Chapter

Potential of Indigenous Vegetable-Fortified Food Products for Improved Human Nutrition and Health in West Africa

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Abstract

The study developed and tested the acceptability of key innovative value-added products, including vegetable-fortified bread and pastry products (cookies and chinchin), using each of these three indigenous vegetables, namely *Telfairia occidentalis* Hook. F. (fluted pumpkin), *Amaranthus virdis* L. (local amaranth), and *Solanum macrocarpon* L. (eggplant). The bread was fortified with each of the individual dried leafy vegetables at levels of 1%, 3%, and 5%. Ogi was also fortified with the equivalent of the dried *Telfaria occidentalis* in the wet form at 1%, 3%, and 5%, while pastry was fortified with the only extract obtained from amaranth leafy vegetable at 1%, 3%, and 5%. Results from the MicroVeg project showed that bread fortified with 3% (w/w) dried vegetable leaf powders had higher nutritional properties. Pastry formulations that included 3% dried vegetable leaf powders had slightly lower consumer acceptability in terms of taste and color; however, due to the associated potential health benefits, consumers were willing to buy the vegetable-fortified products as replacements for the regular products. This chapter discusses the full details of the nutrition and value addition aspects of MicroVeg with empirical examples of the interventions and the potential contributions to dietary diversity and enhanced family nutrition.

Keywords: MicroVeg project, indigenous vegetables, fortification, baked foods, maize porridge

1. Introduction

As previously reported by World Health Organization [1–3], a low intake of vegetables puts people at the risk for micronutrient deficiencies. Appropriate intakes of fruits and vegetables are known to reduce the risk of cardiovascular diseases and cancer, which are the two most common causes of premature death worldwide and

that accounted collectively for 25.5 million deaths in 2013 [4]. The WHO (http://www.who.int/dietphysicalactivity/fruit/en/index2.html) also reports that approximately 14% of gastrointestinal cancer deaths, 11% of ischemic heart disease deaths, and 9% of stroke-related deaths, globally, are due to insufficient intakes of fruits and vegetables. It is also estimated that up to 2.7 million lives could potentially be saved each year if vegetable consumption was sufficiently increased. Given the overwhelming evidence supporting the role of vegetables in the sustenance of human health and well-being, the WHO and Food and Agricultural Organization of the United Nations recommend a minimum intake of 400 g per day of green vegetables [1, 5]. Therefore, to promote and sustain the consumption of vegetables in various forms, a system of including vegetables in the daily human diet is desirable, in form of food fortification to enhance dietary diversity. Food fortification using vegetable products, especially in dessert foods, juices, drinks, and daily flour-based products will constitute a major strategy for making vegetables available for a wide spectrum of the human population.

Over the past 80 years, food fortification, which is a cost-effective and sustainable innovation, has played a vital role in the amelioration of several ailments worldwide [6, 7] because it is a means of reducing the effects of deficiencies that are linked to micronutrients and some macronutrients. The FAO/WHO [8] defined food fortification as the addition of one or more essential nutrients to a food, whether or not it is normally contained in the food, for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population or specific population groups. Indeed, food fortification has been identified as one of the top four strategies for decreasing micronutrient malnutrition at the global level [9]. Based on the 2017 data on the state of food insecurity in the world, an estimated 2 billion people suffer from hidden hunger around the globe and over 25% of people living in sub-Saharan Africa suffer from chronic hunger. These critical nutritional challenges may be ameliorated through the fortification of staple foods with appropriate nutrients.

Food fortification ensures dietary diversity, improved health, and nutrition, as well as financial returns for small and big businesses [6]. As promising as food fortification sounds, especially in relation to the sustenance of human health, there have been a number of important lessons learned in the research on food fortification processes [8] For example, the development of new combinations of fortificants and vehicles are cost-intensive and time-consuming, while the fortificants must meet quality criteria specifications including, chemical stability, appearance, bioavailability, and homogeneity. Economic analysis indicated that food fortification is a high-priority investment [10]. However, if traditional food vehicles are used to convey these beneficial nutrients, there is potential for cost-saving when considered along with the long-term impact. A major step in popularizing fortified foods is promotion and awareness creation to test the acceptability of the foods.

The International Development Research Centre (IDRC) and Global Affairs Canada (GAC) under the Canadian International Food Security Research Fund (CIFSRF) recently provided research grants, which enabled activities of the indigenous vegetables project (MicroVeg). The MicroVeg project developed innovative systems of production, utilization, and value addition options to enhance nutrition and economic empowerment of the resource poor rural populations in Nairobi and Benin Republic, mainly women. Specifically, the value addition and food fortification studies focused on three indigenous vegetables, which are commonly consumed and of high prominence in both the food chain and markets of the West Africa sub-region: local amaranth (*Amaranthus viridis)*, fluted pumpkin (*Telfairia occidentalis*) and African

eggplant (*Solanum macrocarpon*). This approach was taken in order to encourage vegetable consumption by using popular foods as a vehicle. The aim of this paper is to describe the food fortification approach used by the MicroVeg project, with emphasis on potential health benefits to the local population, especially women.

2. Key messages

- Vegetable leaf fortification led to the increased nutritional value of maize porridge (*ogi*), a popular weaning food.
- Wheat bread fortified with vegetable leaves (*green bread*) had lower moisture content and higher polyphenol content than unfortified white bread; the increased polyphenol content led to stronger radical scavenging and metal chelating abilities.
- Economic analyses indicate profitability of the vegetable-fortified bread and pastries, with 3% incorporations as the most promising.
- The MicroVeg project created awareness on the food value and affordable/simple value addition technologies through daily radio jingles and direct training of 5466 persons on different aspects of family nutrition and dietary diversity.

2.1 Strategy for value addition studies and scale up

The value addition aspect of the work was conducted in the southwestern part of the country. The major aim of the value addition studies was to scale up the various innovations developed into adaptable forms for the poor resource populace. In achieving this aim, the project involved some Nigerian-based non-profit organizations, such as the Green Generation Initiative and the Institute for Agricultural Research and Training. Through these organizations, the project was able to scale up the innovations and delivered them to the rural end-users using an extension system called the innovation platform (IP) model (**Box 1**), which is aimed at ensuring innovation delivery systems

- Working with multiple actors for consensus building in vegetable value addition.
- Coordination and collaboration along the value addition chain, which is expected to result in more
- Efficient and equitable linkages of the actors in the vegetable value chain.

The IP is based on the thesis that improved interactions, through dialog along the value chain could help to forge linkages among stakeholders, which could result in enhanced communication and information exchange to address common challenges. This propels the adoption of innovation.

Box 1.
Innovation platform (IP) approach has the following activities:

- Identification of target communities and women groups for training on value addition (41 communities).
- Identification of the other actors/stakeholders involved in the vegetable value chain.
- Development of value addition training materials in the local language (Yoruba).
- Series of visits to the communities and women groups for awareness creation.
- Training of project technical staff on value addition innovations and scaling up activities (12 technical officers).
- Launching of the innovation platform at the selected locations.
- Training of 5466 persons (68% women) at 25 locations in value addition innovations.
- Training 100 bakery owners in southwest Nigeria on the production of vegetable-fortified bread.

Box 2.
Steps for establishing an innovation platform

1. Training of the technical officers on the sensory evaluation template (12 staff).
2. Identification the respondents (41 locations, 250 persons/location, total 10,250 panelists).
3. Sensory evaluation implementation.
4. Reporting.

Box 3.
Sensory evaluation of vegetable-fortified foods

that quickly bring innovations to women and rural farmers, therefore making increased adoption possible, notably through appropriate use of new information and communication technologies (**Box 2**). The recipes for the different formulations of vegetable value-added products were designed by the Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, Nigeria. The University of Manitoba took the lead and utilized its expertise in food chemistry, food processing food product development, and food/nutritional quality evaluation to enhance product and nutritional quality evaluation of vegetable-fortified products. The University of Manitoba with state-of-the-art facilities was used to train food scientists who were involved in the sensory studies of fortified food products in Nigeria (**Box 3**).

2.2 Fortification of local foods with vegetables

Most popular traditional foods, especially the starch-based local foods in Nigeria and the Republic of Benin are not good suppliers of critical micronutrients, thus establishing the need for food fortification, especially for foods targeted at growing children and

vulnerable populations. Newborn babies, especially in the rural areas (65% of the population in Nigeria) are fed with a popular maize-based weaning food, called "*ogi*". In addition, some of the most cherished snacks and desserts, eaten by children and adults, were considered for fortification. Thus, our project developed and tested key innovative value-added products, including vegetable leaf-fortified bread and popular local pastry products (cookies and *Chinchin*). The MicroVeg project conducted a series of studies aimed at improving these traditional foods with each of the three leafy vegetables (amaranth, fluted pumpkin, or African eggplant), including the sensory evaluation and acceptability studies. Green leafy vegetables were chosen as a fortificant because of the abundant bioactive components, polyphenols, that have the potential to defend the human body against degenerative diseases [11, 12]. Ongoing studies by the MicroVeg team have generated results that suggest food fortification with these vegetables could have a significant effect on lowering of blood pressure [13], as well as increasing nutritional and antioxidative properties of the fortified foods [14, 15].

2.3 Fortification of *Ogi*, a local weaning food

Our first case study is on the fortification of a popular Nigerian weaning food known as *ogi* (maize porridge) with a polyphenol-rich extract from leafy vegetables. This study is justified by the state of malnutrition among the women, nursing mothers, and children, in rural Nigeria where fortification of weaning as well as convalescent foods became necessary. For example, UNICEF [16] estimated that 37% of children in Nigeria are stunted (chronically malnourished or low height for age) with more than half of them severely stunted. The same report also highlighted that 18% of children suffer from wasting (acutely malnourished or low weight for height) and 20% of children are underweight (both acutely and chronically malnourished or low weight for age). Several works have been done on the fortification of weaning foods with plant products, such as cocoa solids [17], moringa leaf powder [18], moringa seed [19], pawpaw [20], cowpea [21], melon [22], okra seed meal [23], soybean [24], African yam bean [25], carrot [26] and many others. However, the fortification of maize *ogi* with vegetable polyphenol-rich extract is a promising innovation. The MicroVeg-optimized procedure for the production of vegetable leaf-fortified *ogi* is simple and cost-effective. The maize *ogi* was prepared as a slurry and later dried to produce a cake as shown in **Figure 1**. The vegetable polyphenol was extracted by squeezing vegetable leaves in water at the ratio of 1:2. The extract was filtered to remove vegetable particles and the filtrate was stored in the fridge at 4°C. The *ogi* cake was first made into a slurry by dispersing the cake in water. Thereafter, the polyphenolic filtrate and *ogi* slurry were mixed together at varying proportions (10/100, 25/100, 50/100, 75/100, and 100/100 ml/g of filtrate to slurry) prior to drying at 55°C in a hot air cabinet oven to produce vegetable leaf-fortified *ogi* flour [27]. The vegetable leaf-fortified maize *ogi* powder was reconstituted by adding 1.5 parts of water to make a suspension. To the suspension, 100 ml of hot water was added with continuous stirring to produce maize *ogi* hot porridge of desired consistency. The fortified *ogi* samples were subjected to sensory evaluation, in terms of acceptability of taste, color, flavor, texture, appearance, and overall acceptability.

2.4 Fortification of bread with indigenous vegetables

The development of enriched bakery products and pastries has recently increased and is attracting much attention from researchers, especially in the optimization of

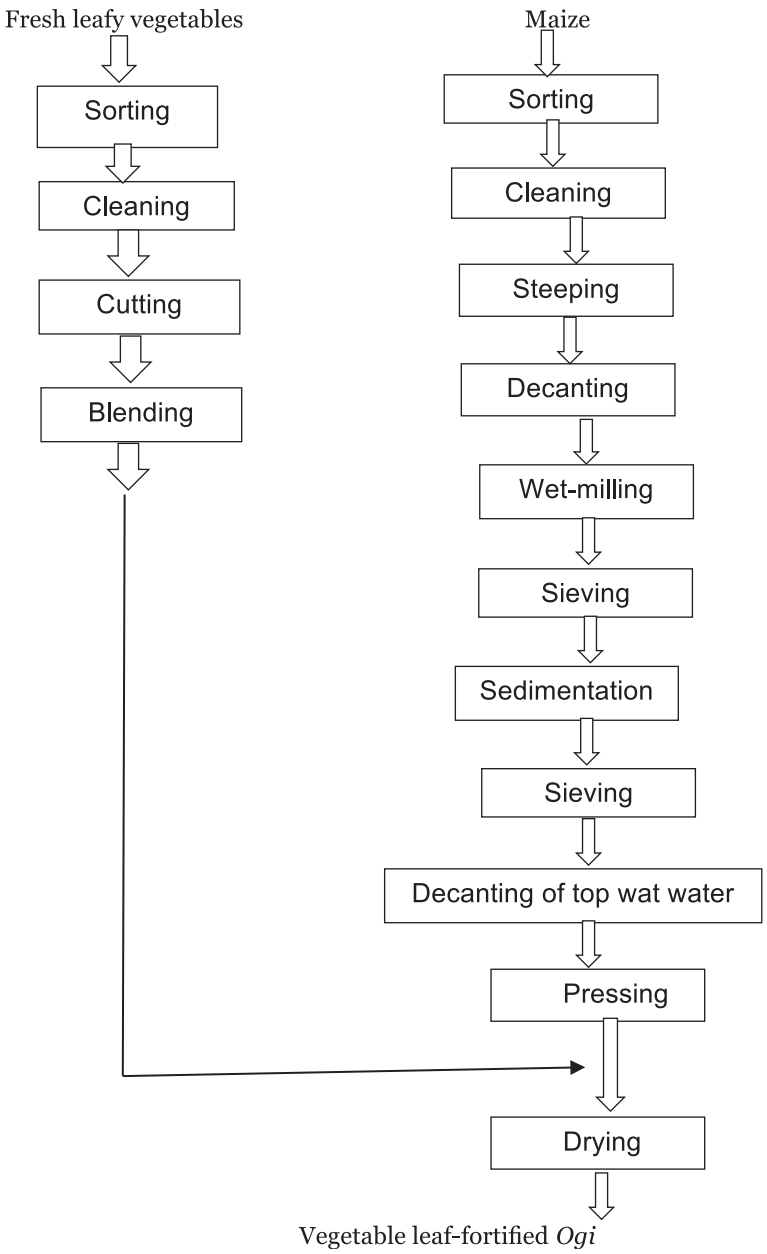


Figure 1.
Process flowchart for the production of vegetable leaf-fortified ogi.

nutritional values. This is because evidence from food consumption surveys in many developing countries has revealed an astronomical rise in the consumption of these floury products, due to changing eating habits, a steadily growing population, and readiness to spend a large proportion of incomes on processed foods [28, 29]. The bread was chosen as a vehicle for vegetable consumption because it is a vital food product that is cherished and consumed all over West Africa. The likeness of bread is not in its nutritional profile but in its sensorial and textural properties,

and because it requires no further preparation before consumption. Being a wheat flour product, it contributes greatly to the dietary energy of the population of most West African countries due to its high carbohydrate content [30–32]. Nevertheless, this baked food product is not exceptionally rich in the nutrients that are required for maintaining proper growth and good health, a phenomenon that is attributable to the perceived loss of nutrients during the processing of wheat seeds into flour [33].

As a result of this, research was embarked upon to improve the nutritional base of bread through fortification or enrichment using vegetable-based products [34–37]. Judging from the reported increase in malnutrition and other cardiovascular diseases in less privileged countries of the world, with an ever-increasing interest in the consumption of bread, as a convenience food, there is no other time to improve the nutrient of bread, than now [15]. Improving the nutrient base of bread involves improvement in the protein content and mineral content. It also involves enhancing the radical scavenging ability of the bread, thereby reducing the incidence of the occurrence of some of these degenerative diseases. Therefore, for any material to act as fortificant in bread it must be a good deposit of these nutrients [35, 38, 39]. However, some sensorial properties, such as color, texture, and taste of the fortified bread, were affected by fortification, depending on the plant materials used [40–43]. One of the major challenges being faced in the quest by researchers to fortify bread with these plant materials is the level of inclusion. There is a threshold at which these plant materials can be added to wheat flour during bread making that would preserve both the physical, sensory, and baking quality of the products [44]. Some successes have been recorded with regard to the level at which these materials are included in bread, but this varies with the type of plant materials.

Indigenous leafy vegetables have been shown to possess highly valuable nutritional benefits as a result of the contents of fiber, vitamins, minerals, proteins, and some phytochemicals. These vegetables have been shown to be readily affordable and ready sources of food and nutrients for indigent families in many African countries for a number of years. African population for centuries have been consuming traditional leafy vegetables in large quantities in the preparation of soups and culinary [45, 46]. Based on the information gathered from the literature, there is a dearth of information on the use African leafy vegetables for bread fortification. However, recent MicroVeg works have reported optimization of bread fortification with indigenous African leafy vegetable polyphenolic extracts in addition to the chemical composition and quality characteristics of wheat bread supplemented with *T. occidentalis*, *A. viridis*, and *S. macrocarpon* [15, 27, 29].

The MicroVeg process for the production of vegetable leaf-fortified bread is simple and easily adoptable for homemade bread and industrial purposes. The leafy vegetable to be used for the bread fortification was processed as illustrated in **Figure 2**. The leafy vegetables could be used in two forms: dried powder or as an aqueous slurry, both of which are polyphenol-rich. For the vegetable powder fortified bread, a premix of the wheat flour-vegetable powder was first made. The advantage of this premixing stage is to ensure even distribution of the vegetable powder in the wheat flour. This was done by replacing a known proportion of the wheat flour according to the proportions shown in **Table 1**. After the premixing stage, the required amounts of other standard baking ingredients were added step-wise. All other dry ingredients, such as sugar, salt, and yeast, were added to the mixture. The fat and required quantity of water were added and mixed. Water is a very crucial ingredient in bread baking as it determines the overall quality of the baked product. However, the quantity of water and other

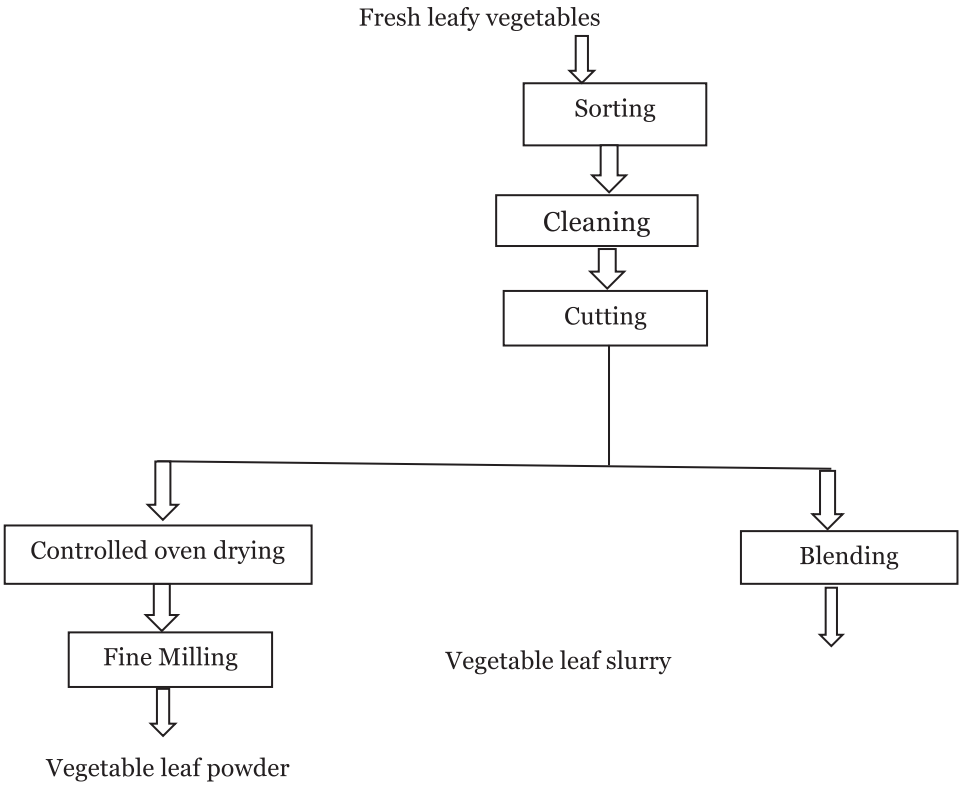


Figure 2.
Process scheme for the production of leafy vegetable dried powder or wet slurry.

standard ingredients needed during bread baking varies, due to differences in the water absorption capacities of different wheat flours. But for vegetable-fortified bread, the standard recipe in **Tables 1** and **2** resulted in good quality vegetable leaf-fortified bread.

For bread fortified with the vegetable leaf slurry, the process differs slightly from that of the dried leaf powder described above. Based on the different levels of vegetable inclusion in the wheat flour (**Table 2**) the water content of the leaf slurry and the balance of water required for blending were taken into consideration. After sorting

Ingredient	Quantity			
	Control	1%	3%	5%
Wheat flour (g)	100	99	97	95
Vegetable powder (g)	—	1	3	5
Sugar (g)	5.00	5.00	5.00	5.00
Yeast (g)	2.00	2.00	2.00	2.00
Margarine (g)	4.00	4.00	4.00	4.00
Salt (g)	1.00	1.00	1.00	1.00
Water (ml)	60.00	60.00	60.00	60.00

Table 1.
Formulation of wheat-vegetable powder composite flour for bread fortification.

Ingredient	Quantity			
	Control	1%	3%	5%
Wheat flour (g)	100.00	99.00	97.00	95.00
Vegetable slurry (g)	—	14.28	42.90	71.43
Sugar (g)	5.00	5.00	5.00	5.00
Yeast (g)	2.00	2.00	2.00	2.00
Margarine (g)	4.00	4.00	4.00	4.00
Salt (g)	1.00	1.00	1.00	1.00
Water (ml)	60.00	48.00	24.00	—

Table 2.
Formulation of wheat-vegetable slurry composite flour for bread fortification.

the vegetable leaves, a slurry was prepared with the understanding that the moisture content of fresh leaves is ~86% (dry matter = 14%). Blending about 100 g of fresh leafy vegetable requires 100 ml of water to obtain a smooth vegetable slurry (200 ml). Of the 200 ml slurry, 186 ml is water, and the solid content is 14 g. With this knowledge, the 1%, 3%, and 5% vegetable leaf slurry to be added during the preparation of bread translated to 14.3 g, 42.9 g, and 71.4 g, respectively. On the basis of 86% (average moisture content of vegetables), ~12.3, 36.9 and 61.4 ml water will be present in 14.3 g (1%), 42.9 g (3%), and 71.4 g (5%) vegetable slurries, respectively. Since water is required during the mixing stage to form an acceptable dough, the quantity of water in the slurry was deducted from the water required. This is necessary in order to establish a basis for comparing the nutritional values of dried vegetable leaf-fortified bread with slurry-fortified bread. In vegetable bread production, the optimum mixing time and proofing time proposed by Famuwagun et al. [29] resulted in good quality vegetable-fortified bread. The products were then baked according to the conditions highlighted in **Figure 3** and allowed to cool to room temperature before packaging to ensure good quality vegetable-fortified bread as shown in figure.

2.5 Vegetable leaf-fortified pastry products

Consumption of pastry products, such as snacks (cookies, *Chinchin*), sandwiches, and burgers, especially among children is on the rise in most West African countries because they are affordable, ready-to-eat, attractive, and have long shelf life [46]. The importance of these pastry products to humanity goes beyond convenience eating but is sometimes used in various feeding programs for school children and areas where there are natural disasters [47]. The MicroVeg project, therefore, concentrated a major effort to develop the fortification of these pastry products as a means of improving their nutritional qualities to meet the health-promoting needs of women and children.

Various plant products that are rich in micronutrients, vitamins, protein, and fiber have been used by researchers to fortify these pastry products with a view to improving their nutritional qualities. Adegunwa et al. [48] improved the nutritional composition of *Chinchin* through the addition of millet flour. The authors showed that up to 30% wheat flour was replaced with millet flour without a pronounced effect on the physical properties of the snack but with improved nutritional qualities. Shrestha and Noomhorm [49] produced high-protein cookies using composite flours that contained

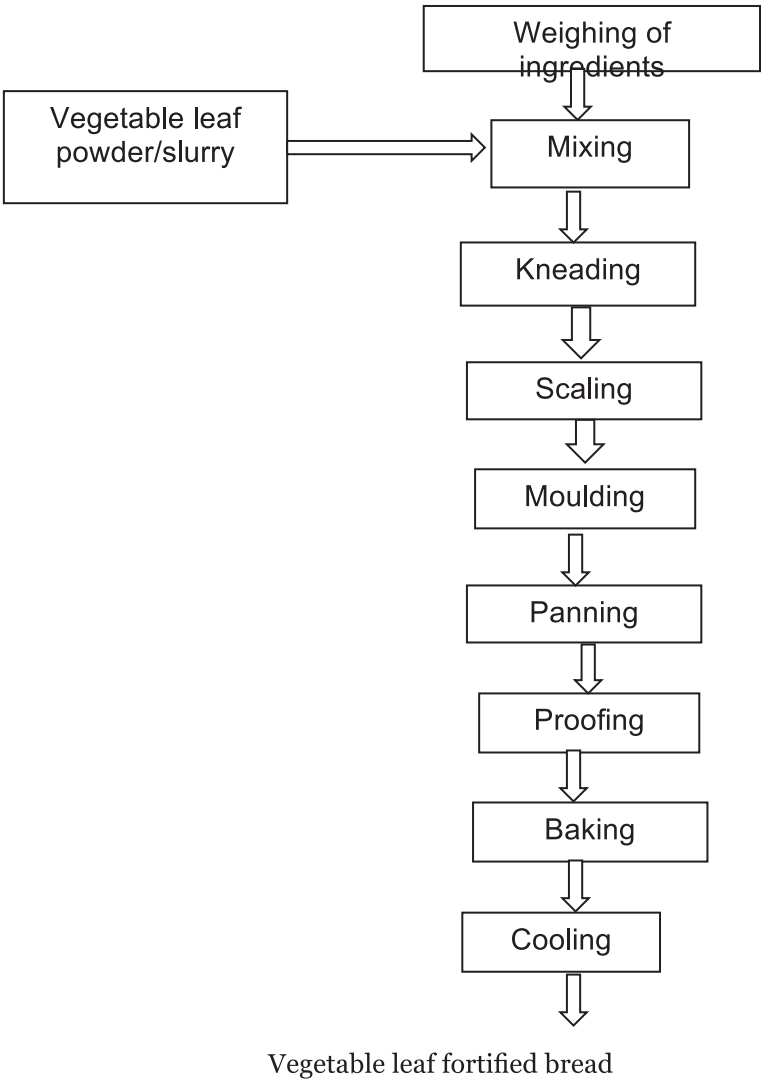


Figure 3.
Process flowchart for the production of vegetable leaf-fortified bread.

blends of wheat-soy flour, defatted peanut, and pea flour, replacing up to 30% of wheat flour without any marked changes in the physical properties of the final products. Cowpea and peanuts flours have been reported to replace about 20% of wheat flour in the production of highly nutritious cookies without any significant effects on the physical characteristics of the products [46, 50, 51]. There are also reports of the production of high-fiber cookies using sesame seeds and pigeon pea flours [52]. Therefore, fortification with indigenous vegetable leaf powder is one of the new approaches aimed at improving the nutritional composition of pastry products.

Cookies and *Chinchin* were fortified with leafy vegetables. The major difference in the production technique of these two commonly consumed pastries lies in the final stage of production. While vegetable cookie doughs were baked, the *Chinchin* dough was fried; therefore, the equipment used and their operating conditions vary. For the two products, it is important to premix the wheat flour and the vegetable powder to be

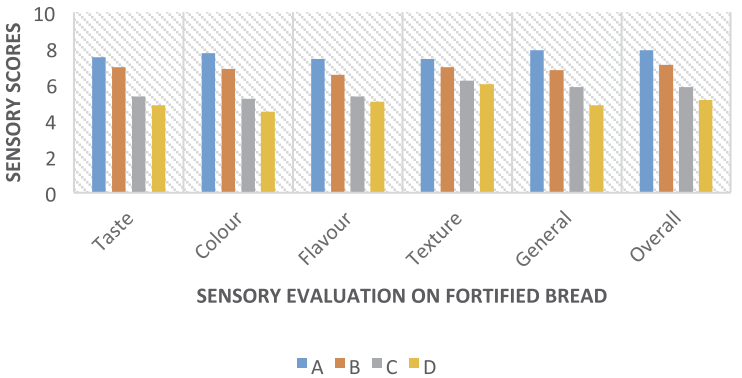
used in fortifying the product. This is to ensure the even distribution of the vegetable powder in the wheat flour matrix. Other ingredients, such as salt, flavoring (nutmeg), margarine, and baking powder (for cookies), can be added after the premixing stage and properly mixed to fine particles without any lumps. Since vegetable-fortified pastries differ from conventional pastries, due to the addition of vegetables, it is important to have an accurate measurement of these ingredients to ensure good quality of the final products. The sweetener (sucrose) was dissolved in the whipped egg (whole egg for *Chinchin,* while only egg yolk is used for cookies) to ensure proper dissolution before adding to the mixture [14]. Beaten eggs or whipped eggs are necessary in order to give the dough a light and airy texture. Liquid milk can be added or in powdered form (must be dissolved with water before use) and then the required amount of water is added to ensure good consistency of the final products. After proper mixing of all the ingredients, the dough was then kneaded. For cookies, the dough was allowed to rest for about 20 min to allow the baking powder to release enough aerating gas before shaping. The cookie dough was then properly shaped into desired sizes and baked for 20 min at 180°C, while the *Chinchin* dough was cut into desired pieces and fried 10 min in hot (~180°C) vegetable oil. The fried *Chinchin* was removed; oil was drained off and the product was allowed to cool down to room temperature. The baked cookie and fried *Chinchin* were separately packaged in air-tight containers.

3. Outcome of the studies

3.1 Sensory evaluation and acceptability of vegetable leaf-fortified bread

Sensory evaluation deals with human sensory perception and their effective responses to food and its components. Sensory evaluation of food products is a function of five major sense organs; the sense of sight, smell, taste, touch, and ear to answer questions related to the preference of the food products under evaluation [53, 54]. In the sensory test, panelists, who are familiar with the products under evaluation are given a range of samples and asked to rate the samples by choosing a point on a scale ranging from "*dislike extremely*" to "*like extremely*" for different attributes of the products. The general sensory attribute of food products includes taste, flavor, aroma, texture, and appearance. Taste is one of the main attributes for evaluating the sensory quality of vegetable fortified bread since the addition of vegetables has the potential on changing the nutritional bread. We evaluated the sensory attributes and acceptability of the vegetable-fortified bread at 41 locations in Nigeria with 250 panelists per location, for a total of 10,250 panelists. As we have reported, taste preference for the bread decreased as the level of inclusion of vegetables increased in the bread [16]. The results suggest that the vegetable taste could be masked by the sweet taste of sugar but this effect diminishes as the vegetable fortification level increased from 1% to 3%.

Color of food products is one of the important attributes for acceptability of any baked product, especially vegetable-fortified bread. Leafy vegetables are green and this color becomes imparted on the dough as the fortification level is increased in the bread formulations. The intensity of the green color on the vegetable-fortified bread depends on the type of vegetable used (**Figure 4**). In the study by Odunlade et al. [16], vegetable bread-fortified with fluted pumpkin leaf (*Telfaria occidentalis*) was preferred up to the 3% inclusion level, while bread-fortified with 1% *Amaranthus* vegetable was mostly preferred compared with the higher level of inclusions (**Table 3**). This is an indication that the likeness of vegetable-fortified bread also depends on the type of vegetable used.



A: control; **B**: 1% leaf slurry; **C**: 3% leaf slurry; **D**: 5% leaf slurry

Figure 4.
Sensory evaluation on bread with fluted pumpkin leaf slurry.

	Taste	Color	Flavor	Texture	Appearance	Overall acceptability
99% WF: 1% TOL	7.5 ± 0.45c	8.0 ± 0.12b	6.0 ± 0.14c	7.3 ± 0.04b	7.2 ± 0.16b	7.9 ± 0.05b
98% WF: 2% TOL	6.4 ± 0.05f	7.7 ± 0.14c	5.5 ± 0.07e	6.9 ± 0.04d	6.7 ± 0.05d	7.2 ± 0.06c
97% WF: 3% TOL	6.2 ± 0.11 g	5.0 ± 0.10f	5.0 ± 0.08 g	6.1 ± 0.05 g	5.0 ± 0.08 g	4.0 ± 0.04j
99% WF: 1% AVL	7.7 ± 0.08b	6.2 ± 0.19d	5.9 ± 0.02d	7.0 ± 0.13c	7.0 ± 0.03c	6.5 ± 0.06d
98% WF: 2% AVL	6.9 ± 0.09e	5.5 ± 0.12e	5.4 ± 0.04f	6.3 ± 0.10f	6.2 ± 0.06e	5.9 ± 0.06 g
97% WF: 3% AVL	5.9 ± 0.31 h	4.9 ± 0.45 g	5.2 ± 0.09 g	6.0 ± 0.04 h	4.8 ± 0.05i	4.4 ± 0.05i
99% WF: 1% SML	7.2 ± 0.21d	6.2 ± 0.37d	6.2 ± 0.03b	7.0 ± 0.04c	6.6 ± 0.03d	6.1 ± 0.06e
98% WF: 2% SML	6.9 ± 0.12e	5.4 ± 0.12e	5.4 ± 0.05e	6.7 ± 0.10e	5.3 ± 0.05f	6.0 ± 0.05f
97% WF: 3% SML	5.1 ± 0.22i	4.8 ± 0.25 h	4.9 ± 0.14 g	6.1 ± 0.04 h	4.9 ± 0.04 h	5.0 ± 0.07 h
100% WF	8.2 ± 0.12a	7.00 ± 0.21a	8.5 ± 0.31a	8.5 ± 0.07a	7.5 ± 0.07a	8.7 ± 0.04a

Mean values along the same column with different superscripts are significantly different (P < 0.05); WF: heat flour; TOL: T. occidentalis *leaf powder; AVL:* A. viridis *leaf powder; SML:* S. macrocarpon *leaf powder.*

Table 3.
Sensory properties of wheat bread fortified with green leafy vegetable powders.

Studies have shown that consumer acceptance of a product can be enhanced through additional information on potential health benefits or when the actual health benefits have been proven [55, 56]. For the green bread, consumer acceptance improved when potential health benefits, such as antioxidant effects, cardiovascular health, and blood glucose control, were included in the information package.

3.2 Sensory evaluation and acceptability of vegetable leaf-fortified weaning food

The evaluated sensorial quality attributes were taste, color, flavor appearance, and acceptability. We engaged 100 participants comprising nursing parents, elderly, and university undergraduates who currently utilize maize porridge as weekly meals

during the sensory evaluation of the cooked vegetable leaf-fortified weaning food. For all the evaluated sensory parameters, the samples without the addition of leaf extracts were the most acceptable. This was also observed by Aminigo and Akingbala [23] for non-supplemented maize *ogi* samples. It was however observed that the preference for the fortified *ogi* samples ranged from *liked moderately* to *liked slightly*. The maize porridge samples with the inclusion of 10 ml vegetable leaf extract (10 ml of leaf extract to 100 g of *ogi* slurry) were the most preferred among the fortified samples.

With increased inclusion of vegetable leaf extract to maize porridge from 10 to 100 ml, the preferences of the samples for taste, color, flavor, texture, appearance, and general acceptance were observed to significantly ($P < 0.05$) reduce, though within the acceptance range of hedonic scales for sensory analysis. This same trend was reported by Abioye and Aka [18] for moringa fortified maize porridge and Aminigo and Akingbala [18] for okra fortified maize porridge. There were however no significant differences on all the evaluated sensory parameters between the inclusion of 25, 50, and 75 ml of vegetable leaf extract in maize porridge samples. Based on all the sensory parameters, it was further observed that the samples with the incorporation of 100 ml vegetable leaf extract to maize porridge were *neither liked* nor *disliked* by the panelists. It is noteworthy that the addition of vegetable leaf extract to the popular weaning food did not result in rejection of the products by the sensory panelists. However, the better acceptability of the non-fortified product is suspected to be due to the age-long preference and adaption to it, while the change in the color and taste of the fortified products reduced the degree of acceptability. However, a rigorous system of advocacy and awareness creation about the food value of the vegetable leaf extract-fortified weaning food is expected to promote better adoption and utilization of the products by the populace.

3.3 Sensory evaluation and acceptability of vegetable leaf-fortified pastry products

In sensory evaluations of vegetable-fortified pastry, the quality attributes of interest are color, flavor, taste, texture, appearance, and acceptability. In the study conducted by Fasogbon et al. [14] on the quality attributes of *Chinchin* and cookie enriched with *Telfaria occidentalis*, *Amaranthus viridis,* and *Solanum macrocarpon* leaf powders, wheat flours were substituted up to 10% with the vegetable powders. It was observed from the studies that an increase in the level of inclusion of the leaf powders decreased the level of acceptability of the products. Cookies and *Chinchin* fortified with 2% and 5% leaf powder were not significantly different in taste when compared with non-fortified equivalents. In a similar study conducted by Akindele [57], wheat flour was replaced with 1%, 3%, and 5% *Basella alba* and *Telfaria occidentalis* leaf powders in the production of high-quality and acceptable *Chinchin* and cookies. In the study, it was observed that incorporation of the leaf powders did not affect the taste of the snacks when compared with cookies and *Chinchin* produced with 100% wheat flour. Replacement of wheat flour with vegetable leaf powders up to 5% did not affect flavor and texture of the cookies and *Chinchin* [57]. Results from the MicroVeg project are superior to those reported for *Chinchin* and cookies fortified with 5% soybean, which had very low consumer acceptance in terms of flavor and taste [49]. The poor consumer acceptance of the soybean-fortified pastries was attributed to the imparted beany flavor. The green color of vegetable leaf-fortified pastry increased significantly as the inclusion level increased. However, despite the green color, vegetable leaf-fortified pastries were acceptable to consumers to the 5% level of incorporation [14, 57].

3.4 Training of local population on vegetable fortification of foods

The MicroVeg value addition team with the support of the extension personnel trained a total of 5466 persons (68% women) across 25 locations on the promising value addition innovations between September 2016 and July 2017. The training focused on various aspects of vegetable leaf drying, especially the use of a locally designed charcoal-fired system and the production of vegetable-enriched products based on practical demonstrations and video instructions. During the practical sessions, women had hands-on experience producing some of the vegetable-fortified pastry products. The team also trained 100 bakery owners in southwest Nigeria on the practical production of vegetable fortified bread. A combination of video and practical demonstrations of the entire process of vegetable fortification of baked products was used during the training exercise. Participants at the different training sessions also participated in sensory evaluation of the bread and pastry products. In order to create awareness on the nutritional values of vegetables and vegetable-fortified products, the MicroVeg project sponsored daily enlightenment programs on local radio stations. The radio programs reached an estimated 5 million listeners every day in southwest Nigeria. For enhanced technology transfer to the local population (especially women in rural areas), the recipes for green bread and vegetable leaf-fortified snacks have been translated into the local language (Yoruba), the main spoken language in Southwest Nigeria (**Table 4**).

4. Conclusions

Results from the value-addition component of the MicroVeg project have led to the development of novel vegetable leaf-fortified bread and pastry formulation with higher contents of nutrients and bioactive polyphenols. The work also produced a vegetable leaf-enriched traditional maize-based breakfast hot cereal with superior nutritional value than regular food. These vegetable-enriched products constitute an important component of the diets of women and children in Nigeria. Therefore, the availability of these vegetable-enriched food products could enhance maternal and child nutrition through improved nutrient supply in addition to a healthier status due to the free radical scavenging ability of the incorporated polyphenolic compounds. Extension activities led to the training of rural thousands of women and local bakers on the technology for the production of fortified food products. Additional activities

Sample	Color	Aroma	Taste	Mouth feel	Acceptability
A	8.10 ± 0.74^{a}	7.10 ± 0.57^{a}	7.40 ± 1.07^{a}	6.60 ± 1.07^{a}	7.90 ± 0.74^{a}
B	7.20 ± 1.40^{b}	7.00 ± 1.05^{a}	7.40 ± 0.70^{a}	6.70 ± 0.48^{a}	7.30 ± 1.49^{a}
C	6.50 ± 0.53^{b}	7.10 ± 0.57^{a}	7.00 ± 0.69^{ab}	7.30 ± 0.82^{a}	6.90 ± 0.74^{a}
D	5.60 ± 1.07^{c}	6.80 ± 1.22^{a}	6.80 ± 0.79^{ab}	6.70 ± 0.67^{a}	5.70 ± 1.34^{b}
E	4.30 ± 0.67^{d}	6.70 ± 1.49^{a}	6.20 ± 1.32^{b}	6.80 ± 0.92^{a}	5.00 ± 1.33^{b}

*The mean values along the same row with different superscripts are significantly different (*P *0.05) using Duncan multiple range test. A—100% wheat* Chinchin*; B*—Chinchin *enriched with 1% vegetable polyphenol; C*—Chinchin *enriched with 2% vegetable polyphenol; D*—Chinchin *enriched with 3% vegetable polyphenol; E*—Chinchin *enriched with 5% vegetable polyphenol.*

Table 4.
Mean sensory score of chinchin *enriched with polyphenol from* Amaranthus viridis *L.*

are underway to obtain regulatory approval for these vegetable-fortified food products with the aim of eventual commercialization of the respective technologies.

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Conflict of interest

The authors declare no conflict of interest.

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References

[1] WHO/FAO. Diet, Nutrition and the Prevention of Chronic Diseases. Report of a Joint FAO/WHO Expert Consultation, WHO Technical Report Series 916. Geneva: World Health Organization; 2002

[2] Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: A systematic analysis for the global burden of disease study. Lancet. 2012;**380**:2224-2260. DOI: 10.1016/S0140-6736(12)61766-8

[3] Adebooye OC. "African indigenous vegetable resources in a changing world" Promoting green economy. In: Ayuk ET, Oku EE, editors. Implications for Natural Resources Development. The United Nations University; 2014

[4] Aune DE, Boffetta LT, Fadnes N, Keum T, Norat DC, Greenwood E, et al. Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality—A systematic review and dose-response meta-analysis of prospective studies. International Journal of Epidemiology. 2017;**46**: 1029-1056. DOI: 10.1093/ije/dyw319

[5] WHO. Promoting Fruit and Vegetable Consumption around the World. Geneva: World Health Organization; 2015 https://www.who.int/dietphysicalactivity/fruit/en/. [Accessed: November 29, 2017]

[6] Nestel P. Food fortification in low-income countries: A new approach to an old standby. In: Food Fortification in Developing Countries U.S. Washington, DC: Agency for International Development; 1993

[7] West CE, Eilander A, van Lieshout M. Consequences of revised estimates of carotenoid bioefficacy for dietary control of vitamin a deficiency in developing countries. Journal of Nutrition. 2002, 2002;(132):2920S-2926S

[8] FAO/WHO. Development of Guidelines on the Fortification Requirements of Lower Fat Products. Rome: FAO; 1995; CX/NFSDU 95/9

[9] FAO. Preventing micronutrient deficiencies: Food abundance and diversity are fundamental. Food, Nutrition and Agriculture. 1993;**1993**(7): 8-17

[10] Horton S. The economics of food fortification. The Journal of Nutrition. 2006;**36**:1068-1071

[11] Adebooye OC, Alashi MA, Aluko RE. Economic potentials of polyphenols. Journal of Food Biochemistry. 2017; **2017**(1):21-29

[12] Famuwagun AA, Taiwo KA, Gbadamosi SO, Oyedele DJ, Aluko RE, Adebooye OC. Extraction optimization and antioxidant properties of African eggplant (*Solanum macrocarpon*) leaf polyphenols. Journal of Food Quality. 2017; Article ID 2159183. DOI: 10.1155/2017/2159183

[13] Alashi AM, Taiwo KA, Oyedele DJ, Adebooye OC, Aluko RE. Blood pressure lowering ability of vegetable-fortified bread. In Afri-veg Forum, 2017 Forum on African Vegetables, Cotonou, November 20–22, 2017. Acta Horticulture. 2017

[14] Fasogbon BM, Taiwo KA, Oyedele DJ. Nutritional assessment and consumer acceptability of snacks

(chinchin and cookies) enriched with underutilized indigenous vegetables. International Journal of Food and Nutritional Sciences. 2017;**6**:97-107

[15] Odunlade TV, Famuwagun AA, Taiwo KA, Gbadamosi SO, Oyedele DJ, Adebooye OC. Chemical composition and quality characteristics of wheat bread supplemented with leafy vegetable powders. Journal of Food Quality. 2017; Article ID 9536716. DOI: 10.1155/2017/9536716

[16] UNICEF. (2017). Malnutrition rates in children under 5 years. 2017. https://www.unicef.org/nigeria/factsheets_NUTRITION_low.pdf . [Accessed November 26, 2017].

[17] Odunlade TV, Taiwo KA, Adeniran HA. Functional and antioxidative properties of sorghum Ogi flour enriched with cocoa. Annals Food Science and Technology. 2016;***17***: 497-506

[18] Abioye VF, Aka MO. Proximate composition and sensory properties of moringa fortified maize-Ogi. Journal of Nutrition and Food Sciences. 2015;**12**: 234–242

[19] Oladeji OA, Taiwo KA, Ishola MM, Oladeji BS. Nutritional and quality characteristics of white maize *Ogi* flour enriched with *Moringa oleifera* seed. Biotechnology Journal International. 2017;**18**:1-11

[20] Ajanaku KO, Ogunniran KO, Ajani OO, James OO, Nwinyi OC. Improvement of nutritive value of sorghum Ogi fortified with pawpaw (*Carica papaya* L.) fruit vegetable cereal science. Biotechnology. 2010;**4**:98-101

[21] Sanni AI, Asiedu M, Ayernor GS. Influence of processing conditions on the nutritive value of *Ogi-baba*, a Nigerian fermented sorghum gruel. Plant Foods for Human Nutrition. 2001;**56**: 217-223

[22] Osundahunsi OF, Aworh OC. Nutritional evaluation, with emphasis on protein quality, of maize-based complementary foods enriched with soya bean and cowpea tempe. International Journal of Food Science and Technology. 2003;***38***:809-813

[23] Aminigo ER, Akingbala JO. Nutritive composition of Ogi fortified with okra seed meal. Journal of Applied Sciences and Environmental Management. 2004; **8**:23-28

[24] Aminigo ER, Ossai GEA. Production and evaluation of high-protein roasted maize meal. Journal of Applied Sciences and Environmental Management. 1999; **3**:17-22

[25] Ijarotimi SO, Bakere SS. Evaluation of proximate, mineral and antinutritional factor homemade processed complementary diet from locally available food materials (*Sorghum bicolor* and *Sphenostylis stenocarpa*). Journal of Food Technology. 2006;**4**: 339-344

[26] Oladeji BS, Akanbi CT, Ibironke SI. Physicochemical and nutritional evaluation of co-processed fermented yellow maize Ogi (an infant diet) and carrot blends. Annals Food Science and Technology. 2014;**15**:82-91

[27] Odunlade TV. Famuwagun AA, Taiwo KA, Gbadamosi SO, Oyedele DJ, Adebooye OC. Development of maize ogi fortified with fluted pumpkin leaf polyphenolic rich extract. Microveg/Afriveg Forum, 2017. African Vegetables: From Pot to Plate, November 19–22, Sun Beach Hotel, Cotonou, Benin Republic 91.

[28] Anyika JU, Uwaegbute AC. Frequency of consumption and nutrient content of some snacks eaten by an adolescent secondary and university student in Abia state. Nigerian Journal of Nutritional Sciences. 2005;***26***:10-15

[29] Famuwagun AA, Taiwo KA, Gbadamosi SO, Oyedele DJ. Optimization of production of bread enriched with leafy vegetable powder. Journal of Food Processing and Technology. 2016;***7***:7

[30] Onoja US, Dibua UME, Eze JI, Odo GE. Physico-chemical properties, energy, mineral, vitamin and sensory evaluation of wheat-based bread supplemented with legume, root, tuber and plantain flour. Global Journal of Pure and Applied Science. 2011;**17**: 319-327

[31] Akubor PI. Influence of germination and fermentation on the qualities of bread prepared from cowpea and wheat flour blends. Nigeria Journal of Nutritional Science. 2008;**29**:156-166

[32] Mastromatteo M, Danza A, Lacce L, Spinelli S, Lampignano V, Laverse J, et al. Effect of durum wheat varieties on bread quality. International Journal of Food Science and Technology. 2013; **2013**(49):72-81

[33] WHO/FAO. The joint World Health Organization/food and agricultural organization expert consultation on diet, nutrition and the prevention of chronic diseases: Process, product and policy implications. Public Health Nutrition. 2004;**7**(*1A*):245-250

[34] Peng X, Ma J, Cheng KW, Jiang Y, Chen F, Wang M. The effects of grape seed extract fortification on the antioxidant activity and quality attributes of bread. Food Chemistry. 2010;**119**:49-53

[35] Ranawana DV, Raikos V, Campbell F, Bestwick C, Nicol P, Milne L, et al. Breads fortified with freeze-dried vegetables: Quality and nutritional attributes. Part 1: Breads containing oil as an ingredient. Food. 2016;***5***:19

[36] Świeca M, Gawlik-Dziki U, Dziki D, Baraniak B, Czyż J. The influence of protein–flavonoid interactions on protein digestibility in vitro and the antioxidant quality of breads enriched with onion skin. Food Chemistry. 2013; **141**:451-458

[37] Świeca M, Sęczyk L, Gawlik-Dziki U, Dziki D. Bread enriched with quinoa leaves—The influence of protein–phenolics interactions on the nutritional and antioxidant quality. Food Chemistry. 2014;***162***:54-62

[38] United States Department of Agriculture and States Department of Agriculture and United States Department of Health. Dietary Guidelines for Americans. 7th ed. United Washington, DC, USA; 2010

[39] Ogunsina B, Radha C, Indrani D. Quality characteristics of bread and cookies enriched with debittered *Moringa oleifera* seed flour. International Journal of Food Science and Nutrition. 2010;***62***:185-194

[40] Ameh MOI, Gernah D, Igbabul BD. Physico-chemical and sensory evaluation of wheat bread supplemented with stabilized undefatted rice bran. Journal of Food and Nutrition Sciences. 2013;**4**: 43-48

[41] Igbabul B, Num G, Amove J. Quality evaluation of composite bread produced from wheat, maize and orange fleshed sweet potato flours. American Journal of Food Science and Technology. 2014;***2***: 109-115

[42] Bolarinwa IF, Aruna FE, Raji AO. Nutritive value and acceptability of bread fortified with moringa seed powder. Journal of the Saudi Society of Agricultural Sciences. 2017. DOI: 10.1016/j.jssas.2017.05.002

[43] Abdelghafor RF, Mustafa AI, Ibrahim AMH, Krishnan PG. Quality of bread from composite flour of sorghum and hard white winter wheat. Advanced Journal of Food Science and Technology. 2011;**3**:9-15

[44] Gellynck X, Kühne B, Van Bockstaele F, Van de Walle D, Dewettinck K. Consumer perception of bread quality. Appetite. 2008;**53**:16-22

[45] George P. Encyclopedia of Foods. Vol. 1. Washington: Humane Press; 2003. p. 526

[46] Noorfarahzilah M, Lee JS, Sharifudin MS, Mohd Fadzelly AB, Hasmadi M. Applications of composite flour in development of food products. International Food Research Journal. 2014;***21***:2061-2074

[47] Hooda S, Jood S. Organoleptic and nutritional evaluation of wheat biscuits supplemented with untreated and treated fenugreek flour. Food Chemistry. 2005;**90**:427-435

[48] Adegunwa MO, Ganiyu AA, Bakare HA, Adebowale AA. Quality evaluation of composite millet-wheat Chinchin. Agriculture and Biology Journal of North America. 2014. DOI: 10.5251/abjna.2014.5.1.33.39

[49] Shrestha AK, Noomhorm A. Comparison of physicochemical properties of biscuits supplemented with soy and kinema flours. International Journal of Food Science and Technology. 2002;**37**:361-368

[50] McWatters KH, Ouedraogo JB, Resurrection AVA, Hung YC, Philips RD. Physical and sensory characteristics of sugar cookies containing mixtures of wheat, fonio (*Digitaria exilis*) and cowpea (*Vigna unguiculata*) flours. International Journal of Food Science and Technology. 2003; **38**:403-410

[51] Akubor PI. Protein contents, physical and s lensory properties of Nigerian snack foods (cake, chin-chin and puff-puff) prepared from cowpea-wheat flour blends. International Journal of Food Science and Technology. 2004;**9**: 419-424

[52] Piteira MF, Maia JM, Raymundo A, Sousa I. Extensional flow behaviour of natural fibre-filled dough and its relationship with structure and properties. Journal of Non-Newtonian Fluid Mechanics. 2006;**137**:72-80

[53] Carpenter RP, Lyon DH, Hasdell TA. Guidelines for Sensory Analysis in Food Product Development and Quality Control. Springer Open; 2000

[54] Tuorila H, Cardello AV. Consumer responses to an off-flavor in juice in the presence of specific health claims. Food Quality and Preference. 2002;**13**:561-569

[55] Frewer L, Scholderer J, Lambert N. Consumer acceptance of functional foods: Issues for the future. British Food Journal. 2003;**105**:714-731

[56] Urala N, Lähteenmäki L. Consumers 'changing attitudes towards functional foods. Food Quality and Preference. 2007;**18**:1-12

[57] Akindele O. Studies on production of *chinchin* enriched with vegetables. [M. Sc. Thesis]. Ile-Ife, Osun State, Nigeria: Obafemi Awolowo University; 2016