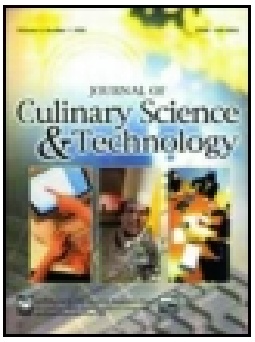

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Addition of Orange-Fleshed Sweet Potato and Iron-Rich Beans Improves Sensory, Nutritional and Physical Properties But Reduces Microbial Shelf Life of Cassava-Based Pancake (*Kabalagala*) Designed for Children 2-5 Years Old

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ABSTRACT

Innovative use of locally available food resources to develop products of enhanced nutritional quality is one of the strategies believed to alleviate deficiencies of essential micronutrients such as vitamin A and iron that are endemic among children 2–5 years in developing countries such as Uganda. New cassava-based pancake (*kabalagala*) formulae composed of orange-fleshed sweet potato, iron-rich beans, cassava and sweet banana were developed to target vitamin A and iron needs of children 2–5 years in Uganda. The new products had better sensory appeal and nutrient density, had better physical properties during storage, were stable to oxidative rancidity but had lower microbial shelf-life compared to the original pancake formula (composed of cassava and sweet banana). Notwithstanding bioavailability constraints, theoretical nutritional computation revealed that serving 100 g (approximately four pieces) of the new products would contribute approximately 99–102% of vitamin A and 110–119% of iron requirements of the targeted children.

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Cassava-based pancake; nutritional composition; sensory preference; storage stability

Introduction

Globally, the prevalence of stunting, wasting and overweight has reached an estimated 21.3% (144.0 million), 6.9% (47.0 million) and 5.6% (38.3 million), respectively, amongst children under 5 years of age (FAO et al. 2020). Whereas 340 million children suffered from micronutrient deficiencies, about 50% of all deaths of children under 5 years in developing countries are related to undernutrition (FAO, IFAD, UNICEF, WFP and WHO, 2020). Among developing regions, Sub-Sahara Africa ranks first in terms of child undernutrition (Swinburn et al., 2019). Micronutrient deficiency is one of the most devastating forms of malnutrition affecting 2 billion people worldwide (Beal, Massiot, Arsenault, Smith, & Hijmans, 2017) and 720 million are located in Sub-Saharan Africa (Lovedeep, Harvinder, Aayushi, & Manish, 2018).

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Vitamin A and iron deficiencies are listed amongst the most common and severe micronutrient deficiencies with children being the most affected in Sub-Sahara Africa (Beal et al., 2017). About 48% of children aged 6 to 59 months in Sub-Saharan Africa are affected by vitamin A deficiency (Wirth et al., 2017). The significance of vitamin A and iron deficiency on child health is well documented. Vitamin A deficiency is highly associated with preventable blindness and can potentially increase the risk of disease and death from severe infections. Lack of iron negatively affects overall growth, weakens the immune system and negatively affects cognitive development in children (Lopez, Cacoub, Macdougall, & Peyrin-Biroulet, 2016).

Several strategies have been developed to address deficiencies of micronutrients such as Vitamin A and iron in developing countries. Key among them are medical supplementation, physical fortification, biofortification, and food composite formulation (Bhutta, Salam, & Das, 2013). Despite its usefulness, lack of supplies and poor compliance has consistently affected the success of medical supplementation (Dwyer, Coates, & Smith, 2018). On the other hand, iron-enhanced food products that are manufactured through industrial fortification hardly reach poor rural households due to their low purchasing power (Hambidge, 2010). Consumers' skepticism about the safety of biofortified crops, especially those biofortified through genetic modification (GM) approach has limited access to nutrients through the biofortification pathway (Low, Mwanga, Andrade, Carey, & Ball, 2017).

Based on the challenges associated with other strategies highlighted above, food composite formulation is believed to be a good strategy to counteract micronutrient deficiency (Akonor, Tortoe, & Buckman, 2018). Food composite formulation relies on locally available food resources and therefore provides a sustainable and effective means of addressing nutrition challenges in localities where food resources of interest are available (Akoja, Adebowale, Makanjuola, & Salaam, 2017). Food composites are made from various food ingredients and additives, and as such have multifactorial character. This property makes it essential for food composites to be tested for practicality (e.g., sensory appeal) prior to promotion or production in large quantities (Adeyeye, 2020). On the other hand, most food composite formulations have targeted improvement in energy and protein (Akoja et al., 2017). However, affordable products targeting micronutrients such as vitamin A and iron and tailored for uptake by the rural poor are hardly available (Bain et al., 2013).

Orange fleshed sweet potato (OFSP) and iron-rich beans have been promoted in a number of developing countries such as Uganda (Mwanga et al., 2007). OFSP are varieties of sweet potato (*Ipomoea batatas*) that contain significantly high levels of β-carotene (up to 1600 μg RAE)/100 g) compared to other varieties (Nazrul et al., 2016; Mwanga *et al.* (2016). Iron-rich beans (bio-fortified beans) are bean (*Phaseolus vulgaris*) varieties that accumulate higher amounts of iron than other bean varieties (Lockyer et al., 2018). These food materials (OFSP and iron-rich beans) have the potential to be included in local food composites to improve iron and vitamin A intakes, along with increased intake of other nutrients, as opposed to each providing high concentration of the respective nutrient.

Kabalagala is a pancake popularly consumed in Uganda and highly liked by women and children (Wheatley & Loechl, 2008). It is made of cassava (*Manihot esculenta* Crantz) and banana (Musa) and as such it is largely energy dense but limited in essential nutrients, such as vitamin A and iron. It is easy to make and is highly consumed in both rural and urban areas. These scenarios make it a suitable product for nutritional intervention among vulnerable segments of the society such as children. Processing *kabalagala* also lies within the realm of activities of women who engage in small-scale food businesses including production of *kabalagala* for sale and consumption by household members. Whereas women in Uganda have vast experience in processing pancakes, they lack recipes tailored to match the nutrition needs of vulnerable groups such as iron and vitamin A requirements of children 2–5 years old. The objective of this study was to investigate the potential of OFSP and iron-rich beans to improve Vitamin A and iron contents of the *Kabalagala*. Specifically, the study examined the effect of addition of OFSP and iron-rich beans on consumer sensory preference and overall acceptability, nutritional composition, and storage stability of *Kabalagala*.

Materials and methods

Raw materials

Fresh cassava tubers and bananas were purchased from local markets in Gulu district (Northern Uganda) while iron-rich beans (variety, NAROBEAN 4 C) and OFSP (variety, NASPOT 13) were purchased from National Agricultural Research Organization (NARO), Kampala, Uganda. Cassava flour was prepared using the method described by Maziya-Dixon, Alamu, Popoola, and Yomeni (2017) taking into account local practice. Cassava, iron-rich beans, and OFSP were transformed into flour using different approaches taking into account local practice. Cassava roots were peeled, washed, grated, dried, milled, and sieved (sieve size, 0.5 mm). OFSP was processed into flour according to the method described by Rangel et al. (2011). OFSP roots were sorted and washed. The roots were then peeled, sliced, dried (until it reached 10% moisture), and milled into flour. For iron-rich beans, the seeds were washed, sun dried, winnowed, and milled into flour. The flours were packed in LDPE bags and stored at room temperature (25–30°C) till used.

Product development

Development of vitamin A and iron enhanced *kabalagala* involved the participation of community women that usually produce them for sale. In the preliminary stage, the products were developed in the study communities (Gulu and Omoro districts, Northern Uganda) to integrate the experience of local pancake processors in the study. In the second stage, the community-adapted procedure was used to prepare pancakes in the laboratory for the actual study. According to Wheatley and Loechl (2008), the original *kabalagala* is made up of cassava flour (65–70%) and banana pulp (30–35%). In the current study, vitamin A and iron enhanced formulae were produced by substituting a calculated quantity of cassava flour and banana pulp with a measured quantity of iron-rich beans and OFSP. The formulae were segregated by age of children (2–3 and 4–5 years) on the basis of the Recommended Daily Allowance (RDA) for vitamin A and iron according to FAO/WHO recommendations (Food and Agriculture Organization & World Health Organization, 2001). Table 1 shows data on the levels of inclusion of various ingredients calculated based on Harvest Plus Food Composition Table (Hotz, Lubowa, Sison, Moursi, & Loechl, 2012). The formulations were designed to meet at least 50% of RDA for the two micronutrients.

On the basis of the ingredient blending ratios presented in (Table 1), nutritionally enhanced *kabalagala* was prepared following the process that experienced community women were already practicing. Briefly, the process involved smashing the ripe banana (for 3.5 minutes) into a paste followed by addition of cassava flour, OFSP flour and iron-rich beans flour. The mixture was kneaded for 5 minutes (until the dough became non-sticky). The resulting dough was molded into rolls on a rolling board and fried. In the original *kabalagala* production, the end point of the frying process reaches when the products turn golden brown. However, in this study, a preliminary experiment was undertaken to determine the frying time.

Table 1. Levels of inclusion of iron-rich beans, OFSP, cassava and sweet banana.

Ingredients	Formula identity	Mixing ratios (%) for various ingredients
		Original *Kabalagala*
Cassava flour, banana	K00	70% cassava flour, 30% banana
		Children (2–3 years)
Cassava flour, OFSP flour, Iron rich beans flour, banana	K11	30% OFSP, 10% Fe-beans flour, 45%cassava, 15% banana
″	K12	33% OFSP, 12% Fe-beans flour, 43%cassava, 12% banana
″	K13	35% OFSP, 13% Fe-beans flour, 42%cassava, 10% banana
		Children (4–5 years)
Cassava flour, OFSP flour, Iron rich beans flour, banana	K21	37% OFSP, 15% Fe-beans flour, 40%cassava, 8% banana
″	K22	40% OFSP, 15% Fe-beans flour, 40%cassava, 5 banana
″	K23	43% OFSP, 19% Fe-beans flour, 33% cassava, 5 banana

Edible vegetable cooking oil was first heated in a frying pan for 10 minutes and the pancake was fried until it turned golden brown. The process was repeated three times to ascertain consistency. This preliminary test revealed that the optimum frying duration for *kabalagala* is 3 minutes at 150°C. In the actual experiment, for each treatment (original *kabalagala*, nutritionally enhanced *kabalagala*), formulations were made in triplicate. For each age category (children 2–3 years and children 4–5 years), three products were developed and subjected to sensory evaluation among caregivers following the procedure explained under subsection 2.3 and were used in subsequent analyses.

Sensory evaluation

Sensory evaluation was conducted in two stages. First, a preliminary evaluation was conducted to enable selection of the most preferred formula among the three nutritionally enhanced *kabalagala* developed for each age group. The second evaluation exercise was carried out to compare each of the preferred nutritionally enhanced *kabalagala* with the original product. In all cases, evaluation exercise was conducted in Gulu and Omoro districts of Northern Uganda using untrained participants. The participants of the preliminary sensory evaluation test were not involved in the second sensory evaluation exercise to avoid bias. The participants' ages ranged from 16 to 52 years and they were all female. The two districts were chosen because various Non-governmental Organizations were promoting production of OFSP and iron-rich beans in them. Participants involved consisted of volunteer caregivers of children 2–5 years who had been resident in the two districts for at least six months and were willing to participate in the study. In each evaluation stage, 97 caregivers participated in line with previous studies (Omoba, Olagunju, Iwaeni, & Olajumoke Obafaye, 2020; Otolowo & Olapade, 2018).

A 5-point hedonic scale (labeled as 1 = dislike extremely, 2 = dislike, 3 = neither like nor dislike, 4 = like and 5 = like extremely) was used to rate sensory attributes (color, appearance, aroma, flavor, texture, taste and overall acceptability). Samples were served at 25°C in white bowls coded with three random digit numbers. Participants were positioned in such a way that they were far from each other to avoid interference. During the evaluation exercise participants rinsed their mouths with clean warm water between tasting different products. This was to minimize carry-over effects. In each of the evaluation stage, participants were requested to choose the best product among the set of products presented for each age category (three and two products in the first and second stage, respectively) and were used in subsequent analyses.

Determination of nutritional composition

Nutritional composition was determined in terms of proximate composition and micronutrient content. Proximate constituents analyzed were moisture, total fiber, crude protein, ash, total carbohydrate, and energy. All analyses were conducted using the AOAC procedures (Association of Official Analytical Chemists, 1990). For moisture, about 1.5 g of each sample was weighed and dried at 100–105°C for 24 hours and the moisture content was calculated on a dry weight basis (Fikiru et al., 2017). For ash, samples were incinerated at 600 °C for 5 hours in a VULCAN furnace model 3–1750 (CNSI, California, USA). The weights of incinerated samples were recorded as ash content. Protein content was determined by the Kjeldahl method using Kjeltec™ model 2300 (FOSS, Hilleroed, Denmark), as described by Barroso et al. (2019). A factor of 5.28 was used to convert total nitrogen to percentage crude protein (Mariotti et al., 2008). Crude fat content was determined using a Soxtec System HT2 fat extractor (FOSS, Hilleroed, Denmark) using hexane as the extraction solvent, and the fat yielded after the solvent had evaporated off. The difference between the initial and final weight of the extraction cup was recorded as the crude fat content. For fiber, approximatively 0.153 g sample was dried at 150°C for 1 h and cooled down in a desiccator and the weight was recorded. The crucible was placed in a muffle furnace at 55°C for 3–4 hours and cooled again in the desiccator and the new weight was taken. The percentage crude fiber was calculated on a dry weight basis as previously reported by Edun et al. (2019). Carbohydrate content was determined by the method of difference (Adeyeye, 2020) while energy content was determined using the Atwater factor approach as previously used by (Omoba et al., 2020).

Micronutrients determined included iron, zinc, calcium, phosphorus, magnesium, vitamin C, and vitamin A. These micronutrients were selected because of their importance in child growth and development (Yakoob & Lo, 2017). The content of calcium, zinc, iron, magnesium and phosphorus was each determined using Atomic absorption spectrophotometer (AAS) following the standard curve procedure previously used by Agbon, Ngozi, and Onabanjo (2010). The AAS model 2300 (FOSS, Shelton, USA) was used while the calibration curves and equations were developed by plotting the concentration of the standards against the absorbance for each micronutrient. The developed calibration equations were used to calculate the concentration of each mineral in the sample. Vitamin C was determined using the isocratic gradient HPLC method. The HPLC analyses were performed with a Merck Hitachi LaChrom system (Merck, Geneva, Switzerland) equipped with a reversed-phase C_{18} column and a UV detector system (Merck Geneva, Switzerland). Vitamin A was determined using colorimetric method involving Antimony trichloride (SbCl3) as previously reported by Blake & Moran (1976). Measurements were performed using a GENESYS 10 UV spectrophotometer (NEW YORK, USA) set at 450 nm making use of the extinction coefficient of β-carotene. The calculated β-carotene content was converted to retinol equivalent (Tadesse et al., 2015a).

Determination of storage stability

Pancake samples were packed in commercial-grade plastic containers and stored at room temperature, replicating practice in the study community. Preliminary discussions with producers of *Kabalagala* revealed that the products have a shelf life of three days. Therefore, analysis of stability was conducted every 12 hours for three days. Storage stability parameters evaluated included pH, diameter, thickness, spread ratio, specific volume, acid value, peroxide value and microbial levels. Sample pH was determined using a portable pH meter (Model 323, WTW 82362, Weilheim, Germany) according to Ayo-Omogie (2020). Diameter and thickness were measured using a calliper according to Messaoudi and Fahloul (2018). Spread ratio and specific volume (volume to mass ratio) (cm^3/g) were determined using the rapeseed replacement method according to Messaoudi and Fahloul (2018) and Ayo-Omogie (2020). The acid value was determined by the titration method according to Adegunwa et al. (2015) while measurement of peroxide value was performed as previously reported by Dada, Barber, Ngoma, and Mwanza (2018). Microbial tests conducted included total microbial count and the load of yeast and molds. Microbial parameters were determined according to procedures described by Adeyeye et al. (2017). All chemicals used were of analytical grade and supplied by BDH (BDH, Kampala, Uganda).

Data analysis

One-way analysis of variance (ANOVA) was used for data analysis. Specifically, the analysis was used to compare: (i) the level of consumer rating for each sensory parameter between the three formulae recipes developed for each age category; (ii) consumer ratings for sensory parameters between the original and consumer selected products; (iii) the levels of proximate parameters and micronutrient contents between the original and consumer selected products; (iv) and the levels of physical and chemical parameters and microbial load between the original and consumer selected products at each sampling stage during storage. The level of statistical significance was fixed at 5%. LSD test was run to determine which samples were significantly different.

Results

Effect of addition of OFSP and iron-rich beans on consumer sensory preference

Results of the sensory evaluation conducted to compare consumer sensory preference between the original *kabalagala* and the most preferred formulae for children 2–3 years (K13) and 4–5 years old (K23) are presented in (Table 2). The sensory scores obtained for K13 were significantly higher than values recorded for K00 (control formula) ($p \leq 0.05$). In quantitative terms, the mean score for K13 for all sensory attributes ranged between 3.53 and 4.07 while scores recorded for K00 for all sensory parameters ranged between 1.87 and 2.14. Similarly, scores recorded for K23 were also higher than values recorded for K00 ($p \leq 0.05$). The caregivers exhibited a significantly higher preference for the nutritionally enhanced *kabalagala* K23 compared to K13 ($p \leq 0.05$) across all sensory attributes.

Effect of addition of OFSP and iron-rich beans on nutritional composition

Data on the effect of the addition of OFSP and iron-rich beans on the proximate composition of *kabalagala* are presented in (Table 3). Product K13 had significantly higher values of protein, fat, ash and energy compared to K00. On the contrary, the contents of carbohydrate and moisture were significantly lower in K13 than in K00 by about 3.04 and 3.99%, respectively. There was no significant difference in the fiber contents of K13 and K00. A similar trend of the proximate profile was observed when K23 was compared with K00 (Table 3).

Results on the effect of the addition of OFSP and iron-rich beans on the micronutrient profile of *kabalagala* are also presented in (Table 3). For K13, the value recorded for vitamin C, phosphorus, iron, vitamin A, calcium, and zinc was significantly higher than recorded for K00 by 10.58, 0.34, 1.83, 201.76, 13.01, and 0.51%, respectively ($p \leq 0.05$). However, there was no difference between K00 and K13 in terms of magnesium content. The scenarios observed between K13 and K00 was also true for K23 and K00 for all micronutrients. Specifically, the content of vitamin C, phosphorus, iron, vitamin A, calcium, and zinc was higher in K23 than in K00 by 27.51, 0.53, 2.19, 221.39, 20.1, and 0.69%, respectively. However, except for magnesium, the content of phosphorus, iron, vitamin A, zinc, calcium, and vitamin C was significantly higher in K23 than in K13 by 5.8, 16, 9.6, 14.8, 13.7, and 82.8%, respectively.

Results showing vitamin A and iron contents of various *kabalagala* products in comparison to the mean daily requirement for the age categories

Table 2. Comparison of caregivers' sensory preference between original and nutritionally enhanced cassava-based pancakes (*kabalagala*).

	Mean sensory score for the formulae			
Sensory attributes	K00	K13	K23	P value
Color	2.10 ± 0.82^{a}	3.58 ± 0.63^{b}	4.77 ± 0.44^{c}	0.04
Appearance	2.07 ± 0.88^{a}	3.53 ± 0.07^{b}	4.53 ± 0.71^{c}	0.03
Aroma	1.87 ± 0.93^{a}	3.82 ± 0.58^{b}	4.87 ± 0.41^{c}	0.01
Flavor	1.98 ± 0.87^{a}	3.89 ± 0.58^{b}	4.89 ± 0.37^{c}	0.00
Texture	2.14 ± 0.95^{a}	3.53 ± 0.84^{b}	4.61 ± 0.61^{c}	0.01
Taste	1.98 ± 0.86^{a}	3.92 ± 0.64^{b}	4.85 ± 0.49^{c}	0.02
Overall acceptability	2.09 ± 0.94^{a}	4.07 ± 0.58^{b}	4.92 ± 0.44^{c}	0.03

Values (means ±SD, n = 97) in the same row followed by different superscripts are significantly different at 5% ($p \leq 0.05$).K00:control (70% Cassava flour, 30% banana); K13: formula for children 2–3 years (35% OFSP, 13% iron-rich beans flour, 42% cassava, 10% banana); K23: formula for children 4–5 years (43% OFSP, 19% iron-rich beans flour, 33% Cassava, 5% banana).

Table 3. Nutritional composition (on dry weight basis) of original and nutritionally enhanced cassava-based pancakes (*kabalagala*).

ParametersNutritional composition of formulae				
	Control	**K13**	**K23**	**P value**
Carbohydrate (%)	63.55 ± 0.00^{a}	61.00 ± 1.04^{b}	58.67 ± 0.23^{b}	0.00
Moisture (%)	31.32 ± 0.14^{a}	27.31 ± 0.74^{b}	27.20 ± 0.65^{b}	0.00
Crude fat (%)	2.23 ± 0.04^{a}	3.20 ± 0.14^{b}	3.35 ± 0.13^{b}	0.00
Crude fiber (%)	0.43 ± 0.02^{a}	2.35 ± 0.01^{b}	3.16 ± 0.11 ^{c}	0.00
Ash (%)	1.56 ± 0.03^{a}	2.57 ± 0.09^{b}	3.44 ± 0.3 ^{c}	0.00
Crude protein (%)	1.08 ± 0.00^{a}	4.23 ± 0.02^{b}	4.95 ± 0.01 ^{c}	0.00
Energy (Kcal)/100 g	277.91 ± 0.4^{a}	287.08 ± 0.2^{b}	281.55 ^{c}	0.00
Vitamin A (µRAE/100 g)	3.04 ± 0.03^{a}	204.80 ± 0.03^{b}	224.43 ± 0.04 ^{c}	0.00
Vitamin C (mg/100 g)	9.86 ± 0.51^{a}	20.44 ± 0.49^{b}	37.37 ± 0.0.26 ^{c}	0.00
Phosphorous(mg/100 g)	2.91 ± 0.01^{a}	3.25 ± 0.02^{b}	3.44 ± 0.05 ^{c}	0.00
Iron (mg/100 g)	0.31 ± 0.32^{a}	2.14 ± 0.03^{b}	2.50 ± 0.13 ^{c}	0.00
Zinc (mg/100 g)	0.71 ± 0.02^{a}	1.22 ± 0.09^{b}	1.40 ± 0.04 ^{c}	0.00
Mg (mg/100 g)	1.24 ± 0.08^{a}	1.26 ± 0.35^{a}	1.59 ± 0.09^{a}	0.17
Ca (mg/100 g)	38.85 ± 0.09^{a}	51.86 ± 0.08^{b}	58.95 ± 0.09 ^{c}	0.00

Values (means ±SD, n = 3) in the same row followed by different superscripts are significantly different at 5% ($p \leq 0.05$). K00: control (70% Cassava flour, 30% banana); K13: formula for children 2–3 years (35% OFSP, 13% iron-rich beans flour, 42% Cassava, 10% banana); K23: formula for children 4–5 years (43% OFSP, 19% Fe-beans flour, 33% Cassava, 5% banana).

studied are presented in (Tables 4 and 5), respectively. For vitamin A, apparently, consumption of 100 g (approximatively 4 pieces) of the nutritionally enhanced *kabalagala* pancake by children in the targeted age categories would be sufficient to meet their daily mean vitamin A requirements (Table 4). For iron (Table 5), 100 g of the nutritionally enhanced *kabalagala* products contain more iron than can be expected on the basis of the RDA.

Effect of addition of OFSP and iron-rich beans on storage stability

In terms pH, values recorded for nutritionally enhanced *kabalagala* K13 and K23 were significantly higher than that observed for the original *kabalagala* (K00) ($p \leq 0.05$) throughout the storage period except at the initial time and 12 hours of storage time (Figure 1).

Results comparing diameter, thickness, spread ratio, and specific volume of the various *kabalagala* products during storage are presented in Figure 2. Generally, the diameters of K13 and K23 were significantly higher than recorded for K00 for the whole duration of storage ($p \leq 0.05$) (Figure 2.a).

Table 4. Vitamin A content of original and nutritionally enhanced cassava-based pancakes (*kabalagala*) and the contribution to mean daily vitamin A requirements of children.

Target age category	Pancake formula	β-carotene (µg/ 100 g)	Vitamin A content (µRAE)	Daily mean Vitamin A requirement (RAE)	Contribution to the daily Vitamin A mean requirement
-	K00	36.49 ± 0.42^{a}	3.04 ± 0.03^{a}		1.52%
2–3 years	K13	2457.71 ± 0.44^{b}	204.80 ± 0.03^{b}	200	102.4%
4–5 years	K23	2693.22 ± 0.50 ^{c}	224.43 ± 0.04 ^{c}	225	99.74%

Values (mean ±SD, n = 3) in the same column followed by different superscripts are significantly different at 5% ($p \leq 0.05$) K00: control; K13: formula for children 2–3 years; K23: formula for children 4–5 years.

Table 5. Iron content of original and nutritionally enhanced cassava-based pancakes (*kabalagala*) and the contribution to the daily iron requirement of children.

Age category (in years)	Composite formula	Iron (mg/ 100 g)	Daily mean iron requirement (mg)	Contribution to the daily iron mean requirement
-	K00	0.31 ± 0.02^{a}		
2–3	K13	2.14 ± 0.03^{b}	1.95	110%
4–5	K23	2.50 ± 0.13 ^{c}	2.1	119%

Values (means ±SD, n = 3) in the same column followed by different superscripts are significantly different at 5% ($p \leq 0.05$).K00: control; K13: formula for children 2–3 years; K23: formula for children 4–5 years.

The difference was generally in the range of 0.3 to 0.5 cm. Values recorded for thickness of K13 and K23 were significantly higher than that recorded for K00 ($p \leq 0.05$) at 48, 60 and 72 hours (Figure 2.b). The difference was largely associated with a faster drop in thickness of K00. In the case of the spread ratio (Figure 2.c), generally, the level of the parameter increased with storage time. The increase was more pronounced for K00 compared to K13 and K23. On the other hand, the specific volume of K00 was significantly lower than recorded for K13 and K23 for the larger part of the storage period (Figure 2.c). The difference increased with storage duration due to the larger drop in the parameter value for K00.

With regard to oxidative quality parameters, generally, K13 and K23 had significantly higher acid values compared to K00 ($p \leq 0.05$) (Figure 3). However, no significant difference was observed between values obtained for K13 and K23 during the first 24 hours. The difference became noticeable from 36 hours till the endpoint of storage. Peroxides were not detected in all the

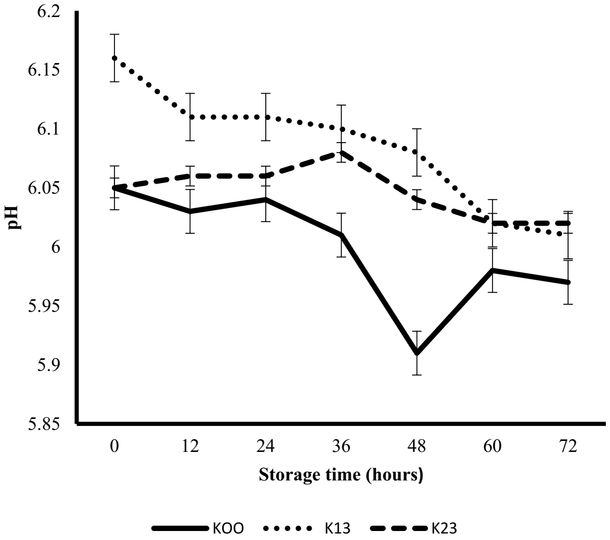
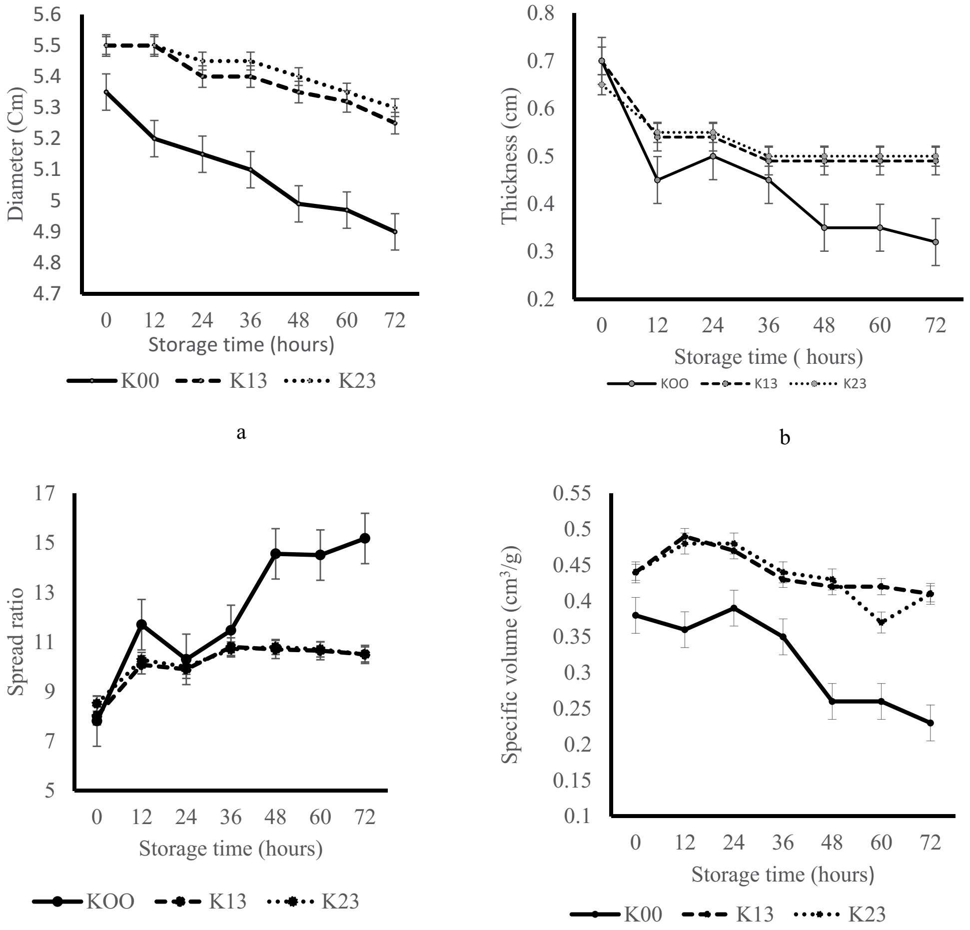


Figure 1. Variation in the pH of original and nutritionally enhanced cassava-based pancakes (*kabalagala*) stored at ambient temperature (25–30°C) for 72 hours. K00: control; K13: formula for children 2–3 years; K23: formula for children 4–5 years.



a

b

c

d

Figure 2. Variation in physical properties; (a) diameter, (b) thickness, (c) spread ratio, (d) specific volume of original and nutritionally enhanced cassava-based pancakes (*Kabalagala*) stored at ambient temperature (25–30°C) for 72 hours. K00: control; K13: formula for children 2–3 years; K23: formula for children 4–5 years.

types of *kabalagala* throughout the storage period, therefore, no result is presented on this aspect of the oxidative quality of the samples.

Results comparing the total microbial count (log CFU/g) of various *kabalagala* products are presented in (Figure 4). Total microbial counts were significantly higher ($p \leq 0.05$) in K13 and K23 compared to K00 throughout the storage period except at the initial time and 12 hours of storage. At sampling points for which the total microbial counts were higher K13 and K23, the difference in the counts of the organisms between the product K13 or K23, and K00 ranged from 1.98 to 3.56 log CFU/g.

Counts of yeast and molds in various *kabalagala* products during storage are presented in (Table 6). Two scenarios were apparent and dependent on the

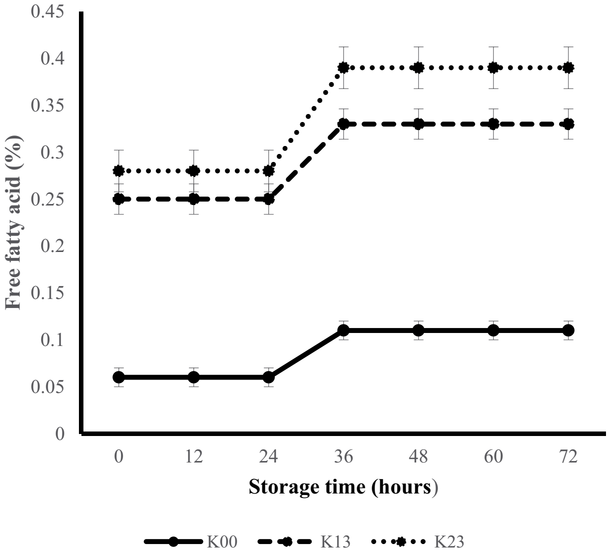


Figure 3. Variation in acid values of original and nutritionally enhanced cassava-based pancakes (*Kabalagala*) stored at ambient temperature (25–30°C) for 72 hours. K00: control; K13: formula for children 2–3 years; K23: formula for children 4–5 years.

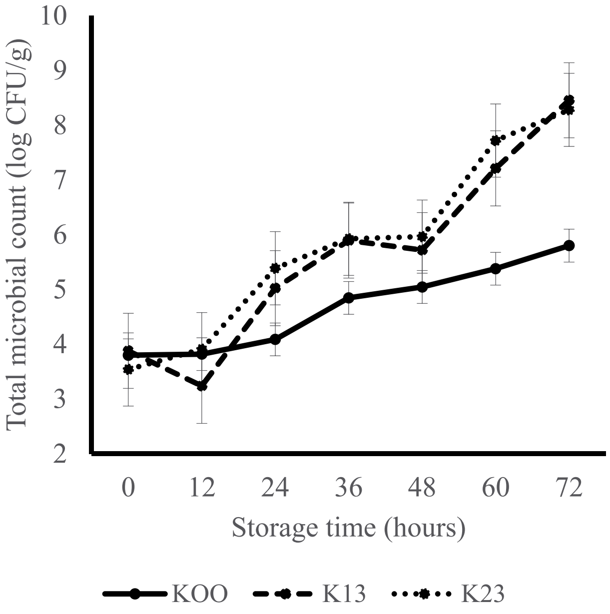


Figure 4. Total microbial count (log CFU/g) in original and nutritionally enhanced cassava-based pancakes (*kabalagala*) stored at ambient temperature (25–30°C) for 72 hours. K00: control; K13: formula for children 2–3 years; K23: formula for children 4–5 years.

formula type. First, for K13 and K23, counts of yeasts and molds were at the detection level of the plate count method (2 log CFU/g) and remained at that

Table 6. Yeast and mold counts (log CFU/g) in original and nutritionally enhanced cassava-based pancakes (*kabalagala*) stored at ambient temperature (25–30°C) for 72 hours.

Pancake formulae	Counts of molds and yeast (logCFU/g)						
Time (Hrs)	**00**	**12**	**24**	**36**	**48**	**60**	**72**
KOO	<LOD ^{a}	<LOD ^{a}	<LOD^{a}	<LOD ^{a}	<LOD ^{a}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}
K13	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}
K23	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}	2.00 ± 0.00^{b}

Values (means ±SD, n = 3) in the same column followed by different superscripts are significantly different at 5% ($p \leq 0.05$). K00: control; K13: formula for children 2–3 years; K23: formula for children 4–5 years; <LOD: below level of detection (2 log CFU/g).

level throughout the storage period. The other scenario which was peculiar to K00 is that counts of those organisms were below the detection level of the plating method and remained at that level till 60 hours when they became detectable and thereafter remained at the detection level of the plate count method till the end of the storage period (72 hours) (Table 6).

Discussion

Sensory acceptability

Consumer acceptability is an important factor that has been shown to affect the success of food-based nutritional inventions in the community (Hely & Monteleoneb, 2009). Acceptability is largely driven by the degree of consumer preference for sensory attributes of the food product in question. Sensory attributes depend largely on the nature of various ingredients used in the formulation (Leksrisompong, Whitson, Truong, & Drake, 2012), the blending ratios (Fikiru et al., 2017) and the processing methods applied (Otolowo & Olapade, 2018). Therefore, the fact that nutritionally enhanced *kabalagala* types (K13 and K23) were most preferred compared to the original *kabalagala* product (K00) could be attributed to improvement in sensory appeal occasioned by the addition of OFSP and iron-rich beans. The findings on color and appearance are in tandem with results obtained in the study by Gebretsadikan, Bultosa, Forsido, and Astatkie (2015) where the addition of OFSP and cowpea in composite porridge ameliorated color and appearance detest by consumers. These results align well with the report of a previous study which shows that the bright orange color of OFSP was more appealing to consumers compared to the common white colored sweet varieties (Leksrisompong et al., 2012).

Flavor and aroma are sensory attributes that occasionally exalt the largest impact on the acceptability of foods and are affected by the kind of ingredients used in food preparation (Cordero, Kiefl, Schieberle, Reichenbach, & Bicchi, 2015). Generally, the aroma arising from beans is generally less preferred by consumers. Thus, the higher score for the aroma of the nutritionally enhanced *kabalagala* types could be due to the presence of OFSP. The stronger and more appealing flavor of OFSP could have masked the undesirable flavor and aroma of iron-rich beans thus making the nutritionally enhanced *kabalagala* types more desirable. This finding corroborates with what was reported by Gebretsadikan et al. (2015) for composite porridge made of sweet potato, soybean and moringa in Ethiopia. In addition, the release of flavor compounds by non-enzymatic (Maillard) reaction during the frying process could have contributed to the higher score for aroma and flavor of the nutritionally enhanced *kabalagala*. This is because the nutritionally enhanced *kabalagala* types had higher protein content, a key macromolecule that provides reactants (amino acids) for Maillard reaction types (Lawal, Idowu, Malomo, Badejo, & Fagbemi, 2021). This assertion also draws credence from the fact that Maillard reaction enhanced the acceptability of ready-to-eat snacks made from cowpea flour, an ingredient that contains high amount of protein (Agbon et al., 2010).

The higher scores for the texture of nutritionally enhanced *kabalagala* types compared to original *kabalagala* could be due to higher level of fiber contained in OFSP and iron-rich beans (Kotue et al., 2018). This inference is based on the findings of a study that showed that dietary fiber reduced firmness in food products thus making the texture more desirable (Raju & Pal, 2014). The sense of taste is a chemical phenomenon that involves taste stimuli falling on the taste receptors (Tadesse, Nigusse, & Kurabachew, 2015a and sensory attributes depend on ingredients (Adeyeye, 2020). Thus the higher scores for the taste of the nutritionally enhanced *kabalagala* types compared to the original *kabalagala* could be attributed to the relatively high sugar content due to inclusion of OFSP (Honi, Mukisa, & Mongi, 2017) and the associated chemical processes following heat treatment. The result which show a significantly higher score in terms of overall acceptability for the nutritionally enhanced *kabalagala* types is in agreement with the outcome of investigations conducted by Haile and Getahun (2018) which showed high overall acceptability of complementary processed food formulated using OFSP and common beans. This indeed provides additional evidence illustrating the contribution of OFSP to the positive sensory attributes of nutritionally enhanced products observed in the current study.

Nutritional composition

Determination of nutritional composition is essential to provide evidence of enhanced nutritional quality arising from food composite formulation. Whereas this study focused on vitamin A and iron, the source ingredients (OFSP and iron-rich beans) inevitably contain other nutrients. This implies that inclusion of OFSP and iron-rich beans in the original *kabalagala* did not only affect the iron and vitamin A contents but the levels of other macro and micronutrients as well.

Indeed, proximate contents of nutritionally enhanced *kabalagala* types were higher than in the original *kabalagala*. The increase in crude protein upon addition of OFSP and iron-rich beans could be due to the higher concentration of protein in iron-rich beans. Legumes such as beans are known to be good plant sources of proteins (Messina, 2014) and their inclusion in recipe formulation can lead to significant improvement in the protein contents of the final products. This was illustrated in a previous study where the addition of cowpea flour to cassava was found to improve protein content of *fufu* (Agbon et al., 2010). Despite the improvement in protein content of the nutritionally enhanced *kabalagala* types observed in the current study, it is important to appreciate that legumes generally contain anti-nutritional factors that affect the bioavailability of proteins (Adeyeye et al., 2019). Future studies need to investigate the bioavailability of proteins in the newly designed products.

The crude fat content increased with the addition of OFSP and iron-rich beans although the two ingredients do not contain substantial quantities of fat. This observation can be attributed to increased level of protein in the nutritionally enhanced *kabalagala* types occasioned by the inclusion of iron-rich beans. The increase in protein content could have led to a higher quantity of oil absorbed by the nutritionally enhanced *kabalagala* types. This is because proteins have a high oil binding capacity (Meinlschmidt, Sussmann, Schweiggert-weisz, & Eisner, 2015). Previously, it was reported that soybean flour inclusion in wheat flour increased the fat content of a cake and the increase was largely attributed to the high protein content of soybean (Sanful, Sadik, & Darko, 2010). A similar result was also reported by Adeyeye et al. (2019) for cookies food made of sorghum and soybeans. Dry beans are a good source of fiber (Messina, 2014), and this could have contributed significantly to the higher fiber content of products containing OFSP and iron-rich beans. Fiber found in dry beans is mostly in the form of a soluble fraction (Messina, 2014). Soluble fiber dissolves in the presence of water, softening the stool and making it easier to pass through the gastrointestinal tract, thus leading to reduced chances of occurrence of constipation (Loening-baucke, Miele, & Staiano, 2017). This is likely to exert a positive effect on the gut-health of children considering the fact that the presence of a sufficient amount of fiber in food has been reported to be just as effective as lactulose in alleviating constipation in children (Kokke et al., 2008). The higher level of carbohydrate detected in pancakes without OFSP and iron-rich beans can be attributed to the higher share of cassava flour, which has a high carbohydrate content (Agbon et al., 2010). Therefore, the high calorie content detected in the nutritionally enhanced *kabalagala* types despite the lower carbohydrate content indicates that fat is the major contributor in this case because iron-rich beans contain a high level of protein, a macromolecule with a high propensity for fat absorption (Kaushik et al., 2016). A similar finding was also reported by

Bassey, Mcwatters, Edem, and Iwegbue (2013) for weaning food made of cowpeas, bananas, and peanuts.

The lower levels of moisture recorded for nutritionally enhanced *kabalagala* types could be attributed to a reduction in starch levels in the nutritionally enhanced *kabalagala* types because of the substitution effect of iron-rich beans and OFSP on the cassava fraction in the formulae. This is because cassava contains about 80% starch and has a high ability to bind water due to its high content of amylopectin (Montagnac, Davis, & Tanumihardjo, 2009). The low level of moisture in the nutritionally enhanced *kabalagala* types implies that children consuming them will have access to substantial amounts of nutrients that are usually lacking in the household diet.

The higher content of ash in the nutritionally enhanced *kabalagala* types is likely due to the higher concentration of minerals in iron-rich beans (Amongi, Mukankusi, Sebuliba, & Mukamuhirwa, 2018). Similar results were reported by Adegunwa et al. (2015) in a product made of maize and pigeon pea flours. Furthermore, in a study conducted by Gebretsadikan et al. (2015), the total ash content of a composite porridge was positively influenced by OFSP, soybean and moringa inclusion. The improvement was attributed to the high content of minerals in soybean and moringa. The higher total mineral content of the nutritionally enhanced *kabalagala* types suggests that such products would contribute to the general mineral nutrition of the children targeted beyond just iron and Vitamin A. For example, Amagloh and Coad (2014) reported a higher level of calcium in OFSP and legume blend compared to maize and legume blend. Higher levels of magnesium, phosphorus, and zinc were reported in food containing a higher ratio of beans (Mahmoud, Mohammed, & Anany, 2018). Relatedly, the higher level of vitamin C detected in the nutritionally enhanced *kabalagala* types could have been triggered by the inclusion of OFSP. This is because a substantial quantity of vitamin C has been detected in OFSP (Koala et al., 2013). Similar results were observed by Bibiana, Grace, and Julius (2014) who reported a significant increment in vitamin C level when OFSP was blended with maize. The high amount of vitamin C found in the nutritionally enhanced *kabalagala* types is of particular importance because of its ability to enhance the bioavailability of non-heme iron in plant based-foods (Amagloh & Coad, 2014). This is likely to improve the bioavailability of iron from the nutritionally enhanced *kabalagala* types. However, the level of antinutritional factors that could affect the bioavailability of iron and other nutrients in the nutritionally enhanced *kabalagala* types was not investigated. This is a potential area for future investigation.

OFSP flour is an excellent source of bioavailable β-carotene which is the carotenoid with the highest pro-vitamin A activity (100%) because it can be entirely converted into two molecules of vitamin A (retinol) (Omoba et al., 2020). In the current study, it has been adduced that consumption of 100 g (approximately four pieces) of the nutritionally enhanced *kabalagala* types by the target children would be sufficient to meet their daily mean vitamin A requirements. This implies that consumption of the nutritionally enhanced *kabalagala* products can potentially contribute to alleviating vitamin A deficiency among children and should therefore be promoted among communities where *kabalagala* is consumed. The observed improvement in the β-carotene content of the *Kabalagala* following the addition of OFSP and iron-rich beans concurs with the findings of previous studies. Typical examples are the works that demonstrated that an increase in β-carotene content corresponded with an increase in the proportion of OFSP supplementation in different products (Edun et al., 2019; Amagloh et al., 2012). On the other hand, the higher iron content recorded in nutritionally enhanced *kabalagala* products can directly be attributed to the addition of iron-rich beans since this particular type of beans is a good source of iron (Mulambu, 2017). As illustrated in the results section, 100 g (approximately four pieces) of the nutritionally enhanced *kabalagala* types contain more iron than can be expected on the basis of RDA for children in the age categories for which the products were developed. In general terms, therefore, results on nutritional composition illustrate clearly that the addition of OFSP and iron-rich beans to kabalagala, increases not only the vitamin A and iron contents of the product but also other essential nutrients needed to promote the healthy growth of children. By extrapolation, it can therefore be postulated that promotion of the nutritionally enhanced *kabalagala* products can contribute to improved intake of iron by children 2–5 years old.

Storage stability

The pH of a food product is not only an indicator of storage stability but also determines the sensory acceptability of food products (Tahsiri, Niakousari, Seyed, & Hosseini, 2017). The generally lower pH recorded in the original *kabalagala* during storage could be due to the higher proportion of cassava in the formula. Cassava flour contributes to the increased acidity of food products due to its high content of fermentable carbohydrate (Fasoyiro, 2015). On the other hand, the higher pH of the nutritionally enhanced *kabalagala* types could be due to the buffering effect of protein (Coda et al., 2015), contributed by the added iron-rich beans. This is because beans are a major source of protein and iron-rich beans, in particular, contain up to 30% protein (Nakitto, Muyonga, & Nakimbugwe, 2015). The range of pH values observed in this study (5.91 to 6.16) for both the original *kabalagala* and nutritionally enhanced *kabalagala* types are within the acceptable level of pH for ready to eat food products. Low pH values are known to inhibit the growth of undesirable microorganisms in food (Yassoralipour, Bakar, Rahman, Bakar, & Golkhandan, 2013). Thus, the higher pH values detected in the nutritionally enhanced *kabalagala* types could imply a more rapid growth of microorganisms, leading to a lower shelf life of the products compared to the original *kabalagala*. This is indeed reflected in the microbiological results component of storage stability which show higher microbial load in the nutritionally enhanced *kabalagala* products compared to the original product.

There were interesting scenarios observed with respect to the physical parameters of the nutritionally enhanced *kabalagala* products during storage. Higher values recorded for the thickness of the nutritionally enhanced *kabalagala* products after 36 hours of storage suggests that OFSP and iron-rich beans contributed positively to maintain the product size. The literature on consumer behavior indicates that consistency in product parameters such as size is important for customer loyalty (Kohajdová, Karovičová, & Magala, 2013). The higher and consistent size of the nutritionally enhanced *kabalagala* products compared to the original product could be attributed to the high water retention capacity of protein in iron-rich beans (Kohajdová et al., 2013). It was interesting to note that the spread ratio was higher for the original *kabalagala* compared to values observed for the nutritionally enhanced products at the endpoint of the storage period. This is largely a consequence of the progressive decrease in the thickness of original *kabalagala* yet diameter remained nearly unchanged throughout the storage period. A similar finding was reported for pancakes enriched with freeze-dried date pomace (Messaoudi & Fahloul, 2018). Specific volume is a more precise measurement of product size. Thus, the higher values recorded for specific volumes of nutritionally enhanced *kabalagala* products illustrates further the significance of OFSP and iron-rich beans in enhancing and maintaining product size. As already indicated for product thickness, the higher value of the specific volume of the nutritionally enhanced *kabalagala* products could be attributed to the interaction between the starch (provided by sweet potato and cassava) and proteins in iron rich-beans leading to volume stability during storage (Oumarou, Issoufou, Tidjani, & Min, 2017). Higher values for thickness and specific volume exhibited by nutritionally enhanced *kabalagala* products are important indicators that consumers prefer (Messaoudi & Fahloul, 2018). This is because, from an economic point of view, consumers prefer to pay for higher product size if other factors are constant (Kohajdová et al., 2013). This implies that incorporation of iron-rich beans and OFSP in product formulation is likely to impact positively on consumer willingness to pay for these products and hence the economic success of the products in the market place.

Lipid deterioration is an important factor that affects the storage stability and the nutritional quality of oily foods (Oke, Idowu, Sobukola, Adeyeye, & Akinsola, 2018). In terms of the integrity of triglycerides and fatty acids, nutritionally enhanced *kabalagala* types had higher levels of free fatty acids indicating that the ingredients (OFSP and/or iron-rich beans) had factors that promoted thermal hydrolysis of the oil during heat processing of the new products. The suggested catalytic effect could be attributed to iron from iron-rich beans. This assertion finds credence from the work of Homma, Johnson, Mcclements, and Decker (2016) which shows that the catalytic effect of metal ions was highest with copper followed by iron and aluminum. Although the free fatty acid content was higher in nutritionally enhanced *kabalagala* products, all the values were within the recommended acceptable range (≤0.5%) for consumption throughout the storage period (Ibeanu, Ene-Obong, Peter-Ogba, & Onyechi, 2015). This implies that the keeping quality in terms of hydrolytic rancidity of *kabalagala* was not affected by the addition of OFSP and iron-rich beans. The fact that peroxides were not detected in any of the *kabalagala* products despite the presence of free fatty acids indicates that lipid oxidation was limited or the storage period investigated was less than the induction period. The rationale for the latter assertion is that the high level of iron in the nutritionally enhanced *kabalagala* products is a good precondition for lipid oxidation because iron is a strong pro-oxidant (Homma et al., 2016).

An important microbiological outcome of the storage stability experiment is that microbial counts were higher and increased significantly in nutritionally enhanced *kabalagala* products during storage. Since microbial stability is influenced by nutrient content (Adeyeye et al., 2019), the higher total microbial load detected in nutritionally enhanced *kabalagala* products at each sampling point during storage is likely a consequence of the higher nutrient contents of the pancakes occasioned by the addition of OFSP and iron-rich beans. Nevertheless, considering that proteinous foods support the growth of microorganisms better than non-proteinous foods, it is plausible to suggest that the higher level of microbial load detected in nutritionally enhanced *kabalagala* products was largely contributed by iron-rich beans because they are the major source of protein. The relatively low levels of yeast and molds in the nutritionally enhanced *kabalagala* products throughout the storage period imply that the high level of total microbial count detected was largely due to bacterial flora. Thus, the shortening of the shelf life of the nutritionally enhanced *kabalagala* products was largely brought about by bacterial growth. Ready-to-eat foods with microbial loads between 4 and 5 log CFU/g are tolerable and those containing 6 log CFU/g and above are unacceptable (Neha & Shobha, 2015). Microbial counts in the products (3.80 to 5.89 log CFU/g) were within the acceptable limit till 48 hours when they exceeded the tolerable limit in the case of nutritionally enhanced *kabalagala* products. This implies that the addition of OFSP and iron-rich beans shortened the shelf life of the *kabalagala* from a microbiological point of view. By inference, therefore, from a microbiological point of view, the nutritionally enhanced *kabalagala* products can remain fit for consumption for up to a period of 48 hours when packed in plastic containers and stored at room temperature. These results clearly illustrate that the addition of OFSP and iron-rich beans improves physical properties but compromises the microbial shelf life of the *kabalagala*. Future studies should therefore look at how to improve the microbial shelf life of the nutritionally enhanced *kabalagala* products to enable nutritional benefits to be adequately realized.

Conclusion

This study has demonstrated the potential of OFSP and iron-rich beans for application in processing *kabalaga* to address vitamin A and iron needs of children 2–5 years old. The new products developed have higher contents of macro and other micronutrients which can potentially enable children to benefit beyond just vitamin A and iron. Enhanced sensory appeal and overall acceptability as well as improved physical properties of the new products position them for wider acceptance and use in society. This means that promoting the nutritionally enhanced *kabalagala* types is unlikely to encounter acceptability challenges. Above all the nutritionally enhanced *kabalagala* products are stable to oxidative rancidity despite the higher level of free fatty acids and iron as compared to the original *kabalagala*. Despite these positive effects, the addition of OFSP and iron-rich beans reduced the shelf life of *kabalagala* from 72 hours to just 48 hours.

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