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NUTRITIVE COMPOSITION AND HEALTH BENEFITS OF *MORINGA OLEIFERA* AND ITS ROLE IN AGRICULTURE

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ABSTRACT
Moringa oleifera is a plant with various uses and has gained recognition in many countries of the world due to its rich nutrient content and beneficial properties. This review article presents an overview of the nutritional constituents, anthelmintic, antimicrobial, antioxidant and anti-inflammatory properties of Moringa. The various uses of Moringa in the agricultural sector were also highlighted. However, many value-added products are yet to be developed from Moringa value chain, if well exploited and utilized Moringa has great potentials to boost agricultural production. Moringa oleifera leaf contains 22.42 to 29.68% crude protein, 7.54 to 14.60% ash, 3.00 to 6.40% ether extract, 10.10 to 21.00% crude fibre, 92.12 to 93.60% dry matter and 37.87 to 49.60% nitrogen free extract. Moringa leaves have higher levels of the essential amino acids than other parts of the plant. It is noteworthy, that Moringa leaf meal contains significant quantities of essential amino acids that are rare in cereals and tubers. The plant is also a rich source of minerals and vitamins. Interestingly, there are vast areas of research on Moringa yet to be exploited. Many researchers have attested and documented that the inclusion of Moringa oleifera in human and animal diet has nutritional and several other good effects. Some important health properties associated with the use of Moringa are; anthelmintic, antimicrobial, antioxidant and anti-inflammatory properties. All parts of the Moringa plant have been found to be very useful in the agricultural sector especially in animal production, crop production, agroforestry, aquaculture and food processing and product development.

Keywords: *Moringa oleifera*, agriculture, beneficial properties, nutritional content

INTRODUCTION
Drumstick tree (*Moringa oleifera*) is a unique plant that is referred to be nature's gift. It is categorized as a medium-size tree, found in many countries of the world (Gandji *et al.*, 2018). *Moringa* plant is endowed with several properties and components that are advantageous in food and industrial applications. Basically, all parts of the *Moringa* plant have been used for several purposes. However, the most popular or commonly used part of *Moringa* plant is the leaf (Abbas, 2013). It is also a majorly used part for feeding animals. Several researchers have documented the nutritional, industrial, agricultural and medicinal uses of *Moringa oleifera*. *Moringa* is also well known to be a plant of significant economic importance. It is also among one of the most important plants used for food and folklore medicine. It is worth noting that this special plant is loaded with bioactive compounds that are beneficial to both man and animal. Some important properties exhibited by *Moringa* are; anthelmintic, antimicrobial, antioxidant and anti-inflammatory properties. The leaves and green fresh pods of *Moringa oleifera* are used as vegetables by humans in Central Africa, the have a good profile of amino acids and are rich sources of ascorbic acid and carotene (Fahey, 2005).

Moringa oleifera has a wide range of adaptation from arid to humid climates with the prospects of being grown in a wide range of ecological zones (Gadzirayi and Mupangwa, 2014). It is also cultivated with ease and it is characterised by fast growth (Martin, 2015). The objective of this paper is to provide a detailed review from relevant research studies on the nutritional potential and beneficial properties of the *Moringa oleifera* plant and its role/uses in various aspects of agriculture.

Nutrient Content of *Moringa*: *Moringa oleifera* seeds are rich sources of dietary minerals, proteins, and fats (Compaoré *et al.*, 2011). Sánchez-Machado *et al.* (2010) analysed the chemical composition of the flowers, immature pods and leaves of *Moringa oleifera* and reported that the leaf had the highest content of lipid (4.96%), protein (22.42%) and ash (14.60%).
The proximate content of *Moringa oleifera* leaf is presented in Table1. The crude protein, ash. ether extract, crude fibre, dry matter, nitrogen free extract ranged from 22.42 to 29.68%, 7.54 to 14.60%, 3.00 to 6.40%, 10.10 to 21.00%, 92.12 to 93.60% and 37.87 to 49.60%, respectively (Table 1).

The nutritional composition of *Moringa oleifera* may differ depending on the proportion of the twigs, small branches mixed with leaves in the leaf meal (Mahmoud, 2013). The variation in the nutritive value of the *Moringa* leaf meal may also be attributed to soil fertility and type, agro-ecological zone where it is planted, age of plant or leaves, frequency of harvest, ecotype and cultivar, condition of handling and storage (Sánchez -Machado *et al.*, 2010; Sultana *et al.*, 2015).

Table 1: Proximate Composition of *Moringa oleifera* Leaf (Dry Matter Basis)

Parameter	Composition (%)	References
Crude protein	28.00	Okiki *et al.* (2015)
	29.68	Fadiyimu *et al.* (2010)
	26.79	Mabruk *et al.* (2010)
	25.10	Makkar and Becker (1996)
	22.90	Sena *et al.* (1988)
	26.40	Abbas (2013)
	22.42	Sánchez-Machado *et al.* (2010)
	23.51	Nouman *et al.* (2014)
	22.60	Tijani *et al.* (2016)
Ether extract	6.40	Mabruk *et al.* (2010)
	4.96	Sánchez-Machado *et al.* (2010)
	3.00	Nouman *et al.* (2014)
	3.40	Tijani *et al.* (2016)
	5.78	Fadiyimu *et al.* (2010)
	3.88	Okiki *et al.* (2015)
Ash	7.54	Fadiyimu *et al.* (2010)
	8.87	Abbas (2013)
	13.89	Mabruk *et al.* (2010)
	14.60	Sánchez-Machado *et al.* (2010)
	13.50	Nouman *et al.* (2014)
	7.90	Tijani *et al.* (2016)
	9.82	Okiki *et al.* (2015)
Crude fibre	21.00	Mabruk *et al.* (2010)
	12.57	Okiki *et al.* (2015)
	10.10	Tijani *et al.* (2016)
	16.98	Fadiyimu *et al.* (2010)
Dry matter	93.00	Mabruk *et al.* (2010)
	92.40	Nouman *et al.* (2014)
	93.60	Tijani *et al.* (2016)
	92.46	Fadiyimu *et al.* (2010)
	92.12	Okiki *et al.* (2015)
Nitrogen free extract	49.60	Tijani *et al.* (2016)
	40.11	Fadiyimu *et al.* (2010)
	37.87	Okiki *et al.* (2015)

The amino acid profile of *Moringa oleifera* leaf is shown in Table 2. *Moringa* leaves have higher levels of the indispensable amino acids (Gopalan *et al.*, 1982; Fuglie, 2001; Fahey, 2005) which are more than those recommended by the Food and Agriculture Organization (FAO), this amino acid balance is a rare occurrence in plants (Paliwal *et al.*, 2011). *Moringa oleifera* leaves contain more amino acid concentration than other parts of the tree (Sánchez-Machado *et al.*, 2010). The total amino acid concentration in *Moringa oleifera* leaves was about twice that of the flowers (Sánchez-Machado *et al.*, 2010).

According to Moyo *et al.* (2011), the high nutrient content level of the dried leaves of *Moringa oleifera* suggests its indispensable role as a potential feed resource in the near future. On the other hand, the anti-nutritional factors present in *Moringa oleifera* leaves are low and negligible (Moyo *et al.*, 2011). *Moringa oleifera* leaf is a good source of minerals and vitamins (Table 3). Okiki *et al.* (2015) reported that *Moringa* leaf contains high levels of magnesium, zinc, potassium, calcium and phosphorus. In addition, it contains substantial levels of vitamins such as thiamine, ascorbic acid, niacin and riboflavin (Okiki *et al.*, 2015).

Health Benefits of *Moringa:* *Moringa oleifera* is a tree associated with some health properties such as; antimicrobial, antioxidant, anti-inflammatory and anthelmintic properties. The potential health benefits of *Moringa* have been linked with potent phytochemicals such as; flavonoids, alkaloids, saponins, tannins, phenols and glycosides, which are major constituents present in *Moringa* (Malliga *et al.*, 2014). The activities of these compounds have made the use of *Moringa* in folklore medicine popular in recent times. Basically, the prophylactic and therapeutic properties of *Moringa* have been documented by Fahey (2005), Patel *et al.* (2011), Makanjuola *et al.* (2014) and Allam *et al.* (2016).

Table 2: Amino Acid Profile of *Moringa oleifera* Leaf

Amino acids	Quantity in leaves (mg/g dry weight basis)
Lysine	15.30
Leucine	17.50
Isoleucine	8.90
Phenylalanine	8.90
Histidine	7.00
Threonine	7.90
Tyrosine	4.80
Valine	11.30
Methionine	1.40
Arginine	12.20
Proline	12.40
Glycine	10.30
Alanine	12.50
Serine	9.40
Glutamate	17.10
Asparatate	15.80

Source: Sánchez-Machado *et al.* (2010)

Table 3: Mineral and Vitamin Content of *Moringa oleifera* Leaf

Parameters	Quantity
Iron (mg/100g)	0.58
Zinc (mg/100g)	64.17
Magnesium (mg/100g)	643.33
Calcium (mg/100g)	82.50
Potassium (mg/100g)	430.00
Phosphate (mg/100g)	50.43
Ascorbic acid (mg/100g)	0.72
Thiamine (mg/100g)	0.22
Niacin (mg/100g)	1.48
Riboflavin (mg/100g)	1.48

Source: Okiki *et al.* (2015)

Antimicrobial Properties of *Moringa*" Extracts from the leaves and pods have been reported to have many health benefits and the seed extracts have been demonstrated to have antimicrobial properties (Atawodi *et al.*, 2010). *In vitro* research studies carried out have established the antibacterial activities of *Moringa* leaf extracts (Patel *et al.*, 2011; Vinoth *et al.*, 2012). In another *in vitro* study conducted by Malliga *et al.* (2014), they confirmed the potent antibacterial properties of extracts from *Moringa oleifera* leaves against several gram positive and gram negative bacteria. Chollom *et al.* (2012) reported that the *Moringa oleifera* seed extract is not only nutritious but also possesses strong antiviral property and activity against Newcastle disease virus *in ovo*. The antibacterial property of the water extract of *Moringa oleifera* leaf stalk was reported by Thilza *et al.* (2010). The seed extracts of *Moringa oleifera* were observed to inhibit a broad spectrum of microbes (mostly gram positive bacteria) more than the leaf extracts (Rockwood *et al.*, 2013). *Moringa oleifera* leaf meal is commonly considered as a plant protein feedstuff in animal nutrition and a potential antimicrobial agent for controlling pathogenic bacteria in livestock production (Atawodi *et al.*, 2010; Makanjuola *et al.*, 2014).

Antioxidant Properties of *Moringa:* The presence of high levels of polyphenols with antioxidant activity in *Moringa* leaves have been reported by Sreelatha and Padma (2009), Verma *et al.* (2009) and Moyo *et al.* (2012). Luquman *et al.* (2012) established from their research results the antioxidant activity of the aqueous and ethanolic extract of *Moringa* fruits and leaves, a pharmacological property that can be used in the field of medicine as a potent and natural antioxidant. The concentration of some antioxidants present in *Moringa oleifera* leaf extract include ascorbic acid 2.91mg/g $\pm$ 0.032, reduced glutathione 32.00nmoles/g $\pm$ 1.000 and total carotenoids 8.75mg/g $\pm$ 0.086 (Malliga *et al.*, 2014). The antioxidant property of *Moringa oleifera* leaf extract was also documented in the research conducted by Allam *et al.* (2016). *Moringa* leaves and fruits contain both phenolic and non-phenolic bioactive constituents which function as an antioxidant by scavenging free radicals, terminating the reaction chain of free radicals and by converting them into a more stable compound (Faizi *et al.*,1994; Luquman *et al.*, 2012).

Qwele *et al.* (2013) reported significant antioxidant effect in meat samples of goats fed *Moringa oleifera* leaf meal, these authors also suggested that dietary *Moringa* could be used as a beneficial means of protecting animals from diseases caused by oxidative stress and as well as improving meat quality. A similar observation was made earlier by Jung *et al.* (2010), they stated that feeding animals with plants containing antioxidants is a way of circulating and retaining the antioxidants in the tissue of the animal.

Anti-Inflammatory Activity of *Moringa oleifera:* Various parts of the *Moringa oleifera* plant, that is the leaves, roots and seeds have been reported to produce anti-inflammatory effect. Fayazuddin *et al.* (2013) posited that the aqueous and ethanolic extracts of *Moringa oleifera* seeds possess anti-inflammatory activity. This anti-inflammatory property may likely be due to the activity of bioactive compounds present in *Moringa oleifera* seeds. The inhibition of the production of pro-inflammatory cytokines by *Moringa oleifera* seeds may be linked to its anti-inflammatory action (Mahajan *et al.*, 2007). Singh *et al.* (2012) posited

from the results obtained from their research studies that the anti-inflammatory action of the leaf extract of *Moringa oleifera* is likely due to its ability to inhibit the enzyme cyclooxygenase and as well as the inhibition of prostaglandin synthesis which is associated with inflammation. Mahajan *et al.* (2009) found that n-butanol extract of *Moringa oleifera* seeds exhibited anti-inflammatory effect against ovalbumin induced airway inflammation in guinea pigs. Conclusively, it has been reported that there are bioactive compounds with potent anti-inflammatory activity present in *Moringa oleifera* which is capable of suppressing the effect of inflammation (Farooq *et al.*, 2012).

Anthelmintic Property of *Moringa oleifera:* The challenge of helminths developing resistance to synthetic anthelminthic drugs over time, its residual effect in meat and other animal products and its high cost for small scale livestock farmers have resulted in the search for natural and affordable alternatives. Research studies have demonstrated the anthelmintic activity of *Moringa oleifera* (Rastogi *et al.*, 2009; Moyo *et al.*, 2013). The use of *Moringa* as a natural anthelmintic will, therefore, reduce the over dependency on synthetic anthelmintic medicines and as well as encourage the production of organically produced healthy meat which is generally preferred by consumers.

According to Mbogning Tayo *et al.* (2014), leaf extracts of *Moringa oleifera* in an *in vitro* study showed potential ovicidal and larvicidal (anthelmintic) activities against *Haemonchus contortus* a blood-sucking abomasal helminth of small ruminants which globally is responsible for huge economic losses of small scale farmers. Srinivasa *et al.* (2011) reported that both chloroform extract and methanol extract of *Moringa oleifera* exhibited anthelmintic activity. However, the chloroform extract of *Moringa oleifera* showed more potency against *Pheretima posthuma* (adult Indian earthworm) than the methanol extract (Srinivasa *et al.*, 2011). Moyo *et al.* (2013) reported that supplementing the diets of cross-breed Xhosa Lop eared goats with *Moringa oleifera* leaves suppressed the coccidian-oocyst and helminth load. This research further supports and demonstrates the anthelmintic property of *Moringa oleifera* which was earlier reported by Rastogi *et al.* (2009). The aqueous and ethanolic extracts of the seeds of *Moringa oleifera* contains potent bioactive compounds with anthelmintic properties against the eggs and third stage larvae of *Haemonchus contortus in vitro* (Cabardo and Portugaliza, 2017). There is, therefore, need for more research into the production of natural anthelmintics particularly from *Moringa oleifera* for future use for livestock.

The Use of *Moringa* in Agricultural Production: Various parts of the *Moringa* tree have been found useful in agricultural production such as animal production, crop production, agroforestry, aquaculture and food science (food processing and product development).

Animal Production: *Moringa oleifera* can be used to improve livestock production. *Moringa oleifera* is one of the plants that can be integrated with livestock production, a cheap protein source which can be used to improve feed quality as well enhancing the digestibility of other diets (Moreki and Gabanakgosi, 2014). Fresh leaves of *Moringa oleifera* are readily consumed by cattle, sheep, goat, pigs and rabbits, it has also been incorporated into rations of poultry and fish (Mulugeta and Fekadu. 2014). Research studies have established that dietary *Moringa* has resulted in the improvement of the productive performance of livestock animals.

There are several beneficial effects of feeding *Moringa oleifera* in livestock production, namely; improvement in milk quality and production (Sanchez *et al.*, 2006; Basitan and Jacia 2013; Khalel *et al.*, 2014; Kholif *et al.*, 2015 ; Cohen-zindera *et al.*, 2016), increase in weight gain (Aregheore, 2002; Sultana *et al.*, 2015; Briones *et al.*, 2017), better meat quality attributes (Wapi *et al.*, 2013; Mukumbo *et al.*, 2014; Moyo *et al.*, 2014), improved haematological profile (Fadiyimu *et al.*, 2010; Fayomi *et al.*, 2014), better diet digestibility (Aregheore, 2002; Sanchez *et al.*, 2006; Kholif *et al.*, 2015), improved egg quality and production (Ebenebe *et al.*, 2013; Briones *et al.*, 2017), better feed efficiency (Mahmoud, 2013; Briones *et al.*, 2017).

Crop Production: *Moringa* farmers have observed over time the use of *Moringa oleifera* in promoting the growth and vitality of other crops and the usefulness of spraying *Moringa* leaf extract on crops (Martin, 2015). Research studies have revealed that *Moringa* leaf spray has several advantages on crops. The spray produced increased growth of young plants that were firmer and more resistant to diseases and pests (Foidl *et al.*, 2001). In addition, the crops on which *Moringa* spray was applied had a longer lifespan, heavier stems, roots and leaves, produced more and bigger fruit and increase in yield of 20 to 35 percentage (Foidl *et al.*, 2001).

Agroforestry: Agroforestry involves the cultivation and management of tree in farmlands and surrounding landscapes. *Moringa* has great potential as an agroforestry tree and can play a significant role in sustainable economic development in many developing countries of the world. This multipurpose tree has been recommended for cultivation in rural areas prone to deforestation and

to help rural dwellers in developing their forest resource as well as meeting their nutritional and economic needs (Suthari and Prasad, 2016).

Smallholder farmers in Zimbabwe plant *Moringa oleifera* as one of the trees grown with crops. It is a very useful tree for traditional agroforestry among smallholder farmers because of its multiple benefits (Palada, 1996). In addition, the farmers used *Moringa* tree as an inter-crop in a multi-storey system, hedge or ornamental plant (Gadzirayi and Mupangwa, 2014).

Aquaculture: Akinwole (2014) documented that *Moringa oleifera* seed powder was found to be useful and effective as a coagulation aid for the removal of suspended solids in the treatment of fish culture waste-water. The incorporation of *Moringa* leaf in the diet of Tilapia fish (*Oreochromis mossambicus*) resulted in significant increase in weight gain and specific growth rate (Karpagam and Krishnaveni, 2014). Additionally, Egwui (2013) suggested the use of *Moringa* as an alternative source of protein in aquaculture feeds and advocated the need for further research on other aspects of the utilization of *Moringa oleifera* in aquaculture.

Food Processing and Product Development: The knowledge about the relationship between food, health and nutrition is of paramount importance globally, as well as the need to develop foods with functional ingredients from plant sources. Agriculturalists, food scientists and nutritionists encourage the cultivation, incorporation and consumption of plant sources like *Moringa oleifera* due to its multiple beneficial properties. Many studies have shown the potential use of different parts of *Moringa oleifera* in food applications (Babayeju *et al.*, 2014; Abou-Zaid *et al.*, 2014; Arise *et al.*, 2014; Hekmat *et al.*, 2015; Emilike *et al.*, 2016; Salama *et al.*, 2017).

Fombang and Saa (2016) reported the production of antioxidant rich tea from *Moringa oleifera* leaf powder. *Moringa* seed, leaf and flower have been utilized in the preparation of complementary weaning foods and as composite blends in baked products. Arise *et al.* (2014) used *Moringa oleifera* flower in preparing weaning food. Ogunsina *et al.* (2011) reported incorporating 10% of debittered *Moringa* seed flour in baking bread, which had higher levels of iron, protein and calcium content. In addition, these researchers recommended that up to 20% inclusion level of debittered *Moringa* seed can be effectively used in the preparation of acceptable cookies with improved nutritional quality. The use of *Moringa* as food fortificant is becoming popular, for instance in the preparation of cakes (Kolawole *et al.*, 2013), bread (Ogunsina *et al.*, 2011; Chinma *et al.*, 2014), soup (Babayeju *et al.*, 2014), fortifying cereal gruel (Abioye and Aka, 2015). Srinivasamurthy *et al.* (2017) reported the successful inclusion of 12% dried *Moringa oleifera* leaf powder in the production of muffins with better nutritional value and overall sensory acceptability.

CONCLUSION

Moringa is a special plant with multiple uses and benefits. It is a plant with good nutritional and medicinal value. It is worth noting that the presence of bioactive compounds in *Moringa* is responsible for some of its beneficial properties. It has also been found to be useful in various agricultural sector. One of the unique advantages of *Moringa* is that it can be produced with ease and can strive in low fertile soils or under relatively harsh conditions where other plants cannot withstand or strive well. Farmers and rural dwellers need to be encouraged to engage in extensive cultivation and use of *Moringa* plant particularly, in the developing countries of the world, because of its numerous benefits. There are wide aspects of research yet to be fully exploited by utilizing *Moringa* plant, which has the potentials to boost agricultural production, therefore, more research should be directed towards the use and application of *Moringa* in hydroponic farming, micro-livestock production and horticulture.

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