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The Potential of *Moringa oleifera* as Non-Conventional Animal Feed: A Review

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Abstract

In Nigeria, the greatest challenge to livestock production especially poultry is feeding cost which is between 60 - 80% of the production cost in intensified poultry management. Essential feed ingredients for poultry diet formulation are also in great demand by man, animal and industries. Thus, the need to source for alternative feeding stuff to prevent the competition between these categories of users. To reduce feed cost, there have been several efforts by researchers, nutritionists and producers to find alternative feed ingredients by considering novel feedstuffs which are safer, cheaper, locally available and nutritionally adequate and contain lesser toxin in which case their method of detoxification will be also be cheaper. Although rich in nutrients such as protein and minerals, *Moringa oleifera* is one of those plants that have not been studied for many years but now is being investigated for its fast growth, higher nutritional value, and utilization as a livestock fodder crop. Therefore, the purpose of this review is to present a detailed discussion on the nutritional importance of the use of *M. oleifera* in poultry diets.

Keywords: *Moringa oleifera*, Nutrition, Phytochemicals, Processing methods.

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Introduction

Overwhelmed by the numerous economic benefits of *Moringa oleifera* tree in the tropical world where the plant is considered a miracle tree due to its nutritive, industrial, and medicinal attributes, the area of its anti-nutritional or toxic factors remains to be fully dealt with. Ramachandran *et al*. (1980) reported that the seeds consist between 30-42% non-drying oil used for human consumption with minimal propensity for spoilage, stale or being gummed. The oil cake achieved as end-product of oil extraction has superior proteins and it is used as fertilizer and to offset the mixture in muddy or filthy water due to the negative electrical charges of the colloids. The protein of the cake meal is therefore used as an innocuous natural polypeptide coagulating agent for settling mineral particles, organics and cleaning of domestic water and purification of vegetable oil or for coagulating fibres in juice and beer companies. It is preferably used in place of industrial coagulating agents such as alum which can be poisonous and expensive. Most of the tree parts can be utilized in traditional medical practices particularly the leaves and root barks. Details on the curative and preventive features of *M. oleifera* are given in Trees for Life Journal (Fahey, 2005). In developing tropical countries, the tree unripe (green) pods are the most often and frequently utilized among the tree parts due to their nutritious content with the essential nutrients. Its leaves can be consumed fresh or processed without losing its nutritional value. According to Optima of Africa (Donovan, 2007), 25g/day leaf powder provides 42% protein, 61% magnesium, 41% potassium, 125% calcium, 71% iron, 22% vitamins C and 272% Vitamin A Details of other possible major nutritional benefits of *M. oleifera* tree can be obtained from Morton (1991), Makkar and Becker (1996a).

Phytochemistry of *Moringa oleifera* shows that the plant contains biologically active organic compounds (Duke, 1983) which could elicit anti-nutritional and toxic responses. Anti-nutrients are generally contained by the plant kingdom particularly those used in human nutrition and as animal feeding stuff (Igile, 1996). Reports have shown that some of these chemicals, described as "secondary metabolites" are highly biologically active (Zenk, 1991) .

Moringa (*Moringa oleifera*) tree

Makkar and Becker (1997) reported Moringa (*Moringa oleifera*) originating from the north-west zone of India, and South of the Himalayan mountaintop. It belongs to the Moringaceae family. Fahey *et al*., (2001), reported Moringa to have adapted well and cultivated in several parts of the tropics. Kristin (2000) discovered that although there are thirteen species of moringa tree, it is only *Moringa oleifera* that is most widely grown. The tree has an average height of 5-12m, with a straight trunk of 10-30cm thick bark. It has fleshy tap root that made it to be drought resistant. Moringa can be cultivated easily by seeds and cuttings. The images of *Moringa oleifera* seed, tree and pods can be found in figures 1-3.

Moringa *(Moringa oleifera*) as medicinal plant

History has it that earliest past kings and queens used Moringa parts in their diets to maintain their healthy skin and mental awareness. Jahn, (1996), discovered that Moringa dates back to 150 B.C. past Maurian fighters of India used Moringa Leaf Extract in their diet during war. The belief was that Moringa drink gave them additional energy and lessen the sufferings sustained in the war front. Report on Moringa drink made researchers to analyze its nutritional benefits. Makkar *et al*., (1997), reported on the outstanding nutritional constituents of Moringa leaves and fruits.

Phytochemicals in moringa tree

Reports have shown that Moringa species have notable amounts of compounds containing simple sugar, rahmnose, glucosinolates and isothiocyanates (Bennett *et al*., 2003; Fahey *et al*., 2001). Win and Jongen, (1996) also reported antioxidant activity of these compounds.

Anti-nutrient factors in novel feedstuffs and their effects on animals

Anti-nutritional factors that can also be called 'secondary metabolites' are chemical compounds synthesized by the normal metabolism of species in natural foods or feedstuffs. Anti-nutritional factors can be categorized into two main groups. These are: (1). Proteins that are reactive to standard treatment temperatures eg lectins and protease inhibitors. (2). Other materials that are resistance to usual processing temperatures eg polyphenols (mainly condensed tannins), non-protein amino acids and galactomannan gums (Osagie, 1998). Habtamu and Nigussie, (2014) reported that these anti-nutritional factors have been implicated to be extremely organically active and lower utilization of nutrients. Toxicity caused by the intake of different forages is also frequent among the farm animals. Intake of feed containing antinutrients in some cases cause, chronic intoxication, obstructs the usage of dietary protein and carbohydrate, hinders some minerals availability, thus growth rate, feed efficiency, and the production of edible products are negatively affected. Though antinutrients are present in many conventional feeds, Nityanand, (1997) reported that they are more prevalent in most of the non-conventional feed ingredients. Plants having multiple noxious compounds, emanating from the two sources, escalate the hinderance of their decontamination.

Phytates

Pytates also known as inositol hexakisphosphate, are known to be an organically bound form of phosphorus in plants. Bello *et al*., (2008) reported that phytates in foods complexed with vital minerals like calcium, magnesium in the process of digestion leading to mineral insufficiency. They complexed with inorganic substances forming insoluble salts, consequently lowering their rate of utilization (Thompson, 1993; Guil and Isasa, 1997; Muhammad *et al*., 2011). Walter *et al.,* (2002), reported that the availability of phytate in feeds is linked with reduction in mineral usage attributable to phyate structure that has high concentration of phosphate groups that are negatively charged that form very stable networks with mineral ions causing unavailability for intestinal absorption.

Tannins

Tannins are plant polyphenolic compounds that bind with several other organic compounds including amino acids and alkaloids. Presence of tannins in livestock feeds lower its productivity and weight gain in chicks (Armstrong *et al*., 1974; Dei *et al*., 2007). Tannins are reported to be the most widely occurring anti-nutrients in plants. Dube *et al*., (2001), reported that these compounds are found in various trees, shrubs, seeds and industrial by-products.

Tannins are heat stable and reduced digestion of protein in humans and animals possibly by hindering enzymes of digestion and increasing fecal nitrogen or making protein partially unavailable. Reduced feed intake, feed efficiency, growth rate, and protein digestibility in experimental animals are known to be caused by tannins in feeds. Tannins also form insoluble complexes with proteins and the tannin-protein complexes may be responsible for the anti-nutritional effects of tannin containing foods (Habtamu and Nigussie, 2014).

Saponins

Dei *et al*., (2007), discovered saponins to be organic compounds present in many plants which have soap character due to their surfactant properties. Moringa seed meal inclusion in diets lowers feed consumption as a result of the inherent anti-nutrients particularly mimosine and tannins (Atawodi *et al*., 2008). Lower feed intake was due to the bitterness of saponins (Cheeke, 1971) and attributable to its unplesant taste (Oleszek *et al*., 1994). Over consumption of saponins leads to hypocholesterolaemia because they combined with cholesterol, rendering it inaccessible for absorption (Soetan and Oyewole, 2009). Saponins have been reported to cause reduction in growth, feed efficiency in chickens and interfere the absorption of dietary lipids and vitamins A & E (Jenkins and Atwal, 1994).

Trypsin inhibitor

Trypsin inhibitor has been discovered to hinder trypsin and chymotrypsin which perform vital task in broiler chickens protein digestion. Aletor and Fetuga, (1987), reported that trypsin inhibitors cause pancreatic enlargement and growth reduction. Hydrogen cyanide, present in moringa seeds, is poisonous if taken by non-ruminants in high amounts. Processing of plant products by soaking or boiling in water is reported to lower its deleterious consequences and enhance feed consumption and digestion of protein (Okai *et al*., 1995; Dei *et al*., 2007).

The use of *Moringa oleifera* as non-ruminant feeds

In poultry, absolute absence of anti-nutritient content and the great protein, lipid and sulphur containing amino acid attributes support using moringa seed as an ingredient for animal feed. It is an outstanding source of protein for non-ruminant. (Ferreira *et al*., 2008). Ferreira *et al*., (2008) reported that given the seed meal to a week old broiler chickens to a status of 50 g/kg, growth rate, feed intake and efficiency of feed are enhanced. Various researchers have used leaf meal, seed meal or leaf extract of this plant in poultry diet with positive results. Improvement in bowel health, increased weight gain, decrease feed intake, improved feed conversion ratio, increased immune response and good anti-oxidant responses in broilers has been attributed to the use of Moringa leaf meal as feed. Research has also shown that broilers supplemented with *Moringa oleifera* have considerable increase in the level of high density lipoproteins in serum along with a significant decrease in Low density lipoproteins which has been associated with higher fiber content in Moringa and results in lowering of cholesterol levels in the body. Olugbemi *et al*. (2010) has observed hypocholesterolemic effect in egg cholesterol content which is much lower when poultry feed is supplemented with Moringa leaves

Nuhu (2010) reported that weaner rabbits fed with Moringa leaf meal at an inclusion level of 0-20% resulted in increase in average daily weight gain but no significant difference was observed in blood parameters. The growing rabbits fed with Moringa leaf meal at varying inclusion levels in diets up to 15% exhibited no adverse effects on the hematological and serum biochemical response (Ewuola *et al*., 2012). It was also observed by Sun *et al*. (2018) that feeding New Zealand white rabbits with Moringa leaf meal as a substitute for alfalfa meal at levels of 0%, 10%, 20% and 30% showed significant impact on growth performance, nutrient digestibility, meat quality, antioxidant capacity and biochemical parameters. The average daily weight gain and feed conversion ratio was much better at 20% inclusion level of Moringa leaf meal.

The leaf meal also had a significant impact on serum albumin, low density lipoproteins, cholesterol levels and superoxide dismutase activity. Rabbits fed with 30% Moringa leaf meal had a significant increase in body weight (Safwat *et al*., 2014). Some researchers have studied the impact of using Moringa foliage as a replacement for conventional pig feed. Mukumbo *et al*., (2014) observed that finisher pig when fed with Moringa leaf at 5% level of inclusion showed no negative impact on feed conversion ratio, cutability, backfat thickness and other carcass traits but when fed with more than 5% inclusion level, they exhibited better daily feed intake but with lower feed conversion ratio compared with those fed at 5% or below intake levels. The research findings of Dany *et al*., (2016) suggested that inclusion of Moringa leaf at 40% inclusion rate in Mexican hairless pigs had no effect on growth performance. However, report has shown that 10% inclusion level of Moringa leaf in feeds of commercial prestarter and starter pigs had no impact on the average daily weight gains, signifying the fact that a specific meal needs to be formulated for pigs based on their growth stage (Acda *et al*., 2010). Weaner pigs fed with Moringa leaf meal at varying inclusion levels ranging between 1-5% showed no significant effect on the final body weight and carcass parameters. However, the growth rate of weaner pigs fed with 5% Moringa leaf meal was better as compared to those fed with 2.5% meal and control diets (Oduro-Owusu *et al*., 2015). Cross bred finishing pigs fed with Moringa meal at inclusion rates 0, 3, 6 and 9%, resulted in significant increase in the daily weight gain with less impact on pork quality and amino acid profile. The fatty acid profile of finishing pigs underwent modification with an increase in unsaturated fatty acid content upon consumption of Moringa meal at 6% inclusion levels (Dong *et al*., 2019).

The use of *Moringa oleifera* as Ruminant Animal feeds.

The potential of *Moringa oleifera* as ruminant feed has been investigated as it is rich in nutrients and its methanogenic inhibitor content which has the capability to decrease methane emission in ruminants. Methanogenic inhibitors of Moringa plant pose a great potential to be utilized on a large scale for livestock feeding programs which aim at minimizing the methane emission. Soliva et al., (2005) and Elghandour et al., (2017) observed around 17% decrease in daily methane emission in animals fed with *Moringa oleifera* and a total of 50% decrease in emission was recorded when it replaced soybean meal as feed.

In cattle conventional low-quality diet supplemented with Moringa leaves as protein additive has been observed to increase the dry matter intake, digestibility of diet and milk production cows of Creole Reyna breed (Reyes Sanchez *et al*., 2006). Total mixed ration at level of 180 g/kg supplemented with Moringa silage fed to lactating Holstein cows resulted in higher milk yield as compared to control cows. The milk was also characterized by better anti-oxidative potential (Cohen-Zinder *et al*., 2016). Cows fed with formulated ration along with 20% inclusion of *Moringa oleifera* leaf had higher mean value of milk fat, total solids, crude protein and casein when compared to those fed with formulated ration containing 20% soybean meal (Mendieta-Araica *et al*., 2011). Dietary supplementation of Moringa at the rate of 6% in dairy cows resulted in milk with improved fat content (Dong *et al*., 2019). Partial substitution of alfalfa hay and maize silage with *Moringa oleifera* silage gave no negative effect on milk yield, nutrient digestibility and biochemical indexes of lactating Holstein cows (Zeng *et al*., 2018). Lactating cross bred cows were fed 15.0 kg of Moringa as green fodder for 90 days to evaluate its effect on milk yield, microbial protein synthesis and blood profile. Shankhpal *et al*., (2019) reported that feeding cows with Moringa resulted in improved carotene content of milk and intestinal flow of microbial nitrogen. In addition, the cholesterol content of milk decreased by 17.60% (Shankhpal *et al*., 2019).

In goats, inclusion of Moringa leaves at 20 and 50% inclusion levels in their diets resulted in increased live weight gain, digestibility of dry matter, crude protein and organic matter (Aregheore 2002). Babiker *et al*. (2017) also reported that there was increase in oxidative stability and vitamin C content of milk in ewes and goats supplemented with *Moringa oleifera* leaf at 25% inclusion level when compared to those with Alfalfa hay. This may be attributed to presence of various nutrients along with essential elements such as calcium, potassium and magnesium (Babiker *et al*., 2017). The concentrate diet of black Bengal goats when replaced by Moringa foliage resulted in improved average daily weight gain and better nitrogen retention clearly depicting the potential of Moringa to serve as alternative to conventional concentrate mixture (Sultana 2015). Inclusion of Moringa leaf meal at a level of 15%, replacing 75% sesame meal in diet of lactating Anglo Nubian goats improved milk yield and composition in terms of total solids and lactose content. It also improved the level of unsaturated fatty acids and conjugated linoleic acid. Moreover, Moringa leaf meal also enhanced rumen fermentation, feed intake and nutrient digestibility (Kholif *et al*., 2015).

In sheep, inclusion of intermediate level *i.e*. 4 g/day Moringa seed meal in their diets resulted in improved rumen fermentation (Ben Salem and Makkar 2009). Replacement of conventional concentrate mixture by Moringa foliage as protein supplement at a level of 75% and 100% in rice straw diet resulted in favorable growth performance, leaner carcass and higher meat proportion in lambs (Sultana *et al*., 2017). *Moringa oleifera* leaf meal at 25% level of inclusion in concentrate mixture resulted in the improvement of body condition score in Deccani lambs being reared under intensive farming system (Bala and Ramana 2020).

In buffalo, effect of substitution of soya bean meal by Moringa leaf meal on rumen fermentation, nutrient digestibility and growth performance of 8-9 months old buffalo calves has been investigated. Abdel-Raheem and Hassan (2021) observed that Moringa leaf inclusion at the rate of 15% and 20% in concentrate mixture resulted in increase in digestibility of dry matter, crude fiber and organic matter, while the digestibility of crude protein showed a decline. They also observed that inclusion of Moringa leaf meal at 15% inclusion rate resulted in improved final body weight, daily weight gain, feed conversion efficiency and plasma insulin growth factor I without any noticeable adverse effect on the growth of buffalo calves. The replacement of concentrate mixture and calf starter up to 10% by Moringa leaf meal resulted in better body weight gain in Murrah calves (Roy *et al*., 2018).

Role of *Moringa oleifera* in disease management.

Moringa oleifera plant with medicinal value could serve as an alternative to synthetic drugs. Extracts of Moringa leaves have been found to be effective against various bacterial, viral and parasitic infections. Research study evaluated the protective function of methanolic moringa extracts in chicken infected with Newcastle disease, which has a profound economic impact on poultry farms due to high mortality rates associated with it. Eze *et al*., (2012) reported that chicken fed with methanolic extracts of moringa at the rate of 200 mg/kg body weight for 42 days exhibited noteworthy survival rates validating the protective effect of Moringa against Newcastle disease.

Acetone extracts of Moringa fed at the rate of 1-5 g/kg body weight of broiler chicken infected with Eimeria species showed improved gain in body weight and a significantly milder faecal scores. Moreover, as compared to infected, untreated group of birds, those fed with moringa extracts had significantly higher hemoglobin and red blood cell count (Ola-Fadunsin and Ademola 2013). Oral administration of aqueous extracts of Moringa leaves at a dose of 150mg/kg body weight for 21 days at an interval of 48 hours to sheep co-infected with *Fasciola gigantica* and *Colostritidium novyi* resulted in reduced fecal egg counts, improved gain in body weight and significant decrease in level of interleukin 2, interleukin 17 and immunoglobulin G (El Shanawany *et al*., 2019).

Different processing methods to lower the feed anti-nutritional contents

High level of anti-nutritients and noxious constituents in plant materials used for foods/feeds is of great concern to nutritionist and researchers in general. Hence, there is the need to find a way of removing or lowering these quantities to the lowest level (Soetan and Oyewole, 2009). Elimination of unwanted constituents is indispensable to promote the nutritive constituents of plant materials and judiciously use their full usefulness as ingredient for poultry feed. Most of the toxic and anti-nutrient effects of these compounds in plants could be removed by several processing methods such as soaking, germination, boiling, autoclaving, fermentation, genetic manipulation and other processing methods (Soetan, 2008).

Soaking

Soaking is one of the procedures being used to eliminate solvable anti-nutritients that can be removed through the soaked discarded solution. Nevertheless, Vidal-Valverde *et al*., (1992), discovered that in the course of soaking some metabolic reactions can occur that can influence some of the constituent compounds. Liener, (1980), reported that canavanine and canaline, anti-nutrients of jack were water soluble.

Cooking (boiling)

Generally, cooking decontaminates heat-labile anti-nutrients like chymotrypsin inhibitors, trypsin and evaporable organic compounds. Cooked water may be thrown off, but some other dissolvable compounds could be eliminated. Bressani and Elias (1980) discovered that 30-40% of polyphenols can be eliminated by cooking *Phaseolus vulgaris.*Trugo *et al*., (1990), reported that cooking *Phaseolus vulgaris* for 60 minutes at 100^{o}C was adequate to decontaminate over 90% of the inherent typsin inhibitor. Udedibie and Nwaiwu (1988) also discovered that cooking jack bean for 60 minutes was sufficient for the removal of most of the identified heat-sensitive anti-nutrients and alkaloids in raw jack beans.

Toasting

Improvement in the nutritive quality of jack beans using toasting technique was first discovered by Borchers and Ackerson (1950). Later, Udedibie *et al*., (1994), observed that roasting alone can enhance its nutritive quality for broiler chickens to the maximum inclusion rate of 100g/kg dietary supplementation. Studies by Esonu *et al*. (1998) showed that toasting jack bean seeds singly as a treatment procedure did not significantly lower the quantity of its noxious constituents.

Gamma irradiation

Hasnat *et al.,* (2014) found that a radiation of 9.33 KGy electron beam (EB) reduced hydrocyanic acid, phytic acid and tannic acid to the extent of 34, 63, and 22%, respectively. Gamma irradiation process with its radiolytic action can eradicate glucosinolate molecules. Other researchers discovered that anti nutrients were seriously decontaminated by gamma irradiation. (Farag, 1989; Sattar *et al.,* 1990; El-Morsi *et al.,* 1992; Farag, 1998).

Kaolin

Of recent, the use of different substitute feed additives for animals like kaolin has been experimented. Mump ton, (1999), discovered that animal feed holding clay minerals such as kaolin enhanced weight gain and feed efficiency. Taugir and Nawaz, (2001), reported that kaolin lowered adulteration of the guts by bacterial and the deleterious consequence of contaminated diets by mycotoxin. Kaolin also defends the mucosa of the intestine, by clinging to pathogen and carefully advance their discharge (Droy-lefain *et al.*, 1985).

Solvent extraction

Extraction of oil from oil-bearing seeds using solvents has been disclosed to also enhance the nutritive quality of such seeds. For example, the anti-nutritional factors in cottonseed is soluble in organic solvents like hexane, ethyl alcohol, aqueous acetone and aliphatic amines. These substances have been disclosed to effectively lower the gossypol constituents in cotton seed meal. Hron et al., (1994), discovered that extraction of cotton seed meal with 95% ethanol resulted in reduction in total gossypol content by about 70%

Conclusion and Recommendation

M. oleifera is a valuable food crop whose nutritive, healing, and socioeconomic potentials are apparent and could be a viable option in areas where traditional crops are being hampered by climate change. Furthermore, because all parts of *M. oleifera* are edible, they can be included into a variety of food matrices, enriching their nutritional profile with high quantities of proteins, fibre, vitamins and antioxidants. It is claimed to contain anti-inflammatory, anti-asthmatic, cholesterol-lowering, antimicrobial and analgesic properties. *Moringa oleifera* has been used as feed ingredient for different animals by various researchers with conventional feeds at different levels of inclusion, stressing its potential to be used as an alternative to conventional feeds.

Many of the studies reviewed in this article particularly those on the medicinal benefits of the tree, require further validation to corroborate their findings. Further scientific research and more rigorous clinical studies are required. It is very important to standardize research before adopting parts or preparations of *M. oleifera* as a supplement or curative measure. It is also quite necessary to pretreat the moringa feed in order to inactivate its anti-nutritional factors and also properly investigate optimum dose or inclusion levels to be used in order to avoid any negative influence on the growth and reproductive performance of animals.

Conflict of Interest.

The authors did not declare any conflict of interest

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Tables

Table 1: Analysis of nutritional value of *Moringa* pods, fresh (raw) leaves and dried leaf powder per 100g of edible portion.

Components	**Pod**	**Leaves**	**Leave powder**
Moisture (%)	86.9	75.0	7.5
Calories	26	92	205
Protein (g)	2.5	6.7	27.1
Fat (g)	0.1	1.7	2.3
Carbohydrate (g)	3.7	13.4	38.2
Fiber (g)	4.8	0.9	19.2
Minerals (g)	2.0	2.3	-
Ca (mg)	30	440	2,003
Mg (mg)	24	24	368
P (mg)	110	70	204
K (mg)	259	259	1,324
Cu (mg)	3.1	1.1	0.57
Fe (mg)	5.3	7	28.2
S (mg)	137	137	870
Oxalic acid (mg)	10	101	1.6%
Vitamin A - B carotene (mg)	0.11	6.8	16.3
Vitamin B -choline (mg)	423	423	-
Vitamin B1 -thiamin (mg)	0.05	0.21	2.64
Vitamin B2 -riboflavin (mg)	0.07	0.05	20.5
Vitamin B3 -nicotinic acid (mg)	0.2	0.8	8.2
Vitamin C -ascorbic acid (mg)	120	220	17.3
Vitamin E -tocopherol acetate (mg)	-	-	113
Arginine (g/16g N)	3.6	6.0	1.33%
Histidine (g/16g N)	1.1	2.1	0.61%
Lysine (g/16g N)	1.5	4.3	1.32%
Tryptophan (g/16g N)	0.8	1.9	0.43%
Phenylanaline (g/16g N)	4.3	6.4	1.39%
Methionine (g/16g N)	1.4	2.0	0.35%
Threonine (g/16g N)	3.9	4.9	1.19%
Leucine (g/16g N)	6.5	9.3	1.95%
Isoleucine (g/16g N)	4.4	6.3	0.83%
Valine (g/16g N)	5.4	7.1	1.06%

Source: Fahey (2005)

Figures



Figure 1: *Moringa oleifera* seeds with seed coating



Figure 2: Moringa oleifera tree



Figure 3: *Moringa oleifera* pod