The effect of *Moringa oleifera* leaves and termite (*Isoptera*) powders on nutritional and sensory properties of an instant-maize porridge

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Declaration

I, Netshiheni Khavhatondwi Rinah (11602027), hereby declare that this mini-dissertation for Master of Science (MSc) in Food Science and Technology hereby submitted by me to the Department of Food Science and Technology at the University of Venda, has not previously been submitted by me for a degree at this or any other university or institution of higher learning. I further declare that this research project is original in design and execution and all reference material contained has been dully acknowledged.

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Student signature Date

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Abstract

White maize-based porridge is a staple food for about 80% consumers in South Africa and sub-Saharan African countries contributing significantly to the diet of rural populations 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 (*Isoptera spp.*) are known to contain a substantially high amount of protein. The aim 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. Inclusion of MO and termite powders in instant-maize porridge, at different treatments, was considered using a completely randomised design. Factor levels were: AOB-control (maize flour); BEA (maize, powders of cooked dried MO and termite); CIA (maize, powders of blanched dried MO and termite) and DJE (maize, powders of uncooked dried MO and termite). Data were analysed using SPSS version 23. The protein content of fortified instant-maize porridge (FMP) significantly ($p < 0.05$) increased from 10.02 to 21.20% compared to unfortified porridges. The mineral content of FMP was higher in terms of Zn, Fe, Ca and Mg. Moisture content of FMP increased from 5.00 to 6.00%. Sensory analysis showed that among fortified porridges, CIA was rated high for colour and texture, BEA higher in taste and DJE higher for aroma. AOB had higher acceptance than fortified porridges for taste. Powder from MO leaves and termite could be used in complementary foods and food supplements to increase protein and mineral contents.

Keywords: Instant-maize porridge, *Moringa*, termite, protein, mineral, acceptability

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Chapter One: Introduction

1.1. Background of the study

Maize porridge is a staple food for most people in Southern Africa and contributes significantly to the dietary intake of most households in Limpopo province (Mushaphi *et al.,* 2015). Primarily 60% of white maize is used for human consumption in South Africa and in spite of all the carbohydrates that maize has, it does not provide adequate nutrients. The bio-availability of minerals which are vital for proper nutrition and health is often affected by phytic acid which is contained in the maize grain. This interferes with the absorption of minerals (Hulse *et al*., 1980), such as, iron (Fe), zinc (Zn) and calcium (Ca) and inadequate intake of these elements causes Anemia *osteomalacia,* Zn deficiency and rickets, respectively (Widdowson, 2002). According to Motadi *et al.* (2015) the prevalence of Zn and Fe deficiency among children (under 5 years) in the Vhembe district of Limpopo province was 42.6% and 28%, respectively in 2014. Being anaemic and deficient of Zn in children result in growth retardation, movements' disorders, blackouts, inadequate reaction of the immune and change in conduct (Bothwell, 2007; Baltimore, 2009).

Cereals, maize in particular, are known to contain low amount of lysine and have been reported to have poor protein digestibility (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. Several nutrition intervention strategies have been implemented such as supplementation, fortification, nutrition education and dietary diversification (Ruel & Levine, 2000). Bio-fortification has also been introduced and its purpose is to enhance the nutritional and health status of people in rural places (Nestel *et al*., 2006). Bio-fortification is the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology (Welch & Graham, 2005).

The anticipated impact of fortifying instant-maize porridge with *Moringa oleifera (*MO*)* leaves and termite powders should be important since maize-based porridge contributes significantly to the dietary intake of many households in the Limpopo province. Otherwise, over-dependency on maize-based porridge may lead to high prevalence of malnutrition-related health conditions. Use of these locally available sources of nutrients could be one of the sustainable strategies towards the alleviation of malnutrition. In Vhembe district, there is an abundance of MO and edible termites which are known to be rich in most essential nutrients. MO leaves contain substantial amounts of Fe, Zn, Ca, amino acids, antioxidants and omega-3 fatty acids and have also been shown clinically to enhance breast milk production when consumed before or after birth and therefore highly recommended for expecting and lactating mothers. Termites have been proven to be high in protein and the essential amino acid tryptophan which is limited in maize (Defloliart, 2002). A combination, therefore, of these essential nutrient sources could potentially help prevent protein energy malnutrition (PEM) and improve Fe and Zn status of children and maize porridge consumers in the Vhembe district.

1.2. Problem statement

1.2.1. Maize-porridge is the leading staple food which is consumed by 80% of South Africans (Mushaphi *et al*., 2015). However, maize is deficient in minerals such as Fe, Zn and Ca. Over-dependency on maize-based porridge has led to a high prevalence of malnutrition-related health conditions in South Africa (Motadi *et al*., 2015).

1.2.2. Maize-porridge has a low bio-availability of Zn and Fe (Michaelsen & Friis, 1998). In addition, in 2014 the prevalence of Zn deficiency (42%) and anaemia (28%) among pre-school children of the Vhembe district in Limpopo province was reported.

1.2.3. Rapid population and insufficient provision of protein has resulted in the high prevalence of malnutrition in developing countries (Siddhuraju, 2006).

1.3. Research Aim

To determine the effect of MO leaves and termite powders on the nutritional and sensory properties of an instant-maize porridge.

1.4. Research objectives

1.4.1. To determine the effect of MO leaves and termite powders on the proximate composition (moisture, ash, protein, fat, dietary fibre and carbohydrates) of an instant-maize porridge.

1.4.2. To determine the effect of MO leaves and termite powders on the mineral content of an instant-maize porridge.

1.4.3. To determine the effect of MO leaves and termite powders on the physical properties (texture, colour and viscosity) of fortified instant-maize porridge.

1.4.4. To determine the effect of MO leaves and termite powders on gelatinisation temperature of fortified instant-maize porridge.

1.4.5. To determine the effect of MO leaves and termite powders on the sensory properties of fortified instant-maize porridge.

1.5. Hypotheses

1.5.1. The addition of MO leaves and termite powders may increase proximate, mineral composition of an instant-maize porridge.

1.5.2. The addition of MO leaves and termite powders may have a positive effect on the physical and thermal properties of an instant-maize porridge.

1.5.3. The addition of MO leaves and termite powder may have a negative effect on the sensory properties of an instant-maize porridge.

1.6. Significance of the study

The information derived from evaluating fortified instant-maize porridge with MO leaves and termite powder will be useful in:

1.6.1. Minimising problems caused by poor nutrition, especially those arising from vitamin A and C, Zn deficiency and protein energy malnutrition (PEM) in children, pregnant women and lactating mothers.

1.6.2. Promoting commercial production of instant-maize porridge fortified with MO leaves and termite powders.

1.6.2. Serving as a source of information pertaining to the effects of MO leaves and termite powders on the nutritional and sensory properties of an instant-maize porridge.

Chapter Two: Literature Review

2.1. Production, nutritional value and health benefits of maize, termite and *Moringa oleifera*

2.1.1. Maize

Maize (Figure 1) originated from a wild grass 7000 years back in central Mexico and was transfigured into a source of food by Native Americans (FAOSTAT, 2013). The United States, China and Brazil are reported to produce the highest amount of maize globally. They produce about 563 of the world's 717 million metric tons/year (WHO, 2015). Most of the micronutrients are contained on the outer layer of the maize kernel; eliminating these layers in the process of milling leads to a destruction of essential nutrients. Different kinds of maize are grown worldwide, with one essential variety being the colour. Maize kernels may differ in colour (FAO, 2000).

In the United States, much more yellow maize is produced than white maize. However, in Central America, sub-Saharan African countries people favour white maize (FAOSTAT, 2013). In Africa, yellow maize is related to low economic-social status thus less preferred, it is regarded as food which only poor people consume. In industries yellow maize is used to produce feed (WHO, 2015). White maize is preferred over other varieties because people in these countries are more comfortable with eating white products. People who prefer white maize-porridge take in low amounts of β-carotene and cryptoxanthin, vitamin A precursors, which have been reported to be high in orange and yellow maize (FAO, 2015).Maize contains substantial amounts of energy that is utilised by humans, animals and as fuel (Gwirtz & Garcia-Casal, 2014; Ongol *et al*., 2013; Brockway, 2001), maize contains good amounts of dietary fibre, while containing low amounts of fat and sodium (Sangwan *et al*., 2014).

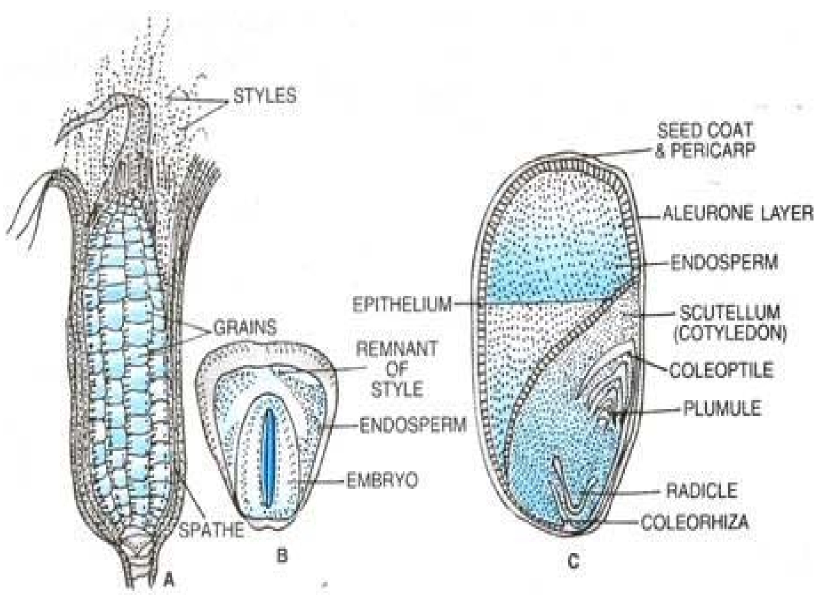

Figure 1. Maize (*Zea mays*). A-Cob, B-The entire grain, C-Maize grain. (FAO, 2012).

In developing countries, 60% of the maize produced is for human consumption, but in the developed economies it is mainly utilised for industrial purposes and as feed (FAO, 2012). The significant growth in population and the insufficient provision of protein is reported to have contributed to the problem of malnutrition in African countries (Siddhuraju, 2006). High prevalence of malnutrition in children under five years in developing countries has been associated with high consumption of cereal-based porridges which are known to be low in essential nutrients (WHO, 2015).

Maize being the grain crop commonly grown in South Africa is used as a staple food for the majority of people. It is grown in South Africa whereby Free State, Mpumalanga and North West provinces accounts for highest production, with approximately 88% of total production (Figure 2). Primarily 60% of white maize grown in South Africa is for human consumption; with the other 40% being utilised for animal feed production (DAFF, 2014). It has been reported that the second highest crop produced in South Africa after sugar cane is maize, with regard to cultivation areas and total production (Michaelsen & Henrik, 2008; Purseglove, 2002; Osagie & Eka, 2008). Maize consists of protein (10.3%), starch (60.5%), sugar (1.2%), crude fibre (2.5%) and other substances (Addo-Quaye *et al*., 2011). It is prepared and consumed differently by various population groups.

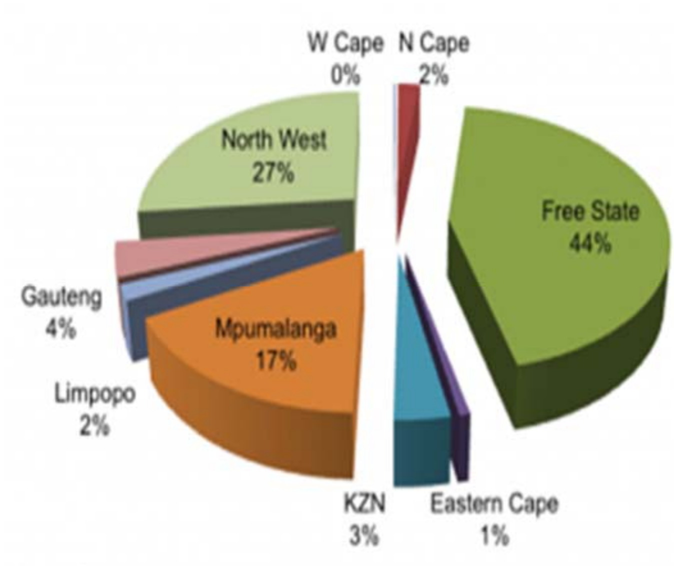

Figure 2. Maize production in South Africa by provinces (Michaelsen & Henrik, 2015).

Figure 2 shows that in the 2014/15 season, the total commercial maize produced in South Africa, in the Free State province was 44%. North West was the second highest producer and harvested 27%, with Mpumalanga in the third position, which produced 17% of total commercial maize production. Northern Cape produced 2%. Gauteng produced 4%, Kwa-Zulu Natal produced 3%, and Limpopo produced 2% while the remaining provinces produced less than 2% of the country’s total maize production.

Maize forms part of the diet for many people in developing countries. It is considered as an important source of carbohydrate. Maize grains are nutritious and assist healthy growth as they are composed of 72% starch, 10% protein, 4-8% oil, 8.5% fibre, 3.0% sugar and 1.7% ash (Hussain *et al*., 2003).Maize facilitates speedy passage of faeces through the intestine. Furthermore, it preserves the digestive tract and also promotes the function of the gall-bladder reducing stomach acidity and development of certain cancers. Maize contains low amounts of cholesterol and fat content and like other cereals or whole grains is a great source of minerals and fibre. The fibre contained in whole grains boosts the immune system and also assists in preventing the high risk of heart diseases and diabetes (Rush, 2014).

2.1.2. Termites (*Isoptera)*

Insects are used for dietary and medicinal purposes by different population groups in the world (Defoliart, 2002). Insects are utilised in about 130 countries of the world as an essential elements of the diet. An increase in the interest in insects based food products has been observed even in the United States in current years (Dossey *et al*., 2016). Termites belong to the family *Isoptera* and play a major role in the tropical ecosystem (Figure 3).Above two thousand edible insects and other small invertebrates are utilised for food purposes by different people of the world (Rush, 2014). Termites are also used as food in sub- Saharan Africa, Asia, Australia, and Latin America for centuries (Table 1). In Africa the number of countries (19) using termites was reported to be higher than in America (5 countries) and Asia (5 countries). According to FAO (2010), the number of people who commonly consume termites in Asia and Africa was reported to be above 2.5 billion. Edible insects are being used by many people around the world because of their good nutritional and therapeutic properties, which could be used to eradicate malnutrition in developing countries. Termites play a major role in terms of dietary purposes in East Africa (Ayieko, 2007). In Western Kenya, termites are consumed by different ethnic groups. They are eaten as part of a meal or as a complete meal with tapioca, bread and roasted corn or simply eaten as a snack. Some mothers mill the dried termites into flour and sprinkle it on babies' porridge (Christensen *et al.,* 2006). Some people consume termites raw directly as they emerge from their holes in the ground (Ayieko *et al*., 2010).

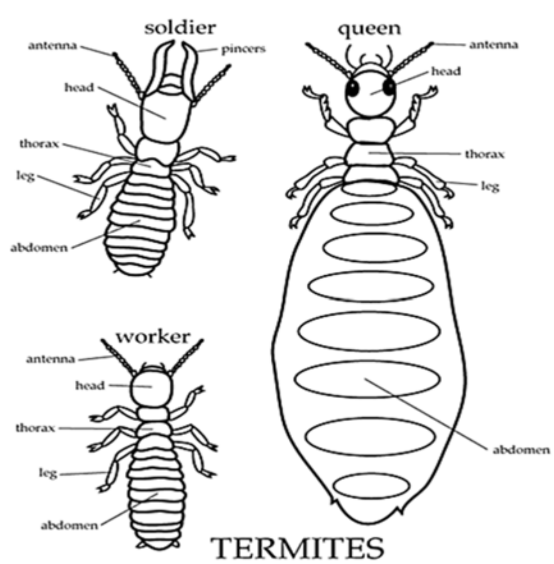

Figure 3. Structure of termites (Defoliart, 2002).

Table 1. Species of termite used for food and medicinal purposes

Species	Treated disease	Country (ies)	Reference
Hodotermitidae			
Hodotermes mossambicus	Child malnutrition	Botswana	Gahukar (2011)
Microhodotermes viator		South Africa	DeFoliart (2002)
Kalotermitidae			
Kalotermes flavicollis		Brazil	Jongema (2014)
Rhinotermitidae			
Coptotermes formosanus		China	Jongema (2014)
Reticulitermes flavipes		Thailand	Wilsanand (2005)
Reticulitermes tibialis		Mexico	DeFoliart (2002)
Termitidae			
Cubitermes atrox		Indonesia	Jongema (2014)
Labiotermes labralis	Suture wounds	Columbia	Jongema (2014)
Macrotermes acrocephalus		China	Jongema (2014)
Macrotermes falciger	Wounds	South Africa	Wilsanand (2005)
Macrotermes gabonensis		Congo	Jongema (2014)
Macrotermes herus		Tanzania	McGrew & Roge (1985)
Macrotermes lilljeborgi		Cameroon	Deblauwe (2008)
Macrotermes michaelseni		Malawi	Sileshi *et al*. (2009)
Macrotermes subhyalinus		Zambia	Lesnik (2014)
Macrotermes vitrialatus	Rheumatics	Zambia	Jongema (2014)
Microcerotermes dubius		Malaysia	Jongema (2014)
Nasutitermes ephratae		Venezuela	Jongema (2014)
Odontotermes badius	Ulcer	South Africa	Jongema (2014)
Odontotermes capensis		South Africa	Jongema (2014)
Odontotermes kibarensis	Antifungal properties	Uganda	Sileshi *et al.* (2009)

Termites have been reported to be a food source of great nutritional value: they are high in protein and essential amino acids such as tryptophan, which is generally minimal in cereal-based foods (Defloliart, 2002). Termites are rich in minerals such as Fe, Ca and other micronutrients as well as essential fatty acids (Jongema, 2014). Termites contain substantial amounts of Fe and their addition in a daily diet could contribute in improving the status of Fe and thereby minimise anaemia in under-developed countries. Edible insects, such as termites contain substantial amounts of vitamins responsible for the stimulation of metabolic processes and enhancing immune system functions. Defloliart (2002) has pinpointed an entire diversity of insects which contain thiamine (4 mg per 100 g of dry matter). Insects are also known to contain substantial amounts of fibre in different forms. Chitin is the most common form of fibre found in insects (Jongema, 2014).

Termites are the frequently utilised insects, in making traditional medicines (Raubenheimer & Rothman, 2012; Solavan *et al*., 2006). They have been reported to treat medical conditions such as influenza, asthma, bronchitis, whooping cough, sinusitis tonsillitis and hoarseness (Table 1). Moreover, termites have previously been reported an essential food source which contributes in enhancing diets for humankind, particularly for people suffering from malnutrition because of inadequate intake of protein (Jongema, 2014).

2.1.2.1. Maize fortification with termites

Insects link bio-diversity preservation and human nutrition in a way that many other food sources do not. Termites have substantial amounts of protein, fat, and carbohydrates more than equal amounts of beef or fish, and a higher energy value than soybeans, maize, beef, fish, lentils, or other beans (FAO, 2012). It has been found that people in Nigeria consume edible insects such as termites (Adepoju & Omatayo, 2014). Dried termites have a substantial quantity of protein, fat and micronutrients. They are low in anti-nutrients and it is recommended that they be included in producing adequate, nutrient-dense complementary foods. Roasted termites have been reported to be very low in moisture content and contain substantial amounts of protein, fat, carbohydrate and gross energy content (Adepoju & Omotayo, 2014). When termite powder was added to maize it significantly increased the mineral value of all fortified weaning food at ($p < 0.05$). The mineral values for all fortified weaning food were found to be significantly different ($p < 0.05$). It was also observed that when 20% of termites were added to maize flour, the nutritional value increased compared to the blend where 10% of termites were added to maize meal flour (Jongema, 2014).When termite powders were added to maize it resulted in a significant increase in β-carotene, niacin, vitamin B6, and B12 content, with significant reduction in thiamine, riboflavin and ascorbic acid content of the enriched complementary foods ($p < 0.05$). It was also observed that as the level of inclusion increased the amount of vitamin A also increased significantly. Vitamin B6 content of the formulated diets was found to be higher than what FAO/WHO recommended (Adepoju & Omatayo, 2014). Reduction in riboflavin and vitamin C content was observed with increase in the inclusion of termite powder to maize. The values for thiamine, riboflavin and vitamin C were also found to be lesser as compared to the commendation made by FAO/WHO (2010).

2.1.3. *Moringa oleifera* (MO)

MO is called the 'miracle plant' or the 'tree of life' in some parts of the world. This name derives from its uses associated with its therapeutic and nutritional purpose. It originated in India, Pakistan, Bangladesh and Afghanistan (Fahey, 2005). MO (Figure 4) has been utilised for thousands of years in Romans, Greece and Egypt where early supreme rulers of the day used MO leaves and its fruit in their diet to keep themselves mentally alert and healthy. In the olden days, *Moringa* leaf extract was given to Maurian soldiers of India in the warfront. They believed that this elixir drink gave them strength and also soothed them from the trauma and agony caused by war (Mossa, 2005). Different species of *Moringa* have gained interest because of their excellent economic potential. Of all the *Moringa* species, MO is the mostly utilised specie because of its nutritious and therapeutic properties that have been acknowledged for many years in different parts of the world (D'Souza & Kulkarni, 2013). Mossa (2005) reported that *M. stenopetala, M. peregrine and M. concanensis* contain therapeutic and nutritional properties as MO (Mossa, 2005).

Figure 4. The *Moringa oleifera* tree. Source: Foidl *et al*. (2001)

Moringa abides under the umbrella *Moringaceae* (Nadkarni, 2006). It has been used in Asia, particularly in India as a source of food for about 5000 years (Anwar *et al*., 2005;

Anwar & Bhanger, 2015; D'Souza & Kulkarni, 2013). MO tree flourishes greatly in a tropical region with average height of 5 - 10 m. *Moringa* can also be grown in a very hot environment including unfertile soil without getting affected (Morton, 2011). It can grow in a wide range of rainfall requirements estimated at 250 mm and maximum at over 3000 mm and a pH of 5.0 to 9.0 (Anwar & Bhanger, 2015). *Moringa*'s trunks are known to be squashy, corky and white; and the branches bear a gummy bark. *Moringa*'s seeds are dispersed during windy seasons. The flowers, tender leaves and pods are eaten as vegetables. MO leaves should be advocated for expecting and lactating mothers because they contain substantial amounts of Fe. MO is called the 'drum stick tree' or the 'horse radish tree', by some people (Anwar & Bhanger, 2015). In other places, it is called *kelor, marango, mlonge, moonga, mulangay, nebeday, saijhan, sajna* or Ben oil tree (Anwar & Bhanger, 2015; Prabhu *et al*., 2011). In India and Pakistan MO is grown all around the country and is called *Sohanjna* (Qaisar, 2003). The family *Moringaceae* is a monotypic family of single genera with around 33 species of which 4 are accepted, 4 are synonym and 25 are unassessed. Out of these, 13 species, native of old world tropics are documented (Table 2).

Table 2. Geographic distribution of documented thirteen *Moringa* species and their morphotypes

Species	Geographical location
Bottle trees	
M. drouhardii	Madagascar
M. hildebrandtii	India
M. ovalifolia	Namibia and South west Angola
M. stenopetala	Kenya and Ethiopia
Slender trees	
M. concanensis	India
M. oleifera Lam.	India, Egypt, South Africa
M. peregrina	Red Sea, Arabia, Horn of Africa
Tuberous shrubs and herbs of North Eastern Africa	
M. arborea	North eastern Kenya
M. borziana	Kenya and Somalia
M. longituba	Kenya, Ethiopia, Somalia
M. pygmaea	North Somalia
M. rivae	Kenya and Ethiopia
M. ruspoliana	Kenya, Ethiopia, Somalia

Source: Mark (2006).

MO contains substantial amounts of essential micronutrients, amino acids, β-carotene, antioxidants, inflammatory nutrients with omega 3 fatty acids (Fahey, 2005; Hsu *et al*., 2006; Kasolo *et al*., 2010). The leaves contain substantial amounts of Ca and therefore highly recommended for expecting mothers, they also contain substantial amounts of vitamin, Ca, β-carotene, potassium (K) and protein (Table 3). The leaves also contain natural antioxidants. Ajit *et al*. (2002) reported that MO is high in nutritional quality. MO fresh leaves (weight per weight) contain Ca which is four times higher than that found in milk; the content of vitamin C is reported to be seven times higher than the one found in oranges. The K is three times compared to the one found in bananas; three times higher than the Fe of spinach, the amount of vitamin A was reported to be four times higher than the one of carrots MO leaves contain seventeen times higher the protein content compared to the one found in milk. The vitamin C content in dried leaves is reported to be twelve times higher than that of oranges, while the K is reported to be fifteen times higher than compared to the one found in bananas, twenty five times the Fe of spinach, ten times the amount of vitamin A in carrots, and nine times the protein in milk, (Kamal, 2008; Fuglie, 2014). Moreover, MO is also recommended to supplement diets low in minerals as the pods are rich in Ca, Mg, K, Mn, P, Zn, Cu, and Fe (Aslam *et al*., 2005).

Table 3. Nutritional composition of *Moringa oleifera* fresh and dried leaves per 100 g.

Nutritional content	**Fresh leaves**	**Dried leaves**
Vitamin A	6.78 mg	18.9 mg
Niacin (B3)	0.8 mg	8.2 mg
Riboflavin (B2)	0.05 mg	20.5 mg
Thiamine (B1)	0.06 mg	2.64 mg
Vitamin C	220 mg	17.3 mg
Calcium	440 mg	2 003 mg
Carbohydrates	12.5 g	38.2 g
Protein	6.70 g	27.1 g
Calories	92 cal	205 cal
Copper	0.07 mg	0.57 mg
Fat	1.70 g	2.3 g
Fibre	0.90 g	19.2 g
Iron	0.85 mg	28.2 mg
Magnesium	42 mg	368 mg
Phosphorus	70 mg	204 mg
Potassium	259 mg	1 324 mg
Zinc	0.16 mg	3.29 mg

Source: USDA National Nutrient Database (2015).

Moringa can prolong the shelf life of foods rich in fats because of the presence of antioxidants such as ascorbic acids, carotenoids and phenolics (Dellard & German, 2000). Anjorin *et al*. (2010) reported the difference in mineral composition of MO which was grown from different locations. Ancient people from different parts of the world depended on plant products for food and medicinal purposes to cure diseases, of which, MO was reported to be high in nutritional composition when compared to all other plants from ancient time. It is known for its excellent therapeutic compounds which can treat several diseases and infections (Kamal, 2008).

MO leaf powder has been reported to significantly increase the production of breast milk when eaten by mothers before or after birth. It was observed that mothers who took MO leaf powder were able to produce more than two times the amount of breast milk as compared to those who did not. *Moringa* is used for medicinal purposes to heal acute and chronic conditions. *In Vitro* and *In Vivo* studies have recommended the MO powder in treating rheumatoid arthritis, hyperlipidaemia, and hyperglycaemia (Bennet *et al.,* 2014 & Mbikay, 2012). The *Moringa* extract exhibited anti-fibrotic effects on liver fibrous in rats (Hamza, 2010) and showed a significant protective effect against carbon tetrachloride induced liver fibrosis in rats. Treatments with *Moringa* stimulates hepatoprotective effects against hepatocellular injury by blocking the increase of two serums, aspartate aminotransferase (AST) and alanine aminotransferase (ALT) which are indicators of liver problems (Verma *et al*., 2012).

The leaves, seeds, seed cotyledon, root bark of MO tree are reported to contain antimicrobial chemical substances. Aqueous and ethanol *Moringa* leaf extract can be used to treat certain bacterial infection (Arora *et al*., 2013). MO is well known for its pharmacological actions and is used for traditional treatment of Diabetes Mellitus (Yoshida *et al.,* 2014) as *Moringa* lowers blood glucose levels within the body (Ajit *et al*., 2002). Hypoglycaemic and anti-hyperglycaemic activity of the leaves of *Moringa* is probably due to the presence of terpernoids which appear to be involved in the stimulation of β-cells and subsequent secretion of performed insulin (Tende *et al*., 2011). *Moringa* is known to contain therapeutic properties which help in fighting cancer, rheumatoid arthritis, and diabetes mellitus. *Moringa* was also found to be a chemo-preventive agent (Budda *et al*., 2011). The presence of fatty acids could account for the chemo-preventive effect from boiled MO which modulates apoptosis in colon carcinogenesis.

2.3.1. Maize fortification with *Moringa oleifera* leaves powder

Cereal porridge is a food preferred for weaning infants and also a food consumed by adults for breakfast. Cereal gruel is a porridge produced from a variety of cereals. It was observed that as MO leaf powder was added to porridge it improved the nutritional composition of maize porridge and also increased its vitamin A content (Olorode *et al*., 2013). The inclusion of MO leaf powder to maize also increased protein, Ca, Fe and phosphorus (P) contents (Abioye & Aka, 2015; Olorode *et al*., 2013).

The inclusion of MO leaf powder in maize was observed to influence the nutritional value and functional properties differently according to different authors (Olorode *et al*., 2013). Abioye & Aka (2015) reported that as 15% of MO leaf powder was added to white maize it increased the protein value by 94%. Olorode *et al*. (2013) also confirmed that as15% of MO leaf powder was added to yellow maize it increased the protein value by 44%. A reduction in swelling power of maize porridge fortified with 15% MO leaf powder was observed. The start-off protein, starch and lipid composition of the maize could have influenced the difference in swelling power.

Based on the study conducted by Olorode *et al*. (2013), it was observed that porridge fortified with 10% MO leaf powder can be accepted by consumers. For maize porridge fortified with MO leaf powder to be accepted more panellists than what was reported by the above authors for sensory evaluation may be required. For example, it was observed that when 2.5% of MO leaf powder was added to stiff dough it was accepted by consumers and also increased the nutritional composition (Karim *et al*., 2015). Abioye & Aka (2015); Olorode *et al*. (2013) recommended a higher percentage of MO leaf powder to be added to stiff dough than what Karim *et al*. (2015) reported. When MO leaves and termite powder is added to most foods, they tend to change colour to dark green which could be due to high content of chlorophyll contained in MO leaves (Karim *et al*., 2013). According to the study done by Arise *et al*. (2014), it was observed that when MO flower powder was added to maize and millet it enhanced the nutritional content of complementary foods made from the two. It was also observed that when 20% MO flower powder was added to complementary foods made from maize and millet it was accepted by consumers. It was also reported that MO leaf powder was more accepted in terms of colour and texture than MOFP when both were added to maize with large quantity. Shiriki *et al*. (2015) recently researched on the nutritional value of weaning food produced from peanut, maize and soya bean fortified with MO leaf using albino rats. High protein content was observed in diets with MO than in diets with no MO leaves and with commercially sold weaning food (Shiriki *et al*., 2015). When an experiment was done in rats it was found that the protein efficiency ratio (PER), net protein ratio (NPR) and feed conversion efficiency (FCE) of the weaning food was found to be higher when 10% of MO leaves was added.

The addition of MO leaves to maize and millet improved the apparent digestibility (AD) as compared to Nestle brand Cerelac, which is known to be a favoured weaning food (Shiriki *et al*., 2015). However, a decrease in the quality of protein parameters (PER, NPR, FCE and AD) was reported when 15% of MO was added to the diets. Shiriki *et al*. (2015)

reported that the quantity of MO leaves ingested by the experimental rats was low due the taste of MO leaves which has been reported to be bitter.

2.4. Summary

The literature reviewed indicates that maize-based porridge contributes significantly to the dietary intake of many households in Limpopo province although it is deficient in minerals, such as, Fe, Zn and Ca. There is an abundance of *Moringa* and edible termites in the Vhembe district, which are known to contain substantial amounts of nutrients and have been used for food, livestock feeding and medicinal purposes because of their curative and therapeutic properties. However, the two have not been combined with maize. Combining these locally available sources of these nutrients could be one of the sustainable strategies towards alleviation of malnutrition and improving maternal and child health in the Vhembe district.

Chapter Three: The effect of *Moringa oleifera* leaves and termite powders on the nutritional composition of an instant-maize porridge

Abstract

The aim of this study was to determine the effect of MO leaves and termite powders on the nutritional properties of an instant-maize porridge. Inclusion of MO leaves and termite powders in instant-maize porridge, at different treatments were considered using a completely randomised design. Factor levels were: AOB-control (maize flour); BEA (maize, cooked dried MO and termite powders); CIA (maize, blanched dried MO and termite powders) and DJE (maize, uncooked dried MO and termite powders). The addition of MO leaves and termite powders (independent variables) at different treatments increased the protein and mineral content (dependant variables) and also showed positive effect on the textural and pasting properties of instant-maize porridge, although a negative effect on colour attributes of instant-maize porridge was observed. Data from three replicates were analysed using SPSS version 23. The protein content of fortified instant-maize porridge (FMP) significantly ($p < 0.05$) increased from 10.02 to 21.20%. The mineral content of FMP was higher in terms of Zn, Fe, Ca and Mg. The moisture content of FMP increased from 5.00 to 6.0%. MO leaves and termite powder could be used in complementary foods to increase their protein and mineral contents.

Keywords: Instant-maize porridge, *Moringa*, termite, mineral, protein.

3.1. Introduction

Maize porridge is a staple food for most (80%) people in South Africa and contributes significantly to the dietary intake of households in Limpopo province (Mushaphi *et al.,* 2015). The bio-availability of minerals which are vital for proper nutrition and health is often affected by phytic acid which is contained in the maize grain. This interferes with the absorption of minerals (Hulse *et al*., 1980), such as, Fe, Zn and Ca and inadequate intake of these elements causes Anemia *osteomalacia,* Zn deficiency and rickets, respectively (Widdowson, 2002). According to Motadi *et al.* (2015) the prevalence of Zn deficiency and anaemia in pre-school children of the Vhembe district in Limpopo province was 42.6% and 28% respectively in 2014. Fortifying instant-maize porridge with *Moringa oleifera (*MO*)* leaves and termite powders should be important since maize-based porridge contributes significantly to the dietary intake of many households in the Limpopo province. Over-dependency on maize-based porridge, therefore may lead to high prevalence of malnutrition-related health conditions. Use of locally available sources of these nutrients could be one of the sustainable strategies towards the alleviation of malnutrition.

3.2. Materials and methods

3.2.1. Experimental site

The study was conducted in the Department of Food Science and Technology, School of Agriculture, University of Venda, Thohoyandou, South Africa.

3.2.2. Experimental design

The inclusion of MO leaves and termite powders in instant-maize porridge, at different treatments were considered. The experiment was set up as a completely randomised design. The factor levels were: T_0-control (100% maize, 0% MO leaves and 0% termites); T_1 (80% maize, 5% cooked MO leaves and 15% termite powders); T_2 (80% maize, 5% blanched MO leaves and 15% termite powders); T_3 (80% maize, 5% uncooked MO leaves and 15% termite powders). The addition of MO leaves and termite powders (independent variables) at different treatments increased the protein and mineral content (dependant variables) and also showed positive effect on the textural and gelation properties of an instant-maize porridge, although a negative effect on colour attributes of instant-maize porridge was observed. Each experiment was done in triplicates and the statistical model was: $Yij = M + Ti + Eij$

where: Yij = Observation, M = Overall mean, Ti = Effect of i^{th}treatment on instant maize porridge, Eij = Random error

3.2.3. Sample collection and preparation

Judgemental or purposive sampling was used for the selection of samples wherein non-probability sampling technique was used to sample maize meal, MO leaves and termites. Judgemental or purposive sampling is a non-probability technique that is based on the knowledge and professional judgement of the researcher. Maize meal, salt, sugar, stainless steel pots, stainless steel 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. The process for the production of a fortified instant-maize porridge is shown in Figure 5.

Maize meal, MO leaves and termites (*Isoptera*)

↓

Cooking at 92˚C: maize meal (35 min), MO leaves (20 min), termites (30 min)

↓

Drying at 50ºC: Maize (8 h), MO leaves (2 h), termites (12 h)

↓

Milling

↓

Compositing

↓

Fortified instant porridge

Figure 5. Flow diagram of fortified instant maize porridge processing(Gutierrez *et al*., 2007).

3.2.4. Proximate analysis of instant-maize porridge

The moisture, protein, fat, fibre, ash and carbohydrate contents of samples were analysed according to AOAC (2000).

Moisture determination

Moisture (g water/100 g sample) was determined using AOAC (2000) method 925.09. Moisture was determined by the loss in weight that occurred when a sample was dried to a constant weight in an oven. About 2 g of a feed sample was weighed into a silica dish (crucible) previously dried and weighed. The sample was then dried in an oven for 65˚C for 36 h, cooled in a desiccator and weighed. The drying and weighing continued until a constant weight was achieved:

$$\% \, Moisture = \frac{wt\ of\ sample + dish\ before\ - wt\ of\ sample + dish\ before\ drying}{wt\ of\ sample\ taken}\ x\ 100$$

Fat determination

Fat (g fat/100 g sample) was analysed by soxhlet extraction method (AOAC, 2000: 920.39). About 150 ml of an anhydrous diethyl ether (petroleum ether) of boiling point of 40-60˚C was placed in the flask. About 2 – 5 g of the sample was weighed into a thimble and the thimble was plugged with cotton wool. The thimble with content was placed into the extractor; the ether in the flask was then heated. As the ether vapour reached the condenser through the side arm of the extractor, it condensed to liquid form and dropped back into the sample in the thimble; the ether soluble substances were dissolved and were carried into solution through the siphon tube back into the flask. The extraction continued for at least 4 h. The thimble was removed and most of the solvent was distilled from the flask into the extractor. The flask was then disconnected and placed in an oven at 65˚C for 4 h, cool in desiccator and weighed (AOAC, 2006).

$$\% \, Fat = \frac{wt\ of\ flask + extract - tare\ wt\ of\ flask\ x\ 100}{wt\ of\ sample\ taken}$$

Fibre determination

Fibre as (g crude fibre/100 g sample) was determined using AOAC (2000) method 992.16. The organic residue left after sequential extraction of feed with ether was used to determine the crude fibre, however a fresh sample was used and the fat in it was extracted by adding petroleum ether, stirred, allowed to settling and decanting. This was done three times. The fat-free material was then transferred into a flask/beaker and 200 ml of pre-heated 1.25% H2SO4 was added and the solution was gently boiled for about 30 min, maintaining constant volume of acid by the addition of hot water. The Buckner flask funnel fitted with whatman filter was pre-heated by pouring hot water into the funnel. The boiled acid sample mixture was then filtered hot through the funnel under sufficient suction. The residue was then washed several times with boiling water (until the residue was neutral to litmus paper) and transferred back into the beaker. Then 200 ml of pre-heated 1.25% Na2SO4 was added and boiled for another 30 min. It was filtered under suction and washed thoroughly with hot water and twice with ethanol. The residue was dried at 65˚C for about 24 h and weighed. The residue was transferred into a crucible and placed in muffle furnace (400 - 600˚C) and ashed for 4 h, then cooled in desiccator and weighed.

$$\%\ Crude\ fibre = \frac{Dry\ wt\ of\ residue\ before\ ashing - wt\ of\ residue\ after\ ashing\ x\ 100}{wt\ of\ sample\ taken}$$

Protein Determination

Protein (g protein/100 g sample) was analysed using Kjeldahl method (AOAC, 2000: 979.09). Protein was determined by measuring the nitrogen content of the feed and multiplying it by a factor of 6.25. This factor was based on the fact that most protein contains 16% nitrogen. Crude protein was determined by Kjeldahl method. The method involves: Digestion, distillation and titration. Digestion: About 2 g of the sample was weighed into Kjeldahl flask and 25 ml of concentrated sulphuric acid, 0.5 g of copper sulphate, 5 g of sodium sulphate and a speck of selenium tablet were added. Heat in a fume cupboard was applied and digested for 45 min slowly at first to prevent undue frothing until the digesta became clear pale green and was allowed to completely cool and rapidly 100 ml of distilled water was added. The digestion flask was rinsed 2-3 times. Distillation: Markham distillation apparatus was used for distillation. The distillation apparatus was steamed up and 10 ml of the digest was added into a funnel and allowed it to boil. About 10 ml of sodium hydroxide from the measuring cylinder was added so that ammonia was not lost and distilled into 50 ml of 2% boric acid containing screened methyl red indicator.

Titration: the alkaline ammonium borate formed was added titrated directly with 0.1N HCl. The volume of acid used was added fitted into the formula:

$$\% \, N = \frac{14 \, x \, VA \, x \, 0.1 \, x \, w \, x \, 100}{1000 \, x \, 100}$$

VA = volume of acid used w= weight of sample
% protein = %N x 6.25

Ash

Ashing was performed using AOAC (2000) method 923.03. Ash is the inorganic residue obtained by burning off the organic matter of feedstuff at 400-600˚C in muffle furnace for 4 h. About 2 g of the sample was weighed into a pre-heated crucible. The crucible was placed into muffle furnace at 400-600˚C over night and whitish-grey ash was obtained (AOAC, 2006). The crucible was then placed in the desiccator and weighed:

$$\% \, Ash = \frac{wt \, of \, crucible + ash - wt \, of \, crucible}{wt \, of \, sample}$$

Carbohydrate

Carbohydrate was determined by mathematical calculation. It was obtained by subtracting the sum of percentages of all the nutrients already determined from 100(AOAC, 2006).

$$\% \, Carbohydrate = 100 - (moisture + \% \, Fibre + \% \, protein + Fat + \% \, Ash$$

3.2.5. Minerals analysis of instant-maize porridge

In order to solubilise the acid-extractable elemental content of the sample, digestion was performed on a microwave accelerated reaction system (MARS microwave digester), using ultra-pure HNO_3 + H_2O_2 at elevated temperature (250˚C) and pressure (1200 PSI). After a cooling period, the extractant was diluted 10x with deionised water, then analysed by ICP-AES. Minerals were analysed on a Thermo ICap 6200 inductively coupled plasma optical emission spectrometry (ICP-AES). The instrument was calibrated using the National Institute of Standards and Technology (Gaithersburg MD, USA) traceable standards purchased from Inorganic Ventures (INORGANIC VENTURES, 300 Technology

Drive Christiansburg, VA 24073) to quantify selected elements. A NIST-traceable quality control standard from De Bruyn Spectroscopic Solutions (Bryanston, South Africa) were analysed to verify the accuracy of the calibration before sample analysis, as well as throughout the analysis to monitor drift.

3.2.6. Statistical analysis

All analyses were carried out in triplicate. Results from this study were analysed using statistical Package of the Social Sciences (SPSS version 23). Data was subjected to analysis of variance and means were separated using Duncan's multiple range test at $p < 0.05$ (Duncan, 1955).

3.3. Results and Discussion

3.3.1. Proximate composition of instant-maize porridge

The proximate composition of fortified and instant-maize porridge (FMP) and unfortified samples are shown in Table 4. The values for moisture of FMP increased from 5.0% to 6.0% and higher moisture content was observed in FMP than in AOB at $p < 0.05$. This observation indicates that FMP may have shorter shelf life, when compared to AOB because of higher moisture content since low moisture content of less than 5.0% is recommended by FAO (2015) for weaning food. Higher moisture content is known to enhance the growth of microorganisms in food, which causes food to spoil, resulting in food being nutritionally poor (Udensi *et al*., 2012). However, the moisture values reported in this study are lower than what Adepoju & Ajayi (2016) reported for maize enriched with termite powder (10.7to 11.4%). Moreover, Abioye & Aka (2015) reported higher moisture content of 8.8 to 9.1% for yellow-maize fortified with MO leaves. This observation could be attributed to different drying methods used, since some drying methods are considered more effective and safe than others. In the present study oven drying was used than air drying method used by the above authors.

Table 4. Proximate composition of instant-maize porridge fortified with MO and termite powders.

Composition (%)	**AOB**	**BEA**	**CIA**	**DJE**
Moisture	5.00 ± 0.00^{a}	5.33 ± 0.58^{a}	5.67 ± 1.54^{a}	6.0 ± 0.00^{b}
Ash	0.32 ± 0.43^{b}	0.34 ± 0.05^{a}	0.36 ± 0.11^{b}	0.49 ± 0.54^{ab}
Fiber	1.38 ± 0.03^{a}	2.45 ± 0.07^{a}	2.47 ± 0.49^{a}	2.49 ± 0.03^{a}
Fat	1.06 ± 0.00^{a}	2.06 ± 0.08^{b}	2.15 ± 0.01^{c}	2.26 ± 0.26^{d}
Protein	10.02 ± 1.15^{a}	19.33 ± 0.06^{b}	20.22 ± 1.15^{c}	21.20 ± 0.06^{d}
Carbohydrates	81.51 ± 0.60^{d}	64.38 ± 0.50^{c}	61.85 ± 1.26^{b}	56.59 ± 0.11^{a}

Means ± SD. Mean values followed by different letters in the same row are significantly different at $p<0.05$. AOB = Control sample (maize), BEA = maize, termites and cooked *Moringa oleifera* blend, CIA = maize, termites and blanched *Moringa oleifera* blend and DJE = maize, termites and uncooked *Moringa oleifera* blend.

The ash content in this present study ranged from 0.3 to 0.5%. An increase in ash content of FMP was not significantly ($p < 0.05$) different. This indicates that MO leaves and termites could be a good source of minerals. An increase in ash content is due to the fact that MO leaves and termite powder are known to be high in minerals. Minerals are essential to the proper functioning of many body processes. The ash values in this present study are lower than what Adepoju & Ajayi (2016) reported for maize enriched with termite powder (2.9 to 3.5%). Moreover, Ojarotimi & Oluwalana (2013) reported higher ash values for blanched popcorn-moringa leaves (1. 8%). The lower ash content observed in the present study could be attributed to the leaching out of minerals during processing (washing, cooking and blanching) of MO leaves. This could also be attributed to different weather conditions (Palada *et al*., 2007) since the present study and studies by other authors were conducted in different places and seasons. Although the ash values in this study are lower compared to what was reported by Adepoju & Ajayi (2016) and Ojarotimi & Oluwalana (2013) the ash percentage in this study is within what Amankwah *et al*. (2009) & FAO (2015) recommended (< 3%) for weaning food.

An increase in fibre content (1.4% to 2.5%) of FMP was observed with the addition of MO leaves and termite powder at $p < 0.05$. An increase in fibre (Table 4) makes FMP more commendable as it would facilitate digestion. The fibre values in this present study are higher than what was reported by Ojarotimi & Oluwalana (2013) for blanched popcorn-moringa leaves (2.4 %) and are still within the amount recommended (< 5) by FAO for weaning food. This could be attributed to that insects are known to contain substantial amounts of fibre in different forms; with chitin being the highest fibre in insects (Jongema, 2014). Moreover, this could also be attributed to different weather conditions, since the study of Ojarotimi & Oluwalana (2013) was conducted in Nigeria which is known to be tropical. MO was reported to grow well in temperatures around 25 - 35˚C and also requires a rainfall of 250 - 3000 mm (Thurber *et al*., 2010). In addition, the application of different fertilizers (Palada *et al*., 2007) may have contributed to an increase in fibre content of the present study. Poultry manure was used in the present study to nurture MO tree and has been reported by Dania *et al*. (2014) to be the best in increasing nutritional composition of a plant. The fibre content (1.3%) reported by Niaba *et al*. (2013) also increased when wheat biscuits were fortified with termite powder. An increase in fibre content of the study conducted by Niaba *et al.* (2013) could be attributed to the wheat flour used to make biscuits, since wheat flour has been reported to be high in fibre. This observation indicates that fortified samples may be a good source of fibre compared to AOB because of their higher fibre contents.

The fat content of AOB (1.1%) was lower than of fortified samples (2.1, 2.15 and 2.3%) at $p < 0.05$. Upon addition of MO leaves and termite powder, the fat content in this present study was observed to be lower than what was reported (2.53 to 2.7%) by Niaba *et al*. (2013). This could be attributed to high fat content of termites (Defoliart, 2002) and use of shortenings in making wheat biscuits. Moreover, Ojarotimi & Oluwalana (2013) reported low fat content for fermented popcorn-*moringa* leaves to be 2.0%. This can be a result of microbial activity during fermentation (Ijarotimi *et al*., 2013). This could be attributed to the addition of termites which have been reported to be rich in fat (Jongema, 2014) and might have increased the fat content when added to maize porridge. However, the fat values in this present study are lower than what was reported by Adepoju & Ajayi (2016) for complementary foods enriched with termite powder (5.1%). This could be because MO leaves added have been reported to be low in fat (Rajaratnam *et al*., 2010). A low fat content of 2.0– 4.0% is recommended for weaning food (Demaeyer, 1976)as high fat content in a food sample can influence its shelf life. Sample BEA, CIA and DJE may be of advantage to human health and also in extending shelf life because of their lower fat contents. Food with high fat content is bound to spoil faster compared to the one with low fat content (Niaba *et al*., 2013).

The protein content of sample AOB (10.0%) was lower than of FMP. Among the fortified samples, DJE (21.2%) was observed to be higher than BEA (19.3%), CIA (20.2%) at $p < 0.05$ and could be because of substitution effect, since fresh uncooked MO leaves are reported to be high in protein. In addition the protein content in sample BEA and CIA might have reduced during processing (cooking and blanching) of MO leaves (Otunola *et al.,* 2007) and termites. At higher temperature, proteins get denatured and this could be the cause for the difference in nutrient content (Asante *et al*., 2014). The protein content of the fortified samples in this study were significantly higher than the protein content reported by Oyarekua & Eleyinmi (2004) for *ogi* made from sorghum and millet. This observation could be attributed to that among cereals, maize is reported to contain high amount of protein than other cereals (Iken & Amusa, 2010), although cereals are known to contain more carbohydrate and low amount of protein and essential minerals. Rajaratnam *et al*. (2010) also reported MO leaves to contain substantial amounts of protein, which could be attributed to an increase in protein content in the present study. The protein values in this present study were also higher than what was reported by Ojarotimi & Oluwalana (2013), for blanched popcorn-*moringa* leaves (15.9%). Scientific findings have shown that termites are rich in protein which also could be attributed to an increase in the protein content of FMP (Hotz & Gibson, 2001). Moreover, the 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, since immature MO leaves are known to be rich in protein (Anwar *et al*., 2007). The values in this present study are comparable to what was reported by Karim *et al*.(2013) where the addition of MO leaves powder increased the protein content of *amala* (stiff dough) and was observed to be three times more than the unfortified *amala* (Karim *et al*., 2015). Orolode *et al*. (2013) reported the protein value of 13.93% when MO was mixed with maize porridge. Moreover, the protein content in the present study is also higher than the one obtained by Theodore *et al.* (2009), in the fortification of *ogi* with bambara- nut flour which reached up to 16.4% at a ratio of 80:20 (i.e. maize porridge bambara-nut). Scientific findings have shown that cereal porridges are characterised by protein denseness (Hotz & Gibson, 2001; Lutter & Rivera, 2003; Inyang & Zakari, 2008; Igyor *et al*., 2011) due to that during preparation the substantial water volume relative to its solid matter is used to make porridge.

This implies that MO leaves and termite powders blend could help in increasing the crude protein in food products. However, the protein contents of FMP in this study were higher than what was recommended by FAO/WHO (2015) for infant complementary food (≥ 15.0%). The high protein values observed in this study, particularly of samples BEA, CIA and DJE, shows that the fortified instant-maize porridge 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*., 2000; Amankwah *et al.,* 2009; Bruyeron *et al*., 2010; Muhimbula *et al*.(2011). 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).

Ibeanu (2009) advocated that legumes and cereals should be used to enhance the nutritional value of weaning foods for children and adults in sub-Saharan countries. Foods used to feed infants should be adequate in protein intake and other essential nutrients (Solomon, 2005). The results of this study revealed that MO leaves and termites possess good nutritional properties. Their protein content 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 1000 days of life, therefore should be taken seriously. Exclusive breastfeeding is crucial to the infant in the first six months of life (Lutter & Rivera, 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 carbohydrate content of AOB (81.5%) was observed to be higher than of BEA (64.4%), CIA (61.85 %) and DJE (56.6%) at $p < 0.05$. Cereals have been reported to contain more carbohydrate and fewer amounts of protein and essential minerals. The carbohydrate content of fortified samples decreased with addition of MO leaves and termite powder (Table 4). Mbata *et al*. (2009) also reported carbohydrate reduction when plant was added to cereal-based traditional foods. MO leaves are known to be low in carbohydrate (Rajaratnam *et al*., 2010). The carbohydrate values of sample BEA and CIA in this present study are higher than what was reported by Adepoju & Ajayi (2016), for complementary foods enriched with termite powder (60.5 to 61.7%). The decrease in carbohydrate content of sample DJE in this study could be due to substitution effect. Although the carbohydrate content of the samples in this study decreased from 81.5% to 56.6%, the percentage of carbohydrate content of sample BEA is within the amount recommended (64.0%) by Amankwah *et al*. (2009) for weaning food. This observation indicates that sample BEA may be a good source of carbohydrate compared to CIA and DJE because of their lower carbohydrate contents. Carbohydrates help in providing energy for all forms of body activity. Deficiency can cause the body to divert proteins and body fat to produce needed energy, thus leading to depletion of body tissues.

3.3.2. Mineral content of instant-maize porridge

The mineral content of FMP and control samples is presented in Table 5. It was found that fortified samples contained substantial amounts of Zn, Fe, Ca and Mg and significantly higher than AOB at $p < 0.05$. Cereals have higher carbohydrate and lower essential mineral content (Iken & Amusa, 2010). Moreover, MO and termites are known to contain substantial amounts of minerals. Higher Ca values (220.95 - 276.77 mg/100 g) in this present study were recorded. Akingbala *et al. (*2005); Aminigo & Akingbala (2004) & Otunola *et al. (*2007) recorded Ca values of 95.00 to 538 mg/100g, in the substitution of *ogi* with okra seed flour. Processing methods may lead to a change in mineral content of food (Prasanthi *et al*., 2017). The Ca content in this study is higher than the one (115.64 - 128.40 mg/100 g) obtained by Theodore *et al.* (2009), in the fortification of *ogi* with Bambara ground-nut. This observation could be as a result of substitution effect, since MO leaves have been reported to contain four times the amount of Ca found in cow's milk which is especially important for children (Edward *et al.,* 2005). MO leaves have been reported to differ in nutrient composition at different locations (Aslam *et al*., 2005). The MO tree grown in Nigeria might be different with the one grown in South Africa in terms of nutritional composition. Moreover, Niaba *et al*. (2013) outlined a gradual increase in the content of Ca (17.43 - 79.72 mg/100 g) for wheat biscuits fortified with termite powder, although the values reported by Niaba *et al*. (2013) are lower than in the present study. The increase in Ca in sample BEA, CIA and DJE may be due to the addition of MO, since it has been reported to be high in potassium and Ca (Jideani & Diedericks, 2014). This indicates that sample BEA, CIA and DJE can be appropriate in the formation of teeth and bones of young children if consumed as weaning food.

Table 5. Mineral composition (mg/100g) of instant-maize porridge fortified with *Moringa oleifera* and termite powders.

Composition (%)	**AOB**	**BEA**	**CIA**	**DJE**
Calcium	7.08 ± 0.03[a]	220.95 ± 1.74[b]	267.77 ± 3.05[d]	234.69 ± 0.48[c]
Iron	7.73 ± 0.07[a]	32.30 ± 0.20[c]	36.85 ± 0.12[d]	27.87 ± 0.16[b]
Magnesium	31.42 ± 0.14[a]	97.04 ± 0.36[c]	92.31 ± 0.39[b]	91.96 ± 0.26[b]
Zinc	3.40 ± 0.31[a]	6.54 ± 0.45[b]	7.12 ± 0.20[c]	7.57 ± 0.64[b]

Means ± SD. Mean values followed by different letters in the same row are significantly different at $p < 0.05$. AOB = Control sample (maize), BEA = maize, termites and cooked *Moringa oleifera* blend, CIA = maize, termites and blanched *Moringa oleifera* blend and DJE = maize, termites and uncooked *Moringa oleifera* blend.

Zn content of AOB (3.40 mg/100 g) was observed to be lower than of BEA (6.54 mg/100 g), CIA (7.12 mg/100 g) and DJE (7.57 mg/100 g) at $p < 0.05$ (Table 5). Upon the addition of MO leaves and termite powder, the Zn content was observed to be higher than what was reported by Ojarotimi & Oluwalana (2013). The application of different fertilizers (Palada *et al*., 2007; Prasanthi *et al*., 2017) could also be attributed to an increase in Zn content. Moreover, the Zn content of FMP in this present study was higher than what was recommended (3. 2 mg/100g) by FAO/WHO (2015) for weaning food. This observation may be attributed to that MO is known to contain substantial amounts of Zn (Edward *et al*., 2005). Factors such as location, climate and the environment can significantly influence nutritional content of MO tree (Moyo *et al*., 2011). 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 Fe content of AOB (7.73 mg/100 g) was lower than of BEA (32.30 mg/100 g), CIA (36.85 mg/100 g) and DJE (27.87 mg/100 g) at $p < 0.05$ (Table 5). Higher Fe values (27.87 – 36.85 mg/100 g) in this present study were observed among fortified samples and this could be as a result of substitution effect, since fresh uncooked MO leaves are reported to have over three times the amount of Fe than spinach (Edward *et al.,* 2005). Akingbala *et al*. (2005); Aminigo & Akingbala (2004); Otunola *et al.* (2007) recorded Fe values of 7.50 to 18.00 mg/100 g in the substitution of *ogi* with okra seed flour. Upon the addition of MO leaves and termite powder, the iron content was observed to be higher than what was reported by Ojarotimi & Oluwalana (2013), where the Fe content of fermented popcorn-moringa leaves was 4.12 g/100 g. This may be attributed to the fact that MO leaves and termites contain substantial amounts of Fe. Moreover, the Fe values in this present study are lower than what was reported by Adepoju & Ajayi (2016), where the Fe content of complementary foods enriched with termite powder was 4.13 mg/100 g. The nutritional composition also varies due to 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. Nutrient loss may occur during harvesting, handling and transportation, processing, storage and distribution (Selinger, 2016).

The Mg content of AOB (31.42 mg/100 g) was lower than of BEA (97.04 mg/100 g), CIA (92.31 mg/100 g) and DJE (91.96 mg/100 g) at $p < 0.05$ (Table 5). This observation could be as a result of substitution effect, since MO leaves and termites has been reported to contain four times the amount of Mg. Upon the addition of MO leaves and termite powder, the Mg content was observed to be lower than what was reported by Ojarotimi & Oluwalana (2013), for fermented popcorn-*moringa* leaves (284.40 - 285.71 mg/100 g). The type of soil can contribute to the nutrient content and strength of the plant. Dania *et al*. (2014) reported that the type of fertilizers used to nurture plants also plays a major role in nutritional value of a product. In addition, the Mg content of FMP was found to be more compared to the commendation made by FAO/WHO (2015) for weaning food (76 mg/100 g).

The increase in Ca, Fe, Zn and Mg contents of sample BEA, CIA and DJE may be attributed to the addition of MO and termites which contain substantial amounts of Fe, Zn and Mg (Defoliart, 2002). This indicates that sample BEA, CIA and DJE could help improve Fe and Zn status and help prevent anaemia and Zn deficiency of the pre-school children in the Vhembe district who were reported to be Fe and Zn deficient in 2015 (Motadi *et al*., 2015). Food fortification has been recommended by many researchers to enhance essential nutrients lost during the processing of food (Rosalind *et al*., 2000; Lutter & Dewey, 2003).

Conclusion

The nutritional properties of an instant-maize porridge fortified with MO and termite powders were determined. It was observed that the addition of MO leaves and termite powders to maize increased the nutritional content of fortified instant-maize porridge. The findings also showed that the fortified samples, particularly samples DJE (maize, uncooked MO leaves and termite powders blend), CIA (maize, blanched MO leaves and termite powders blend), and BEA (maize, cooked MO leaves and termite powders blend) were higher in terms of protein and mineral contents than the control sample (maize-AOB). Hence, these formulations could be used as food for pregnant women, lactating mothers and infants, particularly underprivileged families, which are unable to afford nutritious and healthy weaning food. In addition the nutrient composition of instant-maize porridge fortified with MO leaves and termites based weaning food may be proper to be used as supplement for weaning food, which contains low amount of essential nutrients.

Chapter Four: The *effect of Moringa oleifera* leaves and termite powders on the physical, pasting and sensory properties of an instant-maize porridge.

Abstract

Moringa oleifera (MO) and termite are known to contain a substantial amount of protein. The aim of this study was to determine the effect of MO leaves and termite powders on the physical, pasting and sensory properties of instant-maize porridge. Inclusion of MO leaves and termite powders in instant-maize porridge, at different treatments were considered using a completely randomised design. Factor levels were: AOB-control (maize flour); BEA (maize, cooked dried MO and termite powders); CIA (maize, blanched dried MO and termite powders) and DJE (maize, uncooked dried MO and termite powders). Data from three replications were analysed using SPSS version 23. The viscosity of sample AOB, BEA, CIA and DJE of the uncooked paste was significantly different at $p < 0.05$. The least gelation concentration increased as MO and termite powder was added to maize. The colour values of the raw and cooked FMP were significantly different at $p < 0.05$. The L*, a*, b*, c* and h˚ values of the instant-maize flour were higher values as compared to the instant-maize porridge. Sensory results showed that among fortified porridges, CIA was rated high for colour and texture, BEA higher in taste and DJE higher for aroma. AOB had higher acceptance than fortified porridges for taste. Generally sample BEA was highly accepted by consumers among the fortified samples (CIA and DJE).

Keywords: Instant-maize porridge, *Moringa*, termites, gelatinisation, viscosity, acceptability.

4.1. Introduction

Functional properties are the intrinsic physicochemical characteristics which may affect the behaviour of food systems during processing and storage (Fasasi *et al.,* 2006). Sensory evaluation is traditionally defined as a scientific method used to kindle, measure, analyse and interpret those products as perceived through the senses of sight, smell, touch, taste and hearing (Igyor *et al.,* 2011). It can be divided into two areas: objective (analytic) and subjective (hedonic). In objective testing, the sensory attributes of a product are evaluated by the use of an instrument. Subjective testing evaluates the reactions of consumers to the sensory properties of the product. The power of sensory evaluation is realised when these two elements are combined to reveal insights into the way in which sensory properties drive consumer acceptance.

4.2. Materials and methods

Experimental design is as described in chapter three

4.2.1. Colour analysis of instant-maize porridge

The colour of raw and prepared samples was determined using Lovibond LC 100 Spectrocolorimeter whereby individual L^*, a^* and b^*, c^* and h° parameters were measured.

4.2.2. Texture analysis of instant-maize porridge

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.

4.2.3. Gelatinisation analysis of instant-maize porridge

Properties of gelatinisation 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% 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.

4.2.4. Viscosity of instant-maize porridge

A Brookfield viscometer (Model RV, Brookfield Engineering Inc., Stoughton, USA) was used to measure viscosity as follows: 10 g of the sample was mixed with 90 mL of distilled water at 30˚C (10% slurry, w/v) and allowed to hydrate for 30 min with occasional stirring. Subsequently, the slurry was heated to boiling in a water bath for 20 min and cooled to 30˚C.The cooked paste viscosity was measured (Fubara, 2008).

4.2.5. Sensory evaluation of fortified instant-maize porridge

Sensory evaluation was carried out by using 60 untrained panellists on the following sensory attributes: appearance, texture, taste and aroma; and overall acceptability of fortified instant-maze porridge were evaluated. Panellists who formed part of the study were contacted by the researcher and agreed. A nine-point hedonic scale, varying from dislike extremely (score 1) to like extremely (score 9) was used according to Mbata *et al*. (2009). Error due to bias was reduced by not including on the panel those persons who were directly involved with the preparation of samples during the sensory evaluation of fortified instant-maize porridge. 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 testing of the porridge samples (Igyor *et al*., 2011).

4.2.6. Ethical clearance

Ethical clearance to conduct sensory evaluation was sought and obtained (Appendix B) from the University Research Ethics Committee. Panellists were asked to read and sign the consent form before they participated in this study (REPOPA, 2011; WHO, 2012).

4.3. Results and Discussion

4.3.1. Colour and texture attributes of instant-maize porridge

The physical and pasting properties of instant-maize porridge are presented in Table 6. The L*, b* and c* values of the raw instant-maize flour were 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 samples AOB, BEA, CIA and DJE of the raw flour were significantly different at $p < 0.05$. The L* values of the cooked porridge was observed to be higher in sample AOB. The L* value of sample BEA, CIA and DJE were not significantly different at $p < 0.05$. The L* values of both raw (83.87 – 52.03) and cooked (61.61 – 33.66) 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*., 2006). 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 – -2.53) and cooked (- 1.46 – 0.47) instant-maize porridge increased with the addition of MO leaves and termite powder (Table 6). An increase in the b* values of raw (11.97 – 20.17) and cooked (10.03 – 18.17) instant-maize porridge with the addition of MO leaves and termite powder was also observed.

In general the inclusion of MO leaves and termite powders in instant-maize porridge resulted in darker instant-maize porridge because of the presence of chlorophyll and carotenoid pigments (Muhammad & 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 (α-carotene, β-carotene) and chlorophyll (Owusu, 2008).Pigments (Chlorophyll A, Chlorophyll B and carotenoids) play a role in photosynthesis, the process that cause light energy to turn into chemical energy in organic compounds. The β-carotene, a carotenoid, is also known as pro vitamin A because it is converted to form vitamin A which protect human eyes (Owusu, 2008).

The texture of sample AOB was significantly higher in terms of hardness than FMP at $p < 0.05$. The inclusion of MO and termite powder had a positive effect on the texture as shown by the softness of FMP compared to AOB which was harder. This could be attributed to the lower starch content in sample BEA, CIA and DJE which was diluted by the addition of MO 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.

Table 6. Pasting and physical properties of instant-maize porridge fortified with leaves and termite powders (n = 12)

Values	AOB	BEA	CIA	DJE
Flour				
L^*	83.87 ± 0.42[d]	57.90 ± 0.72[c]	55.50 ± 1.47[b]	52.03 ± 0.46[a]
a^*	-0.20 ± 0.10[b]	1.77 ± 0.11[d]	0.87 ± 0.58[c]	-2.53 ± 0.58[a]
b^*	11.97 ± 0.74[a]	14.17 ± 1.00[b]	19.53 ± 0.25[c]	20.17 ± 0.59[c]
c^*	11.97 ± 0.74[a]	14.20 ± 1.00[b]	19.63 ± 0.30[c]	20.30 ± 0.62[c]
h°	84.80 ± 0.45[a]	86.53 ± 0.17[b]	90.87 ± 0.58[c]	97.16 ± 0.15[d]
Cooked porridge				
L^*	61.61 ± 0.86[b]	34.70 ± 1.73[a]	35.46 ± 1.59[a]	33.66 ± 1.09[a]
a^*	-1.46 ± 0.42[a]	1.93 ± 0.55[c]	1.53 ± 0.31[b]	0.47 ± 0.52[c]
b^*	10.03 ± 0.38[a]	13.70 ± 1.47[c]	16.60 ± 0.44[b]	18.17 ± 0.44[d]
c^*	10.07 ± 0.58[a]	16.70 ± 0.91[c]	13.73 ± 0.22[b]	18.20 ± 0.25[c]
h°	191.10 ± 12.56[b]	83.47 ± 1.26[a]	85.23 ± 1.26[a]	88.03 ± 0.55[a]
Texture	37.67 ± 2.15[d]	30.17 ± 4.90[c]	28.10 ± 5.39[b]	24.70 ± 9.49[a]
Viscosity				
Uncooked paste	13.73 ± 0.58[d]	12.67 ± 0.57[c]	12.33 ± 0.57[b]	12.30 ± 0.57[a]
Cooked paste	443.33±18.15[d]	223 ± 2.08[c]	216.67 ± 7.64[b]	210.33 ± 9.87[a]
Gelatinisation temperature (°)	89.30±18.15 [a]	97.10 ±13.11[b]	97.18 ± 17.16[c]	98.19 ±19.21[d]

Means ± SD. Mean values followed by different letters in the same row are significantly different at $p < 0.05$. AOB = Control sample (maize), BEA = maize, termites and cooked *M. oleifera* (MO) blend, CIA = maize, termites and blanched MO and DJE = maize, termites and uncooked MO blend.

4.3.2. Viscosity and gelatinisation properties of instant-maize porridge

The viscosity of sample AOB, BEA, CIA and DJE of the uncooked paste was significantly different at $p < 0.05$. The viscosity of sample AOB, BEA, CIA and DJE of the cooked paste was significantly different at $p < 0.05$ (Table 6). The viscosity of samples AOB, BEA, CIA and DJE of the cooked paste was higher compared to the viscosity level of samples AOB, BEA, CIA and DJE 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 and termite powder was found to cause FMP of both the cooked and uncooked paste to be less viscous as compared to AOB, though the viscosity of sample BEA was more than of sample CIA and DJE in both cooked and uncooked paste at $p < 0.05$. This could be because that starch content in samples BEA, CIA and DJE was diluted by the addition of MO leaves and termite powder.

The decrease in viscosity with addition of MO and termite powders (Table 6) in samples BEA, CIA and DJE makes the fortified instant-maize porridge 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*. (2015), where a decrease in viscosity 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 of '*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 due to 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 by (Akingbala *et al.,* 2005; Aminigo & Akingbala, 2004; Otunola *et al.*, 2007), on the substitution of '*ogi*' with okra seed flour. A report given by Theodore *et al.* (2009) on the substitution of '*ogi*' with *bambara*-nut gives a similar report and stated that a low viscosity food contains higher nutrients since the volume of the food is low.

The least gelatinisation concentration in the present study increased as MO leaves and termite powders were added to maize (Table 6). 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 maize porridge FMP would not gel easily as compared to maize porridge without MO and termite powders. The addition of MO leaves and termite powders reduced the ability of the blends to gel. It is also desirable since high least gelation concentration will lead to reduction in viscosity thus increasing nutrient density and is favourable for weaning food (Olorode *et al*., 2013).

4.3.3. Sensory properties of instant-maize porridge

The sensory attributes (colour, texture, taste and aroma) are presented in Figure 6. The results show that sample AOB had higher acceptance scores than the fortified samples (BEA, CIA and DJE) at $p < 0.05$. Among the fortified samples, sample CIA was rated high in colour (6.78) and texture (6.65), BEA was more acceptable for taste (6.60) and DJE was rated high in aroma (6.79), (Figure 6). Generally, these results indicate that sample BEA had higher acceptability among the fortified samples (CIA and DJE). There was no much significant difference in the colour of sample BEA, CIA and DJE (Figure 6) at $p < 0.05$. Sample BEA, CIA and DJE are the least accepted for colour, though CIA had higher acceptance than the two. This may be due to the dark green colour of MO leaves caused by chrorophyll and carotenoids, which is different from the normal white or yellow colour of maize and leafy flavour imparted by the MO leaf powder (Otunola *et al.*, 2007). A similar observation was also reported on the use of okra seed in substitution of maize powder which imparted a bland taste and dark brown colour to the maize powder (Akingbala *et al.,* 2005; Otunola *et al.*, 2007). The decrease in the likeness for the aroma of the fortified instant-maize porridge could be attributed to the herbal flavour of the MO leaf powder. Enujiugha (2006) showed that there was an undesirable colour and flavour imparted on the maize supplementation with African oil bean seed as level of supplementation increased. On the contrary, an improved colour of maize when pawpaw slurry was added to it was reported, thus improving consumer acceptability. Moreover, the dark green colour of sample CIA and DJE 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).

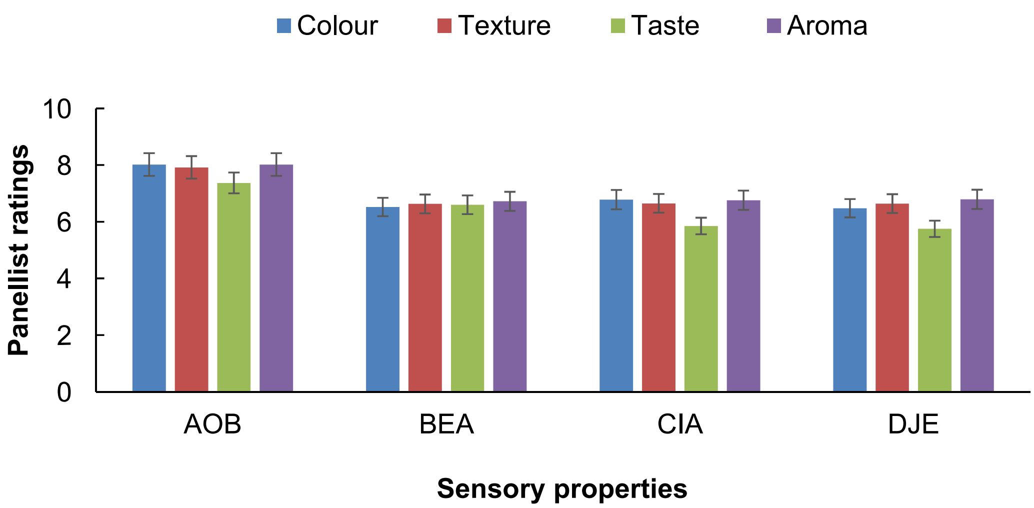

Figure 6. Sensory properties of instant-maize porridge fortified with *M. oleifera* (MO) leaves and termite powder. AOB = Control sample (maize), BEA = maize, termites and cooked MO blend, CIA = maize, termites and blanched MO blend and DJE = maize, termites and uncooked MO blend.

The ratings for the taste and aroma of the FMP decreased with the inclusion of MO leaves and termites (Figure 6). The high ratings for taste of sample BEA 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 ($p < 0.05$) among these fortified samples (BEA, CIA and DJE) in terms of texture (Akingbala *et al.,* 2005). The slight lower ratings may be as a result of inclusion of MO leaves and termite powder. Nevertheless, the inclusion of MO leaves and termite powder still retained 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.

Conclusion

The viscosity of the control sample (AOB), maize, termites and cooked MO blend (BEA), maize, termites and blanched MO blend (CIA) and maize, termites and uncooked MO blend (DJE) of the cooked paste was higher compared to the viscosity level of the uncooked paste. This could be that starch swells less at lower temperatures and swells more at higher temperatures. The least gelatinisation concentration in the present study increased as the MO and termite powder were added to maize. This could lead to an increase in nutrient density and is favourable for weaning food. Sample CIA had high acceptance in colour and texture among the fortified samples. Samples BEA and DJE received low ratings for colour. This could be attributed to the dark green colour of MO leaves which is contrary to the normal white or yellow colour of maize. The high acceptance for the taste of sample BEA may be ascribed to the cooked MO leaves which were less bitter as compared to the blanched and uncooked MO leaves.

General conclusion and recommendations

General conclusion

The nutritional and sensory properties of instant-maize porridge fortified with *Moringa oleifera* (MO) leaves and termite powders were studied. It was observed that the addition of MO leaves and termite powders to instant-maize porridge resulted insignificant increase in the protein and mineral content of fortified instant-maize porridge. The addition of MO leaves and termite powders (independent variables) at different treatments increased the protein and mineral content (dependant variables) and also showed positive effect on the textural and pasting properties of instant-maize porridge, although a negative effect on colour attributes of instant-maize porridge was observed. Fortified samples received low ratings for colour and aroma attributable to the dark green colour of MO leaves which is contrary to the normal white or yellow colour of maize and the unpleasant smell from termites. Moreover, fortified instant-maize porridge can be used in food industries to produce complementary food and livestock feeding and still be acceptable. This could also be one of the sustainable strategies towards alleviation of malnutrition and improving maternal and child health in the Vhembe district and globally.

Recommendations

1. Further research should be considered on the effect of MO leaves and termite powders on the microbial and micro-structural properties of an instant-maize porridge.

2. Further research should be considered on the physicochemical and antioxidants capacity of instant-maize porridge fortified with MO leaves and termite powders.

3. Investigation should be done on reducing the undesirable colour and aroma imparted by the uncooked MO and termite powders if consumer acceptability is to be enhanced.

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Appendix A: Sensory evaluation tool of instant-maize porridge fortified with *Moringaoleifera* leaves and termite powder

Set number:……….. **Sample code:………..**

Name……………………………………………

Above 18 years? Yes ☐ or No ☐

Date:……………………..

Instructions: ***You are given four (4) porridges to taste. Indicate, based on the 9-point Hedonic scale given below, whether you like or do not like the attributes indicated by marking with (X).***

Please, start from left to right and take a sip of water before and in-between tasting.

1. Appearance (Colour)

Dislike extremely	Dislike very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

2. Aroma

Dislike extremely	Dislike very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

3. Taste

Dislike extremely	Dislike very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

4. Texture

Dislike extremely	Dislike very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

5. Overall acceptability

Dislike extremely	Dislike very much	Dislike Moderately	Dislike Slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
1	2	3	4	5	6	7	8	9

Comments……..
………

Appendix B: Ethical clearance certificate

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Ms KR Netshiheni

Student No:
11602027

PROJECT TITLE: **The effect of *Moringa Oleifera* leaves and termites *(Isoptera-Microhodotermes viator)* powder on the nutritional and sensory properties of instant-maize porridge.**

PROJECT NO: SARDF/16/FST/10/0602

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Prof AIO Jideani	University of Venda	Supervisor
Dr D Beswa	University of South Africa	Co- Supervisor
Mr M Mashau	University of Venda	Co- Supervisor
Ms KR Netshiheni	University of Venda	Investigator – Student

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: February 2017
Decision by Ethical Clearance Committee Granted
Signature of Chairperson of the Committee: ....
Name of the Chairperson of the Committee: Prof. G.E. Ekosse

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Appendix C: Conference paper and publication

Submitted conference papers

Netshiheni, K. R., Mashau, M. E., Beswa, D., Jideani, A. I. O. The effect of *Moringa oleifera* leaves and termite powder on the nutritional and sensory properties of instant-maize porridge. 22nd Biennial international Congress & Exhibition. 3 –6 September 2017, Century City, Cape Town, South Africa. (Accepted)

Manuscripts sent for publication

Jideani, A.I.O., Netshiheni, K.R. (2017). Selected edible insects and their products in traditional medicine, food and pharmaceutical industries in sub-Sahara Africa: utilization and prospects. In*Future Foods*. 1st edition. InTech; Croatia (In Press).