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Review

Multi-functional application of *Moringa oleifera* Lam. in nutrition and animal food products: A review

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ABSTRACT

Research on the use of various parts of the *Moringa oleifera* Lam. plant (*M. oleifera*) as a nutritional and neutraceutical resource for human and animal diets has increased in recent years, emanating from the widespread use of the plant in traditional cuisines and medicinal remedies in several regions of the world. Analytical studies have identified *M. oleifera* as an important source of essential nutrients; rich in protein, essential amino acids, minerals, and vitamins, with a relatively low amount of antinutrients. It is also a rich source of other bio active compounds including flavonoids and phenolic compounds; with several studies detailing demonstrated *in vitro* and *in vivo* functional properties, most substantially, antioxidant activities. *Moringa oleifera* consumption has been reported to improve the health status, feed conversion efficiency, growth performance and product quality of several livestock species, at dietary inclusion rates generally not exceeding 5% of total dry matter intake. Fortification of processed foods with *M. oleifera* has been reported to increase nutritional value, some organoleptic properties, oxidative stability and product shelf life; with a notable need for further analytical and consumer studies in the development of these products. There is a paucity of literature detailing clinical studies, nutrient bioavailability, toxicity and the mode of action of the bioactive compounds to which the health claims associated with *M. oleifera* consumption are attributed. Many of these are not yet fully understood; therefore more research in these areas is required in order to fully utilize the potential benefits of this plant in human and livestock nutrition.

1. Introduction

In many countries in tropical and sub-tropical regions, *Moringa oleifera* (*M. oleifera*) is used as a rich source of food and food products due to its considerable inherent nutritional, antioxidant and phytochemical benefits; as well as its ability to survive in diverse climatic conditions. Generally, the plant is known to be a fast growing and multi-functional plant with varying applications in agriculture, medicine, livestock, human and other biological systems (Fig. 1) (Ndubuaku, Uchenna, Baiyeri, & Ukonze, 2015). The plant has been used to improve nutrition and boost food security in some developing countries (Fahey, 2005; Fuglie, 1999; Saini, Manoj, Shetty, Srinivasan, & Giridhar, 2014). Interestingly, every part of the *M. oleifera* plant, including the leaf, root, bark, seed, flower and pod is edible and contains compounds that are important for human and livestock wellness (Kadhim & AL-Shammaa, 2014). Consumption of this plant has been reported to contribute significantly to the intake of some essential nutrients and health-promoting phytochemicals in humans (Bamishaiye, Olayemi, Awagu, & Bamshaiye, 2011). With regards to its nutritional composition, *M. oleifera* leaves have been reported to have higher proportion of vitamins C and A, calcium, potassium, iron and proteins than those found in other food products such as orange, carrots, milk, bananas, yoghurt and spinach, respectively (Gopalakrishnan, Doriya, & Kumar, 2016; Rockwood, Anderson, & Casamatta, 2013). On a nutritional basis, the leaves of *M. oleifera* have been extensively used to combat malnutrition among infants, pregnant women and nursing mothers as well as increase milk production in lactating mothers (Fahey, 2005; Fuglie, 1999; Saini et al., 2014). Dietary supplementation with *M. oleifera* leaves has been observed to protect humans against iron deficiency and oxidative stress (Saini et al., 2014). The inclusion of *M. oleifera* leaves as a fortificant in food products such as bread, biscuits, cereal porridge, cake, yoghurts and cheese has been reported to improve their sensory properties and shelf life with the consequent boosting of consumer endogenous antioxidant ability to scavenge free radicals and reduce

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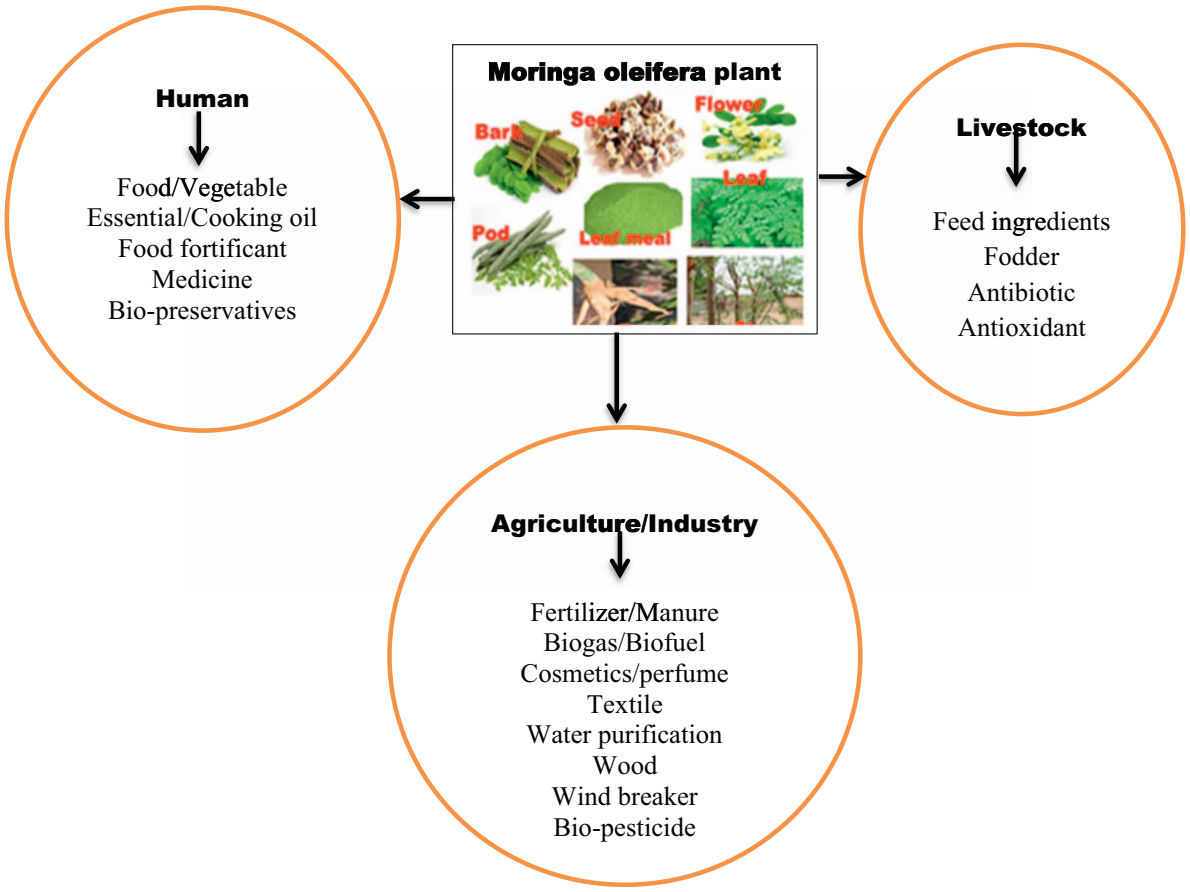

Fig. 1. Multi-functional application of *Moringa oleifera* plant in food systems and agro-processing.

health related diseases (Oyeyinka & Oyeyinka, 2016). Furthermore, the application of *M. oleifera* in livestock feed as a source of protein, antibiotic and antioxidant compounds has been reported in literature with impressive success; including demonstrated to improve growth performance, milk let down (the release of milk from the alveoli in the animal udder) and quality, meat oxidative stability and organoleptic quality as well as reducing the rate of microbial growth in meat products after processing and cold storage (Adeniji & Lawal, 2012; Mendieta-Araica, Sporndly, Reyes-Sanchez, & Sporndly, 2011; Moyo, Oyedemi, Masika, & Muchenje, 2012; Mukumbo et al., 2014; Nkukwana et al., 2014; Nkukwana et al., 2014). The seeds of *M. oleifera* have also been used as an effective coagulant and antimicrobial agent to remove hardness, undesirable chemicals and biological contaminants in water (Saini, Sivanesan, & Keum, 2016). The bark of the plant is known to produce fibre which is a suitable raw material for the production of high alpha cellulose pulp for use in cellophane and textiles (Duke, 2001). Based on the aforementioned qualities, *M. oleifera* has attracted the interest of several researchers on the utilization of this plant for the purpose of improving the efficiency of food production systems, nutrition and human health. Therefore, the aim of this paper is to highlight the potential of *M. oleifera* Lam. as source of antioxidants and phytochemicals for human diets, the livestock production and processing industry, and their probable impact as novel ingredients in food systems.

2. Description and composition of *Moringa oleifera*

Moringa oleifera is the most widely cultivated tree species in the family *Moringaceae* (Bellostas et al., 2010). Taxonomically, *M. oleifera* is assigned to the family *Moringa*ceae of sole genus *Moringa* (Table 1). The genus "*Moringa*" is estimated to include 13 species of which 11 of them originated from Africa (*M. drouhardii*, *M. stenopetala*, *M. hildebrandtii*, *M. ovalifolia*, *M peregrine*, *M. rivae*, *M. ruspoliana*, *M. arborea*, *M. borziana*, *M. pygmaea* and *M. longituba*) and Arabia and 2 from India (*M. concanensis* and *M. oleifera*) (Table 1) (Nasir & Ali, 1972). Historically, *M. oleifera* is native to India, but is now grown in both tropical and subtropical countries of the world because of its resilient adaptive features, such as, ability to grow fast, survive in drought condition and its longevity. *Moringa oleifera* species bear a lot of traditional names depending on their location and uses which include superfood tree, drumstick, miracle tree, tree of life, horseradish, benzoil tree or moringa. On estimate, the mature plant grows to an average height of 5 m and a maximum of 10 m in favorable environments (Zhao & Zhang, 2013). The leaf is greenish in colour and grows mostly at the tips of branches. The flower has yellowish-white petals, ranging from 1.0–1.5 cm long and 2.0–2.5 cm broad. The stem/bark is whitish-gray

Table 1
Taxonomy of *Moringa oleifera* Lam.

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Rosanae
Order	Brassicales
Family	Moringaceae
Genus	Moringa
Species	*M. oleifera*, *M. arborea*, *M. borziana*, *M. concanensis* *M. drouhardii*, *M. hildebrandtii*, *M. longituba* *M. ovalifolia*, *M. peregrine*, *M. rivae*, *M. Ruspoliana* *M. pygmaea*, *M. stenopetala*