PRODUCT DEVELOPMENT, NUTRIENT ANALYSIS AND SENSORY EVALUATION OF MAIZE CHIPS, ENHANCED WITH MORINGA *OLIEFERA*

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ABSTRACT

Product development of nutritionally enhanced foods, to improve food and nutrition security in developing countries, has gained momentum over the years. This study involved the product development optimization, analysis of nutrient and physiochemical content of a maize chip, enhanced with moringa *oliefera*, as a nutritious and safe snack for children. Food product development trials, nutritional analysis and microbiological testing were conducted. Two samples of moringa maize chip were developed: sample 1 (1 g moringa / 22 g portion of maize chips) and sample 2 (2 g moringa / 22g portion of maize chips). Samples 1 and 2 contained 1.81 g and 2.27 g of fat, 84.9 µg and 100.2 µg of vitamin A and 220 mg and 273 mg of calcium, respectively. Sensory evaluation of the product developed was conducted through a cross-sectional study. One hundred children, aged 9–13 years from four schools were recruited through stratified random sampling from Verulam, Durban, South Africa. Using a validated five-point facial hedonic scale, sensory evaluation revealed that the chips, containing 2 g moringa, were preferred to those with 1 g moringa, for taste and texture. The promising nutritional analysis results and sensory evaluation outcomes indicated the potential for maize chips containing moringa, to serve as a healthier, sensory acceptable snack suitable for children.

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ARTICLE INFO

Received August 2019
Revised April 2020
Accepted August 2020

KEYWORDS

children, moringa, chips, sensory, nutrient deficiencies

INTRODUCTION

The South African National Health and Nutrition Survey (SANHANES-1 Report), as well as the United Nations Children's Fund, identified vitamin A and zinc as two of the micronutrients that are especially important for women and children who live in developing countries (Shisana, 2013; UNICEF, 2009). A review of 55 studies on the levels of iron, zinc, iodine and vitamin A in adolescents in four African countries, revealed that deficiencies of these nutrients are a widespread problem that needs to be addressed (Harika *et al.*, 2017). Vitamin A deficiency (VAD) is regarded as one of the main contributory factors towards preventable blindness in children. This deficiency also increases a child's risk of disease and possible mortality as a result of severe infections. Hence, VAD is regarded as a public health problem observed in several low-income countries, with children and pregnant women being mostly affected (World Health Organisation, 2016). A number of strategies have been used as solutions to micronutrient deficiencies, including supplementation, fortification of food products, public health approaches and food-based approaches (Institute of Medicine, 1998). Planning for sustained intervention should ideally consider all four strategies where appropriate and feasible however, the long-term goal of intervention is rather to move emphasis away from supplementation towards a combination of food fortification and food-based approaches where necessary and feasible to maintain change (Institute of Medicine, 1998). The use of locally available, affordable and culturally acceptable nutrient dense foods would be a more suitable strategy for combating child malnutrition among low-income, rural communities (Adedodun *et al.,* 2010)

Part of the solution of a food based approach could be found in the incorporation of moringa (Moringa *oliefera* L.) in value added products, aimed at children, as it is a sustainable solution for malnutrition (Gopalakrishnan *et al.,* 2016). Whilst snacks play an integral part of a child's diet, the current school food environment in resource-constrained settings in South Africa is filled with energy dense, low micronutrient snacks, raising concerns about the effects of these snacks on child nutritional outcomes (Faber *et al*., 2014). With increasing popularity of moringa products in South Africa, product development of a sensorially acceptable snack enhanced with moringa is warranted as a solution to create a healthy snack with the potential for a positive nutritional outcome (Potter *et al*., 2013).

Belonging to the Moringaceae family, this fast-growing tree, which is native to India, but grown throughout the world, is commonly referred to as a 'miracle tree (Foidl *et al*., 2001). Moringa arrived in South Africa (SA) several years ago, however it is only recently that this super food has gained popularity (Naidoo & Coopoosamy, 2011). Not many settlers were informed about the nutritional benefits of plants and the Ayurvedic properties (India's natural and traditional system of medicine) these plants possess (Naidoo & Coopoosamy, 2011). The moringa tree was planted once the settlers arrived in SA, and provided a nutrient rich food source (Naidoo & Coopoosamy, 2011). The provinces in SA that are cultivating the moringa tree are Limpopo, KwaZulu-Natal (KZN) and Mpumalanga. Moringa is grown on a subsistence and commercial level in these provinces. Moringa was first reported being planted for a feeding project for children in rural South African communities (Lekgau, 2012).

Practically, the tree does not require much water or soil nutrients, thus, reducing cultivation costs. Another advantage, is that it is in "full leaf" during dry seasons, when few vegetative crops are available for consumption (Foidl *et al*., 2001). In many countries, notably India, the Philippines, Pakistan, Hawaii and numerous other parts of Africa, moringa (leaves, berries, flowers and pods) is used as a nutrient-dense plant. The moringa leaf is of particular importance, having been identified as containing several nutrients (Foidl *et al*., 2001), such as vitamin A, vitamin C, digestible protein, calcium and non-heme iron (Fahey, 2005; Foidl *et al*., 2001; Naidoo & Coopoosamy, 2011). The leaves can be consumed fresh (raw), in cooked form, or dried and crushed into a powder. The long shelf-life of dried moringa is especially important in rural households, where refrigeration facilities are limited (Fahey, 2005; Foidl *et al*., 2001).

Moringa can be regarded as a sustainable route to nutritionally enhance food items. Studies, using moringa as a means of nutritional enhancement, displayed positive results in terms of higher nutrient levels (such as iron, beta-carotene, vitamin C, calcium and potassium), sensory acceptance, as well as improvement in nutritional status (Manaois *et al*., 2013; Ntila *et al*., 2018; Srinivasamurthy *et al.,* 2017). However, there is a scarcity of research on product development using moringa in SA. Food product development, using moringa, presents obstacles, due to the inherent bitterness of the plant. One study reported that an increase in the amount of moringa, used in food product development of rice crackers, was proportional to the decline in consumer acceptability (Manaois *et al*., 2013). This highlights the importance of achieving consumer acceptance during the food product development process, which is vital to the overall success of products (Manaois *et al*., 2013).

The results of a preliminary study on snacking preferences, preceding the product development reported in this study (observation study, focus group discussion and snack food frequency questionnaire), showed that maize snacks were popular among school children in low socio-economic settings (Govender *et al*., 2018). Therefore, the aim of this study was to develop a safe and sensorially acceptable snack chip, enhanced with moringa, as a healthier alternative to currently available snacks (corn chips) (Govender *et al*., 2018; Manaois *et al*., 2013; Potter *et al*., 2013).

METHODOLOGY

Setting

Primary schools in Verulam from the eThekwini municipality in Kwa- Zulu Natal (KZN) were used in this study. A list of the schools in quintile 1-4 was obtained from the Department of Education for KZN and from this 41 primary schools where identified in the Verulam area. We then randomly selected six schools from a list of 11 schools within a 10km radius from Verulam central area. We contacted all the schools telephonically to gauge their interest to participate in this study. Four primary schools agreed to participate in this study after a formal meeting with their management. We thereafter concluded the permission to conduct research at the schools. Letters of information were given to all potential participants through the registration teacher, to obtain permission from their parents/ guardian, to partake in the study. Stratified random sampling, which entailed separating the population into strata (in terms of grades 4-7), was used to obtain a sample of 100 children between the ages of 9-13 years. For sensory evaluation, it has been documented that 60-100 participants are sufficient for a sensory evaluation test (Blaak *et al.,* 2018). Upon receipt of the completed informed consent, the consumer acceptance testing was conducted among 100 children (25 children from each grade, giving a total of 62 girls and 38 boys).

Product development of the moringa enhanced chip

Using the steps for food product development, chip development was subjected to three trials in a test kitchen with in- house sensory evaluation by a trained panel. The ingredient specification involved the sourcing of ingredients and sample retention for consistency. The dried moringa leaf (coarsely crushed) was sourced from a certified local supplier, based in KZN. White maize meal (Ace) and polenta (Woolworths), for colour, were purchased from a local commercial shop. Wheat was omitted from the ingredients, to limit the risk of an allergic reaction to gluten. A retention sample of the gold standard used for each trial was kept in a temperature-controlled environment. The particle size of the moringa to be used in the chip development was determined by an internal screening panel whereby it was established the coarsely crushed moringa leaf was preferred over powdered moringa. It was agreed that a small amount of flavour enhancer; sugar would be added to the recipe to mask the natural bitterness of moringa (Fahey, 2005; Foidl *et al*., 2001; Manaois *et al*., 2013). Given that the usual methods of cooking chips use large amounts of fat; it was decided to use a Philips Air-Fryer HD9220/56™ to lower the fat content of the chips. Air-frying lowers the fat content while maintaining acceptable sensory scores. A heating element and a fan is used to circulate the air, hence the name "air-fryer" (Shaker, 2015). In formulating the recipe and portion yield, cooked weight loss was taken into account to comply with the predetermined portion size. The portion size of the chip was determined using the standardized size of chip packets commonly purchased at schools identified in the formative part of this study.

Nutritional analysis and microbiological testing

Nutrient testing was conducted on the formulations, to determine the carbohydrate, protein, sodium, vitamin A, zinc and calcium content. A South African National Accreditation Systems (SANAS) laboratory was used to determine the micronutrient content, according to the Association of Analytical Communities (AOAC) standardised methods of analysis (Govender *et al.* 2016). Laboratory technicians from the Department of Food Technology at the Durban University of Technology (DUT) calculated the carbohydrate, fat, energy and sodium values, using AOAC standardized methods (Association of Analytical Chemists, 2005; Govender *et al*., 2016). Microbiological testing (total plate count, yeasts and moulds) was also conducted, to make certain that the snack food item was suitable for human consumption. The testing indicated the products safe for consumption according to the Foodstuffs, Cosmetics and Disinfectants Act, Government notice R427 Regulations, governing microbiological standards for foodstuffs and related matters (Department of Health, 2002). Moringa is regarded as being safe for consumption since there are no known allergens (Ferreira *et al*., 2008; Pakade, *et al.,* 2013).

Sensory evaluation

The sensory evaluation was conducted at four schools before the first break in the school day. Each sample was assigned a different three-digit code, acquired from a table of random numbers. To further reduce bias, the children were seated a metre away from each other and were requested not to communicate during the sessions (Ntila *et al*., 2018). All children were provided with a glass of water, a serviette and two small tubs, containing 10 g of the two samples. The validated sensory evaluation questionnaires were in the form of a five-point facial hedonic scale (1 = super bad; 5 = super good) (Govender, 2016; Guinard, 2000).

The following instructions were given:

- please be as honest as possible;
- drink a sip of water;
- open the container on your left hand side, remove a chip and look at the chip. Now tick under the face that you think best describes the chip's appearance;
- next take another chip from the container and taste it. Now tick under the face that you think best describes the chip's taste;
- take another chip from the same container and place it in your mouth. Now tick under the face that you think best describes the chip's mouth feel / texture; and
- repeat for the sample on the right hand side (Govender, 2016).

Data analysis

The Statistical Package for Social Sciences (SPSS) version 23® (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY) was used to analyse the collected data. The results were reported as descriptive statistics in the form of cross tabulations. Fisher's Exact Test ($P<0.05$) was used to determine a significant relationship between gender and grade for sample 1 and 2 with the sensory variables (appearance, taste and texture)

Ethical considerations – Permission to conduct the research study was obtained from the Durban University of Technology (DUT) (IREC 040/14), South African Department of Education (by written consent), the participants' parents (by written consent) and the participants (by verbal consent).

Validity – Validation of the consumer acceptance questionnaire was conducted prior to the sensory evaluation sessions. A pilot study was conducted (n=5) with five children, who reflected the sample population. These children were excluded from the main study, to reduce bias.

RESULTS

Product development

Two samples of the chips were made, each containing a different amount of moringa (1 g and 2 g moringa / 22 g portion of maize chip) after three trials to perfect the formulation. The method used (Table 1) was a hybrid version of the process used to make maize chips and a South African method for preparing maize flat bread (Govender, 2016; Feroni, 2018; Mayat, 1993). The recipe was formulated to yield 110 g of moringa chips (5 x 22 g portion), hence each batch contained either 5 g or 10 g of moringa per 110 g of chips (Table 1).

Nutritional composition and microbiological testing

Nutritional analysis indicated there was relatively more vitamin A, calcium and total fat in sample 2, compared to sample 1, while the two samples had approximately the same amount of total carbohydrates, protein, sodium and zinc (Table 2).
A comparison between the nutritional content of the two moringa chip samples and a popular brand of maize chips indicated the latter to be higher in energy, protein, fat and sodium than the moringa samples (Table 3).

Microbiological testing indicated that the chips were safe for consumption as the yeast and mould counts were within the acceptable limits (Department of Health, 2002) (Table 4).

Sensory evaluation

The number of informed consents received dictated the participation level by gender. Figure 1 shows a considerable difference in gender distribution among the grade 5 & 6 participants, with more girls participating in the sensory evaluation. However, gender distribution was fairly equal in grades 4 & 7.

In terms of the sensory evaluation results (Table 5), on average the appearance of sample 2 was selected as the first choice slightly over sample 1. In terms of appearance, the younger children (Grades 4 & 5) rated sample 2 more favourably than the older children (Grades 6 & 7). The majority of children in all grades rated the taste of sample 2 as being acceptable, compared to sample 1 (Table 6). In terms of texture, sample 2 was preferred over sample 1, by all the children (Table 7).

With regards to the sensory attributes, there was no significant relationship with either the learner's grade or gender for sample 1 ($p>0.05$) (Table 8). However, the grade of the learner (i.e., age) influenced whether the appearance appealed to them or not ($p=0.040$) for sample 2. Likewise, gender of the learner influenced the acceptance of the texture of sample 2 (2 g moringa /22 g serving) ($p=0.040$) (Table 9). It was apparent that the appearance of sample 2 was preferred by the younger children.

DISCUSSION

Product development

product development systematically, a chip enhanced with moringa was developed. Numerous ideas can be generated at the concept stage, but a challenge exists in selecting the most viable ideas or concepts (Institute of Food Science and Technology, 2015). With this in mind, a number of small scale kitchen trials of chip recipes enhanced with moringa were conducted. The testing process was used to assist in selecting and improving the most viable recipe for further development (Winger, 2009: 457). During the development of the moringa maize chip several in-house sensory evaluation tests were done in a quest to

TABLE 1: MORINGA CHIPS RECIPE

Recipe yield	110 g of chips
Special equipment	Pasta machine Air-fryer
Cooking temperature	100°C – for the dough 160°C – in the air-fryer
Number of servings	5 portions (22 g/ portion)

Ingredient	Qty.	Step	Method
Water (ml)	125	1	Place the water, salt, sugar and sunflower oil in a pot and bring to the boil.
Salt (g)	3.5	2	In a bowl, mix the polenta and maize meal until well combined.
Sugar (g)	0.35	3	Slowly add the polenta and maize meal to the boiling water while constantly stirring to a smooth paste.
Sunflower oil (ml)	1.25	4	Reduce the heat to low and stir for 7 minutes or until the mixture forms a skin on the bottom of the pot.
Polenta (g)	50 (sample 1) 45 (sample 2)	5	Place the mixture into a bowl and leave to cool before adding the dried moringa leaf.
Maize meal (g)	50	6	Divide the dough into smaller portions and pass through pasta machine (thinnest setting).
*Moringa leaf (dried) (g)	5 (sample 1) 10 (sample 2)	7	Cut the chips into 4 cm x 2.5 cm rectangular pieces; add a light coating of cooking spray over the chips.
BBQ seasoning (g)	4	8	Place the chips in the air-fryer basket and then into the air-fryer. Set the control for 9 minutes at 160°C.
		9	Remove from the air-fryer; coat the chips with cooking spray and place into a plastic packet with the seasoning. Shake the packet, allowing for the chips to be evenly coated with the seasoning.

TABLE 2: NUTRIENT ANALYSIS OF MORINGA CHIPS (100 G), SAMPLES 1 AND 2, CONTAINING 1 G AND 2 G OF MORINGA LEAF PER 22 G SAMPLE, RESPECTIVELY

Nutrient/ 100 g	Sample 1 (1 g moringa/22 g)	Sample 2 (2 g moringa/22 g)
Total fat (g)	1.81	2.27
Total carbohydrates (g)	90.8	88.5
Protein (g)	0.4	0.4
Sodium (mg)	239.2	239.7
Vitamin A as retinol (µg)	84.9	100.2
Calcium (mg)	220	273
Zinc	2.05	1.9

TABLE 3: NUTRITIONAL COMPARISON OF A POPULAR BRAND OF CORN CHIPS AND THE MORINGA CORN CHIPS PER 22 G PORTION

	Energy (kJ)	Protein (g)	Total carbohydrates (g)	Total fat (g)	Sodium (mg)
Sample 1	336	0.1	20	0.4	52.7
Sample 2	333	0.1	19.5	0.5	52.8
***Popular corn chip**	504	1.4	12	8	100

*Identified in the formative study.

TABLE 4: RESULTS OF THE MICROBIOLOGICAL TESTING OF THE MORINGA CHIPS

	*Permitted number of colonies/1g	Sample 1 (number of colonies/1g)	Sample 2 (number of colonies/1g)
Aerobic bacteria	10^6	328	272
Yeast and moulds	10^4	2568	2128

*Foodstuffs, Cosmetics and Disinfectants Act, Regulations governing microbiological standards for foodstuffs and related matters (2002: 4).

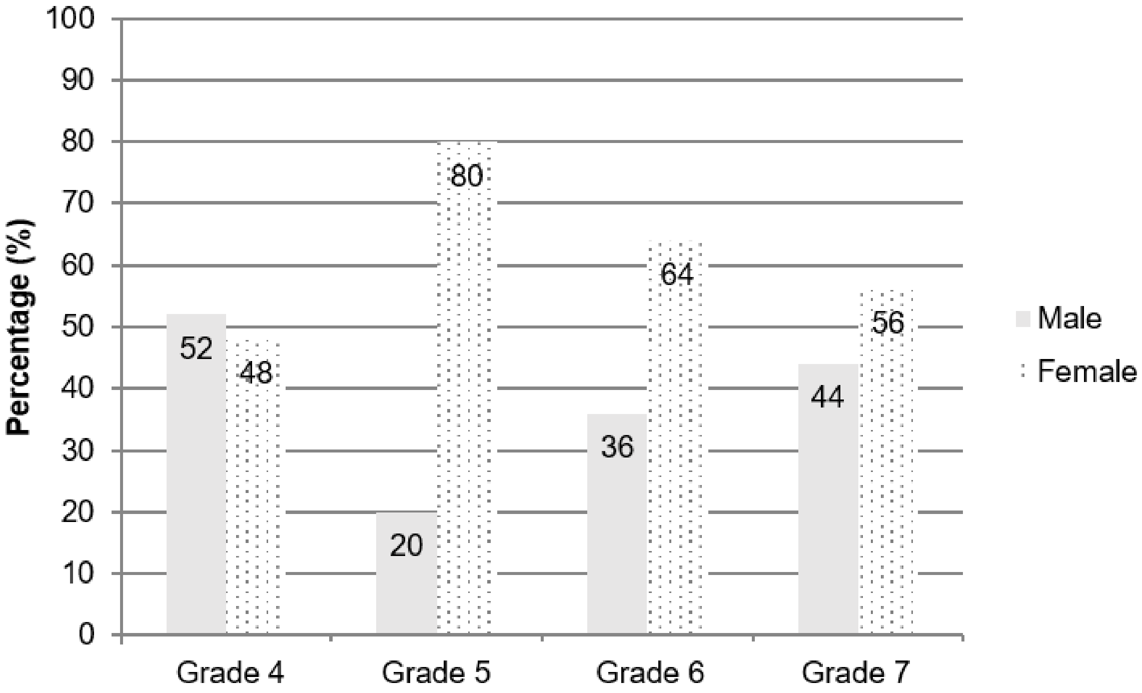

FIGURE 1: GENDER DISTRIBUTION AMONG GRADES 4-7 (N=100) FOR CONSUMER ACCEPTANCE SENSORY EVALUATION

TABLE 5: SENSORY ACCEPTANCE RECORDED BY 100 SCHOOL CHILDREN, IN TERMS OF THEIR SCHOOL GRADE, FOR THE APPEARANCE OF SAMPLE 1 AND SAMPLE 2

Category	Sample 1: Appearance					Sample 2: Appearance				
Grade	Super bad (%)	Bad (%)	Maybe good/ bad (%)	Good (%)	Super good (%)	Super bad (%)	Bad (%)	Maybe good/ bad (%)	Good (%)	Super good (%)
Grade 4 (n=25)	0.0	4.0	20.0	48.0	28.0	8.0	12.0	4.0	24.0	52.0
Grade 5 (n=25)	0.0	0.0	32.0	52.0	16.0	0.0	4.0	20.0	44.0	32.0
Mean Grade 4 & 5	0.0	2.0	26.0	50.0	22.0	4.0	8.0	12.0	34.0	42.0
Grade 6 (n=25)	4.0	12.0	32.0	24.0	28.0	8.0	16.0	20.0	28.0	28.0
Grade 7 (n=25)	4.0	20.0	28.0	40.0	8.0	0.0	28.0	20.0	40.0	12.0
Mean Grade 6 & 7	4.0	16.0	30.0	32.0	18.0	4.0	22.0	20.0	34.0	20.0

TABLE 6: SENSORY ACCEPTANCE RECORDED BY 100 SCHOOL CHILDREN, IN TERMS OF THEIR SCHOOL GRADE, FOR THE TASTE OF SAMPLE 1 AND SAMPLE 2

Category	Sample 1: Taste					Sample 2: Taste				
Grade	Super bad (%)	Bad (%)	Maybe good/ bad (%)	Good (%)	Super good (%)	Super bad (%)	Bad (%)	Maybe good/ bad (%)	Good (%)	Super good (%)
Grade 4 (n=25)	0.0	20.0	12.0	52.0	16.0	4.0	4.0	12.0	36.0	44.0
Grade 5 (n=25)	0.0	12.0	24.0	44.0	20.0	0.0	12.0	20.0	16.0	52.0
Mean Grade 4 & 5	0.0	16.0	18.0	48.0	18.0	2.0	8.0	16.0	26.0	48.0
Grade 6 (n=25)	4.0	24.0	16.0	36.0	20.0	0.0	8.0	8.0	36.0	48.0
Grade 7 (n=25)	8.0	20.0	36.0	28.0	8.0	0.0	16.0	28.0	36.0	20.0
Mean Grade 6 & 7	6.0	22.0	26.0	32.0	14.0	0.0	12.0	18.0	36.0	34.0

TABLE 7: SENSORY ACCEPTANCE RECORDED BY 100 SCHOOL CHILDREN, IN TERMS OF THEIR SCHOOL GRADE, FOR THE TEXTURE OF SAMPLE 1 AND SAMPLE 2

Category	Sample 1: Texture					Sample 2: Texture				
Grade	Super bad (%)	Bad (%)	Maybe good/ bad (%)	Good (%)	Super good (%)	Super bad (%)	Bad (%)	Maybe good/ bad (%)	Good (%)	Super good (%)
Grade 4	12.0	4.0	28.0	20.0	36.0	12.0	0.0	4.0	40.0	44.0
Grade 5	0.0	24.0	20.0	36.0	20.0	4.0	8.0	16.0	44.0	28.0
Mean Grade 4 & 5	6.0	14.0	24.0	28.0	28.0	8.0	4.0	10.0	42.0	36.0
Grade 6	0.0	16.0	24.0	44.0	16.0	0.0	8.0	20.0	32.0	40.0
Grade 7	4.0	36.0	20.0	20.0	20.0	0.0	20.0	20.0	40.0	20.0
Mean Grade 6 & 7	2.0	26.0	22.0	32.0	18.0	0.0	14.0	20	36.0	30.0

TABLE 8: SENSORIAL RELATIONSHIP (FISHER'S EXACT TEST) BETWEEN SAMPLE 1 (1 G MORINGA/22 G SERVING) WITH GENDER AND GRADE (N=100)

	Grade (p value)	Gender (p value)
Appearance	0.141	0.436
Taste	0.490	0.471
Texture	0.096	0.755

Fisher's Exact Test

TABLE 9: SENSORIAL RELATIONSHIP (FISHER'S EXACT TEST) BETWEEN SAMPLE 2 (2 G MORINGA/22 G SERVING) WITH GENDER AND GRADE (N=100)

	Grade (p value)	Gender (p value)
Appearance	0.040*	0.863
Taste	0.197	0.132
Texture	0.141	0.040*

*p value < 0.05 is considered significant
Fisher's Exact Test

perfect the recipe prior to sensory evaluation by the children. Likewise, it had been noted in a study that varying the product formulation and processing methods may contribute to increased success and acceptability of moringa-based foods (Ntila *et al*., 2019).

Nutritional composition and food safety

The nutritional composition of what people eat, is essential to their overall nutritional status. Snacks contribute a significant part of a child's food intake; therefore, the nutritional composition of snacks cannot be ignored (Govender *et al*., 2018; Joseph, 2014; Steiner-Asiedu *et al.,* 2012). Both kinds of moringa chips contained approximately half the quantity of sodium compared with equivalent portion of a popular maize chip brand. Mandatory legislation promulgated in 2016 is directed towards decreasing the amount of sodium in items, such as breakfast cereal, margarines and butter, savoury snacks, potato crisps, processed meats, sausages, soup and gravy powders (Bertram *et al*., 2012). It could, therefore, be deduced that the developed product is in keeping with current legislation requirements, to reduce sodium in developed products.

Diets, high in fats, are reported to contribute to the global obesity pandemic (Swinburn *et al.*, 2011). The nutritional analysis in the present study indicated that both samples of the moringa chips contained almost less than 1 g of fat, compared to 8 g of fat found in an equivalent quantity of maize chips children usually consume. A change in the diet, to consuming foods with reduced fat, may assist in preventing several lifestyle diseases associated with high fat intake (Swinburn *et al.*, 2011).

A study on the food consumption of African - American males revealed that a large percentage of boys, aged 14-16 years, reported to have consumed chips (66%), sweetened juices (62%) and carbonated beverages (62%). The dietary assessment also indicated that the children did not meet the Estimated Average Requirement (EAR) for zinc (Kolahdooz *et al*., 2015). The moringa chips contained 26.0% (sample 1) and 24.0% (sample 2) of the EAR for zinc for children aged 9-13 years old. In addition, the chips contained between 14.0% (sample 1) and 17.0% (sample 2) of the EAR for vitamin A, for children aged 9-13 years old.

A comparison of the nutritional composition of the two kinds of moringa chips, with that of a popular brand of maize chips, indicated that the energy, total fat and sodium content of both the moringa chips were superior to the commercial product. The moringa chips were notably lower in fat. The popular brand of maize chips contained a higher amount of protein, due to the inclusion of hydrolysed vegetable protein (soy), added by the manufacturer (Govender, 2016).
Producing safe food products for consumption is imperative. Guided by food safety principles during the production, the chip was deemed safe for consumption through microbiological testing. However, upscaling the product for commercialization would require further food safety tests.

Sensory evaluation

Moringa is naturally bitter and, if used in powder form, affects the taste of food products. It was, therefore, imperative that sensory analysis was conducted to determine the acceptability of the developed product. The need to develop products that are innovative and sensorially acceptable is essential to their success in the consumer market (Sengev *et al*., 2013).

The appearance of a product also affects its acceptability. From the consumer acceptance test, the appearance of sample 2 was regarded as more acceptable. This is contrary to earlier studies, in which bread and crackers, fortified with moringa leaf powder, resulted in poor sensory acceptability scores, especially in terms of the appearance of the product (Manaois *et al.*, 2013; Sengev *et al*., 2013). The form in which the moringa is used, is also crucial towards acceptability of the product, in terms of appearance and taste. Crushed moringa leaf was used to prepare the moringa chips, instead of moringa powder, which would have turned the colour of the chips green, as was the case for the bread fortified with moringa powder (Sengev *et al*., 2013). Hence, the addition of crushed moringa leaf resulted in a positive response to the final product.

The younger participants (grades 4 & 5) rated the taste for both samples 1 and 2 favourably, whereas a smaller number in grades 6 & 7, indicated a positive response for the taste of sample 1; however, a larger number preferred sample 2. Overall, sample 2 was rated more positively by all grades, compared to sample 1. This is in line with research that indicates that preference for sweetness levels increases with age (Vennerød *et al*., 2018).

Generally, sample 2 was ranked higher in regard to texture. The majority of the children from grades 4 & 5 rated the texture of sample 2 as being acceptable (either “super good” or “good” for the respective grades). In contrast, sample 1 received a higher percentage of the “unacceptable” rating, by all the grades (“bad” and “super bad”). It was established that the texture of sample 2 was more acceptable than that of sample 1. Overall, sample 2 was regarded as more acceptable, in terms of the appearance and texture than sample 1. It could be assumed that the increased moringa in sample 2 had a positive impact on the texture.

Following the steps of product development systematically, ensured the development of an acceptable end product from laboratory to consumer. Limitations existed, where permission to participate in the research study was not obtained from certain children, which contributed to lower participation among boys. Future research should be conducted to evaluate the sensory threshold acceptability of increased moringa content in products developed for maximum impact on nutritional outcomes. The chip developed here shows good potential for introducing it as a snack into national nutrition school feeding programs, however cost effectiveness and product optimization should be explored further for upscaling the recipe.

CONCLUSION

The nutritional content of the moringa chips was generally superior to that of the market chips, for all the nutrients, except protein. Overall, the nutritional content of the formulated moringa chips, together with the positive sensory results, indicated promising results for being a healthier option, compared to the currently available maize chips.

Disclosure statement – No conflict of interest was reported by the authors.

Funding – This research was funded by Nestlé Nutrition Institute of Africa (NNIA). The NNIA had no role in the design, analysis or writing of this article.

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