UTILIZATION OF BETA-CAROTENE-RICH SWEET POTATOES, MILLET AND PIGEON PEAS IN DEVELOPMENT OF AN ALTERNATIVE BREAD

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This thesis is my original work and has not been presented for a degree in any other university.

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To my father and mother John and Janet

My husband Humphrey and sons Michael and Mark.
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ABSTRACT

Vitamin A deficiency is one of the most prevalent and potentially serious forms of micronutrient malnutrition in the world today. Increasing recognition of the negative health effects of vitamin A deficiency has led to increased efforts to develop sustainable solutions to the nutritional problem. Diet diversification is among the food-based approaches used to curb the deficiency today. The aim of the study was to utilize the orange-fleshed sweet potatoes, millet and pigeon peas to develop an alternative bread. The study was based on the idea that food-based approaches are the most suitable for preventing and controlling micronutrient malnutrition. Two flour formulations were used in making the bread variations. The first formulation consisted of 30% wheat, 30% sweet potato, 20% millet and 20% pigeon pea flours. The second one was made up of 40% sweet potato, 40% millet and 20% pigeon pea flours. From each formulation variations were prepared with and without ascorbic acid as a flour improver. The straight dough method was used to bake the bread. The finished product was analyzed for proximate composition and β-carotene content. Sensory evaluation was done using descriptive and affective tests. The protein content of the samples ranged from 11.0% - 13.5%, with the control bread having the lowest content. The crude fat content was higher in the wheatless alternative bread compared to the variations with wheat flour. Ash content recorded ranged from 2.7% - 3.2%. The moisture content of the bread ranged from 33.6% to 38.7%. The calorific value was highest in the control bread having 4.9Kcal/g. The alternative bread with 30% wheat flour both had 4.5Kcal/g. Wheatless variations had calorific value of 4.8Kcal/g. The β-carotene of the samples was lowest in the control bread. The alternative bread with wheat had 3.3μg/g. The wheatless variations had 3.4μg/g. All the four bread variations had above 95% retention levels of β-carotene. Sensory results indicated that when 30% wheat flour was used in the alternative bread, the colour was not adversely affected. The geometric characteristics of the bread were affected by use of wheat flour in the formulations. Cell structure scores showed that the bread with 30% wheat flour had a better crumb structure than the wheatless variations. Similar improvement in the scores was noted on the texture quality of the variations. A tender crumb was achieved in the variations with wheat flour. Chewiness scores were better in the variation that had the ascorbic acid. The crumb of the wheatless variations was found to be moist compared to the variations with 30% wheat flour. A slight yeast flavour was noted in the variations with wheat while the wheatless variations had a pronounced yeasty flavour. Moderate aftertaste was observed in the variations with wheat while the wheatless bread had longer aftertaste. Ranking results showed that the variation with 30% wheat flour and ascorbic acid had the best scores. It rated well when compared with the control bread. The findings show that with the use of 30% wheat flour, sweet potato, millet and pigeon pea flours acceptable alternative bread would be prepared. Such bread if promoted for consumption would enhance the intake of pro-vitamin A due to its high β-carotene content. A cost analysis of the composite flour used in the study should be done for commercialization. An analysis of the shelf life of the composite flour in conventional packages could be done as well as a similar study using highly trained panelists.
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CHAPTER ONE

1.1 BACKGROUND OF THE STUDY

Hundreds of millions of the world's people suffer from nutritional deficiencies due to diets inadequate in quality and variety. Micronutrient malnutrition is one of the major problems experienced today with Vitamin A deficiency (VAD) having the highest prevalence in many regions of the world (FAO, 1992). Although VAD occurs in all age groups, the most vulnerable are young children and pregnant women. More than 90 countries worldwide have a public health problem concerning clinical and/or sub-clinical VAD, with more than 3.1 million children having clinical VAD and 227.6 million having sub-clinical VAD (IVACG, 1995). Kenya is classified as one of the countries in Africa with widespread sub-clinical VAD (UNICEF, 1998). According to the 1999 micronutrient survey, the inferred prevalence of VAD based on serum-retinol deficiency among preschoolers was nearly twice that reported in the 1994 survey (GOK/MOH, 1999).

Extremely low serum retinol levels are found in populations living in the arid and semi-arid northeast, along the coast and throughout the densely populated western part of the country.

Measures to prevent and control micronutrient malnutrition as part of an overall framework to improve nutritional well being were identified and adopted at the International Conference on Nutrition (ICN) in Rome in 1992. Representatives from 152 countries endorsed the world declaration on nutrition. The declaration pledged to make all efforts to eliminate VAD and iodine deficiencies and substantially reduce other important micronutrient deficiencies including iron (FAO, 1992). One of the strategies given in the plan of action is to formulate and implement programmes aimed at correcting
micronutrient deficiencies, prevent their occurrence by promoting the dissemination of nutrition information and other sustainable food-based approaches that encourage dietary diversification through production and consumption of micronutrient rich food, including appropriate traditional food (FAO, 1992). Apart from diet diversification, the other approaches used in solving micronutrient malnutrition are supplementation and food fortification. Supplementation has been widely used to control vitamin A and other micronutrient deficiencies (FAO and ILSI, 1997). Although the strategy is necessary for groups at high risk and as a short-term emergency measure, supplementation does not address the root causes of micronutrient deficiencies. In addition, it does not assist communities and households to adequately feed and nourish themselves in both the short and long term.

In view of the limitations of the other strategies, the emphasis today is being placed on food-based approaches to solving micronutrient deficiency. According to the Salt Lake City Conference Declaration in November 1992, food-based approach is the only system that can offer a sustainable solution to micronutrient malnutrition (FAO, 1992). Food-based approach focuses on improving access to, availability and consumption of micronutrient-rich foods through proper production, processing, storage and distribution (FAO and ILSI, 1997). Efforts are being geared towards the production of micronutrient rich food, but little is being done to ensure that they become part and parcel of the daily diet. While it is undeniably important to increase yields of these micronutrient-rich foods, an even greater amount of food available would be realized by proper processing of local foods (Dupont and Osman, 1987).
Micronutrient malnutrition exists in Kenya in the midst of production of some local foods that could be processed for consumption. Among the common food crops, the green leafy vegetables, sweet potatoes and pumpkins are among the richest source of pro-vitamin A with the green leafy vegetables supplying about 550 micrograms / 100 grams, while the yellow and orange-fleshed sweet potato varieties contain about 1250 micrograms / 100 grams (Low et al., 1995). In spite of the high pro-vitamin A content of the sweet potatoes, the crops are usually seen as a poor man’s crop in many areas in Kenya (Wainaina, 2000). The beta-carotene-rich sweet potatoes when sliced through have a distinctive orange or yellow color. Extensive collaborative work is being carried out in the country between the government and other non-governmental organizations aimed at promoting growth and consumption of the sweet potato varieties (Gor, 1989). These agencies include the Kenya Agricultural Research Institute (KARI), UNICEF and Care-Kenya and the International Potato Center (CIP) mainly in Western and Nyanza provinces, which are the biggest producers of sweet potatoes in Kenya. The crop should be processed into various products to achieve higher unit value and increase consumer acceptance in terms of its nutritive value and versality in the diet (Ratemo, 1990).

In many African countries, various efforts have been geared towards incorporating the main traditional crops into modern food products especially baked products (Hulse et al., 1980). This has been brought about by the realization that traditional food crops have a higher nutritive value than wheat, the commonly used cereal in baking. Moreover, developing countries are using more and more foreign currency to import wheat to satisfy the difference between production and consumption (Unklesbay, 1992). Over the past 20 years, a lot of research has been done in Kenya and other African countries on composite
flours and most of the research work has mainly concentrated on cassava, sorghum and millets (Gomez et al., 1992). Pigeon peas are locally grown legumes that are under-exploited and yet they do well even in the arid and semi-arid areas. Finger millet is a common hardy cereal in the diets of many communities in Kenya but its full potential in baking has not been realized.

The need for development of new products from traditional and locally grown food crops is justified by the need to provide alternative but equally acceptable cheap food products in cases of wheat or other cereal deficits. It is further justified by the need to provide more nutritious flour combinations and the need to offer increased incentive to domestic producers. In addition, the existence of specific nutrient deficiencies supports the need to incorporate the specific crops, which are rich in the micronutrients, into processed products. In Kenya, this would be in line with the specific objectives stated in the National Plan of Action for Nutrition that is aimed at promoting production, accessibility and consumption of traditional micronutrient-rich food country-wide (Government of Kenya, 1994).

1.2 STATEMENT OF THE PROBLEM

Sub-clinical vitamin A deficiency is widespread in Kenya. While calls have been made for expansion of massive vitamin A capsule distribution to include children at risk and lactating mothers, such programs are costly, depend on donations from UNICEF and are rarely implemented countrywide. Fortification is also a costly undertaking and depends on choice of an appropriate food vehicle and technology. Alternative preventive approaches should be examined for cost-effectiveness and sustainability in the Kenyan case.
While a diversity of plant and animal sources of vitamin A and its pre-cursors are available, cheaper crop sources that can be easily grown in home gardens are not fully exploited. Animal sources such as fish liver oil, chicken liver and milk are frequently beyond the means of the poor. The study sought to use flours from the sweet potato varieties that are rich in pro-vitamin A, combined with pigeon peas and finger millet to develop a bread of better nutritive value than wheat-only bread. The product would have the convenience of bread combined with the appeal of tradition. Sweet potatoes, millet and pigeon peas are important food security crops especially in the arid and semi-arid areas that are under-exploited.

1.3 PURPOSE OF THE STUDY

Based on the idea that food-based approaches are the most suitable for building food security worldwide in the future, the study utilized beta-carotene-rich sweet potato varieties, finger millet and pigeon peas to make an alternative bread.

1.4 SPECIFIC OBJECTIVES

The objectives of the study were to:

1. Develop an alternative bread product using orange-fleshed sweet potato, millet and pigeon pea flours combined in different proportions.

2. Determine the beta-carotene content of the flour formulations and finished products thus, establish the efficacy of the materials and methods as carriers of the pro-vitamin A.

3. Determine the compositional content of the bread in terms of moisture, crude fat, crude protein and crude ash, and calorific value.
4. Compare the characteristics of the bread made using non-wheat flours with those made with a small percentage of wheat flour combined with the sweet potatoes, millet and pigeon peas flours.

5. Assess the effect of using ascorbic acid as a flour improver on the quality of the alternative bread.

6. Assess the physical and sensory properties of the bread.

7. Determine the acceptability of the alternative bread by carrying out sensory evaluation tests

1.5 SIGNIFICANCE OF THE STUDY

The successful development of beta-carotene-rich bread would serve as a step in increasing the supply of micronutrient-rich foods, once introduced in the community. The intake of the bread would enhance vitamin A status especially within the vulnerable groups. The recipe will help produce bread that is likely to be richer in protein content than that made from wheat only. Utilization of the selected food crops in baking could serve as an increased incentive to domestically produced crops through creation of market for farmers who grow the crops as well as improve rural employment and incomes.

Unlike wheat which is one of the most expensively produced cereals in the world, sweet potatoes, millet and pigeon peas do not need high mechanization for production. Consequently, their use in the bakery products would enhance the production of previously neglected low-cost crops. The food crops used in the study are drought resistant. Utilization of these crops in making a convenience food would help to promote local marginalized food crops that contribute substantially to food security of many communities in Kenya.
1.6 SCOPE

The study only used specific food crops that are grown in the arid and semi-arid areas of Kenya. These included orange-fleshed sweet potatoes (*Ipomoea batatas*), finger millet (*Eleusine coracana*) and pigeon peas (*Cajanus cajan*).

1.7 ASSUMPTIONS

The assumption of the study was that the panelists used for sensory evaluation had at least one bread-like product in their diet and hence the bread to be evaluated was not unfamiliar to them.

1.8 DEFINITION OF TERMS

Food – Based Approaches

These are preventive and comprehensive strategies that use whole food, refined forms, processed, fortified or a combination, as a tool to overcome micronutrient deficiencies.

Micronutrient Malnutrition

A condition caused by deficiency in nutrients that are needed in small amounts in the body but yet play a key role to an individual’s well being.

Beta Carotene

This is one of the important carotenoid substances, the yellow or red pigment found in some foods. It is a pre-cursor of vitamin A to which it is converted in the body. It is expressed as retinol equivalent (RE), whereby 0.006 micrograms of beta-carotene make up 1 retinol equivalent.
Micronutrients

These are nutrients mainly vitamins and minerals that are needed in small quantities by the body as distinct from fats, carbohydrates and proteins which are needed in greater amounts.

Traditional Food Plants

These are food crops that form the customary part of the farming system of specific areas. They provide either the staple or complementary foods in these localities and have a place in the community food preferences and eating habits.

Beta-carotene-rich sweet potatoes

These are high energy-yielding root crops that have a distinct yellow or orange-coloured flesh when sliced through. They contain vitamin A pre-cursors in form of carotene, are drought-resistant and grow well in soils with limited fertility.

Finger Millet

An extremely drought-resistant crop that grows on poor soils where other cereals fail. Its edible seeds are round and have a colour varying from red, dark brown to nearly black.

Pigeon Peas

A perennial woody shrub usually grown as an annual. It grows well on lands normally unsuitable for other crops due to infertility, aridity or topography.

Alternative bread

A baked product made using the conventional baking procedure of bread but from non-wheat flours.
2.0 LITERATURE REVIEW

In line with the idea of using the available food crops to alleviate vitamin A deficiency, it is important to look at the causes and consequences of VAD, measures that are in place to prevent and control the deficiency and benefits of food-based approaches as a major strategy used in curbing the malnutrition. It is also paramount to look at beta-carotene, a pre-cursor of vitamin A and the form in which the vitamin is found in plant sources. All these have been reviewed in the literature. Literature on use of flours in baked products, effects of additives on baking properties of flours and potential advantages of using the traditional food crops in baking has also been reviewed.

2.1 CAUSES AND CONSEQUENCES OF VITAMIN A DEFICIENCY

The primary causes of VAD are inadequate intake of micronutrient-rich foods and impaired absorption and/or utilization of nutrients in these foods. Poor utilization and absorption may be as a result of infection and parasitic infestation, which may increase the metabolic needs of the micronutrient (FAO and ILSI, 1997). Poverty is often at the root of VAD and is linked to inadequate access to food, sanitation and safe water. It is also linked to lack of knowledge on proper food handling and preparation techniques. Many nutrients are lost due to improper food handling techniques. The immediate, underlying and basic causes of VAD are shown in Table 2.1 below.
Table 2.1: Causes of vitamin A deficiency

**Immediate:**
- Low intake of foods rich in the micronutrient
- High incidences of measles, diarrhoea and parasitic infections
- Maternal deficiencies

**Underlying:**
- Inadequate breastfeeding practices
- Inadequate and/or incorrect complementary feeding practices
- Inadequate caring capacity; time, knowledge etc.
- Low levels of family education, awareness, knowledge and motivation
- Intra-household maldistribution of access to food, health care services
- Poor cooking, food preparation, storage, preservation and processing facilities and practices at household level
- Beliefs and practices that restrict access to certain foods by family members
- Poor health service and/or agricultural infrastructure
- Lack of institutional capacity in nutrition and/or personnel trained in various components of micronutrient malnutrition prevention programmes.
- Low production of micronutrient-rich foods
- Lack of household-level gardening
- Insufficient marketing of key foods
- Poorly developed commercial food processing industry

**Basic:**
- Lack of resources to produce micronutrient-rich foods
- Failure to consider micronutrient needs in agriculture and health
- Poor economic and physical access to markets
- Little or no productive land
- Lack of access to seeds and other inputs
- Lack of access to water for drinking, hygiene and/or irrigation
- Seasonality of food availability
- Low status and lack of resource control by women
- High prevalence of certain endemic diseases

Adapted from Gillespie and Mason (1994)

Vitamin A is an essential micronutrient for the normal functioning of the visual system, growth and development, maintenance of the epithelial cellular integrity, immune function and reproduction (ACC/SCN, 2000). Vitamin A deficiency occurs when body stores are depleted to the extent that physiological functions are impaired. At first the integrity of the
epithelial barriers and the immune system are compromised followed by the impairment of the visual system. Consequently, there is increased severity of infections such as malaria and measles and increased risk of death especially among children. Young children are the most vulnerable to VAD, since requirements are closely linked to growth rate; childhood infectious diseases and protein energy malnutrition often exacerbate deficiency. Available data from various studies suggest that there is both an opportunity and a need to target major vitamin A control measures to particular countries; and particular groups within affected countries (Nalubola and Nestrel, 1999).

2.2 MEASURES TO PREVENT AND CONTROL VITAMIN A DEFICIENCY

Unlike other deficiencies that may be associated with geo-chemical and other conditions affecting the whole population within geographic areas, vitamin A deficiency is linked more to the nature of foods available and feeding practices (ACC/SCN, 2000). Vitamin A deficiency occurs when diets lack in variety. The nutrients needed to prevent the deficiency are present in a wide range of food. These include foods that contain high levels of vitamin A in form of retinol such as fish liver oil, livers of mammals, milk and eggs. Plant foods contain β-carotene; a pre-cursor to vitamin A, the highest sources being green leafy vegetables, carrots, pawpaws and orange-fleshed sweet potatoes and other yellow/orange coloured fruits and vegetables. Foods that contain low levels of the micronutrient but are eaten in large quantities may also be considered to be rich suppliers of the nutrient. During the past two decades, the donor community, governments, development agencies and NGO’s have made significant progress in identifying groups at highest risk of the micronutrient deficiency. They have come up with programmes that
outline various preventive and control measures. These include supplementation with vitamin A capsules, fortification, nutrition education and diet diversification.

2.2.1 Supplementation with vitamin A capsules

This is the addition of pharmaceutical preparations of nutrients-capsules, tablets or syrups to the diet (Gillespie and Mason, 1994). There are two forms of supplementation, universal and targeted supplementation. Universal delivery is a single-purpose distribution of large doses of vitamin A to all children of defined age (and other designated groups) within communities in specified regions according to a pre-established time schedule. Targeted delivery refers to distribution of large doses of vitamin A through contacts with high-risk individuals and existing health service infrastructure and/or existing community-based health/nutrition programmes (Gillespie and Mason, 1994). Intervention programmes using supplementation include four to six monthly administrations of high dose vitamin A supplements to children aged below five years (Nalubola and Nestrel, 1999).

Supplementation is generally regarded as a temporary measure in control of VAD (UNICEF, 1990). It has been widely suggested that vitamin A capsule distribution needs additional methods like food fortification and agricultural programmes to improve its efficacy. As compared to food sources, medicinal supplements of Vitamin A are more readily absorbed in the body. However, this strategy should be regarded as a therapeutic intervention for at-risk groups in areas of endemic VAD (FAO, 1997). Large-scale prophylactic supplementation programs using the capsules are not recommended because they are expensive, not sustainable, and tend to foster dependency on donor support (FAO, 1997). Such programs may divert political and government support away from establishment of more sustainable food-based approaches, and have low coverage (Frigg,
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1999). Whereas the method has been used to curb VAD, many children at risk of the deficiency have not been reached. Moreover, the initial vitamin A status accompanied by poor nutritional status in general has minimized the effect that one 200,000 IU capsule can have (UNICEF, 1990). Poor supervision of the capsule distribution and lack of community knowledge on the importance of vitamin A in the body also contributes to the poor performance of most vitamin A capsule supplement programmes (UNICEF, 1990). In addition, in most cases of micronutrient malnutrition, individuals are not deficient in one nutrient. Multiple micronutrient deficiencies occur because micronutrients interact hence the deficiency of one of the nutrients cause deficiency in others (Gross et al., 2000). For example, studies have shown that poor vitamin A status may contribute to iron deficiency. Supplementation is therefore considered a stop-gap measure in management of VAD.

In Kenya, vitamin A capsules are distributed and given to children during the national immunization days especially in the high-risk areas. Various non-governmental organizations located in the arid and semi-arid areas are also involved in projects that give two doses of the vitamin per year to children under 5 years (UNICEF, 1990). Despite the use of vitamin A capsule worldwide, it is a short-term measure that should be used to curb an emergency. The long-term goal should be to eradicate micronutrient deficiencies using other sustainable measures.

2.2.2 Food Fortification

Food fortification is the addition of micronutrients to foods. Commonly consumed and widely available foods are used as vehicles for the selected micronutrient. It is one of the most convenient methods for supplying vitamin A to a targeted population due to its high
coverage (FAO and ILSI, 1997). It is achieved through fortification of foods such as sugar, milk, shortenings and margarines.

Fortification is a major undertaking that involves the government, the producers (the food industry) and consumer groups and NGOs. Like dietary and horticultural interventions, it is a long-term measure with a broader development approach as opposed to capsule distribution. The major limitations of fortification are choice of appropriate food vehicle, method of incorporation and increased costs of the fortified food. In addition, there is need for education, resources and the policy framework required to implement the fortification programmes (UNICEF, 1990). The effectiveness of a fortification programme critically depends on the choice of an appropriate food vehicle (Frigg, 1990).

Currently, efforts in Kenya are being geared towards fortification of sugar with vitamin A by UNICEF. The only available products that are said to have added vitamin A are margarine and some vegetable cooking fat and fortified maize meal (UNICEF, 1990). Fortification of common foods would be a positive step towards curbing VAD but those at risk of the deficiency must consume the food regularly and in large enough quantities, to make a difference in their vitamin A status. Fortification must not also alter the palatability of the product for the consumers and must not put the product out of their financial reach by being too expensive.

2.2.3 Nutrition Education

Nutrition education has been used to prevent and control occurrence of micronutrient malnutrition including VAD. It is more easily implemented on a small scale and includes sensitizing the community, extension workers, educators and policy makers on
micronutrient and their control measures (UNICEF, 1990). The process is achieved through the print and mass media, seminars, workshops and meetings. Entertainment-type education programs and media messages have been found to reach the widest audience. Nevertheless, interpersonal communication is a crucial factor in determining the success of vitamin A education programs (Nalubola and Nestrel, 1999).

In Tanzania, nutrition education has been broadened to include the review of curricula of health and agricultural training schools and colleges to include vitamin A relevant subjects (Frigg, 1999). In Kenya, the Family Life Programme Training Centres, operated by non-governmental organizations in high-risk areas and government health institutions carry out this function (Frigg, 1999). At such centers, mothers and children's caretakers are taught about foods that are rich in vitamin A, recipe development and how to prepare them in order to ensure that the vitamin A content is retained. Nutrition curriculum for the health sector has been enhanced to include more on micronutrient deficiencies and dietary measures that are necessary to curb the problem (UNICEF, 1990). The NGO's involved in nutrition projects in the affected areas have sensitized the communities on vitamin A deficiency, its prevention and control by use of available indigenous and other locally available food crops. Nutrition education is however a formidable task considering the rigidity with which different communities often hold dietary habits. In addition, the cost and resources needed for implementation makes it viable only for a small group at a time (UNICEF, 1990).

2.2.4 Diet diversification

The ultimate method to overcoming VAD lies in the promotion of an adequate intake of vitamin A from locally available foodstuffs, together with control of factors that impair
utilization of such foodstuffs (FAO and ILSI, 1997). Diet diversification addresses the availability and consumption of micronutrient-rich foods with a focus of preventing their deficiencies. The strategies also look into processing and preservation of the micronutrient rich food commodities with a special interest of the local indigenous food crops in order to curb seasonal shortages (Frigg, 1999).

Small-scale community vegetable and fruit garden can play a significant role in increasing production of micronutrient-rich foods. Agricultural extension officers have over time been involved in encouraging growth of both indigenous and non-indigenous vegetables that are rich in micronutrients. Promotion of growth of vitamin A rich foods and especially the orange fleshed sweet potatoes is currently being carried out in Western and Nyanza provinces by the International Potato Center, UNICEF and Care-Kenya (Wainaina, 2000). The International Plant Genetics Resources Institute (IPGRI) and other organizations like the Kenya Agricultural Research Institute (KARI) are currently involved in the plant dietary diversity in order to enhance nutrition and health (IPGRI, 2002). Currently IPGRI has an ongoing project on the African leafy vegetables with an aim of conserving the plants. To improve the nutritional status, gardening projects must lead to increased consumption of the food produced. Success requires a good understanding of the local conditions. Community participation and the involvement of women are usually key to building support and achieving nutritionally beneficial change. Land and water limitation are common constraints, which may require local government intervention or assistance.

Production of small animals like rabbits, goats and guinea pigs, poultry and fish can provide excellent sources of essential micronutrients. This would include bio-available vitamin A. However, projects to promote small livestock and fishery should address cost
constraints and the need for education and support to the producers. In West Africa, red palm oil cultivation present opportunities for improving vitamin A status (Gillespie and Mason, 1994). The commercial oil seed production is a major means of providing low-cost dietary fat, which is necessary for the absorption of beta-carotene. The only drawback to agricultural interventions is that the strategies must overcome cultural preferences as well as region specific obstacles as they promote production and consumption of these micronutrient-rich foods (UNICEF, 1990). The low bioavailability of carotenoids in some plants limits the success of gardening interventions.

Of the four measures to curb VAD three are regarded as food-based. These are fortification, nutrition education and agricultural interventions. This is because the strategies aim at curbing the deficiency using food either as the vehicle for the vitamin or as the source from where the body gets its vitamin A supply (FAO and ILSI 1997).

2.3 BENEFITS OF FOOD – BASED STRATEGIES

Diet and food-based approaches play an essential role in preventing micronutrient malnutrition. Their benefits go beyond prevention and control of the deficiencies. They are preventive, cost-effective and sustainable. The strategies encourage people to produce and consume micronutrient – rich food and this ensures an adequate supply needed by the body. In addition, food is basic to all individuals and therefore if used as a way of combating the deficiencies, it serves as a long-term approach to the problem.

Food-based strategies can also be adapted to different cultural and dietary traditions. Here the emphasis is placed on the specific foods grown and consumed by specific communities. This being the case, different micronutrient- rich foodstuffs consumed by
various communities can be promoted in the specific regions. This makes the strategies locally feasible (FAO, 1992). Another benefit is that food-based approach is broad-based as it aims at improving the overall quality of the diet of a population (FAO and ILSI, 1997). The strategies can therefore address multiple nutrient deficiencies simultaneously. In addition, physiologic interactions between vitamins and minerals consumed in the foods promoted can enhance the body’s ability to absorb essential micronutrients. For example, many foods that promote iron absorption, especially green leafy vegetables, animal products and some fruits are also good sources of vitamin A. Improving vitamin A status can also improve iron status through interaction between these two nutrients (Gillespie and Mason, 1994).

Apart from that, food based strategies support the crucial role of breast-feeding and the special diet and care needs of infants and young children. They foster development of sustainable environmentally sound production systems. Agricultural planners are alerted of the need to protect the micronutrient content of soils and crops. Food based strategies also help to build partnerships among government, consumer groups, the food industry and other organizations. This helps to achieve the shared goal of overcoming micronutrient malnutrition. Fortification, a specific food based approach, is advantageous in that it can provide wide coverage and so is industrial processing of micronutrient-rich foods. The foods processed can also help address multiple deficiencies. It also encourages industries to be socially concerned and to add nutritional value to their products.
The food-based strategies that focus on processing and preservation of pro-vitamin A rich foods in particular serve in solving the problem of seasonal shortages. Most of the food crops processed and preserved are fruits and vegetables (Frigg, 1999). There exists a need to do the same for other pro-vitamin A rich crops like the orange-fleshed sweet potato in order to ensure availability of more foodstuffs rich in the vitamin. Among the products that sweet potato can be processed into are baked products (Unklesbay, 1992).

2.4 β-CAROTENE AS A SOURCE OF VITAMIN A

Vitamin A occurs only in animal tissues such as fish liver oil, livers of mammals, in milk fat and in egg yolk (Belitz and Grosch, 1985). Plants are devoid of the vitamin. Vitamin A in nature originates from carotenoids, which are the yellow and red pigments responsible for colour of many vegetables and fruits. Of the 500 or so naturally occurring carotenoids, about 60 possess vitamin A activity in varying degrees but only 5 or 6 of these are commonly found in food. The major carotenoids are β-carotene, α-carotene, cryptoxanthin, lutein, zeaxanthin, and lycopene. The most common and active of the provitamins is β-carotene, found in fruits and vegetables. It exists naturally as the all-trans isomer (Frigg, 1999). One of the most important features of carotenoids is that they are organic compounds with long unsaturated chains. These chains are responsible for their bright colour. The unsaturated property is easily destroyed by oxidation in air or by hydrogenation oxidation (Ihekoronye and Ngoddy, 1985). Below is a figure showing the structure of β-carotene and its asymmetric cleavage.
The carotenoids yield vitamin A by cleavage of the centrally-located double bond (Belitz and Grosch, 1986). The carotenoids which have unsubstituted β-ionone ring can be cleaved oxidatively to yield retinaldehyde which is reduced to retinol (Bender, 1992). Once ingested, β-carotene and other pro-vitamin A carotenoids are cleaved in the intestinal mucosal by carotene dioxygenase yielding retinaldehyde (Combs, 1992). Central oxidative cleavage of β-carotene shown in figure 2.1 gives rise to two molecules of retinaldehyde. This is reduced to retinol, which is esterified and enters the circulation in chylomicrons. Animals are unable to biosynthesize carotenoids, but assimilate them through their diet as a source of Vitamin A (Woolfe, 1992). Pro-vitamin A accounts for between 60% to 90% of vitamin A intake; dependence on them as a source of vitamin A being particularly high in Southeast Asia, Africa and Western Pacific (WHO, 1995). The biological value of dietary carotene varies widely depending on the efficiency of absorption but it is taken an average of one-sixth that of all-trans-retinols (Woolfe, 1992). This disparity in biological activity is primarily due to inefficiency of carotene absorption.
and subsequent conversion to retinal. The bioavailability is greatly influenced by the nature of the embedding matrix (fibre) and the composition of the accompanying meal (Bender, 1992).

2.4.1 Stability of carotenoids

In general, carotenoids are destroyed or altered by acids and free halogens, particularly in the presence of light and high temperatures (Latham, 1997). The carotenes are easily oxidized in the presence of oxygen or oxidizing agents, in conjunction with the co-oxidation of unsaturated fatty acid. In foods, the carotenoids are dissolved in the fat matrix where they are protected from the oxidizing action of atmospheric oxygen by vitamin E and other antioxidants. Carotenoids are susceptible to isomerization and oxidation during processing and storage (Rodriguez-Amaya and Delia, 2001). The practical consequences are loss of colour and biological activity and the formation of volatile compounds that impart undesirable flavour in some foods, especially in fruits. The occurrence of oxidation depends on the presence of oxygen, metals, unsaturated lipids, enzymes, oxidants; type and physical state of the carotenoid present and the severity of treatment during food preparation (Bender, 1992). Oxidation of the pro-vitamin A may occur when the ultra structure that protects the carotenoid is destroyed, when the surface area is increased and during heat treatment. Heating promotes trans-cis isomerization and therefore the duration and temperature used in food preparation should be controlled (Rodriguez-Amaya and Delia, 2001).

2.4.2 Bioavailability of the carotenes

Vitamin A deficiency does not only occur from inadequate Vitamin A and pro-vitamin A compounds intake but also because of poor intestinal absorption or inadequate conversion
of the pro-vitamins in the body. The efficiency of intestinal absorption of carotenoids from different food sources is low and extremely variable. As the amount ingested increases, the efficiency of absorption falls markedly, but for human beings the average absorption is estimated to be one-third of the pro-vitamin ingested (Ball, 1988). This means that average intestinal absorption of both beta-carotene and other pro-vitamin A carotenoids are three times less efficient than that of retinol and its esters mainly acetate and palmitate (Johnson et al., 1997).

\(\beta\)-carotene is poorly utilized in persons on a low fat diet (Latham, 1997). Dietary fat is needed to stimulate intestinal and pancreatic secretions, which contain lipolytic enzymes for fat digestion and phospholipids and bile salts, needed for micelles to form and solubilize both the preformed vitamin A and carotenoids (Combs, 1992). Only micelle-solubilized carotenoids gain entrance to the enterocytes where bioconversion to retinal, or intact transfer to chylomicra occurs; that is they become bioavailable. The fat-soluble vitamins are all poorly absorbed from the intestine in the absence of bile. Thus, any defect in fat absorption is likely to foster deficiencies of all fat-soluble vitamins. Intestinal diseases such as severe dysentery, celiac disease, and sprue all limit vitamin A absorption.

Several human studies involving \(\beta\)-carotene supplementation and/or consumption of fruits and vegetables have been conducted to find out whether the pro-vitamin can alter vitamin A status. Among the studies are those reviewed by Dee and West (1996). The studies were carried out using vitamin A deficient population. All but two of these studies were conducted among children in countries where VAD is prevalent. Of the 20 studies, 18 showed improvement in vitamin A status after consumption of either purified \(\beta\)-carotene
or foods rich in the carotenoid. The two studies that showed no effect on vitamin A status were conducted among children who did not have overall VAD.

2.5 USE OF TRADITIONAL FOOD CROPS

Africa is rich in nutritious food plants. However, social and economic changes in the recent decades have militated against the propagation and use of these crops (FAO, 1988).

In the development of modern agriculture and its great benefits, the value of traditional food crops has been eclipsed by the economic attraction of other foods and cash crops (Unklesbay, 1992). Moreover, changing eating and food preparation habits have forced many developing nations to become dependant on staple foods that they do not produce in sufficient amounts (FAO, 1992). Government priorities have largely resulted in promotion of the major cereals namely wheat, rice and maize (FAO, 1988). These cereals have become food staples in many African countries, where traditionally they had very little dietary significance if any. Consequently, they rob the traditional food crops of their place in the local diet.

One of the pillars of food security for any nation is diversity. A variety of foods are therefore required to supplement the cereal staples. Traditional food crops form a ready source of essential nutrients. The key element in household food security as well as reduction of the various nutrient deficiencies that are widespread in Africa should be promotion of traditional food crops (FAO, 1992). The benefits of traditional cereals, tubers, roots, legumes and pulses are not fully realized due to insufficient research coupled with poor production, storage, processing and preservation methods (Unklesbay, 1992). Because many of these crops are seasonal, harvest surpluses are often lost without adequate processing and preservation techniques (FAO and ILSI, 1997). Post-harvest
losses are especially high for micronutrient-rich foods that tend to be perishable. Food preparation methods used also hinder realization of the full benefits of the crops. Frying and fermentation decrease levels of β-carotene in foods by about 25%. Since these foods are well adapted to the local environment, they can reduce the risk of food shortages as well as promote healthier diets (Oniango, 2001). Out of the common staples: cereals, tubers, roots and legumes, the study focuses on finger millet, sweet potatoes and pigeon peas.

2.5.1 Finger Millet (*Eleusine coracana*)

This is a drought resistant cereal grown in the semi-arid regions. It is suited to the drier and sandier areas than sorghum and in the lowest rainfall areas early maturing cultivars are used (FAO, 1988). It is a hardy crop tolerant to weed competition and able to give reasonable yields in soil conditions too poor and degraded to support other cereals. The millet is grown throughout Kenya. Unlike in the developed countries where the cereal is used in animal feeds, millet seeds are used almost entirely for human consumption in developing countries (Asiedu, 1990). The seeds constitute a major source of energy and proteins for millions of people in Africa. Below is a diagram showing the finger millet.

Plate 3.1 Finger millet (*Eleusine coracana*)
The millet seeds store better than sorghum and maize and are a rich source of minerals (Sehmi, 1992). Protein content of finger millet is comparable to those of wheat, barley and maize and the millet is high in calcium and iron and contains fairly high levels of methionine, a major limiting amino acid in many tropical cereals (Hulse et al., 1986). The good storage properties of the millet seeds are its greatest asset. Finger millet is a staple food in drier parts of Africa and serves as a famine crop in these areas. Millet like sorghum can be used in many ways. The whole grain may be cooked, baked or fermented in many forms as a nutritious food. Dry-parched grains are milled into flour and consumed in form of porridge or a stiff meal.

2.5.2 Sweet potatoes (*Ipomoea batatas*)

The sweet potato is a dicotyledonous plant that belongs to the family Convolvulaceae. It is an extremely important crop in many parts of the world being cultivated in more than 100 countries and ranked seventh from the viewpoint of total production as a world crop (Woolfe, 1992). Sweet potato is a subsistence crop that grows well even with limited rainfall and is cultivated in both mono and intercropped systems. Its adaptation to and presence in the tropical areas where a high proportion of the world's poor people live, together with its nutritional advantages make it an attractive focus for further increase in its production and consumption (Scott et al., 2000). Sweet potato is an important food security crop especially in the marginal areas where there is chronic crop failure (Woolfe, 1992). In the medium potential areas, it plays a critical role when maize runs out. Sweet potato has been receiving increased attention from agriculturalists and ecologists who are interested in developing sustainable food production systems in the tropics, in part because it grows well in soils with limited fertility, is drought resistant and provides good ground
cover (Low et al., 1997). In parts of West, Central and East Africa, sweet potato is an important source of calories and is consumed by all age groups. The widely consumed varieties are the white and pale-fleshed cultivars due to their high dry matter, while the yellow-fleshed potato and orange-fleshed varieties, which are high in carotenoids, are less eaten (Wainaina, 2000). Using traditional breeding, β-carotene-rich clones with a high content of dry matter have been produced and 40 new varieties have been released in the sub-Saharan Africa (Low, 2003). The orange-fleshed sweet potatoes are high in β-carotene as compared to other traditional crops having an estimated 6400μg/100g of the carotenoid. The following is a picture showing the orange-fleshed sweet potatoes.

Plate 3.2 Orange-fleshed sweet potatoes (*Ipomoea batatas*)
Sweet potato production in Kenya is concentrated in the Western regions around Lake Victoria although the crop is widely grown on a small scale throughout the country (Low et al., 1997). The roots are highly perishable and farmers harvest on piecemeal basis as needed. In-ground storage whereby farmers keep un-harvested mature roots in the field
until they are needed for consumption or sale is the only kind of storage practiced (Woolfe, 1992). As food, the roots are boiled and eaten and in some communities they are sun-dried and pounded into flour for making gruel. However, the most appropriate preservation method is solar drying. Recent findings show that carotene retention after solar drying is much higher than when other traditional sun-drying methods of preservation are used (Latham, 1997).

2.5.3 Pigeon Pea (*Cajanus cajan*)

Pigeon pea is one of the many pea varieties that are grown in arid and semi-arid regions of East Africa. It is a perennial legume, which allows it to take several harvests. It is a good soil conditioner and its deep root system allows it to extract moisture from deep layers of the soil (Ratemo, 1990). Its drought tolerance has earned it a place in the low rainfall areas while its deep root system ability to use iron-bound phosphorous makes it an important crop in marginal areas (Sehmi, 1992).

In Kenya, small-scale farmers produce the crop, and Eastern province accounts for approximately 90% of the national output (Ratemo, 1990). For consumption purposes, the pea is boiled and mashed with potatoes or boiled and mixed with maize. The legume seeds possess good keeping qualities when dried and can be milled into flour which when used in baking would complement the cereal flours, thereby enhance the protein content of the products (Penfield and Campbell, 1990). The legume contains some enzymes that may cause off-flavors and contain antinutrients such as phytates but roasting of the seeds before milling them into flour destroys the unwanted components (Dupont and Osman, 1987). Below is a picture showing the pigeon peas pods and plant.
2.6 USE OF FLOURS IN BAKED PRODUCTS

Wheat flour is commonly used in baked products. Among the grains, wheat is unique because of its gluten protein. Gluten is the protein complex formed in batters and doughs when wheat flour is mixed with water (Belitz and Grosch, 1986). No other grain, legume or oilseed has the properties of gluten that allow the formation of cohesive, elastic dough (Dupont and Osman 1987). These visco-elastic properties are the basis for many of the desirable qualities of wheat products especially bread. When gluten is damaged or diluted, the result is almost invariably poorer baking performance. A lot of research has concentrated on partial replacement of wheat flour with the indigenous cereals, root/tubers and legumes (Unklesbay, 1992). The aim of formulating composite flours has been to stretch the use of wheat flour as well as provide more nutritious flour combinations than when a single food crop is used.

Of the baked products, leavened breads have the greatest sensitivity to non-wheat flours (Dupont and Osman, 1987). Composite flour dough have reduced cohesiveness and thus their ability to capture and hold leavening gases is impaired. The result is a less appetizing, dense and heavy loaf that tends to be crumbly. Gumminess during mastication
appetizing, dense and heavy loaf that tends to be crumbly. Gumminess during mastication is another problem. These physical effects are often apparent before colour and flavour changes become objectionable. The physical effects may however be reduced by use of additives such as oxidants (bromate, ascorbic acid), surfactants (calcium or sodium stearoly lactylate) or fats and by modification in the dough production process such as increased absorption and yeast level and reducing mixing and fermentation times (Lee, 1983). Gums such as xanthan gum can also be used as gluten substitutes.

2.6.1 Effects of additives on baking properties of flours

The baking qualities of flours differ widely. Bakers can use their expertise to compensate for changes in quality of raw materials through flexibility in formulations, dough handling, baking time and conditions (Belitz and Grosch, 1986). All these parameters can be adjusted in order to obtain the desired product. Additives are used when necessary to adjust the flour characteristics to match the baking process and to ensure the end product meets the existing standards. Incorporation of ascorbic acid, or enzyme-active soyflour improves the quality of weak gluten flours as done in bread and bun baking (Lee, 1983). The result is drier dough with a high resistance to extensibility, mixing tolerance, and fermentation stability.

In contrast, addition of cysteine or proteinases results in softening of gluten. Additives that affect the rheological quality of the dough include emulsifiers, shortenings, salt, milk, soyflour, amlayse preparations and starch syrups (Baker et al., 1994). The effect of ascorbic acid as a flour improver is that it increases both the dough strength and bread volume (Belitz and Grosch, 1986). These effects are related to a rapid reaction with endogenous glutathione converting it to its disulphide form during dough kneading.
Gluten becomes softer in the presence of glutathione since its protein molecules are depolymerised. By adding ascorbic acid, part of the glutathione is removed from the reaction resulting in a stronger gluten and consequently stronger dough (Penfied and Campbell, 1990).

2.6.2 Potential advantages of use of traditional food crops in baking

There are a number of beneficial feedbacks that result from using the traditional crops in food processing. One of the most obvious advantages is the promotion of the food crops. A strategy to maintain adequate diets among the poor that gained attention in the 1980s was promotion of traditional crops such as vegetables, fruits, pulses and certain cereals and tubers that are habitually consumed in rural areas (FAO, 1992). With strong emphasis on production of staple cereals in earlier years, the so-called minor crops have been neglected (FAO, 1992). Encouraging production of these crops is now recognized as a way to broaden the food base and ensure a minimum supply of food before harvest. The traditional crops are especially important in poor households and women who tend to be the main producers and consumers of traditional food crops (Asiedu, 1990).

Promotion of diet diversification is another direct benefit of processing the indigenous food crops. It is often said that food habits are difficult and slow to change. This may well be so if change is a voluntary act. Food has an important physiological association with family, community and security; familiar food is satisfying and reassuring particularly the traditional foods of childhood that evoke a deep-seated emotional response. Many African countries have in the past three generations experienced extensive changes in the family food supplies and the household diet (Unklesbay, 1992). In some urban areas, introduced foods now predominate as the accepted staple foods. For example, rice is the
preferred cereal while wheat flour bread is a much sought after luxury (FAO and ILSI, 1997). Even in rural areas, the range of traditional domestic foodstuffs has been considerably reduced. When traditional foods become scarce and expensive and when time and labour is no longer available for their production, processing and domestic preparation, their contribution to the family diet is reduced. However, despite urbanization there is evidence that people still like traditional foods as the products typically sold in African city streets are largely traditional dishes and local food items (Dupont and Osman, 1987). Utilization of traditional food crops in baking to produce bread would serve as a campaign to diversify consumption patterns building well on the preferences of people targeted.

Initiation of village-based industries processing the local food crops would create off-farm employment opportunities. These may represent the first instrument to solving the widespread unemployment. Hence, it is such an important factor in capital accumulation in rural areas. Food-processing industries also acts as a stimulus to agricultural production. This happens through market expansion as a result of utilization of the indigenous food crops, which means more market for the farmers. In the West African countries, success has been achieved with the initiation of village-based cottage industries that utilize the indigenous crops (Gomez et al., 1992). Women have immensely benefited from the jobs created through processing of cassava, millet and sorghum into a wide range of products. The emergence of industries processing the crops also means better terms of trade for the farmers. When the terms shift in favor of agricultural go-ahead farmers and urban dwellers too begin to invest their savings in the sector (FAO, 1992). An entrepreneurial class of middle-size farmers begins to emerge who can act as the leading
edge in introducing more advanced technology and commercial methods, bridging the formal and informal sector. These entrepreneurs come from diverse backgrounds but they all have one thing in common. They see farming as a sector where money can be made. The emergence of this class of entrepreneurs solely depends on the agro-processing industries (Dupont and Osman, 1987).

Seasonal food scarcity accentuates the severity and incidences of malnutrition. Many traditional food plants are drought resistant, can be grown without expensive inputs and have good food storage properties (Latham, 1997). Utilization of the traditional food crops would also lead to production of more nutritious baked products. The use of root and tuber crops, legumes and cereals in baking means production of a bread with different nutritional value as compared to the traditional wheat bread. In terms of vitamin A, the yellow-fleshed sweet potato is said to contain a very high content of beta-carotene, which is a pre-cursor to vitamin A (Wainaina, 2000). The legumes are high in protein content and when used in baking together with cereals complement each other to offer a more complete protein (FAO, 1992).

2.7 SUMMARY

There are four main approaches that are being used to prevent and control VAD. These are supplementation by use of vitamin A capsule, fortification of selected foods, nutrition education and diet and food-based interventions. Supplementation is an essential and complementary bridge to more sustainable measures such as food fortification, food-based approaches and other supportive health interventions. The food-based approaches aim at encouraging people to produce, consume and process the micronutrient rich foods. In the rural areas, the major food-based efforts focus on horticultural and production of small
animals like rabbits and guinea pigs. It can also involve poultry and fishery projects. In the urban setting, there is generally better food availability as well as potential of access to fortified food products. It would also be beneficial to promote home gardens in peri-urban areas. No matter what location, nutrition education activities strengthen and complement efforts to enhance availability of micronutrient-rich foods. The general benefits of these approaches are that they are preventive, sustainable and cost-effective.

Some of the products that the micronutrient-rich foods can be processed into are flour-based products. The use of indigenous food crops in baking is not new and its advantages include diet diversification, production of more nutritious products, creation of off-farm employment and stimulation to the agricultural production of the crops. However, there are various problems associated with use of the crops in baking but with proper regulatory mechanisms in place, most of them can be overcome.

There is need to promote sustainable measures to curb the nutritional problem experienced today. This can be done through various strategies of promoting traditional foods that are rich nutritionally yet under-exploited.
CHAPTER THREE
3.0 MATERIALS AND METHODS

3.1 RESEARCH DESIGN

The study employed a completely randomized balanced block design. Four variations of the alternative bread were made and common wheat bread was used as the control. Proximate composition and β-carotene analysis of the flour formulations and the bread samples were carried out. Sensory evaluation was carried out to assess different characteristics of the bread variations as well as determine consumer preferences. There were two sensory panel sessions and all bread variations occurred in the same group during testing and appeared equally in the two blocks. The aim of using this design was to remove inter-block differences in analysis and to prevent interference in treatment comparisons. Having all the samples being tested in the same block enabled comparison with the same degree of accuracy (Amerine et al., 1965). The study was carried out in the Department of Foods, Nutrition and Dietetics, Kenyatta University.

3.2 MATERIALS

3.2.1 Chemicals

All the reagents used in the nutrient analysis of the bread samples were analar grade purchased from Sigma Chemicals.

3.2.2 Ingredients

Flours from wheat, sweet potatoes, millet and pigeon peas were used in the study. The Exe wheat flour brand was used and this was purchased from Uchumi Supermarket in Nairobi together with margarine, sugar, salt and yeast. The orange-fleshed sweet potato flour, millet and pigeon peas flours were bought from Kirinyaga Flour Mills. The dried
sweet potatoes for milling were supplied by the Vitamin A project (VITA) being carried out by the International Potato Center and the Kenya Agricultural Research Institute (KARI). The ascorbic acid was bought from a health store in Nairobi Kenya. Tap water was used in the dough preparation.

3.3 BREAD FORMULATION

The bread formulations used in the study are shown in Table 3.1. Four other variations of the alternative bread were made. One variation was made using 30% wheat flour and 70% sweet potato, millet and pigeon pea flours combined with added ascorbic acid as a flour improver. Variation 2 had the same proportion of the wheat and non-wheat flours as variation one with no flour improver. For variation 3, no wheat flour was used but instead 100% sweet potato, millet and pigeon pea flours were used with no flour improver. Variation 4 was made using the same flours as variation three but with added flour improver. The experiment and testing was replicated three times.
### Table 3.1: Formulation of the alternative bread

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<th>INGREDIENTS</th>
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<tr>
<td></td>
<td>Wt (g)</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>200</td>
</tr>
<tr>
<td>Pearl millet flour</td>
<td>-</td>
</tr>
<tr>
<td>Pigeon pea flour</td>
<td>-</td>
</tr>
<tr>
<td>Sweet potato flour</td>
<td>-</td>
</tr>
<tr>
<td>Ascorbic Acid</td>
<td>-</td>
</tr>
</tbody>
</table>

**Key:**

- **Control** - Bread made using wheat flour only
- **B₁** - Variation of the alternative bread made using 30% wheat flour and 70% sweet potato, millet and pigeon pea flours with added ascorbic acid as the flour improver.
- **B₂** - Variation of the alternative bread made using 70% of the non-wheat flours and 30% wheat flour without ascorbic acid.
- **B₃** - Variation made with 100% sweet potato, pigeon pea and millet flours combined and ascorbic acid.
- **B₄** - Variation made with 100% sweet potato, pigeon pea and millet flours combined without ascorbic acid.

**Common Ingredients**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Wt (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Margarine</td>
<td>10</td>
</tr>
<tr>
<td>Yeast</td>
<td>5</td>
</tr>
<tr>
<td>Sugar</td>
<td>10</td>
</tr>
<tr>
<td>Salt</td>
<td>2</td>
</tr>
<tr>
<td>Tepid water</td>
<td>Variable</td>
</tr>
</tbody>
</table>

3.3.2 Preparation and Baking

The straight dough method was used in preparing the bread. This is a method used for making yeast bread products by combining and kneading the dough prior to the proofing time and mixing is relatively quick. The method is suitable when weak flours are used for bread baking (Penfield and Campbell, 1990). All the ingredients were weighed before use. Below is a flow chart showing the bread formulation and procedure.
Control flour ~ (100% wheat flour) ~ Flour blends

Baking formula (% flour weight)
1. Flour 200g
2. Salt 2g
3. Sugar 10g
4. Fat 10g
5. Dry yeast 5g
6. Water: variable

↓
MIXING: 2 minutes

↓
FERMENTATION: 90 minutes at 30°C

↓
SCALING

↓
MOULDING

↓
INTERMEDIATE PROOF; 10 minutes at 30°C

↓
FINAL PROOF: 60 minutes at 30°C

↓
BAKING: 160°C - 220°C: 40-45 minutes

Figure 3.1: Flow diagram for bread preparation
3.4 ANALYTICAL METHODS

Objective tests were done with the use of instruments and standard procedures to determine the set parameters.

3.4.1 Determination of β-carotene

The open-column method was used for determination of β-carotene, the main vitamin A precursors. This method was adopted from Rodriguez-Amaya and Delia (2001). A sample of 100gm of the flour formulations and the bread samples were weighed to the nearest 0.1g. The samples were blended in a mechanical blender for 30-40 seconds with enough cold acetone to cover. Filtration through a buchner funnel followed and the blender, funnel and the residue were washed with small amounts of acetone, receiving the washings in the suction flask with the extract. The extraction and filtration was repeated until the residue was devoid of any colour and the washings were colourless.

The extract was then partitioned in petroleum ether. A 100 ml of petroleum ether was put in a separatory funnel and a small portion of the acetone extract added. Distilled water was added slowly letting it flow along the walls of the funnel. The two phases were left to separate and the lower aqueous-acetone phase was discarded. Another portion of the extract was added and the operation repeated until all the extract was transferred in the petroleum ether. The phase was collected and dried with Sodium Sulphate (NaSO₄). This was followed by saponification using butylated hydroxytoluene (0.1% in petroleum ether) and an equal volume of 10% Potassium Hydroxide (KOH) in methanol. Before being introduced in the carotenoid column, the carotenoid solution was decanted and concentrated in a rotary flask to 20 ml. This was introduced to the alumina column and the
sample let to go down almost to the NaSO₄ layer before adding the petroleum ether rinse. The elution solutions were added in sequence in order from 4 to 12 % diethyl ether in petroleum ether. The α-carotene present was eluted. In sequence, 16 to 40 % diethyl ether in petroleum ether was added. The deep orange coloured zone of β-carotene was collected. Spectrophotometric reading was done at wavelength between 425 to 450 nm. The spectrum was recorded in a 1-cm cuvette. Using the spectrum readings, the concentration of the beta-carotene was calculated. The following formula was used.

\[ X(\mu g) = \frac{A_y(\text{ml})}{A_{\%cm}} \times 10^6 \]

\[ X(\mu g/g) = \frac{X(\mu g)}{\text{Weight of sample (g)}} \]

Where:

- \( X \) = weight or concentration of the carotenoid
- \( Y \) = volume of solution that gave an absorbance \( A \) at specified wavelength
- \( A \) = absorption coefficient of carotenoid in the solvent used (β-carotene in petroleum ether, the absorbance \( A \) at 450nm).
- \( A_{\%cm} = 2592 \)

For calibration, pure beta-carotene was used as a standard. The ultra violet spectrophotometer was used to record the absorbance of the samples and the data attained used to draw the calibration curve shown in Figure 3.2.
The retention levels of β-carotene were calculated. The aim of this was to find out how much of the β-carotene obtained from the flour samples was retained in the baked alternative bread on dry weight basis. The formula below was used.

\[
\text{% retention} = \frac{\text{carotenoid content per gram obtained from the baked bread}}{\text{carotenoid content per gram of raw food}} \times 100
\]

Figure 3.2: Calibration curve for the β-carotene standard

The standard curve for beta-carotene.
3.4.2 Proximate Compositional Analysis

Compositional analysis was carried out on the flour combinations, dough and the finished product. This was done to determine the moisture content, crude protein, crude fat total ash and the calorific value of the samples.

3.4.2.1 Moisture Content

The samples of flour and the bread were weighed to the nearest 0.1g. The loaf was then cut into 2 - 4mm slices then spread on paper and allowed to dry in a warm room overnight so that they became crisp and brittle. The samples were reweighed and then ground to pass through a No. 20 sieve. They were then mixed and transferred to an airtight container. To determine the total solids, 2g of each sample was dried at 130°C for one hour in a vacuum oven at a pressure less than 25 mmHg. The percent moisture in the samples was calculated as follows.

\[
\text{Percent moisture in original bread} = 100 - \frac{\text{(Weight of air-dried sample) (Total solids)}}{\text{Weight of original bread}}
\]

3.4.2.2 Crude Protein

The Kjeldahl procedure was used to determine the protein content of the samples. A portion of the prepared samples was weighed and transferred to a kjeldahl digestion flask. Mercuric oxide 0.7g was added together with 15g powdered Pottasium Sulphate (KSO₄) and 40 ml concentrated Sulphuric acid (H₂SO₄). The flask was heated gently in an inclined position until frothing ceased, and then boiled briskly for 2 hours. It was allowed to cool after which approximately 200ml water and 25 ml NaSO₄ solution was added and mixed. A piece of granulated zinc was added and sufficient Sodium Hydroxide (NaOH) solution poured carefully down the side of the flask to make the contents strongly alkaline.
Before mixing the acid and alkaline layers, the flask was connected to a distillation apparatus incorporating an efficient splash head and condensed.

The contents of the digestion flask were mixed and boiled until at least 150 ml had distilled into the receiver. Five drops of methyl red indicator solution (0.5g/100ml ethanol) were added and titrated with 0.1M NaOH. A blank titration was then carried out using 1 ml of 0.1M Hydrochloric acid (HCl). The factor nitrogen was multiplied by 5.7 to get the amount of crude protein in the sample (Kirk and Sawyer, 1991).

3.4.2.3 Crude Fat

Acid hydrolysis method was employed to measure the total fat in the samples. Two grams of the samples were stirred with 2ml alcohol and then 7ml of conc. HCl and 3ml of water added. The mixture was heated at about 80°C for 30 minutes, cooled and 10ml of alcohol added to the hydrolyzed mixture. The mixture was then extracted three times with 25ml ether followed by 25ml petroleum. The solvent extracts were combined then removed by evaporation. The residue was weighed to determine the total fat content of the samples.

3.4.2.4 Total ash

From the prepared sample, 5g of the sample were weighed into a silica dish that had previously been ignited and cooled before weighing. The dish and the contents were ignited first gently over a low flame until charred then in a muffle furnace at 500-550°C. The ash was then put in a dessicator and weighed to determine the total ash content in the samples.

The amount of ash was calculated by difference as follows:
Ash value (%) = \( \frac{W_2}{W_1} \times 100 \)

Where:
- \( W_1 \) = weight of sample
- \( W_2 \) = weight of the ash

3.4.2.5 Calorific value

A bomb calorimeter was used to determine the value of the flour combinations and the bread samples. A weighed sample was placed in the calorimeter. The bomb was charged with oxygen, the sample ignited and heat dissipated into a known volume of the water surrounding the bomb. The change in water temperature was noted and the energy value of the food calculated.

3.4.3 Physical Measurements

Using instrumental methods, crumb structure and crust of the alternative bread were assessed. To record the crumb structure, a photocopy machine was used. Placing a sheet of clear plastic film on the glass plate of the machine and placing the sample on the film, the photocopies were made. Copies were made for the three variations of the alternative bread and compared. For the crust, photographs of the bread were taken under controlled light. These were used to compare the outer appearance of the three variations.

3.5 SENSORY EVALUATION

The evaluation tests were carried out to measure and analyze some characteristics of the bread samples as perceived by the consumer panelists. The panelists used to evaluate the baked product were selected using stratified sampling from the department of Foods, Nutrition and Dietetics, Kenyatta University. A list of all the first year postgraduate
students who have taken a unit in sensory evaluation of foods was obtained. Fifteen students from the postgraduate class were selected. The selected panelists were trained prior to the testing period in order to develop a common understanding of the terminology and procedures used in the evaluation of the alternative bread.

Descriptive and affective tests were used and were adopted from Jellinek (1985). The objective of the descriptive tests was to characterize and compare samples with respect to specific characteristics. Attribute rating was applied where scoring techniques were used in evaluation of the bread samples qualities. The colour, cell structure, texture, chewiness, flavour and aftertaste of the bread samples were evaluated. The following sample terms and anchor ends of scale were used in the descriptive testing.

Table 3.3 Terms used in descriptive testing of the bread samples

<table>
<thead>
<tr>
<th>Qualities</th>
<th>Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour intensity</td>
<td>Very light – very dark</td>
</tr>
<tr>
<td>Cell structure</td>
<td>Grainy – extremely coarse</td>
</tr>
<tr>
<td>Texture</td>
<td>Crumbly – tough</td>
</tr>
<tr>
<td>Chewiness</td>
<td>Tender – tough</td>
</tr>
<tr>
<td>Moistness</td>
<td>Dry – very moist</td>
</tr>
<tr>
<td>Flavour</td>
<td>Well-balanced – extremely yeasty</td>
</tr>
<tr>
<td>Aftertaste</td>
<td>Short – very long</td>
</tr>
</tbody>
</table>

Samples of the same size and shape were cut from the 1.25cm slices of bread and were randomly coded using three-digit table of random numbers. The common white wheat bread was used as the control. Each of the 15 judges received the control sample and the four alternative bread samples. These samples were all coded and the control, also
included as a coded sample. The sample codes and the permutations are shown in Appendix 5 and 6 respectively.

Affective tests were done to determine if the panelists liked the alternative bread and if they preferred one of the variations to another. Preference ranking tests were used to achieve the objective. The bread samples were ranked in order of degree of acceptability and numbers were used for ranking. A sample of the ranking sheet is shown in the Appendix 3.

### 3.6 PRE-TESTING OF INSTRUMENTS

Prior to the main research study, trials on the four bread formulations were done. Sensory evaluation of the products was carried out using 2 panelists who were not included in the final tasting sample. The results obtained in the trials and sensory evaluation were used to adjust the procedure used and the record sheets. The aim of the pre-testing was to make any changes necessary to enhance validity and reliability of the procedures and findings of the main study.

### 3.7 DATA ANALYSIS

Once the raw data were obtained, descriptive statistics were used to summarize, organize and simplify the findings. Frequencies, percentages and means were used to achieve this. The statistical package for social sciences (SPSS) was used in the analysis. The data were analyzed using Analysis of Variance (ANOVA). ANOVA is a method that is used to study effects of qualitative factors on a quantitative measurement in food research (Piggott, 1986). For the data obtained from compositional analysis of the bread variations, analysis of variance was used to test whether there was a significant difference in the amounts of
beta-carotene, protein, ash, calorific value and moisture measured in the samples. The bread variations were the independent variables while their nutrient composition were the dependant variables. A post-hoc test using LSD was done to compare the differences observed in the samples. For preference and acceptability of the bread variations, rank analysis was done using the Kramer tables (Kramer, 1981). The rank tests results were checked for significance at 5% significance level to determine the consumer response.

3.8 MEASUREMENT OF VARIABLES

Colour
Visual attribute determined by the appearance of the exterior surface. The brownness of the bread crust was assessed.

Texture
A composite of factors that arise from physical structural elements and the manner in which it registers with the physiological senses. It was used to describe the bread tissue structure

Cell Structure
The granular make-up of the bread crumb.

Chewiness
The cohesiveness of the bread as perceived by the physiological senses.

Aftertaste
The experience that follows the removal of taste stimulus

Flavour
A complete sensation of taste aroma and mouth feel described by terms like sweet, yeasty, floury, flat and wheat-like.
Acceptance

The willingness to use or consume the baked product.

Preference

The acceptance of a product over another when a choice is presented. Also the degree of liking or disliking.
CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

Based on the idea that food-based approaches are the most suitable for building future food security worldwide, the purpose of the study was to utilize the beta carotene-rich sweet potatoes combined with millet and pigeon peas in making an enriched bread product. The researcher sought to find out whether these dry-land crops could be used with or without adding wheat flour to come up with an alternative bread that would not only be acceptable but also rich in beta carotene, a precursor of vitamin A.

The data obtained was presented in means, frequencies and percentages. Analysis of variance was used to find out whether there was significant difference in the means of the parameters measured. The results were organized under the following sub-topics:

1. Proximate composition analysis
2. Beta carotene analysis
3. Sensory evaluation results
4. Physical evaluation of the bread

4.1 PROXIMATE COMPOSITION ANALYSIS

The flour and bread samples were analyzed to determine their crude protein, crude fat, ash, moisture content and calorific value. Table 4.1 below shows the percentages obtained in the samples analyzed on dry weight basis.
Table 4.1 Compositional content of the bread samples and flour formulations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>$B_1$</th>
<th>$B_2$</th>
<th>$B_3$</th>
<th>$B_4$</th>
<th>$F_1$</th>
<th>$F_2$</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein$^1$</td>
<td>11.0</td>
<td>13.1</td>
<td>13.1</td>
<td>13.6</td>
<td>13.5</td>
<td>9.2</td>
<td>10.3</td>
<td>0.0835</td>
</tr>
<tr>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.03$</td>
<td>$\pm 0.02$</td>
<td></td>
</tr>
<tr>
<td>Total fat$^1$</td>
<td>2.0</td>
<td>2.9</td>
<td>2.9</td>
<td>3.0</td>
<td>3.0</td>
<td>2.1</td>
<td>2.6</td>
<td>0.2204</td>
</tr>
<tr>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td></td>
</tr>
<tr>
<td>Total ash$^1$</td>
<td>1.14</td>
<td>2.7</td>
<td>2.6</td>
<td>3.2</td>
<td>3.2</td>
<td>3.3</td>
<td>3.4</td>
<td>0.0047</td>
</tr>
<tr>
<td>$\pm 0.06$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.04$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.04$</td>
<td></td>
</tr>
<tr>
<td>Moisture$^1$</td>
<td>32.4</td>
<td>33.6</td>
<td>33.6</td>
<td>38.7</td>
<td>38.7</td>
<td>10.7</td>
<td>11.0</td>
<td>0.0018</td>
</tr>
<tr>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.06$</td>
<td></td>
</tr>
<tr>
<td>Calorific Value$^2$</td>
<td>4.9</td>
<td>4.6</td>
<td>4.5</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.6</td>
<td>0.0334</td>
</tr>
<tr>
<td>$\pm 0.01$</td>
<td>$\pm 0.02$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.01$</td>
<td>$\pm 0.02$</td>
<td></td>
</tr>
</tbody>
</table>

Key:
- Control – bread made from 100% wheat flour
- $B_1$ – alternative bread made from 30% wheat flour, 30% sweet potatoes flour, 20% millet flour and 20% pigeon peas flour plus ascorbic acid.
- $B_2$ – alternative bread made from 30% wheat flour, 30% sweet potatoes, 20% millet flour and 20% pigeon peas flour.
- $B_3$ – alternative bread made from 40% sweet potatoes, 40% millet and 20% pigeon peas flour plus ascorbic acid.
- $B_4$ – alternative bread made from 40% sweet potatoes, 40% millet and 20% pigeon peas flour.
- $F_1$ – flour formulation used in making bread 1 and 2
- $F_2$ – flour formulation used in making bread 3 and 4
$^1$ denotes that the values are given in percentage.
$^2$ denotes that the values are given in kilocalories.
α level = 0.05
Replications=3

The protein composition of the samples analyzed ranged from 11.0% to 13.6%. The lowest protein content was recorded in the control bread. The alternative $B_3$ and $B_4$ that were made using only the local food crops had the highest protein content of 13.6% and 13.5% respectively. The reported range of protein in the common bread is 8.3%-9.0%.

The results showed that with the increase in the amount of non-wheat flour used in the alternative bread, the protein content increased too. This could be attributed to the increase in the amount of pigeon peas flour in the formulations. Legumes contain a
relatively large amount of proteins, which vary from 17% to 40% (Raterno, 1990). Statistical analysis of the results indicated that there was no significant difference in the protein content of the bread and flour samples. The p-value at 95% confidence level was 0.0835.

The crude fat analysis was conducted by acid hydrolysis. From the results, the alternative bread variations with 30% wheat flour had 2.9% and 2.9% fat respectively. The variations that had no wheat at all recorded 3.0%. The control bread had 2% fat while the flour formulations 1 and 2 had 2.1% and 2.6% respectively. The ANOVA tests gave a p-value of 0.2204 at 5% significance level. This indicated that there was no significance difference in the fat content of the samples analyzed.

High ash content was observed in the alternative bread variations. The wheatless bread variations recorded 3.2%. Lower ash content was observed in the variations that were made from 30% wheat flour, 30% sweet potatoes flour, 20% millet and 20% pigeon peas flours. These had 2.7% and 2.6% ash content respectively. The control bread had 1.1% ash. The flour formulation used in B₁ and B₂ had 3.3% while that used in B₃ and B₄ had 3.4%. Ash content should not exceed 2% in white wheat bread (Kirk and Sawyer, 1991). The control bread was within the expected range. The ash obtained represented the mineral matter in a foodstuff. Sweet potatoes, millet and pigeon peas have a higher mineral content than wheat. The higher mineral content in the non-wheat flours explains the difference in the ash content of B₃ and B₄, the variations that had no wheat flour in their formulation as compared to B₁ and B₂ that had wheat. However, the ash obtained is not necessarily of the same composition as the mineral matter present in the original food. There may be losses due to volatisation or some interaction between constituents. This
explains the difference in the percentages obtained from the flour formulations and the bread samples. ANOVA results indicated a significant difference in the ash content of the samples evaluated that could be explained by the difference in the mineral content of the flours used.

The moisture content of the bread samples ranged from 33.4% to 38.7%. Bread samples B3 and B4 that had no wheat in their flour formulation recorded a moisture content of 38.7% and 38.7% respectively, compared to the variations B1 and B2 that had 30% wheat flour and recorded 33.6% moisture content. The control bread had 32.4% moisture. Flour formulation for bread 1 and 2 had 10.70% moisture while flour formulation for bread 3 and 4 had 11.01%. The reported range of moisture in bread is 13-15% (Kirk and Sawyer, 1991). There was a significant difference in the moisture content of the samples analyzed. The hydration capacity of the flours differed due to their difference in gluten content. The poor hydration of the non-wheat flours resulted into the high moisture content in the alternative bread variations compared to the control.

To determine the calorific value of the bread samples and the flour formulations, a bomb calorimeter was used to read the values. The alternative bread variations recorded a range of 4.5Kcal/g to 4.9Kcal/g for the calorific value. The B1 and B2 composed of 30% wheat flour had 4.8Kcal/g same as B3 and B4. The control bread had the highest calorific value of 4.9Kcal/g. ANOVA results showed a P value of 0.0334 hence indicating a significant difference in the calorific value of the bread and flour samples. Wheat flour has a higher calorific value than millet and the other flours used in the alternative bread. This may be the reason for the significant difference noted in the calorific value of the various bread variations.
To allow for comparison at three different levels, Least Significant Difference (LSD) post hoc test was used. It was used to compare the control and the averages of B₁ and B₂, control and the averages of B₃ and B₄, and between the average of B₁ and B₂ and that of B₃ and B₄. Table 4.2 shows the results of the post hoc test.

Table 4.2 Comparison of the Proximate Content of the Bread Samples

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td></td>
</tr>
<tr>
<td>Control versus B₁B₂</td>
<td>0.00</td>
</tr>
<tr>
<td>Control versus B₁B₄</td>
<td>0.00</td>
</tr>
<tr>
<td>B₁B₂ versus B₁B₄</td>
<td>0.01</td>
</tr>
<tr>
<td>Crude fat</td>
<td></td>
</tr>
<tr>
<td>Control versus B₁B₂</td>
<td>0.00</td>
</tr>
<tr>
<td>Control versus B₁B₄</td>
<td>0.00</td>
</tr>
<tr>
<td>B₁B₂ versus B₁B₄</td>
<td>0.02</td>
</tr>
<tr>
<td>Total ash</td>
<td></td>
</tr>
<tr>
<td>Control versus B₁B₂</td>
<td>0.00</td>
</tr>
<tr>
<td>Control versus B₁B₄</td>
<td>0.00</td>
</tr>
<tr>
<td>B₁B₂ versus B₁B₄</td>
<td>0.00</td>
</tr>
<tr>
<td>Moisture content</td>
<td></td>
</tr>
<tr>
<td>Control versus B₁B₂</td>
<td>0.00</td>
</tr>
<tr>
<td>Control versus B₁B₄</td>
<td>0.00</td>
</tr>
<tr>
<td>B₁B₂ versus B₁B₄</td>
<td>0.00</td>
</tr>
<tr>
<td>Calorific value</td>
<td></td>
</tr>
<tr>
<td>Control versus B₁B₂</td>
<td>0.00</td>
</tr>
<tr>
<td>Control versus B₁B₄</td>
<td>0.00</td>
</tr>
<tr>
<td>B₁B₂ versus B₁B₄</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Control – bread made from 100% wheat flour
B₁ B₂ – alternative bread made from 30% wheat flour, 30% sweet potatoes flour, 20% millet flour and 20% pigeon peas flour plus ascorbic acid.
B₁ B₄ – alternative bread made from 40% sweet potatoes, 40% millet and 20% pigeon peas flours plus ascorbic acid.
The proximate composition for all the samples was found to be significantly different at 95% significance level.

4.2 BETA CAROTENE CONTENT

The open column chromatography method was used to determine the levels of β-carotene, a precursor of vitamin A in the flour formulations and the bread samples. Using spectrophotometer readings, the concentration of β-carotene in the samples was calculated. Below is a histogram showing the carotene content in the bread and flour samples.

![Histogram showing the β-carotene content of the bread samples](image)

**Figure 4.1: Histogram showing the β-carotene content of the bread samples**

**KEY:**
- Control - made from 100% wheat flour.
- B1 - made from 30% wheat flour, 30% sweet potato, 20% millet and 20% pigeon pea flours and ascorbic acid.
- B2 - made from the same flour proportions as B1 without ascorbic acid.
- B3 - made from 40% sweet potato, 40% millet and 20% pigeon pea flours with ascorbic acid.
- B4 - made from the same flour proportions as B3 without ascorbic acid.
- F1 - formulation used for B1 and B2.
- F2 - flour formulation used for B3 and B4.

The alternative bread variations with 40% sweet potatoes flour recorded a higher content of β-carotene as compared to the variations with 30% of the flour. The alternative B1 and
B₂ had 3.3μg/g of the pro-vitamin A while alternative B₃ and B₄ recorded 3.4μg/g. The control bread had the lowest content of β-carotene of 0.7μg/g. The flour formulation 1 had 3.4μg/g while the flour formulation 2 had 3.5μg/g of the pro-vitamin A. With the use of the β-carotene rich sweet potatoes flour in the alternative bread, the amounts of the vitamin A pre-cursor remarkably improved. The results show that by incorporating the orange-fleshed sweet potatoes in bread baking, a product richer in β-carotene can be obtained. Using flour formulation 1, an alternative bread with the standard 400g weight would contain 1316.4μg/g of β-carotene.

The retention levels of the β-carotene in the alternative bread as compared to the flour formulations were determined and are shown in Table 4.2.

### Table 4.3 β-carotene retention in the alternative bread samples

<table>
<thead>
<tr>
<th>Variation</th>
<th>Retention level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B₁</td>
<td>97.7</td>
</tr>
<tr>
<td>B₂</td>
<td>97.4</td>
</tr>
<tr>
<td>B₃</td>
<td>95.3</td>
</tr>
<tr>
<td>B₄</td>
<td>95.5</td>
</tr>
</tbody>
</table>

All the bread variations had high retention levels of the carotene. B₁ that had 30% wheat and ascorbic acid recorded the highest retention. The loss of β-carotene in the baked bread compared to the flour formulations could be associated with the fact that carotenoids are highly unsaturated. This makes them susceptible to isomerization and oxidation, reactions that can easily occur during preparation and processing of food. However, the above 95% retention recorded in all the bread variations showed that the preparation and baking
procedures had minimal destruction effects on the pro-vitamin A. The baking temperature was controlled to minimize destruction of the pro-vitamin A by heat.

4.3 SENSORY EVALUATION RESULTS
Visual and sensory characteristics of food influence food selection and preferences. Scoring and ranking tests were used to evaluate the bread samples.

4.3.1 Scoring Tests
Coded samples were evaluated for the intensity of some specific characteristics. These were colour, cell structure, texture, chewiness, flavour, moistness and aftertaste. The panelists recorded their judgments on a five point graduated scale and the intervals were labeled with descriptive terms. All the panelists evaluated the characteristics at the same time to ensure effective scoring.

4.3.1.1 Colour
Colour is one of the most important visual attributes in food. Often, if the appearance is unattractive, the potential customer may never experience the other attributes. The colour of the alternative bread was evaluated to find out the perceptions of the consumer panelists in the study. A five point scoring sheet was used for the assessment. The lowest score was 1 for very dark brown, 2 was dark brown, 3 was slightly dark brown, 4 was light brown and 5 was very light brown. Table 4.3 below shows the scores for the colour.
Table 4.4 Colour scores for the bread samples.

<table>
<thead>
<tr>
<th>Bread Sample</th>
<th>Colour intensity</th>
<th>S E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very light brown</td>
<td>Light brown</td>
</tr>
<tr>
<td>B1</td>
<td>6.7</td>
<td>46.7</td>
</tr>
<tr>
<td>B2</td>
<td>-</td>
<td>40.0</td>
</tr>
<tr>
<td>B3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Control bread</td>
<td>60.0</td>
<td>40.0</td>
</tr>
</tbody>
</table>

Key:
- B1 - made from 30%, wheat flour and 70% sweet potatoes, millet and pigeon peas flours plus ascorbic acid.
- B2 - alternative bread made from similar flour proportions as bread 1 without ascorbic acid.
- B3 - made from 100% sweet potatoes, millet and pigeon peas flours with ascorbic acid.
- B4 - made from similar flour proportions as bread 3 without ascorbic acid.
- Control - made from 100% wheat flour

The results indicated a dark brown colour in the bread formulations that were made from the non-wheat flours. B1 was rated dark by 13.3% of the panelists while 33.3% found the colour to be slightly dark brown. The rest of the panelists said that the bread had a light brown colour. B2 that had the same flour amounts as B1 but without ascorbic acid was found to be dark by 40% of the panelists, the same percent found it light brown while the rest said the bread had a light brown colour. B3 and B4 that had no wheat were found to have a dark brown colour by majority of the judges. The difference in the colour intensity in B1 and B2 as compared to B3 and B4 was due to the higher proportion of millet and sweet potatoes flours in the wheatless variations. The millet grain is darker in brownness compared to the wheat grain and so is its flour. Use of the millet flour and the sweet potatoes flour which was slightly orange may have resulted to the darker brown colour observed in the alternative bread.
4.3.1.2 Cell structure

This is a geometric feature of bread, which was visually evaluated to determine the granular make-up of the bread sample crumb. The five-point scale used had the following descriptive terms- 1- extremely coarse, 2- coarse, 3- slightly coarse, 4- fine and 5- very fine.

Table 4.5 Cell structure scores

<table>
<thead>
<tr>
<th>Bread</th>
<th>Grainy</th>
<th>Slightly grainy</th>
<th>Slightly coarse</th>
<th>Coarse</th>
<th>Extremely coarse</th>
<th>S E</th>
</tr>
</thead>
<tbody>
<tr>
<td>B₁</td>
<td>-</td>
<td>60.0</td>
<td>33.3</td>
<td>6.7</td>
<td>-</td>
<td>-165</td>
</tr>
<tr>
<td>B₂</td>
<td>6.7</td>
<td>26.7</td>
<td>53.3</td>
<td>13.3</td>
<td>-</td>
<td>-206</td>
</tr>
<tr>
<td>B₃</td>
<td>-</td>
<td>6.7</td>
<td>33.3</td>
<td>53.3</td>
<td>6.7</td>
<td>-190</td>
</tr>
<tr>
<td>B₄</td>
<td>-</td>
<td>-</td>
<td>20.0</td>
<td>73.3</td>
<td>6.7</td>
<td>-133</td>
</tr>
<tr>
<td>Control</td>
<td>46.7</td>
<td>53.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-133</td>
</tr>
</tbody>
</table>

Key:
B₁ - bread made with 30% wheat flour, 30% sweet potatoes flour and 40% millet and pigeon peas flours in equal proportions.
B₂ - bread made with the same flour proportions as B₁ but without ascorbic acid.
B₃ - bread made from 40% sweet potatoes flour, 40% millet flour and 20% pigeon peas flour with ascorbic acid.
B₄ - bread made from the same flour proportions as B₁ but without ascorbic acid.
Control - bread made from 100% wheat flour.

Alternative bread I had a slightly grainy structure as rated by majority (60%) of the judges. The cell structure of B₃ and B₄ was found to be either coarse or slightly coarse by most of the panelists. However, more respondents (73.3%) found B₄ to be coarse as compared to B₃ (53.3%). For B₁, 6.7% found the structure coarse as compared to B₂ that was said to be coarse by 13.3%.

The alternative bread formulations that had 30% wheat recorded a better crumb structure than the wheatless formulations. The results are due to the presence of gluten protein in wheat. The gluten forming properties of protein contribute to the excellent baking qualities in wheat flour in production of wheat bread (Pomeranz, 1991). Starch
participates in this process as the granules take on various shapes to accommodate vacuoles. The ability of films of gluten to retain gases is important during the production of carbon dioxide when the gases within the dough expand. When the bubbles expand, the starch grains are oriented in the films of the proteins, which enclose them. The cohesive gluten that forms from the gas bubbles gives a silky sheen to the cells of the bread. This leads to the production of the desired crumb grain and texture. The interaction of starch and gluten in flour to produce a desired crumb structure explains the poor performance of B3 and B4. Sweet potatoes, millet and pigeon peas flours used in the bread variations contain no gluten hence the denser crumb structure. Use of ascorbic acid led to a better crumb in B1 as compared to B2.

4.3.1.3 Texture
Texture is a composite of those factors that arise from physical structural elements and the manner in which it registers with the physiological senses. It describes a substance tissue structure. The descriptive terms used in the scoring sheet for this characteristic were, 1-hard, 2-slightly hard, 3-tender, 4-very tender and 5-crumbly.

Table 4.6 Texture evaluation of bread samples

<table>
<thead>
<tr>
<th>Bread</th>
<th>Descriptive term</th>
<th>S E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crumbly</td>
<td>Very tender</td>
</tr>
<tr>
<td>B1 33.3</td>
<td>33.3</td>
<td>26.7</td>
</tr>
<tr>
<td>B2 6.7</td>
<td>13.3</td>
<td>60.0</td>
</tr>
<tr>
<td>B3 6.7</td>
<td>-</td>
<td>60.0</td>
</tr>
<tr>
<td>B4 -</td>
<td>-</td>
<td>60.0</td>
</tr>
<tr>
<td>Control 33.3</td>
<td>53.3</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Key:
B1 – bread made from 30% wheat flour, 70% sweet potatoes, millet and pigeon peas with ascorbic acid.
B2 – bread made from the same flour proportions as B1 without ascorbic acid.
B3 – bread made from 100% sweet potatoes, millet and pigeon peas with ascorbic acid.
B4 – bread made from the same flour proportions as B3 without ascorbic acid.
Control – bread made from 100% wheat flour.
The B₁ was rated very soft by 33% panelists while the same percent found it slightly soft. B₂ was rated soft by majority (60%), 20% found it hard while 13.3% said the bread was slightly soft. Both B₃ and B₄ were found tender by 60% respectively, 33.3% found them slightly hard while the rest (6.7%) found the variations to be hard.

The use of wheat flour in B₁ and B₂ resulted into a better crumb texture in the variations compared to B₃ and B₄ made from 100% non-wheat flours. The 70% substitution of wheat flour with 30% sweet potatoes, 30% millet and 20% pigeon peas flours did not have adverse effects on the texture of the alternative bread variations. The better baking characteristics of wheat flour may have resulted in the better texture in variations 1 and 2. With a rise in temperature during baking, protein denaturation and starch swelling occurs. In wheat dough, this solidifies the crumb framework built up of gluten foam and adhering swollen starch granules. Limited starch swelling results in a brittle hard crumb and hence the hard texture in B₃ and B₄.

4.3.1.4 Chewiness
This textural mechanical characteristic was used to evaluate the cohesiveness of the bread. The descriptive terms used in the scoring sheets were: 1-tough, 2-slightly tough, 3-chewy, 4-slightly tender and 5-tender.
Table 4.7 Scoring results for bread samples chewiness

<table>
<thead>
<tr>
<th>Bread Variation</th>
<th>Descriptive term</th>
<th>S E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tender</td>
<td>Slightly Tender</td>
</tr>
<tr>
<td>B₁</td>
<td>80.0</td>
<td>20.0</td>
</tr>
<tr>
<td>B₂</td>
<td>66.6</td>
<td>26.7</td>
</tr>
<tr>
<td>B₃</td>
<td>-</td>
<td>53.3</td>
</tr>
<tr>
<td>B₄</td>
<td>-</td>
<td>46.7</td>
</tr>
<tr>
<td>Control</td>
<td>60.0</td>
<td>33.3</td>
</tr>
</tbody>
</table>

Key:
B₁ - bread made from 30% wheat flour, 70% sweet potatoes, millet and pigeon peas flours plus ascorbic acid.
B₂ - bread made from the same flour proportions as B₁ without ascorbic acid.
B₃ - bread made from 100% sweet potatoes millet and pigeon peas with ascorbic acid.
B₄ - bread made from the same flours as B₃ without ascorbic acid.
Control - bread made from 100% wheat flour.

Alternative B₁ and B₂ were rated slightly soft by majority of the panelists. B₁ was rated slightly soft by 80% of the judges and B₂ by 66.6%. The rest of the panelists (20%) found B₁ to be chewy while B₂ was found chewy by 26.7% and 6.7% found the bread slightly tough. B₃ and B₄ were rated chewy by 53.3% and 46.7% panelists respectively. Majority (60%) of the judges found control bread to be tender, 33.3% found it slightly tender and 6.7% said it was chewy.

The use of 30% wheat flour in B₁ and B₂ showed an effect on the mechanical characteristics of the variations. A tender crumb was achieved in the variations compared to the tough crumb recorded in the B₃ and B₄ that were wheatless. The hydration capacity of wheat flour that enables it to bind water within itself explains the better chewiness in alternative bread 1 and 2 and the control bread as opposed to the poorer scores given to B₃ and B₄. Adequate water absorption and mixing are essential for dough development and
production of good bread. When the levels are too low, dough is stiff and lacks cohesion. The end product is bread with a crumb that is hard and chewy. This may have been the case with B₃ and B₄ that had poor hydration capacity due to lack of gluten and pentosans that greatly determine the capacity in flours.

4.3.1.5 Moistness

The moisture characteristics of the bread variations as perceived by the potential consumers were assessed. The descriptive terms used in the five point graduated scale were; 1-dry, 2-slightly moist, 3-moist, 4-moderately moist and 5-very moist. The results are illustrated below.

<table>
<thead>
<tr>
<th>Bread</th>
<th>Descriptive term</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry</td>
</tr>
<tr>
<td>B₁</td>
<td>20.0</td>
</tr>
<tr>
<td>B₂</td>
<td>20.0</td>
</tr>
<tr>
<td>B₃</td>
<td>13.3</td>
</tr>
<tr>
<td>B₄</td>
<td>-</td>
</tr>
<tr>
<td>Control</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Key

B₁-made from 30% wheat flour, 70% sweet potatoes, millet and pigeon peas flours with ascorbic acid.
B₂-made from the same flour proportions as bread 1 without ascorbic acid.
B₃-made from 100% sweet potatoes, millet and pigeon peas flours with ascorbic acid.
B₄-made from the same flour proportions as bread 3 without ascorbic acid.
Control bread-made from 100% wheat flour
SE-standard error

From the results, both B₁ and B₂ had a slightly moist crumb, as rated by 80% of the judges. B₃ and B₄ were slightly moist as rated by 66.7% and 13.3% panelists respectively. The control bread had a slightly moist crumb as rated by 80% of the panelists while the rest found the crumb dry.
The more moist crumb experienced in the alternative bread variations that had no wheat could have been due to the hydration properties of the flours. Non-wheat flours have poor hydration properties compared to wheat flour. The water holding capacity of the wheat flour leads to desirable dough formation properties in breadmaking. The sensory results show that with the use of 30% wheat flour in the alternative bread flour formulation, it is possible to have desirable crumb moistness.

4.3.1.6 Flavour

This is an attribute of food that includes sensations of taste, smell and other cutaneous sensations. It is the end result and it is greatly influenced by taste. The aim of evaluating this characteristic was to find out whether there was any yeast flavour traces in the bread. The terms used to describe the flavour were; 1-extremely yeasty, 2-moderately yeasty, 3-yeasty, 4-slightly yeasty and 5-well balanced. Table 4.9 illustrates the results.

<table>
<thead>
<tr>
<th>Bread Variations</th>
<th>Descriptive term</th>
<th>S E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Well Balanced</td>
<td>Slightly yeasty</td>
</tr>
<tr>
<td>B1</td>
<td>40.0</td>
<td>53.3</td>
</tr>
<tr>
<td>B2</td>
<td>13.3</td>
<td>60.0</td>
</tr>
<tr>
<td>B3</td>
<td>-</td>
<td>53.3</td>
</tr>
<tr>
<td>B4</td>
<td>-</td>
<td>53.3</td>
</tr>
<tr>
<td>Control bread</td>
<td>86.7</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Key

B1-madefrom 30% wheat flour and 70% sweet potatoes, millet and pigeon peas flours with ascorbic acid.
B2-made from the same flour proportions as bread 1 without ascorbic acid.
B3-madefrom 100% sweet potatoes, millet and pigeon peas flours with ascorbic acid.
B4-made from the same flour proportions as bread 3 without ascorbic acid.
Control bread-made from 100% wheat flour.
SE-standard error
The yeast flavour was detectable in all the bread variations. Majority (53.3%) said B1 was slightly yeasty and a good number (40%) found the bread well balanced in its flavour. Only 6.7% found the bread yeasty, B2 was rated slightly yeasty by 60.0%, yeasty by 26.7% and well balanced by 13.3% of the panelists. Both alternative B3 and B4 were rated yeasty by 53.3% panelists. The control bread was well balanced as rated by 86.7% of the judges.

The final flavour of bread should be pleasant and nut-like without traces of soured or yeasty odour. This flavour is produced during the baking process and is influenced by the formulation and fermentation before the bread baking. The presence of a yeasty flavour indicates incomplete fermentation process. The slight yeast flavour in B1 and B2 could be because of lack of enough α and β-amylase, enzymes that determine the ability of flour to support fermentation. The yeasty flavour was even more pronounced in B3 and B4 that had no wheat. The non-wheat flours used in these variations lacked the enzymes hence the poor flavour performance.

4.3.1.6 Aftertaste
This is an experience that follows after the removal of taste stimulus; it may be continuous with the primary experience or may follow as a different quality after a period during which swallowing and other influences may have affected the stimulus substance (Amerine et al., 1965). The descriptive terms used in the scoring questionnaire were very long, long, slightly long, moderate and short. These terms were given numbers 1-5 respectively. The results are shown below.
Table 4.10 Scores for aftertaste of alternative bread

<table>
<thead>
<tr>
<th>Bread Variation</th>
<th>Descriptive term</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B₁</td>
<td>Short 26.7</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td>moderate 13.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>slightly Long</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>long -</td>
<td></td>
</tr>
<tr>
<td></td>
<td>very Long -</td>
<td></td>
</tr>
<tr>
<td>B₂</td>
<td>Short 13.3</td>
<td>53.3</td>
</tr>
<tr>
<td></td>
<td>moderate 33.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>slightly Long</td>
<td>66.6</td>
</tr>
<tr>
<td></td>
<td>long -</td>
<td></td>
</tr>
<tr>
<td></td>
<td>very Long -</td>
<td></td>
</tr>
<tr>
<td>B₃</td>
<td>Short -</td>
<td>26.7</td>
</tr>
<tr>
<td></td>
<td>moderate 46.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>slightly Long</td>
<td>42.2</td>
</tr>
<tr>
<td></td>
<td>long -</td>
<td></td>
</tr>
<tr>
<td></td>
<td>very Long -</td>
<td></td>
</tr>
<tr>
<td>B₄</td>
<td>Short -</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td>moderate 40.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>slightly Long</td>
<td>40.0</td>
</tr>
<tr>
<td></td>
<td>long -</td>
<td></td>
</tr>
<tr>
<td></td>
<td>very Long -</td>
<td></td>
</tr>
<tr>
<td>Control bread</td>
<td>Short 53.3</td>
<td>40.0</td>
</tr>
<tr>
<td></td>
<td>moderate 6.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>slightly Long</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>long -</td>
<td></td>
</tr>
<tr>
<td></td>
<td>very Long -</td>
<td></td>
</tr>
</tbody>
</table>

Key:
B₁ - made from 30% wheat flour and 70% sweet potatoes, millet and pigeon peas flours with ascorbic acid.
B₂ - made from the same flour proportions as bread 1 without ascorbic acid.
B₃ - made from 100% sweet potatoes, millet and pigeon peas flours with ascorbic acid.
B₄ - made from the same flour proportions as bread 3 without ascorbic acid.
Control bread - made from 100% wheat flour.
SE - standard error

A moderate aftertaste was observed in B₁ and B₂ by 60% and 53.3% panelists respectively. A short aftertaste was noted in the bread variations by 26.6% and 13.3% panelists respectively while 13.3% found bread 1 to be having a slightly long aftertaste compared to 33.3% for B₂. B₃ and B₄ were found to have a slightly long aftertaste by 46.7% and 60.0% respectively. B₃ and B₄ had a long aftertaste as noted by 26.7% and 40% panelists respectively. The control bread had a short aftertaste to majority (53.3%).
The aftertaste noted in the alternative bread variations was associated with the yeasty flavour experienced in the flavour analysis.

4.3.1.7 Scoring tests mean scores

The mean scores for the colour intensity, cell structure, texture, moistness, chewiness, flavour and aftertaste were computed. ANOVA was used to determine whether there were any significant differences in the scores. The table 4.11 below shows the results.
Table 4.11 Mean scores for sensory characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>B₁*</th>
<th>B₂*</th>
<th>B₃*</th>
<th>B₄*</th>
<th>Control*</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>3.47</td>
<td>2.80</td>
<td>1.80</td>
<td>1.67</td>
<td>4.60</td>
<td>0.5001</td>
</tr>
<tr>
<td>Cell structure</td>
<td>3.53</td>
<td>3.87</td>
<td>2.40</td>
<td>2.13</td>
<td>4.53</td>
<td>0.5024</td>
</tr>
<tr>
<td>Texture</td>
<td>3.93</td>
<td>3.07</td>
<td>2.73</td>
<td>2.53</td>
<td>4.13</td>
<td>0.4380</td>
</tr>
<tr>
<td>Chewiness</td>
<td>3.80</td>
<td>2.47</td>
<td>2.27</td>
<td>4.53</td>
<td></td>
<td>0.8243</td>
</tr>
<tr>
<td>Moistness</td>
<td>3.80</td>
<td>2.80</td>
<td>2.93</td>
<td>4.20</td>
<td></td>
<td>0.0023</td>
</tr>
<tr>
<td>Flavour</td>
<td>4.33</td>
<td>2.87</td>
<td>2.47</td>
<td>2.40</td>
<td>4.87</td>
<td>0.7581</td>
</tr>
<tr>
<td>Aftertaste</td>
<td>4.13</td>
<td>3.40</td>
<td>3.00</td>
<td>2.60</td>
<td>4.87</td>
<td>0.3846</td>
</tr>
</tbody>
</table>

Key
* The scores were presented on a five-point graduated scale for each of the characteristic with the score 5 given to the best descriptive term and 1 to the least desirable.
B₁ - alternative bread made with 30% wheat flour, 30% sweet potatoes flour and 40% millet and pigeon peas flours in equal proportions plus ascorbic acid.
B₂ - alternative bread made from the same flour proportions as bread 1 without ascorbic acid.
B₃ - alternative bread made from 40% sweet potatoes, 40% millet and 20% pigeon peas flours plus ascorbic acid.
B₄ - alternative bread made from the same variations as bread 3 without ascorbic acid.
Control - bread made from 100% wheat flour.

The statistical analysis results showed a significant difference in the moistness scores at 5% significance level. There was no significant difference in the scores of the other characteristics of the bread samples. The significant difference noted in the moistness of the variations is due to the use of different flours at different proportions in the making of the bread samples.

4.3.2 Effect of ascorbic acid

The colour intensity, cell structure, chewiness, moistness, flavour and aftertaste for alternative bread 1 were compared with those of bread 2 while the scores of bread 3 were compared with those of bread 4. The purpose of this comparison was to establish whether
the ascorbic acid used in variations 1 and 3 had any effect on the bread characteristics.

Using the independent t-test, the following results were obtained.

Table 4.12 Independent t-tests results for sensory analysis of $B_1$ and $B_2$

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>$B_1$ Mean score</th>
<th>$B_2$ Mean score</th>
<th>Mean difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>3.47</td>
<td>2.80</td>
<td>0.6667</td>
<td>0.677</td>
</tr>
<tr>
<td>Cell structure</td>
<td>3.53</td>
<td>3.27</td>
<td>0.2667</td>
<td>0.662</td>
</tr>
<tr>
<td>Texture</td>
<td>3.93</td>
<td>3.07</td>
<td>0.8667</td>
<td>0.251</td>
</tr>
<tr>
<td>Moistness</td>
<td>4.20</td>
<td>3.80</td>
<td>0.4000</td>
<td>1.000</td>
</tr>
<tr>
<td>Chewiness</td>
<td>3.80</td>
<td>3.60</td>
<td>0.2000</td>
<td>0.046</td>
</tr>
<tr>
<td>Flavour</td>
<td>4.33</td>
<td>2.87</td>
<td>1.4667</td>
<td>0.591</td>
</tr>
<tr>
<td>Aftertaste</td>
<td>4.13</td>
<td>3.40</td>
<td>0.7333</td>
<td>0.207</td>
</tr>
</tbody>
</table>

Key

SD-standard deviation

$B_1$-alternative bread made from 30% wheat flour and 70% sweet potatoes, millet and pigeon peas flours with ascorbic acid.

$B_2$-alternative bread made from the same flour proportions as $B_1$ without ascorbic acid.

The above results indicate a significant difference in chewiness of $B_1$ and $B_2$ at 5% significance level. The p-value was 0.046 lower than the set value 0.05. The other characteristics were not significantly different. The significant difference observed between the chewiness of $B_1$ and $B_2$ could have been as a result of using ascorbic acid in one of the formulations. Ascorbic acid is an oxidizing agent which when added to flour results into desired rheological properties. The effect of ascorbic acid is related to a rapid reaction
with endogenous glutathione converting it into its disulphide form during dough kneading. Gluten becomes softer in the presence of glutathione since its protein molecules are depolymerised via a thiol/disulphide interchange reaction (Belitz and Grosch, 1986). By adding ascorbic acid, part of the glutathione is removed from the reaction resulting in stronger gluten and consequently stronger dough. The result is a tender breadcrumb recorded in $B_1$.

The sensory results of $B_3$ and $B_4$ were compared to find out whether there was any effect of ascorbic acid on the non-wheat flours. Table 4.13 below shows the results.

**Table 4.13 Independent t-tests for sensory analysis of $B_3$ and $B_4$**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean score</th>
<th>SD</th>
<th>Mean difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour $B_3$</td>
<td>1.80</td>
<td>0.414</td>
<td>0.1333</td>
<td>0.034</td>
</tr>
<tr>
<td>$B_4$</td>
<td>1.67</td>
<td>0.617</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell structure $B_3$</td>
<td>2.40</td>
<td>0.737</td>
<td>0.2667</td>
<td>0.060</td>
</tr>
<tr>
<td>$B_4$</td>
<td>2.13</td>
<td>0.516</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chewiness $B_3$</td>
<td>2.47</td>
<td>0.640</td>
<td>0.2000</td>
<td>0.324</td>
</tr>
<tr>
<td>$B_4$</td>
<td>2.27</td>
<td>0.799</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texture $B_3$</td>
<td>2.73</td>
<td>0.594</td>
<td>0.2000</td>
<td>0.509</td>
</tr>
<tr>
<td>$B_4$</td>
<td>2.53</td>
<td>0.640</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moistness $B_3$</td>
<td>3.93</td>
<td>0.594</td>
<td>1.0000</td>
<td>1.000</td>
</tr>
<tr>
<td>$B_4$</td>
<td>2.93</td>
<td>0.594</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavour $B_3$</td>
<td>2.47</td>
<td>0.516</td>
<td>0.667</td>
<td>0.101</td>
</tr>
<tr>
<td>$B_4$</td>
<td>2.40</td>
<td>0.737</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Afters taste $B_3$</td>
<td>3.00</td>
<td>0.756</td>
<td>0.4000</td>
<td>0.698</td>
</tr>
<tr>
<td>$B_4$</td>
<td>2.60</td>
<td>0.507</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Key:**

- $B_3$ made from 100% sweet potatoes, millet and pigeon pea flours with ascorbic acid.
- $B_4$ made from the same flour proportions as bread 3 without ascorbic acid.
- $\alpha$ level = 0.05
The results indicated a significant difference in the colour of B3 and B4. The p-value was 0.034 lower than the expected value of 0.05 at 5% significance level. A darker brown colour was observed in the alternative bread variations with no wheat as they had a higher percentage of the sweet potatoes and millet flours. There was no significant difference in the other characteristics of the wheatless variations as a result of addition of ascorbic acid.

4.3.3 Ranking tests

These tests were done to determine the consumer preference of the bread variations formulated. The method was chosen because it is rapid and allows testing of several samples at once. The bread samples were ranked in order of degree of acceptability, and numbers were used for ranking. The best acceptable sample was given the number 1 while the least acceptable sample was given the value 5. Table 4.14 shows the rank position given to the four alternative bread variations and the control.
Table 4.14 Preference ranking for the alternative bread samples

<table>
<thead>
<tr>
<th>Judges</th>
<th>B₁</th>
<th>B₂</th>
<th>B₃</th>
<th>B₄</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>29</td>
<td>43</td>
<td>66</td>
<td>69</td>
<td>16</td>
</tr>
</tbody>
</table>

**Key:**
- B₁, made from 30% wheat flour, 30% sweet potatoes flour, 20% millet flour and 20% pigeon peas flour with ascorbic acid.
- B₂, made from the same flour formulation as B₁ without ascorbic acid.
- B₃, made from 40% sweet potatoes flour, 40% millet flour and 20% pigeon peas flour with ascorbic acid.
- B₄, made from the same flour proportions as B₁ without ascorbic acid.
- Control bread - made from 100% wheat flour.

The results indicate that out of all the alternative bread variations, B₁ had the best scores. Alternative B₂ came second while B₃ and B₄ got almost the same position. This is indicated by the small difference in the totals 66 and 69 respectively. Using the tables prepared by Kramer (1981), the ranking test results were checked for significance.
From Table 4.13, when the treatments (number of samples) are 5, and the judges are 15, the table entries of the upper pair of values in the block are 32-58. The lowest insignificant rank sum is 32 while the highest rank sum is 58. The lowest rank sum in the bread ranking results was 16, lower than 32 and the highest rank sum was 69, higher than the tabulated 58. The conclusion is that there is a significant difference in the preference of the bread samples at 5% significance level. All the rank sums were then compared to the lower pair in the block that is 36-54 to determine which samples were less acceptable or highly acceptable. It was observed that alternative B₁, which received a rank sum of 29, was more acceptable than B₃ and B₄, which received rank sums of 66 and 69 respectively. The conclusion is that the consumer panelists preferred the B₁ made from 30% wheat, 30% sweet potatoes, 20% millet and 20% pigeon peas flours with ascorbic acid more than B₃ and B₄ made from the sweet potatoes, millet and pigeon peas without wheat. The control bread was also more preferred than alternative B₃ and B₄. The highly acceptable variations were the control bread and alternative bread 1 while the less acceptable were B₄ and B₅.

4.5 PHYSICAL MEASUREMENTS OF THE SAMPLES

Determination of the physical properties of the bread samples provided a useful indication of their quality and the baking potential of the flours used in making the alternative variations. To record the breadcrumb structure, photographs of the bread samples were taken and photocopies of the internal crumb structure were made. The figures below show the exterior features of the bread variations and the internal breadcrumb structure.
Plate 4.1 Photographic presentations of the four alternative bread variations and the control
Plate 4.2 Internal breadcrumb structure of alternative B₁ made from 30% wheat flour, 30% sweet potatoes flour, 20% millet and 20% pigeon peas with ascorbic acid.

Plate 4.3 Internal breadcrumb structure of B₂ made from 30% wheat flour, 30% sweet potatoes flour, 20% millet flour and 20% pigeon peas flour without ascorbic acid.
Plate 4.4 Internal breadcrumb structure of B1 made from 40% sweet potatoes flour, 40% millet flour and 20% pigeon pea flour with ascorbic acid.

Plate 4.5 Internal breadcrumb structure of B2, made from 40% sweet potatoes, 40% millet and 20% pigeon peas flours without ascorbic acid.
Plate 4.6 Internal bread structure of the control bread made from 100% wheat flour

From the above figures, there was no deleterious effect on the loaf and crumb structure when 70% wheat flour was substituted with sweet potatoes, millet and pigeon peas. However, when 100% of the wheat flour was substituted with the sweet potatoes, millet and pigeon peas flours, the loaves showed an obvious sign of a dense crumb that was coarse and firm. The resulting bread from the non-wheat flours lacked any adhesive and binding substance due to the absence of gluten in the flour formulation. The loaves easily broke apart and completely failed to develop any elastic properties during the kneading process.

From the results obtained in the study various conclusions and recommendations were made. These are given in the following chapter.
CHAPTER 5

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The study was based on the idea that food-based approaches are the most suitable for building food security worldwide in the future. The focus of the research was diet diversification through use of traditional foods in the development of a convenient food as a measure to preventing vitamin A deficiency. The study utilized beta-carotene rich sweet potatoes, millet and pigeon peas to make an alternative nutrient-rich bread. To achieve the purpose of the study, the sweet potato, millet and pigeon pea flours were combined at different proportions to develop the alternative bread. The compositional content of the bread was determined in terms of moisture, total fat, crude protein, crude ash and caloric value. The β-carotene content of the flours and the bread was determined to establish the efficacy of the flour and the methods as carriers of the pro-vitamin. The characteristics of the alternative bread made from non-wheat flours with the one made with 30% wheat flour combined with the sweet potatoes, millet and pigeon peas flours were compared. Effect of using ascorbic acid as a flour improver on the quality of the alternative bread products was assessed as well as the physical and sensory properties of the bread. Through the sensory evaluation tests, the acceptability of the alternative bread was determined.

5.1 SUMMARY OF MAJOR FINDINGS

The analytical results indicated that the alternative bread had a higher protein content compared to the control bread. This was attributed to the use of pigeon peas flour in the alternative bread formulation as opposed to the control bread made from wheat only. High ash content was also observed in the alternative bread. The use of millet and the other
flours that have a higher mineral content than wheat could explain the results. Moisture was higher in the wheatless alternative bread than in the variations with 30% wheat flour. The use of wheat flour in the formulations improved their pasting characteristics, hence the lower moisture content in the bread variations. Wheat contains pentosan gums that have a high water-binding capacity thereby exert a large effect on the availability of water for gelatinization. Calorific value was highest in the control bread. The alternative bread variations recorded a lower calorific value due to the fact that the food crops used contain less calories but more of other nutrients as compared to wheat.

The analysis of beta-carotene indicated that with the use of the orange-fleshed sweet potatoes in bread making, a product with a good proportion of the pro-vitamin A can be formulated. All the alternative bread variations showed high retention levels of the carotenoid when the flour and bread results were compared. All the variations recorded retention levels above 95%. This means that the preparation and baking procedures used had minimal destruction effects on the nutrient.

Results from the sensory evaluation showed that the colour of the alternative variations with wheat was desirable to the majority of the consumer panelists. Darker brown colour of the crust was observed in the wheatless variations due to the higher proportions of millet and sweet potato flours in the variations. Cell structure was grainy for the alternative bread with wheat while the wheatless variations were coarse. The lack of gluten that enhances retention of gases within the cells in dough production in the non-wheat flour caused the coarse cell structure in the wheatless variations. The use of wheat flour also had an effect on the mechanical characteristics of the alternative bread. A more tender crumb was achieved compared to the tough crumb in the wheatless bread.
A more moist crumb was observed in the variations made with no wheat at all. This was associated with the poor hydration properties of the non-wheat flours. A slight yeast flavour was noted in the bread variations with some wheat flour incorporated. A more pronounced yeast flavour was experienced in the wheatless variations. The lack of enough α and β-amylase enzymes that determine the ability of flour to support fermentation caused the pronounced yeast flavour in the wheatless variations. Aftertaste was moderate for the alternative bread with wheat while a long aftertaste was noted in the other variations. The use of ascorbic acid had an effect on the chewiness of the bread variations. Adding the acid improved the rheological properties of the dough by softening the gluten in the formulations. The result was an improved crumb structure and tender bread. There was no significant effect of ascorbic acid in the sensory properties of the wheatless bread variations due to lack of gluten.

Ranking tests done to determine consumer preference indicated that of the four alternative variations of bread, the alternative bread with 30% wheat flour and ascorbic acid was the most preferred variation. It rated well with the common white bread, which was the control.

5.2 RECOMMENDATIONS

Based on the findings of this study, the following recommendations were made.

1. To cope with the changing food demand patterns of the urban populations that have had adverse effects on consumption of traditional food crops, persons involved in the food industry should present improved and convenient forms of the food. This may involve development and marketing of a wide range of foods like the alternative bread based on
the traditional food crops. The strategy is most likely to increase the earning capacity of women who are largely responsible for preparation and marketing of the foods.

2. It is time that nutritionists, agriculturists, food scientists and others players in the food arena are involved in bringing out the positive attributes that are there in foods generally regarded as traditional. Many of these foods for example roots and tubers have traditionally been associated with poverty. Their consumption in the urban areas is negligible. The crops remain under threat from alternative, often imported and subsidized cereal crops, which undermine their subsistence farming. Through social marketing, efforts should be geared towards improving practices related to consumption of available vitamin A rich foods and those rich in its pre-cursors.

3. Technologies that seek to increase yield especially for the poor farmers in the marginal areas where traditional food crops like millet, sweet potatoes and pigeon peas make a major contribution to food supply should be introduced. Technologies like mechanization are also needed together with household techniques to improve nutritional value of food and to make post-harvest processing less laborious and time-consuming. Such a strategy would be particularly helpful to women and others involved in the processing activities.

4. A cost analysis should be conducted on the composite flour production used in the study for commercialization.

5.3 SUGGESTIONS FOR FURTHER RESEARCH

Further research could be carried out on the following topics:

1. Research on the same bread variations would be replicated using highly trained panelists for the preference tests. The aim of such a study would be to find out the perceptions of
the panelists on the various characteristics evaluated and whether they would be similar to those of the consumer panelists used in the study.

2. A similar study using the flours but at different ratios could be carried out to optimize the flour properties.

3. A study to determine the bioavailability of the β-carotene present in the orange-fleshed sweet potatoes and the effects of mixing and baking on the functionality of the carotenoid. Such a study should assess the proportion of β-carotene from the orange-fleshed sweet potatoes converted to retinol and whether vitamin A status influences the bioconversion of the carotenoids.

4. A study on the economics of the alternative flours and bread production as well as the feasibility of setting up an up-country production center of the alternative bread could be done.

5. The storage stability of the composite flour in the conventional packages and under conditions prevailing in the country should be analyzed. The goal of such a study would be to assess the shelf-life of the composite flour used in the alternative bread.
BIBLIOGRAPHY


EUNICE NJERI NDUNG’U,  
KENYATTA UNIVERSITY,  
P.O BOX 43844, 
NAIROBI.

RE: REQUEST FOR YOUR PARTICIPATION IN SENSORY EVALUATION TESTS

I am a postgraduate student at the department of Foods, Nutrition and Dietetics undertaking a Master of Science degree course. My research work is entitled *utilization of the orange-fleshed sweet potatoes, millet and pigeon peas in the development of an alternative bread*. The focus of the study is to formulate bread that would be rich in beta-carotene, a pre-cursor of vitamin A; to serve as a food-based approach to the micronutrient deficiency. You have been chosen to be one of the panelists who will participate in the sensory evaluation of the bread formulated. Please avail yourself for the briefing session prior to the exercise.

I look forward to working with you in the tasting. Thank you for your cooperation.

Yours faithfully,

Eunice Ndung’u.
APPENDIX 2 QUESTIONNAIRE FOR SCORING

COLOUR

Test product: --------
Test subject number: --------

Evaluate the five bread samples for the brownness of the bread crust. The evaluation should be in order from left and indicate your judgment of each sample on the scales below.

Sample code --------

<table>
<thead>
<tr>
<th>Colour intensity</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light brown</td>
<td>5</td>
</tr>
<tr>
<td>Light brown</td>
<td>4</td>
</tr>
<tr>
<td>Slightly dark brown</td>
<td>3</td>
</tr>
<tr>
<td>Dark brown</td>
<td>2</td>
</tr>
<tr>
<td>Very dark brown</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments:

CELL STRUCTURE

Test product: --------
Test subject number: --------

Evaluate the cell structure of the five bread samples in the order from left and indicate your judgment of each sample on the scale provided below.

Sample code --------

<table>
<thead>
<tr>
<th>Cell structure</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grainy</td>
<td>5</td>
</tr>
<tr>
<td>Moderately grainy</td>
<td>4</td>
</tr>
<tr>
<td>Slightly coarse</td>
<td>3</td>
</tr>
<tr>
<td>Coarse</td>
<td>2</td>
</tr>
<tr>
<td>Extremely coarse</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments:
TEXTURE

Test product: -------
Test subject number: -------

Evaluate the five bread samples for texture. Taste the samples in order from left and indicate your judgment of each sample on the scale provided below. Retasting is allowed.

Sample code -------

<table>
<thead>
<tr>
<th>Texture characteristic</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very soft</td>
<td>5</td>
</tr>
<tr>
<td>Slightly soft</td>
<td>4</td>
</tr>
<tr>
<td>Tender</td>
<td>3</td>
</tr>
<tr>
<td>Slightly tough</td>
<td>2</td>
</tr>
<tr>
<td>Tough</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments:

CHEWINESS

Test product: -------
Test subject number: -------

Evaluate the five bread samples for chewiness. Taste the samples in order from left and indicate your judgment for each sample on the scales provided below. Retasting is allowed.

Sample code -------

<table>
<thead>
<tr>
<th>Chewiness</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tender</td>
<td>5</td>
</tr>
<tr>
<td>Slightly tender</td>
<td>4</td>
</tr>
<tr>
<td>Chewy</td>
<td>3</td>
</tr>
<tr>
<td>Slightly tough</td>
<td>2</td>
</tr>
<tr>
<td>Tough</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments:
FLAVOUR

Test product: -------
Test subject number: -------

Evaluate the five bread samples for flavour. Taste the samples in the order from left and indicate your judgment of each of the samples in the scales provided below. Retasting is allowed.

<table>
<thead>
<tr>
<th>Flavour</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well balanced</td>
<td>5</td>
</tr>
<tr>
<td>Slightly yeasty</td>
<td>4</td>
</tr>
<tr>
<td>Yeasty</td>
<td>3</td>
</tr>
<tr>
<td>Moderately yeasty</td>
<td>2</td>
</tr>
<tr>
<td>Extremely yeasty</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments:

MOISTNESS

Test product: -------
Test subject number: -------

Evaluate the bread samples for moistness. Taste the samples in the order from left and indicate your judgment of each sample on the scales provided below. Retasting is allowed.

<table>
<thead>
<tr>
<th>Moistness</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>5</td>
</tr>
<tr>
<td>Moist</td>
<td>4</td>
</tr>
<tr>
<td>Slightly wet</td>
<td>3</td>
</tr>
<tr>
<td>Wet</td>
<td>2</td>
</tr>
<tr>
<td>Watery</td>
<td>1</td>
</tr>
</tbody>
</table>

Comments:
Evaluate the five bread samples for aftertaste. Taste the samples in the order from left and indicate your judgment of each sample on the scales provided below. Retasting is allowed.

**Sample code**

<table>
<thead>
<tr>
<th>Aftertaste</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td>5</td>
</tr>
<tr>
<td>Moderate</td>
<td>4</td>
</tr>
<tr>
<td>Slightly long</td>
<td>3</td>
</tr>
<tr>
<td>Long</td>
<td>2</td>
</tr>
<tr>
<td>Very long</td>
<td>1</td>
</tr>
</tbody>
</table>

*Comments:*
APPENDIX 3 RANKING THE DEGREE OF PREFERENCE

Test product: ----------

Test subject number: ----------

Instructions

You will receive five samples of the bread. Please rank them in order of your degree of preference. Write to the very left the code of the sample you like best (to which you give the first position in the degree of preference) and to the very right the code of the sample you like least. Mark the degree of preference for the other samples in between.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>position</td>
<td>position</td>
<td>position</td>
<td>position</td>
<td>position</td>
</tr>
<tr>
<td>Bread variation</td>
<td>Type of Analysis</td>
<td>Amounts obtained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>---------------------------------------</td>
<td>------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control bread made from wheat flour only</td>
<td>Beta-carotene content&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moisture content&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude protein content&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude fat content&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total ash content&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread made from 30% wheat flour, 70% non-</td>
<td>Beta-carotene content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wheat flours with flour improver added</td>
<td>Moisture content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude protein content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude fat content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total ash content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread made from 30% wheat flour, 70% non-</td>
<td>Beta-carotene content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wheat flours with no flour improver added</td>
<td>Moisture content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude protein content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude fat content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total ash content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread made with 100% non-wheat flour with</td>
<td>Beta-carotene content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flour improver added</td>
<td>Moisture content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude protein content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude fat content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total ash content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread made with 100% non-wheat flour</td>
<td>Beta-carotene content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>without a flour improver</td>
<td>Moisture content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude protein content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude fat content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total ash content</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N=3

<sup>1</sup> - Values given in µg/g  
<sup>2</sup> - Values given in percentages.
## APPENDIX 5 SAMPLES EVALUATED AND THEIR SAMPLE CODES

<table>
<thead>
<tr>
<th>Sample</th>
<th>code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative bread 1 made from 30% wheat, 30% sweet potatoes, 20% millet and 20% pigeon peas flours plus ascorbic acid.</td>
<td>179</td>
</tr>
<tr>
<td>Alternative bread 2 made with 30% wheat, 30% sweet potatoes 20% millet and 20% pigeon peas flour without ascorbic acid.</td>
<td>588</td>
</tr>
<tr>
<td>Alternative bread 3 made with 40% sweet potatoes, 40% millet and 20% pigeon peas flours with ascorbic acid.</td>
<td>382</td>
</tr>
<tr>
<td>Alternative bread 3 made with 40% sweet potatoes, 40% millet and 20% pigeon peas flour without ascorbic acid.</td>
<td>841</td>
</tr>
<tr>
<td>Control bread made with 100% wheat flour</td>
<td>853</td>
</tr>
</tbody>
</table>
APPENDIX 6 SAMPLE ORDER PERMUTATIONS

The following was the sample order permutation used for the fifteen judges.

179 853 588 382 841 179 841 853 382 588
588 382 853 841 179 853 588 841 179 382
382 841 179 853 588 588 382 841 853 179
841 179 588 382 853 382 179 588 841 853
853 179 382 841 588 841 382 853 179 588
588 382 853 179 841 853 179 841 382 853
382 179 588 841 853 179 853 588 382 841
841 853 179 588 382

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