	2	3	4	5	6	7	8	9

Comments ____

5. How would you rate the "**OVERALL TEXTURE**" of this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1	2	3	4	5	6	7	8	9

Comments ____

6. **OVERALL**, how do you **(Like)** this product?

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1	2	3	4	5	6	7	8	9

Comments ____