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Nutritional and sensory properties of instant maize porridge fortified with *Moringa oleifera* leaves and termite (*Macrotermes falciger*) powders

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Abstract

Purpose – White maize-based porridge is a staple food for about 80 per cent consumers in South Africa and in other sub-Saharan African countries contributing significantly to the diet of rural population in developing countries. White maize is deficient in some amino acids and over-dependency on its porridge may lead to high prevalence of malnutrition-related health conditions. *Moringa oleifera* (MO) and termite (*Macrotermes falciger*) are known to contain substantial amount of protein. The purpose of this study was to determine the effect of powders from MO leaves and termite on the nutritional and sensory properties of instant maize porridge.

Design/methodology/approach – Inclusion of MO and termite powder in instant maize porridge, using different treatments were considered using a completely randomised design. Factor levels were control (maize flour) cooked, blanched and uncooked MO samples. Data were analysed using SPSS version 23.

Findings – Protein content of fortified instant maize porridge (FMP) significantly increased from 10.0 to 21.2 per cent compared to unfortified porridge, and this could be attributed to the substitution effect, as fresh uncooked MO leaves are reported to be high in protein. Mineral content of FMP was higher in zinc, iron, calcium and magnesium. Calcium values of FMP were higher (276.8 mg/100 g) compared to unfortified porridge (7.1 mg/100 g). Upon the addition of MO leaves and termite powder, the zinc content increased from 3.4 mg/100to 7.6 mg/100 g. Higher iron values (27.9-36.9 mg/100 g) were observed among fortified samples. The sensory result showed that control sample had higher acceptance than the fortified samples ($p = 0.02$). Sensory analysis showed that among fortified porridges, blanched sample was rated high for colour and texture, cooked sample was higher in taste and uncooked sample was higher for aroma. Control sample had higher acceptance than fortified porridges for taste. The results of this study showed that the addition of MO leaves and termite powder to instant maize porridge has led to a substantial increase in the nutritional value of FMP.

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Originality/value – This study was carried out to develop instant maize porridge fortified with MO leaves and termite powder suitable for infants, pregnant mothers and other maize consumers. The author aimed at improving the nutritional content of instant maize porridge by combining it with MO leaves and termite powders. The results showed that the addition of MO leaves and termite powders to instant maize porridge has led to a substantial increase in the nutritional value of FMP. Therefore, powder from MO leaves and termites could be used in complementary foods to increase protein and mineral contents.

Keywords Instant maize porridge, Moringa, Termite, Protein, Mineral, Acceptability

Paper type Research paper

Introduction

The prevalence of zinc and iron deficiency of children under five years in Vhembe district was 42.6 and 28 per cent, respectively, in 2014 (Motadi *et al.*, 2015). Being anaemic and deficient of zinc in children result in growth retardation, movements' disorders, blackouts, inadequate reaction of the immune and change in conduct (Bothwell, 2007). According to Motadi *et al.* (2015), the prevalence of zinc deficiency and anaemia of children in Vhembe District could possibly be attributed to high intake of maize porridge. Maize porridge is a staple food for most people in South Africa and contributes significantly to the dietary intake of 81 per cent of the households in Limpopo (Mushaphi *et al.*, 2015). However, maize does not provide adequate nutrients for proper health and development. Maize grain contains high amount of phytates, a naturally formed compound during maturation (Janet, 2003). Phytates interfere with the absorption of minerals, such as iron, zinc and calcium by the body. Inadequate intake of these elements causes anaemia *osteomalacia,* zinc deficiency and rickets, respectively (Widowson, 2002).

Cereals, maize in particular, are known to contain low amount of lysine and have been reported to have poor protein digestibility which play a role on the nutritional composition of amino acids (Duodu *et al.*, 2003). This has increased the prevalence of malnutrition and hence requires nutrition intervention strategies. Maize is known to be a poor source of essential nutrients; meaning that the need for nutrition intervention strategies implemented towards improving maize's nutritional contribution especially in underprivileged households is crucial. Because of these; several nutrition intervention strategies have been implemented such as supplementation, fortification, nutrition education and dietary diversification (Ruel and Levine, 2000). Bio-fortification has also been introduced, and its purpose is to enhance the nutritional and well-being status of people in rural places (Nestel *et al.*, 2006).

The fortifying of instant maize porridge with *Moringa oleifera* (MO) leaves and termite powders should be important, as maize-based porridge contributes significantly to the dietary intake of many households in the Limpopo province (Mushaphi *et al.*, 2015). Over-dependency on maize-based porridge may lead to high prevalence of malnutrition-related health conditions. MO leaves and termites were chosen for use in the present study because of their high protein and mineral content. Therefore, using these two to enhance the nutritional composition of instant maize porridge could be one of the sustainable strategies towards the alleviation of malnutrition in the Vhembe District. MO leaves contain essential nutrients such as vitamins, minerals, amino acids, β-carotene, antioxidants, anti-inflammatory nutrients and omega 3 fatty acids (Fahey, 2005; Hsu *et al.*, 2006; Kasolo *et al.*, 2011; Tirhas *et al.*, 2015). Edible termites have been proven to be rich in proteins, vitamins, minerals and the essential amino acid tryptophan which is limited in maize (Defoliart, 2002). Fortifying maize, therefore, with termites could help prevent protein energy malnutrition, improve Fe and Zn status of children and maize porridge consumers in developing countries such as South Africa. The overall objective of this study was to investigate the effect of MO leaves and termite (*Macrotermes falciger*) powders on the nutritional and sensory properties of instant maize porridge.

Materials and methods

Sample collection

Judgemental sampling was used for the selection of samples wherein non-probability sampling technique was used to sample maize meal, MO leaves and termites. Maize meal, salt, sugar, stainless pots, stainless and wooden spoons were purchased from Shoprite supermarket, MO leaves were purchased from a farm at *Tshifudi* village and termites were purchased from street vendors, in Thohoyandou. The samples were transported to the Department of Food Science and Technology and stored at room temperature (25°C) until they were analysed.

Experimental design

The inclusion of MO leaves and termite powder in instant maize porridge at different treatments was considered. The experiment was set up as a completely randomised design. The factor levels were control (100 per cent maize, 0 per cent MO leaves and 0 per cent termites); 80 per cent maize, 5 per cent cooked MO leaves and 15 per cent termite powder; 80 per cent maize, 5 per cent blanched MO leaves and 15 per cent termite powder; and 80 per cent maize, 5 per cent uncooked MO leaves and 15 per cent termite powder.

Sample preparation

Maize meal was cooked to make porridge at 92°C for 35 min and cooled to temperatures between 25 and 30°C for 30 min and oven dried at 50°C for 8 h (Gutierrez *et al.*, 2007), and then milled using a Hammer mill and packaged in a polyethylene bag. A stainless steel metal was used to fabricate the hammer mill. MO leaves were destalked, washed, cooked at 92°C for 15 min and cooled at temperatures between 25 and 30°C for 15 min, oven dried at 50°C for 2 h (Aslam *et al.*, 2005) and milled to powder using a Hammer mill, and then packaged in a polyethylene bag. Termites were purchased from street vendors around Thohoyandou, cooked at 95°C for 30 min; oven dried for 12 h at 50°C (Ayieko *et al.*, 2010), milled using a hammer and packed in a polyethylene bag.

Proximate analysis of instant maize porridge

The moisture, protein, fat, fibre, ash and carbohydrate contents of samples were analysed according to Association of Official Analytical Chemists (AOAC, 2002).

To solubilise the acid-extractable elemental content of the sample, digestion was performed on a microwave acid digestion system (MARS) microwave digester, using ultra-pure $HNO_3 + H_2O_2$ at elevated temperature and pressure. After a cooling period, the extractant was diluted 10× with deionised water, and then analysed by inductively coupled plasma atomic emission spectrophotometry (ICP-AES). Minerals were analysed on a Thermo ICap 6200 ICP-AES. Colour of raw and prepared samples was determined using Lovibond LC 100 Spectrocolorimeter (Martinez *et al.*, 2015) following the recording of individual L^*, a^* and b^*, c^* and h° parameters.

Texture analysis of instant maize porridge

The texture analysis was done using TA-XT *plus* Texture Analyser. To make the porridges, boiling water (95°C) was added to the samples with manual stirring. Texture was measured after the porridge (50 mL) achieved room temperature (25°C). A Perspex cylinder probe

(SMS P/20p) of 20 mm diameter was used. The penetration of probe into the product was 8.0 mm, and the test speed was 2.0 mm/s with the same post-test speed.

Gelatinisation analysis of instant maize porridge

Properties of gelation were determined using the method described by Adebowale *et al.* (2005). Suspensions of 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4 and 1.6 g were measured into 10 mL of de-ionised water to make 20 per cent each (w/v) suspension. Test tubes were heated in a boiling water bath for 1 h containing these suspensions, followed by rapid cooling under running tap water and further cooling for 2 h at 4°C. The least gelation concentration was the one at which the sample did not fall down or slip when the test tube was invented.

Viscosity analysis of instant maize porridge

Viscosity was analysed in the following manner: 10 g of the sample was mixed with 90 ml of distilled water at 30°C (10 per cent slurry, w/v) and allowed to hydrate for 30 min with occasional stirring. The viscosity was measured using a Brookfield viscometer (Model RV, Brookfield Engineering Inc., Stoughton, USA). Subsequently, the slurry was heated to boiling in a water bath for 20 min cooled to 30°C, and cooked paste viscosity was measured.

Sensory evaluation of fortified instant maize porridge

Sensory evaluation was carried out by using 60 untrained panellists on sensory attributes: appearance, texture, taste and aroma; and overall acceptability of fortified instant maze porridge (FMP). A nine-point hedonic scale, varying from dislike extremely (Score 1) to like extremely (Score 9) was used (Mbata *et al.*, 2009). Persons who were directly involved in the preparation of samples were excluded during the sensory evaluation of FMP to avoid bias. Samples were also coded so that the panellists could not identify them, as the code itself should introduce no bias. Tap water was provided as a cleanser before and in between the tasting of the porridge samples (Igyor *et al.*, 2011).

Ethical clearance

Ethical clearance was sought from the University Research Ethics Committee because of the sensory evaluation which was conducted. Panellists were asked to read and sign the consent form before they participated in this study (REPOPA, 2011; World Health Organization (WHO), 2012).

Statistical analysis

Results from this study were analysed using statistical Package of the Social Sciences (SPSS version 23, Chicago, USA). Data were subjected to analysis of variance, and means for proximate, mineral and sensory properties were separated using Duncan's multiple range test at $p < 0.05$. Each experiment was done in triplicates and the statistical model was:

$$Y_{ij} = M + T_{i+}E_{ij}$$

where:

Y_{ij} = Observation;
M = Overall mean;
T_i = Effect of ith treatment on instant maize porridge; and
E_{ij} = Random error.

Results and discussion

Proximate properties of instant maize porridge

The proximate composition of FMP and unfortified samples are shown in Table I. In this study, the protein content of the control sample was lower than of fortified samples. Among the fortified samples, uncooked sample was observed to be higher than cooked and blanched samples (p = 0.01). The protein contents of the fortified samples in this study were higher than the protein content reported (Oyarekua and Eleyinmi, 2004) for *ogi* made from sorghum and millet. This observation could be attributed to that among cereals, maize contains high amount of protein than other cereals (Iken and Amusa, 2010), although cereals are known to contain more carbohydrate and low amount of protein and essential minerals. MO leaves contain substantial amounts of protein, which could be attributed to an increase in protein content in the present study (Rajaratnam *et al.*, 2010). Moreover, USDA (2015) reported 6.70 g/100 g of protein in fresh MO leaves. Scientific findings have shown that termites are also rich in protein which also could have led to an increase in the content of protein of FMP (Iken and Amusa, 2010). The crude protein content of termites ranges from 20.4 per cent in *Macrotermes bellicosus* to 35.88 per cent in *Macrotermes nigeriensis* (Netshifhefhe *et al.*, 2018). MO leaves used in this present study were immature leaves and Anwar *et al.* (2007) stated that the maturity stage of MO leaves could also be a contributing factor, as immature MO leaves are known to be rich in protein (Anwar *et al.*, 2007).

This implies that MO leaves and termite powder blend could help in improving the crude protein in food products. However, the protein contents of FMP in this study were higher than what is recommended (FAO, 2015a) for infant complementary food (≥15 per cent). The high protein values observed in this study, particularly of cooked, blanched and uncooked samples show that the FMP could be used as weaning foods for infants, which had been reported to be accountable for causing protein–energy malnutrition in children under the age of five in African countries (Anigo *et al.*, 2009). The prevalence of poverty in Africa is reported to be high which could be attributed to high household food insecurity and malnutrition (Mosha *et al.*, 2010; Bruyeron *et al.*, 2010; Muhimbula *et al.*, 2011). Moreover, these households depend on unfortified porridges made from cereals and sorghum which are known to contain low level of energy and protein (Eka *et al.*, 2010).

Legumes and cereals should be used to enhance the nutritional value of weaning foods for children and adults in sub-Saharan countries (Ibeanu, 2009). Foods used to feed infants should be adequate in protein intake and other essential nutrients (Solomon, 2005). The

Composition	Control	Blanched	Cooked	Uncooked
Moisture (g)	$5.0^{a} \pm 0.0$	$5.7^{a} \pm 1.54$	$5.4^{a} \pm 0.49$	$6.0^{a} \pm 0.0$
Ash (g)	$0.5^{a} \pm 0.4$	$0.7^{a} \pm 0.1$	$0.1^{b} \pm 0.1$	$0.3^{a} \pm 0.5$
Fibre (g)	$1.4^{a} \pm 0.1$	$2.5^{b} \pm 0.0$	$2.5^{c} \pm 0.5$	$2.5^{d} \pm 0.0$
Fat (g)	$1.0^{a} \pm 0.4$	$2.1^{b} \pm 0.0$	$2.1^{b} \pm 0.2$	$2.1^{b} \pm 0.1$
Protein (g)	$10.0^{a} \pm 0.0$	$20.2^{c} \pm 0.0$	$19.3^{b} \pm 0.0$	$21.2^{d} \pm 0.0$
Carbohydrates (g)	$81.8^{a} \pm 0.6$	$61.9^{b} \pm 1.3$	$64.4^{c} \pm 0.5$	$56.6^{d} \pm 0.1$

Notes: All analyses were carried out on four different samples and analysed in triplicate, and figures were averaged. Data were subjected to analysis of variance and means were separated using Duncan's multiple range test at $p < 0.05$. Means ± SD. Mean values followed by different letters in the same row are significantly different at $p < 0.05$; Per 100 g; 100 per cent maize, 0 per cent *Moringa* leaves and 0 per cent termites; 80 per cent maize, 5 per cent blanched *Moringa* leaves and 15 per cent termite powder; 80 per cent maize, 5 per cent cooked *Moringa* leaves and 15 per cent termite powder; and 80 per cent maize, 5 per cent uncooked *Moringa* leaves and 15 per cent termite powder

Table I. Proximate composition of instant maize porridge fortified with MO leaves and termite powders results of this study revealed that MO leaves and termites contain nutritional properties. The content of protein in the present study is of particular nutritional significance, as it may meet infant protein requirement and boost immune system against diseases (Moyo *et al.*, 2013). Introducing proper nutrition and health to infants and children under the age of five is essential in the first 1,000 days of life, therefore should be taken seriously. Exclusive breastfeeding is crucial to the infant in the first six months of life (Lutter and Dewey, 2003). However, breast milk is no longer enough for the baby after six months; thus, introducing proper nutritious weaning food is recommended (UNICEF, 2009).

The ash content in this present study increased. This indicates that MO leaves and termites could be a good source of minerals. An increase in fibre content of FMP was observed with the addition of MO leaves and termite powder. An increase in fibre makes FMP more recommendable, because of its high fibre content which may be suitable for proper and easy digestion.

Mineral content of instant maize porridge

The mineral content of FMP and control samples is presented in Table II. It was found that fortified samples contained substantial amounts of zinc, iron and calcium than control sample. Cereals have higher carbohydrate and less essential mineral content (Iken and Amusa, 2010). Moreover, MO and termites are known to contain substantial amounts of minerals. In addition, USDA (2015) reported 0.85 mg/100 g and 0.16 mg/100 g of zinc in fresh MO leaves. Mbah and Elekima reported termites to be high in minerals, namely calcium (21 mg/100 g) and iron (27 mg/100 g). High calcium values (7.0-276.8 mg/100 g) in this present study were recorded. Calcium values of 95.0 to 538 mg/100g, in the substitution of *ogi* with okra seed flour, were reported (Akingbala *et al.*, 2005; Aminigo and Akingbala, 2004; Otunola *et al.*, 2007). Processing methods may lead to a change in mineral content of food (Prasanthi *et al.*, 2017). MO leaves have been reported to differ in nutrient composition at different locations (Jideani and Diedericks, 2014). The MO tree grown in Nigeria might be different with the one grown in South Africa in terms of nutritional composition. The increase in calcium in cooked, blanched and uncooked samples may be because of the addition of MO, as it has been reported to be high in potassium and calcium (Jideani and Diedericks, 2014). This indicates that the fortified samples in this study can be appropriate in the formation of teeth and bones of young children if consumed as weaning food.

In the present study, the zinc content of control sample was observed to be lower than of cooked, blanched and uncooked samples (Table II). Upon the addition of MO leaves and

Composition	Control	Blanched	Cooked	Uncooked
Calcium (mg)	$7.1^{a} \pm 0.0$	$276.8^{d} \pm 3.0$	$220.9^{b} \pm 1.8$	$234.7^{a} \pm 0.5$
Iron (mg)	$7.7^{a} \pm 0.1$	$36.9^{d} \pm 0.1$	$35.9^{c} \pm 0.1$	$27.9^{b} \pm 0.2$
Magnesium(mg)	$31.4^{a} \pm 0.1$	$97.5^{c} \pm 0.4$	$92.3^{b} \pm 0.4$	$91.9^{b} \pm 0.3$
Zinc (mg)	$3.4^{a} \pm 0.3$	$6.5^{b} \pm 0.5$	$7.1^{c} \pm 0.2$	$7.6^{c} \pm 0.6$

Notes: All analyses were carried out on four different samples and analysed in triplicate, and figures were averaged. Data were subjected to analysis of variance and means were separated using Duncan's multiple range test at $p < 0.05$. Means ± SD. Mean values followed by different letters in the same row are significantly different at $p < 0.05$; Per 100 g; 100 per cent maize, 0 per cent *Moringa* leaves, and 0 per cent termites; 80 per cent maize, 5 per cent blanched Moringa leaves, and 15 per cent termite powder; 80 per cent maize, 5 per cent cooked Moringa leaves, and 15 per cent termite powder; and 80 per cent maize, 5 per cent uncooked Moringa leaves, and 15 per cent termite powder

Table II. Mineral composition (mg/100g) of instant maize porridge fortified with MO leaves and termite powders termite powder, the zinc content was observed to be higher than what was reported (Ojarotimi and Olowalana, 2013). The application of different fertilisers (Prasanthi *et al.*, 2017) could also be attributed to an increase in zinc content of the present study. Moreover, nutritional variability in food can be influenced by factors such as maturity stage, variety/cultivar, post-harvest handling and processing (Prasanthi *et al.*, 2017).

The iron content of control sample was lower as compared to the one of fortified samples (p = 0.01) (Table II). Iron values of the fortified samples increased as a result of substitution effect, as fresh uncooked MO leaves are reported to have over three times the amount of iron than spinach (Edward *et al.*, 2005). The iron content (27.87-32-30) of the fortified samples in the present study can meet the recommended daily allowance (RDA) for infants if 50 g of the fortified samples is consumed per day as WHO/FAO (2015a) recommended 4-8 mg of iron for infants and toddlers. The nutritional composition also varies because of various factors such as the genetics, processing effects and various links in the food chain (Fubara, 2008). Although processing has beneficial effects such as destruction of trypsin inhibitors and the liberation of bound niacin in cereals, loss of nutrients and reduction in the nutritional composition is profound in processed foods than in the raw food material.

Sensory evaluation of instant maize porridge

The sensory attributes (colour, texture, taste and aroma) are presented in Table III. Sensory analysis indicates a significant difference in colour, texture, taste and aroma. The result showed that control sample had higher acceptance than the fortified samples (p = 0.02). Among the fortified samples, blanched sample was rated high in colour and texture, the cooked sample was more acceptable for taste, and the uncooked sample was rated high in aroma (Table III). Generally, these results indicated that cooked sample had higher acceptability among the fortified samples. There was no much significant difference in the colour of cooked, blanched and uncooked samples (Table III) (p = 0.17). The cooked, blanched and uncooked samples are the least accepted for colour, though blanched sample had higher acceptance than the two. This may be because of the dark green colour of MO leaves caused by chlorophyll and carotenoids, which is different from the normal white or yellow colour of maize and leafy flavour imparted by the MO leaf powder. A similar report was also made on the use of okra seed in substitution of *ogi* powder which imparted a bland taste and dark brown colour to the *ogi* powder (Otunola *et al.*, 2007). The decrease in likeness for aroma of the FMP could be attributed to the herbal flavour of the MO leaf powder. An

Table III. Sensory evaluation of instant maize porridge fortified with MO leaves and termite powders by 60 panellists

	Sensory attributes			
Treatments	Colour	Texture	Taste	Aroma
Control	$7.02^{a} \pm 1.4$	$7.92^{a} \pm 1.5$	$7.37^{a} \pm 1.1$	$8.02^{a} \pm 1.4$
Blanched	$6.52^{b} \pm 1.9$	$6.63^{b} \pm 1.7$	$6.60^{b} \pm 2.1$	$6.72^{b} \pm 1.9$
Cooked	$6.78^{b} \pm 1.8$	$6.65^{b} \pm 1.8$	$5.85^{c} \pm 2.2$	$6.76^{b} \pm 1.8$
uncooked	$6.48^{b} \pm 2.0$	$6.64^{b} \pm 1.9$	$5.75^{c} \pm 2.2$	$6.79^{b} \pm 1.7$

Notes: All analyses were carried out on four different samples and analysed in triplicate, and figures were averaged. Data were subjected to analysis of variance and means were separated using Duncan's multiple range test at $p < 0.05$. Means ± SD. Mean values followed by different letters in the same row are significantly different at $p < 0.05$; Per 100 g; 100 per cent maize, 0 per cent *Moringa* leaves, and 0 per cent termites; 80 per cent maize, 5 per cent blanched *Moringa* leaves, and 15 per cent termite powder; 80 per cent maize, 5 per cent cooked *Moringa* leaves, and 15 per cent termite powder; 80 per cent maize, 5 per cent uncooked *Moringa* leaves, and 15 per cent termite powder undesirable colour and flavour imparted on the *ogi* supplementation with African oil bean seed as level of supplementation increased (Enujiugha, 2006). On the contrary, an improved colour of *ogi* when pawpaw slurry was added to it was reported, thus improving consumer acceptability. Moreover, the dark green colour of blanched and uncooked samples may be attributed to the inclusion of blanched and uncooked MO leaves which are known to contain high amount of chlorophyll which is also responsible for masking the colour of foods when the inclusion is in large amount (Karim *et al.*, 2013). The ratings for the taste and aroma of the FMP decreased with the inclusion of MO leaves and termites (Table III). The high ratings for taste of the cooked sample may be ascribed to the cooked MO leaves which were less bitter as compared to the blanched and uncooked MO leaves. There was no significant difference (p = 0.41) among these fortified in terms of texture (Akingbala *et al.*, 2005). The slight lower ratings may be as the result of inclusion of MO leaves and termite powder. Nevertheless, the inclusion of MO leaves and termite powder still returned a good rating for texture as judged by the panellist. None of the panellists developed any side effects such as diarrhoea and emesis after consuming the preparations (Otunola *et al.*, 2007). The use of flavouring agents to mask the unacceptable herbal flavour of MO powder could help improve the acceptability of these products.

Colour and texture attributes of instant maize porridge

The physical and thermal properties of instant maize porridge are presented in Table IV. The L*, b* and c* values of the raw instant maize flour had higher values as compared to the instant maize porridge, the lightness of raw flour was higher as compared to lightness of the cooked porridge. However, the L*, a*, b*, c* and h° values of control, cooked, blanched and

Values	Control	Blanched	Cooked	Uncooked
Uncooked flour				$52.0^{d} \pm 0.5$
L*	$83.9^{a} \pm 0.4$	$57.9^{b} \pm 0.7$	$55.5^{c} \pm 1.5$	$52.0^{d} \pm 0.5$
a*	$-0.2^{a} \pm 0.1$	$1.8^{d} \pm 0.1$	$0.9^{c} \pm 0.6$	$-2.5^{b} \pm 0.6$
b*	$11.9^{a} \pm 0.7^{a}$	$14.2^{b} \pm 1.0^{b}$	$19.5^{c} \pm 0.3^{c}$	$20.2^{c} \pm 0.6^{c}$
c*	$11.9^{a} \pm 0.7^{a}$	$14.2^{b} \pm 1.0^{b}$	$19.6^{c} \pm 0.3^{c}$	$20.3^{c} \pm 0.6^{c}$
h³	$84.8^{a} \pm 0.5^{a}$	$86.5^{b} \pm 0.2^{b}$	$90.9^{c} \pm 0.6^{c}$	$97.2^{d} \pm 0.2^{d}$
Cooked porridge				
L*	$61.6^{a} \pm 0.9$	$34.7^{b} \pm 1.7$	$35.5^{b} \pm 1.6$	$33.7^{b} \pm 1.1$
a*	$-1.5^{a} \pm 0.4$	$1.9^{c} \pm 0.6$	$1.5^{c} \pm 0.3$	$0.5^{b} \pm 0.5$
b*	$10.0^{a} \pm 0.4$	$13.7^{b} \pm 1.5$	$16.6^{c} \pm 0.4$	$18.2^{d} \pm 0.4$
c*	$10.1^{a} \pm 0.6$	$16.7^{c} \pm 0.9$	$13.7^{b} \pm 0.2$	$18.2^{c} \pm 0.3$
h³	$191.1^{a} \pm 12.6$	$83.5^{b} \pm 1.3$	$85.2^{b} \pm 1.3$	$88.0^{b} \pm 0.6$
Texture	$37.7^{a} \pm 2.2^{d}$	$30.2^{b} \pm 4.9^{c}$	$28.1^{c} \pm 5.4^{b}$	$24.7^{d} \pm 9.5$
Viscosity (cP)	$13.7^{a} \pm 0.6$	$12.7^{b} \pm 0.6$	$12.3^{b} \pm 0.6$	$12.3^{b} \pm 0.6$
Uncooked paste	$443.3^{a} \pm 18.2$	$223.1^{b} \pm 2.1$	$216.7^{b} \pm 7.6$	$210.3^{b} \pm 9.9$
Cooked paste	$89.3^{a} \pm 18.2$	$97.1^{b} \pm 13.1$	$97.1^{b} \pm 17.2$	$98.2^{b} \pm 19.2$
Gelatinisation temperature (°C)				

Notes: All analyses were carried out on four different samples and analysed in triplicate, and figures were averaged. Data were subjected to analysis of variance and means were separated using Duncan's multiple range test at p < 0.05. Means ± SD. Mean values followed by different letters in the same row are significantly different at p < 0.05; Per 100 g; 100 per cent maize, 0 per cent *Moringa* leaves and 0 per cent termites; 80 per cent maize, 5 per cent blanched *Moringa* leaves and 15 per cent termite powder; 80 per cent maize, 5 per cent cooked *Moringa* leaves and 15 per cent termite powder; 80 per cent maize, 5 per cent uncooked *Moringa* leaves and 15 per cent termite powder

Table IV. Thermal and physical properties of instant maize porridge fortified with MO leaves and termite powders (n = 12) uncooked samples of the raw flour were significantly different (p = 0.03) The L* values of the cooked porridge were observed to be higher in the control sample. The L* value of cooked, blanched and uncooked samples was not significantly different at $p < 0.05$. The L* values of both raw (83.8-52.0) and cooked (61.6-33.7) instant maize porridge decreased with the addition of MO leaves and termite powder. This could be attributed to prodigiosin in termites. Prodigiosin is a natural red pigment produced by termites (Song *et al.*, 2007). It is an alkaloid secondary metabolite with a unique tripyrrol structure. This pigment has been reported to have antibacterial, antifungal, anti-malarial and anti-neoplastic activity (Khanafari *et al.*, 2006). When measuring for greenness, it was found that a* values of raw (−0.2 to −2.5) and cooked (−1.5 to 0.5) instant maize porridge increased with the addition of MO leaves and termite powder (Table IV). An increase in the b* values of raw (11.9-20.2) and cooked (10.0-18.2) instant maize porridge with the addition of MO leaves and termite powder was also observed. In general the inclusion of MO leaves and termite powder in instant maize porridge resulted in darker instant maize porridge because of the presence of chlorophyll and carotenoid pigments (Muhammad and Waraporn, 2017) present in MO leaves. It has been reported that MO leaves contain appreciable amounts of pigments with demonstrated potent antioxidant properties such as the carotenoids (alpha-carotene and beta- carotene) and chlorophyll (Owusu, 2015). Pigments (Chlorophyll A, Chlorophyll B and carotenoids) are pigments which permit plant to realize photosynthesis, the process that cause light energy to turn into chemical energy in organic compounds. The β-carotene, a carotenoid, is also known as provitamin A because it is converted to form vitamin A which protect human eyes (Owusu, 2015).

The texture of the control sample was significantly higher in terms of hardness than FMP. The inclusion of MO and termite powder had a positive effect on the textural properties of FMP, as FMP became softer as compared to control sample which was harder. This could be attributed to the lower starch content in cooked, blanched and uncooked samples which reduced with the addition of MO leaves and termite powder. MO leaves are known to be low in starch (Rajaratnam *et al.*, 2010) and so are termites. Moreover, the softer texture in fortified samples could be attributed to the differences in amylose–amylopectin ratio in maize, MO leaves and termites. This makes FMP more favourable, as it can be easily digestible by infants and young children. It has been reported that high bulk density foods are a major cause of malnutrition in Africa.

Viscosity and gelatinisation properties of instant maize porridge

The viscosity level of control, cooked, blanched and uncooked samples of the uncooked paste was significantly different (p = 0.03). The viscosity level of control, cooked, blanched and uncooked samples of the cooked paste was significantly different (p = 0.04) (Table IV). The viscosity of control, cooked, blanched and uncooked samples of the cooked paste was higher compared to the viscosity level of control, cooked, blanched and uncooked samples of the uncooked paste; this may be because starch has been reported to swell less at lower temperatures and swells more at higher temperatures. The addition of MO leaves and termite powder was found to cause fortified samples of both the cooked and uncooked paste to be less viscous as compared to control, though the viscosity of cooked sample was more than of sample blanched and uncooked in both cooked and uncooked paste at. This could be because that starch content in cooked, blanched and uncooked samples had reduced with the addition of MO leaves and termite powder. The decrease in viscosity with addition of MO leaves and termite powder (Table IV) in cooked, blanched and uncooked samples make the FMP more favourable, as it can be easily digestible by infants and young children. This is almost similar to what was found by Karim *et al.* (2013), where a continued and decrease in the viscosities of plantain flour was observed when MO leaves powder was added. The reduction in viscosity is important in the storage characteristics of FMP. Olorode *et al.* (2013) reported that the viscosity characteristics of the "*ogi*" - MO mixtures show that, the 100:0 "*ogi*"- MO leaf powder mixture had higher viscosity compared with the other blended mixtures. This had implication on the consistency of the gruel prepared from the mixtures, and it might be because of the fact that MO leaf powder contains little or no amount of starch which shows clearly in the mix, resulting into low viscosity. The pasting viscosity obtained compared favourably (also lower) with the one obtained on the substitution of "*ogi*" with okra seed flour. A report given on the substitution of "*ogi*" with *bambara*-nut gives a similar report and stated that a low viscosity food contains higher nutrients, as the volume of the food is low. The least gelation concentration in the present study increased as the MO leaves and termite powder were added to maize (Table IV). This is similar to what was reported by Olorode *et al.* (2013) in the addition of MO leaves powder to *ogi* increased least gelation (i.e. the poorer the gelation ability). This indicates that FMP would not gel easily as compared to maize porridge without MO and termite powder.

Conclusion

The results of this study showed that the addition of MO leaves and termite powder to instant maize porridge has led to a substantial increase in the nutritional value of FMP, and therefore could be used as one of the sustainable strategies to alleviate malnutrition. It also showed that instant maize porridge fortified with MO leaves and termite powder can be used to produce complementary food and still be acceptable. A survey will be used to determine the acceptability of the instant maize porridge in a community setting. The present study has revealed the potential of MO leaves and termites in food processing. However, the limitation of the study was that treatments were not analysed separately before formulation. Future research should be considered on bioactive compounds and microbial activity of the FMP.

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