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The miraculous moringa trees: From nutritional and medicinal point of views in tropical regions

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Abstract

Moringa plants are among high value trees, belongs to Moringaceae family which consists of 13 species and they are highly distributed in Africa and southern Asia. It is multi-purpose tree with medicinal, nutritional, industrial and socio-economic values. Moringa leaf extracts have potential antihypertensive, antispasmodic, antiulcer, diuretic, hepatoprotective and cholesterol lowering activities. This means, the leaf contain bioactive compounds which perform certain beneficial physiological and biochemical functions in humans. These miraculous tree also have significant activities against cancer, tumor, bacteria and fungus as well as they have anti-leishmanial and anti-fertility activities. Therefore, Moringa tree has potential application in pharmaceutical industry for drugs development. Nowadays Moringa tree become an important food commodity in tropical world. Except the wood, all part of the tree are edible and these edible portions are exceptionally nutritious. Fresh and dried leaves can be cooked in soups or supplements of sauce and immature seeds and pods are often cooked and eaten as a fresh vegetable. The flowers can be cooked or dried and steeped as tea. All these parts of the trees compose vital chemicals and minerals promoting growth and health, therefore, it is used to combat moderate malnutrition in children and nursing mothers. Additionally, it is used as alternative animal feedstock especially for the emerging poultry industries in tropics. The tree is used as a hedge, fence and wind break. The seeds of Moringa is one of the best natural coagulants for water treatments which can substitute expensive synthetic coagulants in developing countries. As compared to conventional oilseeds for edible oil production, Moringa oilseeds are more advantageous in terms of oil content, costs and agronomic properties. Furthermore, oil derived from Moringa seeds can be used as potential sustainable feedstock for biodiesel production. In this review, human healthcare through traditional medicine as well as multiple uses of Moringa trees are discussed. The socioeconomic values of *M. stenopetala* tree in southern Ethiopia is delineated. Finally, future prospects are proposed.

Keywords: Moringa Tree, Nutrition, Traditional Medicine, Ethiopia, Miraculous, Tropics

1. Introduction

The miraculous Moringa trees are commonly used and among high value plants that belongs to the monogeneric family called *Moringaceae* which consists of 13 species. Among 13 Moringa species, 5 of them were found in Ethiopia [1]. These species of Moringa are widely distributed in the tropical regions especially *M. Oleifera* and *M. peregrina* have wide geographic ranges. However, *M. oleifera* and *M. stenopetala* are the most well known and documented compared to the other *Moringaceae* members. Considering their ecological natiivities, *M. stenopetala* and *M. oleifera* often referred to as the African and Indian Moringa tree respectively [2, 3]. These two species have extraordinary nutritional and medicinal properties in various part of the world [1, 4, 5].

Numerous medicinal properties have been attributed to the various parts of these highly esteemed trees. In traditional medicine preparation, nearly all parts of the tree: Leaves, fruits, pods, flowers, root, seed and seed oil have been used for treatment of various human diseases [5, 6]. Crude leaves Ethanol and its fractions extracted from Moringa leaves have wide spectrum activates over ranges of cardiovascular and physiological disorder. Accordingly, ethanol extracts and its fractions have significant potential in antimalaria, antihypertensive, antispasmodic, antiulcer, antimalaria, diuretic, hepatoprotective and cholesterol lowering activities [7, 8, 9]. Thus, bioactive compounds present in leave and root of Moringa perform beneficial physiological and biochemical functions in humans. The miraculous Moringa tree may have potential for prevention and treatment cancers and tumors [10, 11]. It is reported that this tree has significant antibacterial [12], antifungal [13], antihelminthic [14] as well as anti-leishmanial and anti-fertility activities [15].

Furthermore Moringa plants have scavenging activities against oxidative radicals, this all implies its potential applications of bioactive principle in the pharmaceutical industries for drugs developments [16].

Furthermore, Moringa tree is an important natural food commodity in the tropical regions which currently attracting enormous attention in this area to combat moderate malnutrition particularly in children and nursing mothers. Except the wood, all part of the tree are edible and the edible portion is exceptionally nutritious. Leaves are often cooked and eaten as vegetables and leaf powder can be used for soups making or sauce supplement. Likewise, fruits and immature pods are used as a highly nutritive vegetable and flowers can be dried and steeped as tea in various part of Africa and southern Asia [4, 5]. The most interesting properties of Moringa is its composition of vital chemicals and minerals essential for promotion of growth and health particularly for infants in tropics [13, 17]. It is reported that the leaves of Moringa can increase body weight in chickens, therefore it could be used as the best alternative animal feedstock to substitute expensive protein source. This is the most likely opportunities for the emerging poultry industry of tropical regions [18].

Moringa is a multipurpose tree with various socioeconomic values. The tree is also grown as ornamental, boundary/barrier, intercropping, medicinal and nutritional plants as well as used as living hedge, fence and wind break [19, 20]. Furthermore, Moringa seeds can be good source of edible oil and also the oil derived from seeds can be used as potential sustainable feedstock for biodiesel production [21, 22]. Moringa seed is one of the best natural coagulants which can substitute synthetic coagulants for turbid water treatment in developing countries [14].

In Ethiopia, *M. stenopetala* has various names, it is called Shiferaw in Amharic, Aleko/Halako in Gamo/Wolayita and Shelchada in Konso languages where as Cabbage tree is the English version of this tree [23]. The local communities in the southern Ethiopia cook the leaves as cabbage and eat with their traditional food known as "Kurkurfa/Fosses" and "Kama" in Arba Minch/Wolayita and Konso areas respectively [24]. Despite the extensive works on Moringa trees from different

parts of the world, however, comprehensive review has not been compiled from Ethiopia which encompassing this plant in all dimensions. Its versatile utility as a medicine, nutrition, oil and biodiesel and other Miscellaneous potentials motivated to write a comprehensive review particularly from medicinal and nutritional point of view of Moringa trees in the tropical countries.

2. Taxonomic and Geographical Distribution of Moringa Species

Moringa plant is miraculous multipurpose tree which belongs to the monogeneric family, *Moringaceae*. The family *Moringaceae* consists of only one genus called Moringa. The genus Moringa holds 13 species. Figure 1 describe about the taxonomic distribution of *Moringaceae*. Moringa trees are highly distributed in the belt of tropics. Table 1 summarize the geographical distribution and uses of 13 Moringa species. Among these, *Moringa stenopetala* and *Moringa oleifera* are the most well-known species which often referred to as the African and Indian Moringa tree respectively. There are also well established documents about these two Moringa species due to their extraordinary nutritional and medicinal properties in their ecological areas [25-27].

M. oleifera has a wide geographic range, growing from the far East like China along the southern Asia to England and around the Western Africa and Australia. However, unlike *M. oleifera*, *M. stenopetala* has limited geographical distribution which is native to Ethiopia and Kenya. *M. peregrina* is the second widely distributed Moringa species next to *M. oleifera*, it grows around the Red Sea starts from the Dead Sea area up to the northern part of Somalia and around the Arabian Peninsula to the mouth of the Arabian Gulf. It is an extremely fast growing tree or shrub and another promising Moringa species with high potential for oil production [1, 15, 20, 28]. Among *Moringaceae* members, *M. arborea*, *M. pygmaea*, and *M. hildebrandtii* are the limited geographical distribution which is found only in Kenya, Somalia and Madagascar respectively. In this regard, Ethiopia is hold the first place since five out of thirty Moringa species were found the country, this implies Ethiopia is the center of biodiversity.

Table 1: Overview of the geographical distribution and potential uses of Moringa Species

Moringa Species	Growth Form	Geographical Distribution	Use	References
<i>M. peregrina</i>	Shrub or small tree	Most Middle East*	Oil, medicinal plant, water coagulant, ornamental	[28]
<i>M. oleifera</i>	Tree	Most Southern Asia**	Food source, water coagulant, oil, medicinal plant, fodder, ornamental, firewood	[28]
<i>M. concanensis</i>	Tree	Pakistan, India, Arabia,	Oil, medicinal plant	[29]
<i>M. rivae</i>	Shrubs or trees	Kenya, Ethiopia	Medicinal plant	[28]
<i>M. arborea</i>	Shrubs or trees	Kenya	Medicinal plant	[30]
<i>M. borziana</i>	Herbs or small shrubs	Somalia, Kenya	Medicinal plant	[31]
<i>M. pygmaea</i>	Herbs or small shrubs	Somalia	Medicinal plant	[32]
<i>M. ruspoliana</i>	Tree	Ethiopia, Somalia	Medicinal plant	[33]
<i>M. hildebrandtii</i>	Tree	Madagascar	Medicinal plant, ornamental	[34]
<i>M. stenopetala</i>	Tree	Kenya, Ethiopia	Vegetable, oil, fodder, ornamental	[28]
<i>M. ovalifolia</i>	Tree	Angola, Namibia	Vegetable, oil, fodder, ornamental	[28]
<i>M. drouhardii</i>	Tree	Madagascar	Oil, water coagulant, medicinal plant, ornamental	[28]
<i>M. longituba</i>	Trees or shrubs	Somalia, Kenya, Ethiopia	Water coagulant, medicinal plant	[28]

Key:- *Israel, Jordan, Saudi Arabia, Yemen, Pakistan, Egypt, Oman, Sudan, Ethiopia, Somali, Syria

**India, Bangladesh, Sri Lanka, Pakistan, Senegal, England, Egypt, Afghanistan, China, Nepal, Malaysia, Thailand, Vietnam, Indonesia, Philippines, Australia, Sierra Leone, Ghana, Nigeria, Uganda.

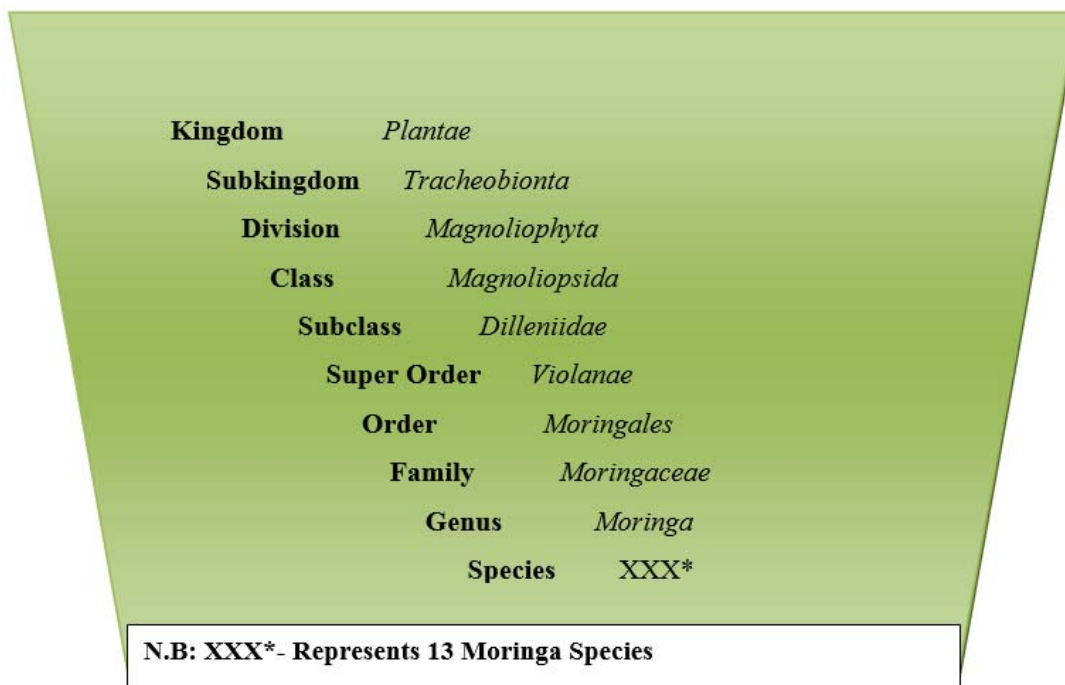


Fig 1: Taxonomic Distribution of Moringa Plants.

3. Human healthcare through traditional medicine

Traditional medicine is a comprehensive term referring to systems of different traditional medicine that often termed as "complementary", "alternative" or "non-conventional" medicine [35]. It is sum total of all knowledge and practices used in diagnosis, prevention and elimination of physical, mental and societal imbalance [36]. It is also encompasses health practices, approaches, beliefs and knowledges incorporating plant, animal and mineral based medicines, spiritual therapies, indigenous theories, manual techniques and exercises applied singularly or in combination to treat, diagnose and prevent illnesses [37].

In 2001 WHO reported that traditional medicine is part of the cultural heritage of each society and it evolved as part of particular cultures and life styles. Indigenous knowledge and culture have valuable role in ensuring the good health and wellbeing of people and this shows the connection of traditional medicine with culture and belief system [38]. It is a broad range of ancient and natural health care practices, which was dominant until the application of the modern medicine [39, 40].

Traditional medicine is a way of protecting and restoring health by using bio-resources which are non-narcotic, mostly with no or lesser side effects, easily available and cost effective for primary health care [41, 42]. It performs a function of getting symptoms, identifying and removing the causes of the illness by using herbal products, animal parts and minerals that plays a predominant role in the healing phenomenon by possessing knowledge of the science of nature, plants and animals and all the science associated with healing and disease [38].

Until realization of modern medicine, traditional medicine has been sustained the health of many millions of peoples over hundreds of years due to its wider application for treatment and prevention of various acute and chronic human diseases [43]. This is because of its efficacy, cultural acceptability and lesser side effects since the ingredients used have better compatibility with the human body. Traditional medicine has been there for over millennia and the earliest recorded

evidence indicates its use in Indian, Chinese, Egyptian, Greek, Roman and Syrian texts dating back to about 5000 years. It is still the mainstay of about 75-80% of the world population mainly in the developing countries [44]. Almost between 70% and 95% of citizens in a majority of developing countries, especially those in Asia, Africa, Latin America and the Middle East, use traditional medicine as primary healthcare [45].

Traditional medicine is also in great demand in the developed world for primary health care, such as Canada, France, Germany and Italy [37]. In Ethiopia, more than 80% of the population uses traditional medicine mainly due to the cultural acceptability, availability and affordability [46]. In addition it plays an important economic role in the country and its market has been expanded significantly over the developing countries.

Although traditional medicine gain high popularity and extensively used in the past years, it has not been officially recognized in most countries [46]. In fact it is practiced in many countries, but it is not always included as part of the healthcare system by many governments, and it is often not well understood and the history of its regulated use is comparatively short [37]. The quantity and quality of data on traditional medicine are far from sufficient to meet the criteria needed to support its use worldwide. In most countries of the world, traditional medicine products are still not officially recognized under the law and there is lack of adequate or accepted research methodology for evaluating traditional medicine.

3.1 Human healthcare delivery using medicinal plants.

Plants are source of medicine for wide varieties of physical and mental disorders in human societies in different parts of the world. Plants are a source of medicine for traditional health care and are an important source of new drug products. The use of plant as a medicine is an age old practice that have been used for thousands of years since the time human realized the preventive and curative properties of plants [47, 48]. Most people in developing countries use wild and

domesticated medicinal plants to treat many diseases [49, 50]. This is not only for human healthcare but also for livestock health, and the interest in using plant remedies for livestock health is progressively rising due to high cost of conventional medicines [51].

Beside meeting primary healthcare, medicinal plants have a role in income generation and other purposes [52]. For instance, plants are a source of pharmaceutically efficient substances which are source for the discovery of new drug [53]. Plants are infinite source for medicine as one fourth of the modern medicines available are of plant origins and most of the modern pharmaceutical industries are paying more attention to these resources recognizing their potential [54]. Considering these scientific societies have been undertaken investigations and highlighted the importance of many plant families, such as Moringaceae, Asteraceae, Liliaceae, Apocynaceae, Solanaceae, Fabaceae, Rutaceae, etc. for medicinal purpose [55]. Such plants contains major and trace elements providing valuable source of new medicines, pharmaceutical entities and bioactive compounds which play important role in treating disease [56, 57].

Commonly, all parts of the plant including fresh or dried leaves, bark, fruits, flowers, roots and seeds are used in medicinal preparations [58, 59]. These all give insight that the leaves, roots, bark, flowers, seeds, stems and fruits of medicinal plants have various health promoting effects on humans and ingredients which found in these plants may be suitable singly or in combination as preventive and treatment of various human diseases.

4. Multiple Uses of Moringa Plants

4.1 Disease Prevention and Treatment (Medicinal Applications)

Traditional medicine has a long history of serving peoples all over the world; and medicinal plants are an important element of indigenous medical systems that Moringa is among such plants which have role in traditional medicine in various part of the world [46, 48]. It chopped and mixed it with water to deliver human healthcare.

Numerous parts of the trees have been used in medicinal preparations in its ecological areas (Figure 2). Cooking of the leaves is an important steps to avoid bitter taste and then consumed for several medical purposes in various parts of the world. It is reported that the leaves and roots are commonly used in folk medicines as antimalaria, antihypertensive, against stomach pain, antidiabetic, anticholesterol, antispasmodic and to expel retained placenta during birth [1, 4, 5, 7, 60]. In southern Ethiopia particularly the natives Konso people use traditionally the leaves to prevent colds and anemia, and the roots to cure epilepsy, and the Gidole and Burji communities use it for treating digestion problems and dysentery [61]. It is also used as herbal medicine in areas where visceral leishmaniasis prevail [15]. Several reports are available in the scientific literature which substantiate the medicinal values of different parts of Moringa plants.

The crude extracts from Moringa leaves, roots, pods and seed have widespread potential for treatment of cardiovascular disorders like hypertension and cholesterol level. In this regard, oil and ethanol extracts from leaves were found to be responsible for lowering of blood pressure [62, 63]. Thus, the

leaf extract causes a plausible increase in the urine volume and concentration of urinary electrolytes in rats since it possess obvious diuretic activity, comparable to that of the standard loop diuretic Furosemide [9]. The leaves extracts were performed the action of cholesterol lowering in the serum of high fat fed rats [7, 64]. This indicate that the leaves of Moringa trees have beneficial physiological and biochemical effects by inhibiting pancreatic cholesterol esterase and pancreatic lipase activities [65].

Similarly, the aqueous ethanol extract as well as its chloroform and butanol fractions of Moringa leaves have active compounds responsible for reduction of serum glucose level in diabetic person [7, 8, 66]. In addition the n-butanol extract and hot tea infusion of leaves also possess anti-hyperglycemic and anti-hyperlipidemic properties and to alleviate pancreatic damage in diabetic rats [67]. Thus, the leaves composes active compounds possessing beneficial biochemical activities, inhibition of intestinal α -glucosidase. Therefore a daily supplement intake of the leaves of Moringa trees particularly *M. stenopetala* may help in reducing hyperglycemia and hyperlipidemia [65]. These all confirms the claim for the traditional antidiabetic use of these miraculous trees. Reports on different parts of Moringa plant and their associated uses in Ethiopia is presented in Table 2.

Furthermore, Moringa plants appears to be promising resource of bioactive principles in pharmaceutical industries. In this regard, the methanolic extract of *M. stenopetala* leaves have a good scavenging activity by hydrogen peroxide when butylated hydroxytoluene as reference compound [16, 17]. This radical scavenging potential of the tree can be used to overcome oxidative stress. It is reported that the chronic exposure to the leaves extract fractions does not lead to toxicity and did not produce adverse effects since these fraction does not significantly induce severe toxic effects on the gross and histopathology of the liver and kidneys of treated rats [68]. Fresh leaf extracts of *M. stenopetala* also possess oxytocic-like function on guinea-pig ileum and mouse uteri [69].

The crude extracts and fractions of leaves also have potential in vasorelaxant action against aorta precontracted. Thus, leaf has ability to perform very important physiological functions such as activation of guanylate cyclase and ATP-sensitive potassium channel [70]. Ethanol extracts from leaves and roots exhibits antispasmodic effects possibly through calcium channel blockade [71]. Acetone and ethanol extract from leaves and roots were found to be active against *Trypanosoma brucei* [72] and have anti-leishmanial and anti-fertility effects [15].

It is reported that the leaves extracts (methanol, ethanol and n-hexane) from Moringa trees have shown antimicrobial activities over certain human pathogenic microorganisms that cause water borne diseases like *Staphylococcus aureus*, *E. coli*, *Salmonella typhi*, *Shigella species* and *Candida albicans* [14, 73, 74, 75]. This potential is associated with the presence of benzyl isothiocyanate which is an active bactericide and fungicide [14, 76]. The leaf extracts of *M. stenopetala* exhibit substantial antibacterial and antifungal activity [13] and management of leaf blight of sunflower [77]. These all implies that the esteemed Moringa plants have promising potential for development of antibiotic drugs [12].

Table 2: Overview of Moringa plant parts and their associated uses, Research reports from Ethiopia

Center	Botanical Name	Plant Parts	Main Purposes	Uses	References
Mekelle University	<i>M. stenopetala</i>	Leaves	The effects on blood parameters and histopathology of liver and kidney in mice.	Nutritional and Management of Blood Glucose and Cholesterol	[7]
Hawassa University	<i>M. stenopetala</i>	Leaves	Evaluation of antihyperglycemic activity on chronic administration	Control of Blood Glucose Level	[8]
Ethiopian Public health institute	<i>M. stenopetala</i>	Leaves	Assessment of diuretic activity of extract and hot tea infusion in saline loaded rats	Hypertension Management	[9]
Addis Ababa University	<i>M. stenopetala</i>	Roots	Isolation of compounds and evaluation of its antibacterial activities	Development of Antibacterial Drugs	[12]
Wollega University	<i>M. stenopetala</i>	Leaves	Determination of nutritive composition and antimicrobial activity	Human Nutrition and Antibiotics	[13]
Wolayita Sodo University	<i>M. stenopetala</i>	Leaves	Determination of potential in hydrogen peroxide scavenging	Pharmaceutical Applications	[16]
Wollega University	<i>M. stenopetala</i>	Leaves	Determination of antifungal and antiradical activity	Control Phytopathogenic fungi and oxidative stress	[17]
Hawassa University	<i>M. stenopetala</i>	Leaves	Evaluation of cheap source of protein in the diets of grower Koekoek chicken breeds	Alternative Animal Feedstock for poultry industry in tropics	[18]
Addis Ababa University	<i>M. stenopetala</i>	Seeds	Assessment of potential sustainable feedstock for biodiesel production	Biodiesel Production for Alternative Energy	[21]
Mekelle University	<i>M. stenopetala</i>	Tree species	The effects of trees on soil properties and its socioeconomic benefits	Environmental and Socioeconomic Values	[63]
Addis Ababa University	<i>M. stenopetala</i>	Leaves	The effect on α -glucosidase, pancreatic lipase and cholesterol esterase activities using mice	Control Blood Glucose and Cholesterol Levels	[65]
Hawassa University	<i>M. stenopetala</i>	leaves	The effects of crude extracts in healthy and alloxan induced diabetic mice	Control of Blood Glucose Level	[66]
Addis Ababa University	<i>M. stenopetala</i>	Leaves	Evaluation of the antidiabetic activity in streptozotocin induced diabetic rats	Antihyperglycemic and Antihyperlipidemic properties	[67]
Addis Ababa University	<i>M. stenopetala</i>	Leaves	Toxicity examination on some blood parameters and histopathology of the liver and kidneys using mice	Chronic Exposure does not Lead to Toxicity. No Adverse Effects	[68]
Ethiopian Public Health Institute	<i>M. stenopetala</i>	Leaves	Evaluation of the <i>in vitro</i> vasodilatory effect and the possible mechanisms in pigs	Vasorelaxant and ATP sensitive potassium channel activation	[70]
Addis Ababa University	<i>M. stenopetala</i>	Leaves and Roots	<i>In vitro</i> test against trypanastigotes of <i>Trypanosoma brucei</i> , <i>T. cruzi</i> and <i>L. donovani</i> amastigotes.	To Control Trypanosomes and leishmaniasis	[72]
Wollega University	<i>M. stenopetala</i>	Leaves	Determination of antifungal against <i>A. helianthi</i> isolated from sunflower leaves	Management of leaf blight of sunflower (Antifungal)	[77]
Mekelle University	<i>M. oleifera</i>	Leaves	Analysis of chemical composition and nutritional values	Nutritional and Commercial Uses.	[78]
Debre Zeit Agri. Research Center	<i>M. stenopetala</i>	Leaves	Evaluation of anticoccidial activity against <i>Eimeria tenella</i> infection in chickens.	Animal (Chickens) Health and Treatments	[79]
Ambo University	<i>M. stenopetala</i>	Leaves	Evaluation of antihyperglycemic and subchronic toxicity in mice	Control of Blood Glucose Level	[80]
Mekelle University	<i>M. stenopetala</i>	Leaves	Hypotensive effect under <i>in vivo</i> and <i>in vitro</i> conditions using male guinea pigs	Control of Blood Pressure	[81]
Hawassa University	<i>M. stenopetala</i>	Leaves	Assessment on nutrient intake and weight gain using Rhode Island Red Chicks	Alternative Feedstock in Poultry Industry	[82]
Arba Minch University	<i>M. stenopetala</i>	Leaves	Analysis of trace metallic contents (Fe, Cr, Pb and Cu)	Managements of Anemia	[83]
Hawassa University	<i>M. stenopetala</i> and <i>M. oleifera</i>	Pods	Analysis of chemical and mineral compositions	Animal Feedstock	[84]

4.1.1 Cancers and Tumors Prevention and Treatment

The most interesting property of Moringa trees is its ability to perform many biological important function like killing cancer cells by inducing apoptosis, depleting ATP and leading the cells to oxidative stress. This anti-cancer activity of this plant is due to the presence of glucosinolates in their seeds [1]. Moringa plants have been recognized by folk medicine practitioners as having role to medical treatment of tumor [85]. In this regard, organic compounds (4-(4'-O-acetyl- α -L-rhamnopyranosyloxy) benzyl isothiocyanate and 4-(L-rhamnopyranosyloxy) benzyl isothiocyanate) have been potential for prevention of cancer [86]. Niazimicin and benzyl isothiocyanate are chemical compounds were revealed as potent inhibitors of phorbol ester (TPA)-induced Epstein-Barr

virus early antigen activation in lymphoblastoid (Burkitt's lymphoma) cells. Niazimicin also inhibited tumor promotion in a mouse two-stage DMBA-TPA tumor model [11]. Study showed that Moringa seedpod extracts have potential in prevention of skin tumor [10].

Nowadays modern practitioners have used crude extracts and isolated bioactive compounds with the aim of cancer prevention and therapy. However, it has not been given recognition by modern medicine since the required proof has not been realized because neither the prevention of cancer nor the modification of relevant biomarkers of the protected state has been adequately demonstrated in human beings. Therefore more rigorous investigation on full biomedical endorsement of Moringa as cancer prevention and therapy is required in the

near future to provide proof in the light of modern medicine. Complication associated with cancers and tumors prevention and treatment may be resolved with this miraculous plant.

4.2 Roles in Human Nutrition and Animal Feedstock

Nowadays Moringa trees become an important food commodity which have enormous attention as the 'natural nutrition of the tropics'. The most interesting point is all part of the trees except the wood are edible and these edible portions are exceptionally nutritious. Therefore it can be serves for humans nutrition and animals feed (Table 2). In this regards many tropical countries uses the leaves, fruits, flowers and immature pods as nutritive vegetable. Furthermore, the tree is in full leaf at the end of the dry season when other foods become scarce. These could play a much more important role in nourishment of people and in the sustainable use of the environment with limited rainfall in tropical regions [5, 13, 84].

Several reports on the nutritional aspects of Moringa trees now exist in both scientific literature. Accordingly, Moringa trees have numerous nutritional qualities than other nutritious food, for instance Moringa leaves contain more calcium than

milk, more Vitamin A than carrots, more Vitamin C than oranges, more iron than spinach, and more potassium than bananas and its protein quality compete with that of milk and eggs. In West Africa lifesaving nutritional rescue is attributed to Moringa tree [19, 20, 23]. Although there is little doubt of the substantial health benefit to be realized by consumption of Moringa trees, currently the nutritional properties of Moringa are well recognized [87, 88].

The leaf of *M. stenopetala* is one of the best vegetable food in Southern Ethiopia and Northern Kenya. In fact both fresh and older leaves are nutritious and edible, it can be cooked and eaten as vegetable. However, older ones are milder and tender, and can be either cooked in soups or boiled. While dried powder can be stored for many months without loss of nutritional value as future soup or sauce supplements. Also like spice a few spoonfuls of the powder can be added to other sauces to make the diet more nutritious. Generally, it is a good source of proteins, carbohydrates and minerals needed for normal physiology of the body and hence, it can be used as food or feed supplement to enhance growth and health in humans as well as animals [13, 18, 83]. Different parts of *M. stenopetala* applied for various uses is presented in Figure 2.

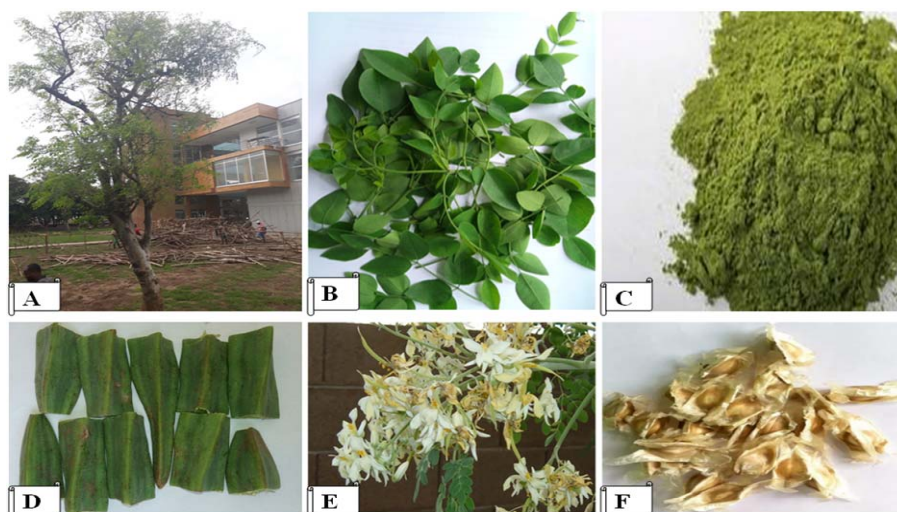


Fig 2: Sample pictures of *M. stenopetala* (photos taken from Arba Minch University (Main Campus) and Sikela Market): (A) Tree; (B) Leaves; (C) Leaf Powder; (D) Fresh Pods; (E) Flowers; and (F) Seeds

Moringa foliage and fruit pods are rich sources essential minerals like calcium and iron, and they consists of vitamins A, B, and C. They are also a good source of sulphur-containing amino acids like methionine and cystine. Usually the green peas and surrounding white material can be removed from larger pods and cooked in various ways and eaten much like green beans. They have been sold fresh and canned in many Asian markets and tinned drumsticks (regional name of *M. oleifera*) are exported from India, Sri Lanka and Kenya to Europe and Asia [4, 5, 24, 27]. The flowers are a good nectar source for honey, it can be cooked and eaten or dried and steeped to make a tea. The roots are often used as flavoring in poultices and the taproot of small Moringa tree used in place of horseradish after mixing with vinegar and salt.

The immature seeds are cooked and eaten as a fresh vegetable, while mature seeds can be dried and roasted. The dry seeds are apparently not used for human consumption, perhaps because the bitter coating becomes hardened. The seeds are rich oil sources with 40% oil contents. It is reported that oil extracted from Moringa seeds could be utilized for human consumption since it contains a high ratio of

monounsaturated to saturated fatty acids, and might be an acceptable substitute for highly monounsaturated oils such as olive oil in diets [2, 21, 23, 89].

Numerous researchers were reported the chemical composition of Moringa leaves and pods. In this regard, the tree consists of essential chemicals which have high nutritional value for people of all ages [23]. For 1-3 years child aged, daily requirements of calcium, about 75% of iron and half protein need of child were compensated by serving only 100 g of fresh leaves. Additionally, it supplies important minerals and vitamins like potassium, vitamins-B complex, copper and all the essential amino acids. In general the fresh leaves provide a child with all the vitamins A and C needed. Similarly, it is important to provide essential minerals and vitamins need of pregnant or nursing woman and it give her important quantities of iron, protein, copper, sulfur and vitamin B. These all implies the extraordinary nutritional properties of Moringa trees, due to this it can be used as nutritional supplement particularly in infants and pregnant/nursing mothers in order to challenges the malnutrition in tropical regions [90]. The chemical composition of Moringa leaves and pods is presented in Table 3.

Table 3: Chemical composition of Moringa leaves and pods.

Chemical and Analytical Parameter	Pods	Leaves	Leaf Powder
Moisture (%)	86.90	75.00	7.50
Calories	26.00	92.00	205.00
Protein (g)	2.50	6.70	27.10
Fat (g)	0.10	1.70	2.30
Carbohydrate (g)	3.70	13.40	38.20
Fiber (g)	4.80	0.90	19.20
Minerals (g)	2.00	2.30	-
Ca (mg)	30.00	440.00	20003.00
Mg (mg)	24.00	24.00	368.00
P (mg)	110.00	70.00	204.00
K (mg)	259.00	259.00	1324.00
Cu (mg)	3.10	1.10	0.60
Fe (mg)	5.30	7.00	28.20
S (mg)	137.00	137.00	870.00
Oxalic acid (mg)	10.00	101.00	0.00
Vitamin A-B carotene(mg)	0.10	6.80	16.30
Vitamin B-choline (mg)	432.00	423.00	-
Vitamin B1 thamin (mg)	0.05	0.21	2.60
Vitamin B2 riboflavin (mg)	0.07	0.05	20.50
Vitamin B3 nicotinic acid (mg)	0.20	0.80	8.20
Vitamin C-ascorbic acid (mg)	120.00	220.00	17.30
Vitamin E-tocopherol acetate (mg)	-	-	113.00
Arginine (g/16 g N)	3.60	6.00	0.00
Histidine (g/16 g N)	1.10	2.10	0.00
Lysine (g/16 g N)	1.50	4.30	0.00
Tryptophan (g/16 g N)	0.80	1.90	0.00
Phenylalanine (g/16 g N)	4.30	6.40	0.00
Methionine (g/16 g N)	1.40	2.00	0.00
Threonine (g/16 g N)	3.90	4.90	0.00
Lucine (g/16 g N)	6.50	9.30	0.00
Isolucine (g/16 g N)	4.40	6.30	0.00
Valine (g/16 g N)	5.40	7.10	0.00

It is reported that Moringa trees are also used as alternative animal feedstock. The fresh pods of the tree could be used as cheap protein supplement sources for feeding ruminant and monogastric animals during dry periods of the year [84]. The aqueous leaf extract of *M. stenopetala* is shown to increase body weight in Koekoek chickens, hence, it can be an alternative animal feedstock for the emerging poultry industry in tropical regions [18]. The leaves extracts is a potential plant protein supplement and could be included to 6% in the diet of grower chicks to substitute expensive conventional protein sources (Table 2) [82].

In Southern Ethiopia, the people of Arba Minch/Wolayita and Konso including their surrounding communities are cooked the leaves of *M. stenopetala* and eaten as cabbage with their special traditional food known as "Fosose" and "Kama" in Gamo/Wolayita and Konso regions respectively. Both "Fosose/Kurkufa" and "Kama" are prepared from flour of maize or sorghum, the only difference is knead and make into balls 2-5 cm in diameter in the case of "Kama" [24]. Beside "Fosose", "Kurkufa" is also prepared among the local communities of Arba Minch/Wolayita, it is similar to that of "Kama".

Moringa tree is also one of the promising crops toward the contribution of increased intake of micronutrients and antioxidants. Since diets rich in micronutrients and antioxidants are strongly recommended for people living with HIV AIDS to challenges the effects of the HIV virus. Sufficient nutrients to enhances the immune responses were obtained through consumption of Moringa trees. In addition, consumption of nutrient and phytochemical-rich vegetables,

like Moringa, leads to a better immune response compared to consumption of vegetables that are rich in fiber but lower in nutrient content, like common cabbage. Moringa should be promoted for greater consumption to improve nutrition and strengthen immune functions for fighting infectious diseases like HIV AIDS [6].

4.3 Socioeconomic Values

Moringa plant is a strategic and unique food tree in drought prone areas and it has high social and economic value. Traditionally Moringa plants are cultivated as agro forestry, cabbage tree and planted as ornamental tree. It is reported that in some parts of Africa there are folk beliefs that Moringa trees planted on graves keep away hyenas and its branches guard against witchcraft. For this reason many families plant Moringa species on and around the graves of their relatives. On the other hand, introduction of this miraculous plant into a farm in any ways could brought beneficial for both the owner of the farm and the surrounding ecosystem (environmental benefits) [23].

Traditionally, different parts of the trees used for human and animal nutrition. In addition to this, unripe and mature seeds of the *Moringaceae* family are used as foodstuff and spices in various countries. The leaves of Moringa tree is the most useful vegetable foods and sold for vegetable use in the local markets in various parts of the world. The leaves of *M. stenopetala* are consumed continuously in the Southern Ethiopia and northern Kenya. Also in several west African countries like Ghana and Sierra Leone dried leaves and seeds of *M. oleifera* are widely sold at local markets [76, 91]. The young seeds of *M. peregrina* are eaten like peas and the mature seeds are roasted like ground nuts and also prepared as infusions, tinctures, capsules and creams [1].

4.3.1 Moringa stenopetala in Southern Ethiopia

Moringa stenopetala is widely cultivated and distributed in the Southern Ethiopia mainly in Gamo Gofa, Wolayita, Konso, Sidama, Bale, Keffa, Borana, Debub Omo zones, Dherashe areas and the adjoining provinces. In Gamo Gofa/Wolayita or Konso, immature leaves of *M. stenopetala* are pan of the staple diet of the population. The delicacy traditional meal among the population of Gamo Gofa/Wolayita is called "Fosose/Kurkufa", which is prepared from the leaves of *M. stenopetala* and flour of maize/sorghum. This miraculous tree has different name with respect to its ecological location, it is called Shiferaw in Amharic, Aleko/Halako in Gamo/Wolayita, Shelchada in Konso people and Cabbage tree in English language. The fresh leaves are sold for vegetable use in the local markets in this part of the country. The local peoples also use boiled leaves as tea and currently leaf powder and tea leaves were produced from this tree and available in the market through the country [7, 15, 24, 27].

In southern Ethiopia, the Konso people thought that the abundance of *M. stenopetala* tree in the garden or on farmland indicates the social status of the owner among the society. The one with many Moringa tree in the garden or on farmland has a higher social status and considered as a rich. Additionally, the number of Moringa trees in the garden or on farmland is the major criteria to be considered in the due process of marriage in the daughter family. They thought that if the husband has many Moringa trees in his garden or farmland then their daughter will have no problem to feed her babies even when drought happens. For this reason Konso people especially young men are encouraged to plant Moringa

in their garden or farmlands. This indicates that culture has a great role in conservation and sustainable utilization of locally important tree species like Moringa [21].

The Moringa tree can also be grown as an ornamental tree in private gardens and home compounds in southern parts of the countries. *M. stenopetala* tree is also planted and grown in mixed multi-story stands with food crops and together with fruit trees in the cropped fields in Konso. It used to provide partial shade for crops like sorghum in the southern part of the country. The whole plants have been used as hedges and live fences and it can also be planted as a windbreak, vegetables cultivated behind it profited from this protection [21, 23].

4.4 Miscellaneous Uses of Moringa Seeds

4.4.1 Water Purification

Multiple Uses of Moringa Trees is summarized in the following Figure 3. Crude extracts from seeds of *M. oleifera* and *M. stenopetala* possesses antimicrobial activities against some human pathogenic bacteria that cause water borne diseases. This properties of the seed is mainly due to the presence of secondary metabolites [14]. Moringa seed is one of the best natural coagulants used for turbid water treatment [92, 93], which is the best alternative for treatment of drinking water in developing countries [94]. The amount of crushed

seeds required to purify 1 liter of muddy water is estimated to be a 100 milligrams (about 1 to 1 ½ seeds) [14]. It is reported that the seed of *M. oleifera* has significant potential for treatment of turbid water, it could reduce turbidity by between 92% and 99% [95]. Moringa seeds were found to be efficient biosorbent for the removal of cadmium and lead from water [96, 97]. The seed of *M. stenopetala* is more effective in lead sorption from water than *M. oleifera* [14]. These all implies the diversified application of this miraculous plant.

4.4.2 Biofuel Production

Moringa seed can be a good candidate of oilseeds like soybean, sunflower and cottonseeds. Oil content of soybean and cottonseed are the leading source of edible oil with about 18-20% moderate oil content, however the seeds of Moringa have 40% oil contents. Edible oil production from Moringa seeds have more advantageous than the conventional oilseeds in terms of oil content, costs and agronomic properties [22]. Furthermore, oil derived from Moringa seed is a potential feedstock for biodiesel production. Biodiesel derived from *M. stenopetala* seed oil is an acceptable substitute for petro diesel [21, 98]. This properties of seed address issues like global climate change and alternative energy from renewable sources.

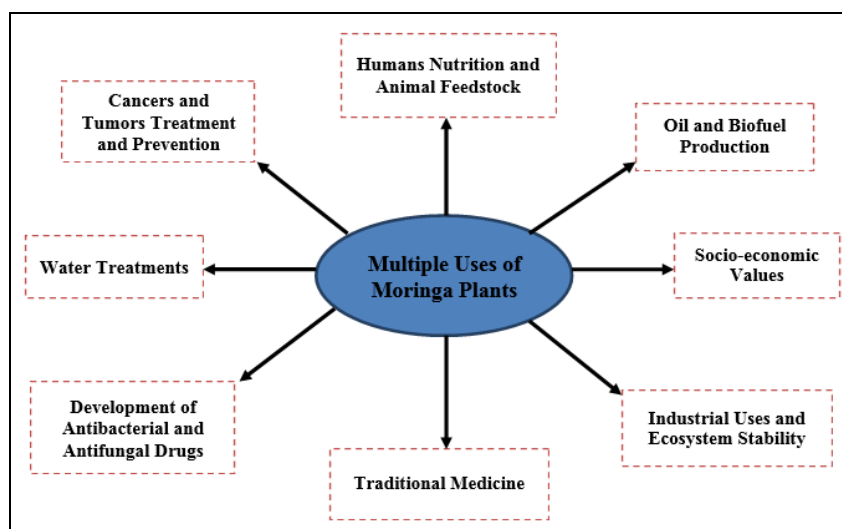


Fig 3: Summary on Multiple Uses of Moringa Trees.

5. Morphology, cultivation and propagation of moringa trees

5.1 Morphology of *M. stenopetala*

Moringa (*Moringa stenopetala*) is a tree 6-12 m tall having a diameter of 60cm (DBH) and a smooth bark having soft wood. It is a tree with trunk up to 60 cm in diameter at breast height; crown strongly branched; sometimes with several trunks, thick at base; bark white to pale grey or silvery, branches with leafy, young stems and leaves densely velvety pubescent [19, 89].

The leave of *Moringa stenopetala* is up to 55 cm long, 2-3 pinnate with five pairs of pinnae and 3-9 leaflets elliptic to ovate, 3.3-6.3 cm long, 1.8-3.3 cm wide, acute, with thickened apiculus at apex, rounded to cuneate at the base, pubescent or glabrous; petiole 10-15 mm long [19, 20, 76]. Moringa tree native to Ethiopia had larger edible leaves, more drought resistance, and larger seeds and by the end of a long dry season the trees have lost their leaves [19]. Leaf stage significantly influenced nutrient contents of Moringa leaves. Mature leaves were more nutritious than young shoots and

could be quickly dried with minimum nutrient loss; however, young shoots exhibited better eating quality and thus were better accepted for fresh market. Cooking increased availability of iron and enhanced aqueous antioxidants agents [6].

In *M. stenopetala* tree inflorescence pubescent, dense many-flowered panicles up to 60 cm long, strong fragrant with cream flushed pink sepals, regular, hypogynous, yellow anthers and, white filaments and yellow-green petals up to 10 mm long. Moringa tree begins flowering after 8 to 12 months and continues year round base [19, 23, 76, 89]. The seeds of *M. stenopetala* elliptical in shape and creamy coloured and contain 40% oil. *M. stenopetala* has elongate reddish with grayish bloom pods having grooved valves. Although *M. stenopetala* wood is very soft and poor charcoal, it makes acceptable firewood and considered as a good live fence tree particularly in southern Ethiopia [23]. Moringa wood also have application for making of excellent paper pulp as good as poplar (*Populus sp.*) [99].

5.2 Cultivation and Propagation

Moringa tree grows best in the hot, semi-arid tropical region. It is drought-tolerant and grows with rainfalls of 250-1500 mm per year. The Moringa plant grows best at an altitudes below 600 m and it also grows up to 1200 m in some tropical areas and has been recorded growing at 2000 m [27]. In southern parts of Ethiopia *M. stenopetala* is found regularly at altitudes up to 1800 m. Some studies also reported as the effective altitude limit for growing Moringa to be 500 m and excessively windy conditions cause the tree to dry out [100].

Although a good temperature range for the tree is 25-35°C, it can tolerate up to 48°C for limited amounts of time. The Moringa tree prefers well-drained sandy or loam soil. It will tolerate a clay soil but not water logging. It tolerates a wide range of pH (5-9), growing quite well in alkaline conditions up to a pH of 9 and it responds well to mulch, water and fertilizer [23, 27, 100]. Moringa is an extremely fast-growing tree, therefore, it is advisable to prune trees frequently to a shrub form to make ease harvestable. Regular breaking off tender tips to cook when trees are about 1.3 m tall, the trees become much bushier [23, 101].

Generally Moringa plants grown easily from seeds or vegetatively propagated tree by cuttings. Seeds should be planted 2 cm deep and germinated within 1-2 weeks. Although germination rate of seeds are usually very good, it come down to 0% after 2 years. Studies from Sudan shows that the optimum light for germination of all Moringa species is half shade [76, 15]. Propagation of *M. stenopetala* were started from cuttings. Cuttings 45-100 cm long with stems 4-10 cm wide has been taken from the woody parts of the branches. It has been cured for three days in the shade and then planted in the field. Although Moringa trees grown from cuttings are known to have much shorter roots, longer roots are an advantage for stabilization or access to water. Therefore, Moringa germination from seedlings is more preferable than its vegetative propagation [76, 19, 76].

6. Future Prospects

So far several investigators have been conducted on different aspects of Moringa plants, but there is a horrible need to isolate and identify new compounds from different parts of the tree, which have possible antitumor promoters as well as inhibitory properties. Nowadays preliminary studies are under way in different parts of the world for production and extraction of bioactive compounds from Moringa tree parts which have antispasmodic, anti-inflammatory, antihypertensive and diuretic activities. These investigation will be forwarded to humans in the forms of the edible nature of the plant in the near future.

Moringa seed, pods, roots and leaves have long been used traditionally to treat different acute and chronic disease like hypertension, diabetes, malaria, atherosclerosis and constipation. Studies to proof these claims need to be carried out in the light of modern medicine for the reported disease treatment activities. Since there is little doubt and contrary to the substantial health benefit to be realized by consumption of Moringa trees. Therefore, the known species differences in the pharmacological actions of medicinal plants may also be taken into account when planning studies involving contradictory results. And there should be well controlled and documented clinical studies were required to proof the medicinal aspects of this miraculous trees.

Since Moringa plants used as food which are considered relatively safe as they are probable to contain synergistic or side effect neutralizing combinations of activities. It is well

known to compose multiple medicinally bioactive compounds, these properties suggest that it could be a good candidate to see if it contains effect enhancing or side-effects neutralizing combinations. Medicinal plants like Moringa are relatively rich in different chemical substance which are known to possess a wide variety of pharmacological activities such as antihypertensive, hepatoprotective, antiulcer, antiasthmatic, antidiabetic, anticholesterial, antispasmodic and antidiarrhoeal. These all need to be extended to the humans in the near future after proof provided by the modern medicine.

7. Conclusions

Moringa plants are among high value and multi-purpose trees with medicinal, nutritional, and socio-economic values and they are highly distributed in tropical regions. The tree is used as a hedge, living fence and wind break. The leaves of Moringa trees have been used traditional for treatment of ailments like hypertension, malaria, leishmaniasis, Trypanosoma, abdominal pain, heal ulcer and, it have also significant diuretic, hepatoprotective and cholesterol lowering activities. It have wider antibiotic spectrum so as to be used for development of drugs. Moreover, daily intake of leaf brought beneficial physiological and biochemical functions in humans to restrict cancers and tumors. In relation to this, all parts of the tree are edible except wood and they are exceptionally nutritious since it is an important food commodity in tropical region. Moreover, all these parts of the trees contain fundamental chemicals and minerals essential for promotion of growth and health. Therefore, it important for providing essential nutritive components and combat moderate malnutrition in infant and nursing mothers particularly in tropics. Additionally, Moringa leaves can substitute expensive protein in animal nutrition and used for treatment of animal diseases. Thus, it can be used alternative animal feedstock for supporting the emerging poultry industries in tropical areas.

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