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The Potential of *Moringa Oleifera* in Enhancing Nutritional Quality and Sensory Attributes of Dairy Products: A Review

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ABSTRACT: *Moringa oleifera*, a highly nutritious plant traditionally used in Asian and African countries, has gained attention for its potential applications in improving the nutritional quality and sensory attributes of dairy products. This review paper provides an overview of the scientific research conducted in the area of incorporation of *Moringa* extracts or powder into various dairy products.

The nutritional composition of *Moringa*, particularly its leaves, flowers, and pods, which are commonly consumed in traditional diets, is highlighted, emphasizing their high protein content, vitamins, minerals, and phenolic compounds. The studies reviewed investigate the effects of *Moringa* on the physicochemical, microbiological, organoleptic, and nutritional properties of dairy products. Findings indicate that the addition of *Moringa* extracts to yogurt enhances its nutritional value and sensory properties while maintaining bacterial growth and activity. Furthermore, *Moringa* leaf extract enriches fermented milk products with bioactive components such as polyphenols, flavonoids, tannins, and iron, resulting in improved rheological properties and higher antioxidant capacity. *Moringa* dry leaves and oil have been successfully incorporated into ice milk to enhance its nutritional quality. *Moringa* possesses antimicrobial properties and can contribute to the development of dairy products with enhanced nutritional value.

Overall, this review highlights the potential of *Moringa oleifera* as a natural mean to improve the nutritional quality and sensory attributes of dairy products. The incorporation of *Moringa* extracts or powder offers opportunities to enhance the nutritional value, antioxidant capacity, and microbial shelf stability of dairy products without compromising their sensory properties. These findings contribute to the understanding of *Moringa*'s potential application in combating malnutrition and improving the health benefits of food products. Further research is warranted to explore the optimal formulations and concentrations of *Moringa* in different dairy products to maximize its potential benefits.

Moringa

Moringa is a great source of nutritional components. It has been known for various medicinal uses, those have been mentioned in the unani and ayurvedic systems of medicine (Mughal *et al.*, 1999). There are 13 species of *moringa*: *Moringa oleifera*, *M. arborea*, *M. borziana*, *M. concanensis*, *M. drouhardii*, *M. hildebrandtii*, *M. longituba*, *M. ovalifolia*, *M. peregrina*, *M. pygmaea*, *M. rivae*, *M. ruspoliana*, and *M. stenopetala* of the family *moringaceae*. The most widely known species *Moringa oleifera* is famous as "moringa" (Mishra *et al.*, 2011). Jaffna or Yazhpanam, grown in various parts of South India, (600-900 mm long pods), Chavakacheri murungai, (900- 1200 mm long pods), Chemmurungai (with red tipped fruits), Kadumurungai, Palmurungai, Puna murungai (with thick pulp and bitter taste) etc. are some major varieties of *moringa* grown in India (Sundarajan *et al.*, 1970).

Almost all parts of this tree (leaves, flowers, and pods) are used in numerous traditional food preparations, medicines and for industrial uses in Asian and African countries (Sreelatha and Padma, 2009). The leaves, pods and flowers of this tree are edible and they are majorly used for preparation of traditional diets in many regions (Siddhuraju and Becker, 2003; Anhwange *et al.*, 2004). *Moringa* is a very good source of proteins, vitamins, beta carotene, amino acids and phenolics but their composition vary from part to part. *Moringa* also contains water purifying powers and high nutritional value, which makes *moringa* very important for medicinal uses. Various parts of *moringa* plant like leaves, roots, seed, bark, pod, and flowers act as cardiac and circulatory stimulants, possess antitumor, antipyretic,

antiepileptic, anti-inflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, cholesterol lowering, antioxidant, antidiabetic, hepatoprotective, antibacterial and antifungal properties, and are being utilized for the treatment of different ailments in the indigenous system of medicine. It is believed that moringa is helpful to cure skin disease that's why moringa oil is applied externally for skin diseases (Foidl *et al.*, 2001; Anwar *et al.*, 2007). Moringa leaves (weight per weight) contains 4X calcium equivalent compared of that of milk, the vitamin C content is 7X that of oranges, while moringa's potassium content is 3X that of bananas, iron content of moringa is 3X of spinach, the amount of vitamin A in 4X of carrots, and it contains 2X protein as compared to milk (Kamal, 2008; Pandey, 2013).

Physical Characteristics and Nutritional Composition of various parts of Moringa:

• Moringa leaves

Moringa leaves are rich source of protein, vitamins A, B and C as well as minerals such as phosphorus, calcium, and iron (Dahot, 1988). Moringa leaves protein can be used as low-cost protein source, as it is easy to extract protein from leaves because of high protein content and low fibre content of moringa leaves (Awasthi and Tondon, 1988). Leaves are rich source of iron, calcium (0.9 to 2.9%), phosphorous (0.4 to 1.2%) and zinc (17.5 to 46.2mg/kg) (Gopalan *et al.*, 2004). As dried moringa leaves can retain their nutrient content which make it suitable to convert them into leaf powder. Mishra *et al.*, (2012) standardized a method for processing of moringa leaves for human consumption and stated that Moringa oleifera is a highly valued plant in terms of rich source of minerals and protein, vitamins, amino acids and various phenolics.

Raghavendra *et al.*, (2015) studied for extraction of phytoconstituents, antioxidant properties, nutrients, minerals, and vitamins from various parts of moringa by using methanol as extraction medium. The results of the study showed that antioxidant activities of leaf extract were on higher side as compared to the pod extract. The IC50 values for DPPH radical scavenging activity was 150 µg/ml for leaf extract and 240 µg/ml for pod extract. The mineral composition of moringa leaves and pod extract included a high concentration of iron and calcium followed by sodium, potassium, and magnesium. It was suggested that the leaves and pod contain good amount of nutrients and can be included in diets to fulfil our daily nutrient requirements. Moringa can be utilised as a great fodder for cattle. The weight of livestock increased up to 32 per cent through Moringa feed and their milk yield of cows increased by 43%. Various uses of moringa leaves in dairy products:

1. Adepoju & Selezneva, 2020 evaluated the physicochemical properties of low-fat yogurt enriched with Moringa oleifera leaf powder during 14 days of storage at 4±1°C. Samples with different concentrations of moringa leaf powder were compared to a control sample. The pH of the samples decreased during storage, while titratable acidity and water holding capacity increased. Samples with moringa leaf powder had higher viscosity and reduced syneresis compared to the control. However, the sample with the highest concentration of moringa was low in viscosity and high in total solids.
2. Elkhtab & Saad, n.d. tested the antimicrobial activity of Moringa oleifera leaf extract at different concentrations against various microorganisms (Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Saccharomyces cerevisiae and Aspergillus fumigatus) using the agar diffusion method. The addition of 0.8% of the extract extended the shelf life of yogurt up to 28 days, while addition of 0.4% had the best effect on the organoleptic properties up to 21 days of refrigerated storage.
3. The study by Dubey *et al.*, 2018 involved preparing Moringa leaf powder Shrikhand at different concentrations (T1-1%, T2-2%, and T3-3%) and evaluating the physico-chemical, organoleptic, and microbiological parameters of the experimental products in comparison to a control sample (T0). The results showed that T1 had the best organoleptic characteristics, while T0 had the best chemical characteristics and T3 had the best microbial characteristics. T1 received the highest score in organoleptic parameters, while T1 and T3 performed better in terms of total solids, carbohydrate, and microbial count, respectively.
4. Al-Ahwal *et al.*, 2017 examined the acceptability, antioxidant activity, and survival of probiotic strains in yoghurt-like products flavored with Moringa oleifera at different concentrations. The products contained probiotic bacteria as a single or mixed culture. Results showed that protein, ash, and antioxidant capacity increased with the increase of the extract of Moringa oleifera dry leaves. Yoghurt-like products flavored with 2% and 4% (w/w) of the extract had increased antioxidant capacity without affecting sensory, texture, and chemical parameters compared to control. Therefore, it was suggested that Moringa oleifera at 2% and 4% (w/w) could be used in the preparation of yoghurt-like products to increase their health benefits and acceptability.
5. Haldayani *et al.*, 2022 investigated the physical and chemical characteristics of Moringa leaf powder and its potential use as a fortification in ice cream. Four treatments were tested with different concentrations of the powder. The results showed that a concentration of 1% Moringa powder, 5% creamer, 15% sugar, 0.5% CMC, and 78.5% milk was preferred by consumers.

6. Kumar Tanwar, 2022 investigated the impact of Moringa leaf powder extracts on the oxidative stability and storage quality of paneer. Paneer was fortified with 2%, 4%, and 6% Moringa leaf powder extracts and compared to a control. The results showed that paneer prepared with 4% Moringa leaf powder was the best based on sensory attributes. The paneer incorporated with Moringa leaf powder was safe for consumption for 28 days at refrigerated storage, without any significant loss in physico-chemical, microbial, and sensory quality. The developed value-added paneer could be packed in LDPE for 28 days without any significant loss of quality.
7. Nadeem and Imran, 2016 aimed to investigate the effect of supplementing whey drink with Moringa oleifera leaf powder (MOLP) on its nutritional and sensory characteristics. Four different concentrations of MOLP were added to the whey drink and compared with a control. The addition of MOLP at any level did not have a negative effect on pH and acidity of the whey drink. The highest concentration of MOLP (4%) significantly increased the iron content (0.17 to 115 mg/100 mL), total phenolic content (1.46 to 2.20 mg/100 g), and vitamin C of the whey drink. The results suggest that adding 4% MOLP to whey drink can increase its nutritional value without compromising its sensory quality.
8. Ismael *et al.*, 2016 investigated the effect of adding Moringa Oleifera leaves powder (MOLP) at different levels on the nutritional and volatile compounds of sweet whey beverage. The results showed that all blends had increased nutritional value, with the highest preference from sensory evaluation given to T1 (5% MOLP). GC and GC-MS analysis identified 26 volatile compounds in the beverage, with acids being the most abundant. Based on the findings, the study suggests that fortifying sweet whey beverage with MOLP can enhance its nutritional and sensory properties.
9. Nadeem *et al.*, 2013 added Different concentrations of LEMO to the butter and compared to a control group that had no LEMO added. The results showed that the addition of LEMO at a concentration of 600 ppm improved the storage stability of the butter without affecting its composition. The butter treated with LEMO had lower levels of free fatty acids, peroxide value, and p-anisidine value after 90 days of storage compared to the control group. This suggests that LEMO can be used as an effective antioxidant to stabilize butter during refrigeration, while maintaining its sensory characteristics.
10. El-Gammal *et al.*, 2017 found that the aqueous extract of Moringa oleifera contains bioactive compounds such as tannins, flavonoids, saponin, alkaloids, and terpenes, and has a high content of total phenolic (340.82 mg/g as gallic acid). The addition of Moringa oleifera extract to yogurt increased its nutritional value and improved its sensory properties. The extract exhibited antibacterial activity against Gram-positive bacteria and had a slightly decreasing effect on pH. The addition of the extract increased curd tension and water-holding capacity, and reduced susceptibility to syneresis. Acetaldehyde and diacetyl content increased in yogurt with Moringa oleifera extract compared to the control. Hardness, adhesiveness, and gumminess were significantly higher in experimental yogurt made with the extract, while cohesiveness and springiness were significantly lower than the control.
11. Lisak Jakopović *et al.*, 2022 investigated the addition of Moringa oleifera leaf extract (ME) to milk before fermentation to enrich fermented milk products with bioactive components such as polyphenols, flavonoids, tannins, and iron. Yoghurts enriched with ME (1%, 3%, and 4%, v/v) were produced and compared to a control yoghurt without ME. The results showed that ME addition resulted in a shorter fermentation time, lower yoghurt pH, increased growth of yoghurt bacteria, better rheological properties, increased total phenols content and antioxidant capacity, higher mineral content, and better sensory properties of yoghurts.
12. Wulansari *et al.*, 2022 examined the impact of adding Moringa leaf powder to goat milk kefir at varying concentrations (0%, 0.5%, 1.0%, 1.5%, and 2.0% w/w) and different storage periods (0, 7, and 14 days) on the quality of the final product. The study observed microbiological and chemical characteristics of the kefir, as well as its fatty acid profiles and antioxidant properties. The results showed that supplementing kefir with Moringa leaf powder increased acidity, total phenol, and DPPH, while decreasing the alcohol level. Storage time decreased TPC, total yeast, and total solids but increased alcohol, total phenol, and DPPH. It was found that 2% Moringa leaf powder combined with 14-day storage produced twice as much total phenol and DPPH as those in the control group, without affecting the quality of the kefir product.
13. Salem *et al.*, 2015 aimed to improve the quality and prolong the shelf life of sour cream by adding Moringa oleifera Leaves Extract (MOLE) or Moringa oleifera Oil (MOO) at concentrations of 600, 800, and 1000 ppm. The results showed that both MOLE and MOO had a positive effect on the chemical and microbiological properties of sour cream. MOLE increased acidity, while MOO decreased it. Peroxide Value (PV) was also affected, with MOO resulting in lower PV than MOLE. The addition of MOLE and MOO improved the sensory acceptability of sour cream and prolonged its shelf life by inhibiting the growth of lipolytic and proteolytic bacteria, yeast, and mold. Overall, the use of MOLE and MOO as sour cream preservatives was

found to have no negative effects on the evaluated parameters, indicating a promising approach for improving sour cream quality and safety.

14. Aha and El-Imam, N.D. aimed to assess the bacterial status and nutritional and sensory properties of West African Soft Cheese treated with different levels (1%, 2%, and 3%) of ethanol and ether extracts of *Moringa oleifera* leaf using a 2x4 factorial design. The results showed that 2% and 3% ethanol extract had the highest inhibitory potential against bacterial populations. Cheese treated with 1% ethanol extract had the highest levels of crude protein and ash, while the control cheese had significantly higher moisture and fat content. Sensory analysis revealed that analysts preferred the cheese preserved with 3% ethanol extract. The use of ethanol extract of *Moringa oleifera* leaf as a cheese preservative led to improved microbial stability, nutritional quality, and higher sensory acceptability.

- **Moringa seeds**

Green moringa seeds can be extracted and eaten after boiling or frying. Dry seeds of moringa cannot be used for human consumption due to bitter taste and hard seed coat. The mature seeds of moringa contains approximately 40% oil. Fatty acid profile of moringa seed oil is similar to olive oil as Moringa oil contains 73% oleic acid. Moringa seed oil sold for many years as "ben oil," for cooking purpose and for formulation of perfumes. It can be used for manufacturing of soaps. In addition to moringa seeds usefulness as a source of oil, moringa seeds can be used for treatment of water. Moringa seed oil can be used on skin as remedy for skin related diseases (Foidl *et al.*, 2001). Moringa oil cake can be used as fertilizer as it contains a good amount of nitrogen (Rashid *et al.*, 2008).

Dry, crushed seed and seed press cake of moringa seeds contain polypeptides which serve as natural coagulants for treatment of water (Ndabigengesere *et al.*, 1995). The seeds of Moringa are antipyretic, acrid, bitter (Oliveira *et al.*, 1999) and antimicrobial activity of moringa seeds make them special. Seeds of moringa can be used for treatment of waste water as seeds contain cationic polyelectrolytes those neutralizes the negatively charged colloids present in dirty and muddy water.

The refined oil of moringa seeds is clear and odourless. Moringa seeds are rich source of different tocopherols (α , β , δ), the concentration of different tocopherols α , β , δ is in the range of 98.82-134.42 mg/kg, 27.90-93.70 mg/kg and 48.00-71.16 mg/kg, respectively (Tsaknis *et al.*, 1999; Anwar and Bhanger, 2003; Mehta *et al.*, 2011).

(Abdulkarim *et al.*, 2007) used moringa seed oil as frying media to fry potato chips for 6 hours per day upto 5 days to determine the performance of moringa seed oil in deep frying as compared to other oils and found that total peroxide value of moringa seed oil is significantly lower than soyabean and palm oils.

The moringa seed oil is known for its ability to absorb and retain volatile substances and this property of moringa seed oil make it valuable in the perfume industry for stabilising scents. The free fatty acid content of moringa seed oil varies from 0.5 to 3 %. Moringa seed oil usually contains 13 % saturated fatty acids and 82 % unsaturated fatty acids. It has a particularly high level of oleic acid (70 %), whereas other vegetable oils normally contain only about 40 % oleic acid. Various uses of moringa seeds in dairy products:

1. Adesina *et al.*, 2022 aimed to optimize the production process of cheese made from cow's milk by using *Moringa oleifera* seeds extract as a coagulant. Response surface methodology was employed to determine the optimal processing conditions, which included a 1.5% concentration of *M. oleifera* seed extract and a coagulation temperature of 55°C. The resulting cheese, referred to as MOC, exhibited higher protein and fat contents compared to cheese produced using *Callotropis procera* extract as a coagulant. Sensory evaluations indicated improved attributes in the MOC cheese, and it also demonstrated a longer shelf life of 8 days at an ambient temperature. Overall, optimizing the cheese production process with *M. oleifera* seed extract yielded cheese with enhanced characteristics, sensory qualities, and increased shelf stability.
2. Mahami *et al.*, 2011 investigated the supplementation of Moringa seed extract at different concentrations (0.5%, 1%, 1.5%, and 2%) in cottage cheese made from fresh cow milk coagulated with *Callotropis procera* latex. The addition of Moringa seed extract resulted in an increase in pH of the cottage cheese, with significant differences observed among the concentrations. The study suggests that Moringa seed extract can enhance the yield, protein content, and mineral composition of cottage cheese, indicating its potential for improving its quality.
3. Alsir and Abdelsalam, 2018 aimed to investigate the physicochemical, microbiological, and sensory properties of cheese made by adding Moringa seeds extract. Different concentrations of Moringa seeds extract (2%, 3%, and 4%) were used in the cheese preparation. The moisture content of the cheese samples did not show a clear pattern with the addition of Moringa seeds extract. However, the protein content increased significantly with higher concentrations of the extract. The fat content was highest in the cheese sample made with 4% Moringa seeds extract. The mineral content, ash content, titratable acidity, and pH were all affected by the addition of Moringa seeds extract. Microbiological analysis showed no detection of Coliform bacteria and Salmonella in

- the cheese samples. Sensory evaluation indicated that all cheese samples were accepted, with a preference for the cheese prepared with 4% Moringa seeds extract.
4. Sánchez-Muñoz *et al.*, 2017 explored the potential use of Moringa oleifera as a clotting agent for various types of milk, including whole, skim, and soy milk. The researchers found that Moringa oleifera seed extract exhibited high milk-clotting activity, surpassing the activity of the flower extract. The specific clotting activity of the seed extract was 200 times higher than that of the flower extract. The seed extract consisted of four main protein bands and demonstrated significant caseinolytic activity, leading to extensive casein degradation. Cheese made from soy milk using the seed extract resulted in a soft and creamy texture, while cheese made from skim milk was harder and crumbly. These findings suggest that Moringa oleifera seed extract possesses effective milk clotting activity suitable for cheese production. Notably, this study provides the first comparative data on Moringa oleifera's milk clotting activity in different types of soy milk.
 5. Gautier *et al.*, 2022 explored different processing methods to produce various products using Moringa oleifera (MO) seeds, including toasted seeds, a MO-based beverage, and yoghurt-like products. The protein content varied among the products, with the beverage containing 3.68%, the yoghurt containing 14.73%, and the toasted seeds containing 40.21%. While a completely debittered beverage could not be achieved, the MO yoghurt-like product had a pleasant flavor. The toasted seeds were found to be rich in minerals such as magnesium, phosphorus, iron, copper, zinc, and manganese. The MO beverage exhibited a less pronounced shear-thinning behavior compared to other vegetable beverages, while the MO yoghurt-like product had a gel structure similar to dairy yoghurt, making it a promising plant-based alternative. Overall, these MO seed-based products offer a new source of high-protein plant-based food.
 6. Wang *et al.*, 2022 investigated the antibacterial activity of (4-[(4'-O-acetyl- α -L-rhamnosyloxy)benzyl] isothiocyanate) (RBITC) from Moringa oleifera seeds against *Bacillus cereus* (*B. cereus*) and *Cronobacter sakazakii* (*C. sakazakii*). The results showed that RBITC inhibited the activity of intracellular enzymes in both bacterial strains, leading to disrupted intracellular homeostasis. Additionally, RBITC effectively inhibited biofilm formation of *B. cereus* and *C. sakazakii*. In goat milk, RBITC exhibited strong antibacterial activity without compromising the quality of the milk. Overall, this study suggests that RBITC has potential as a natural antibacterial agent against *B. cereus* and *C. sakazakii*, with potential application in goat milk.
 7. Dhawi *et al.*, 2020 aimed to develop functional buffalo yoghurt by incorporating fenugreek seed flour (F1 and F2) and Moringa oleifera seed flour (M1 and M2) at 0.1% and 0.2% concentrations. Moringa oleifera seed flour exhibited higher total phenolic content (TPC) and antioxidant activity (AOA) compared to fenugreek seed flour. The fortified yoghurts showed increased TPC and AOA values during storage, with M2 treatment displaying the highest levels. M2 also demonstrated stronger antibacterial activity against various bacteria. The incorporation of Moringa oleifera seed flour resulted in higher levels of calcium, phosphorus, potassium, and iron in the yoghurt.
 8. Wang *et al.*, 2022 investigated the milk-clotting properties of a novel cysteine peptidase (MoCP) derived from germinated Moringa oleifera seeds. MoCP exhibited strong hydrolytic activity on κ -casein, making it suitable for cheesemaking and the production of functional peptides. All three evaluated caseins were efficiently hydrolyzed by MoCP within 3 hours. The cleavage site of κ -casein by MoCP was identified, and a specific peptide was generated. The study also highlighted the importance of the initial 30 minutes of the reaction for milk coagulation, which could impact curd yield. Overall, the findings suggest that MoCP has potential as a plant-derived rennet alternative in cheese production.
 9. Nadeem *et al.*, 2012 aimed to develop a functional fat blend by interesterification of Butter Oil (BO) and Moringa oleifera Oil (MOO). Different ratios of MOO were incorporated into BO, resulting in increased melting points and improved oxidative stability. Cholesterol reduction using beta cyclodextrin was higher in the blends containing MOO compared to the control. The highest cholesterol reduction was observed in the blend with 50% MOO. Overall, the study concluded that the blend of MOO and BO can be utilized to formulate functional and shelf-stable fat.
 10. Fortification with Moringa oleifera dry leaves and *M. oleifera* oil improves the nutritional quality of ice milk (Salama *et al.*, 2016)
 11. Dhawi *et al.*, 2020 added 0.1 and 0.2% of *Moringa oleifera* seed flour to yogurt. It was linked to the maintenance of the sensory acceptance, the higher content of some amino acids (alanine acid, glutamine and tyrosine) and the enhanced antioxidant activity. Furthermore, moringa exerts control against pathogenic bacteria, such as *E. coli*, *S. aureus*, *L.monocytogenes* and *Salmonella* spp, without negatively affecting *L. rhamnosus* or *L. acidophilus* growth, also increasing the content in Ca, P, K, and Fe.

- **Moringa Bark**

The bark of moringa tree is usually whitish-gray in colour, with thick appearance, soft texture, fissured and corky and wood of moringa tree is usually soft and light. The corky bark of moringa tree is good source of coarse fibre, which can be utilized in manufacturing of mats, paper, and cordage. Moringa bark can be utilised to produce dyes, tannins for tanning hides. Stem pulp of moringa is usually used in newsprint cellophane, and textiles industry. Stem of moringa can be used for fencing purpose also (Bhupendra and Neikuo, 2015).

Moringa bark contains two alkaloids, Moringine and moringinine (Anwar *et al.*, 2007) whereas moringa stem contains Vanillin, sitosterol, β -sitostenone, 4-hydroxymellin and octacosanoic acid in good quantity (Faizi *et al.*, 1994). The fresh stem bark contains β - sitosterol and moringine (benzylamine) and traces of other alkaloids (Kumbhare *et al.*, 2012).

Barks of moringa can be boiled in water and soaked in alcohol to produce decoction and extract of moringa bark, respectively. Extract and decoction of bark can be used for treatment of stomach ailments (ease stomach pain, ulcer, and aiding digestion), poor vision, joint pain, diabetes, and hypertension (Abe and Ohtani, 2013). (Popoola, 2014; Yabesh *et al.*, 2014) stated that extract can be used for treatment of toothache, hemorrhoids, uterine disorder. Different parts of moringa such as bark and roots are used as a tonic to cure problems related to circulatory system and in case of cardiac inflammation.

- **Moringa pod**

The name drumsticks derived from the shape of the moringa pod which resembles the slender and curved stick used for drum beating. Drumsticks are rich source of calcium, iron, and fibre. Drumsticks contain 40% soluble fibre of total fibre content. The nutrient value per 100 g raw Moringa pods is 8.53% Carbohydrates, 2.10% Proteins, 2.0% Total fat, 0% Cholesterol, and 2.3% Dietary fiber. (USDA National Nutrient data base, 2014).

The young tender pods of moringa usually are cut into small pieces and added to curries. Sometimes seeds of moringa are removed from more mature pods and eaten like peas or roasted as nuts. Nutritionally, moringa pods are of great value as rich sources of calcium, phosphorus and vitamin C. According to Gopalan *et al.*, (2004) composition of fresh moringa pods contain 86.9% moisture, 2.5% protein, 0.1% fat, 2.0% minerals (calcium- 30mg/100g, phosphorus- 110mg/100g, and Iron 0.18mg/100g), 4.8% fibre, and 3.7% carbohydrates. 100g of fresh moringa pods provides 26KCal energy, and good source of vitamins (Niacin 0.2mg, Thiamine 0.05mg, riboflavin 0.07mg, and 120mg vitamin C).

Ganesan *et al.*, (2014) attempted to assess morphological and molecular diversity among 12 Indian(domestic) moringa populations. It was observed that the average pod length of moringa pods was 70.5 mm, pod girth was 85.2 mm, pod weight was .110 kg, and average number of seeds per pod were 20.17 and oil content in seeds was 28.29 %.

Sudagar *et al.*, (2013) assessed properties of chewable size drumsticks, and reported that average weight of moringa pod from PKM-1 variety was 70.3 g, average width and thickness were 21.7 and 18.3 3m, respectively. He also studied thermal properties of moringa pods such as specific heat, thermal conductivity as well as thermal diffusivity and found the result of same $3.461 \text{ kJ kg}^{-1} \text{ K}^{-1}$, $0.139 \text{ W m}^{-1} \text{ K}^{-1}$ and $1.056 * 10^{-4} \text{ m}^2 \text{ s}^{-1}$, respectively.

Resmi *et al.*, (2005) analysed differences among moringa accessions from central and southern Kerala. He analysed 28 accessions of moringa and reported that morphology, yield, and quality attributes of these accessions were substantially different. He stated that average pod length was 51.6mm, pod girth was 5.68mm, pod weight was 752.32g and average number of seed per pod were 20.47. Various uses of moringa pods in dairy products:

1. Patel *et al.*, 2017 aimed to develop a therapeutic fermented beverage by incorporating Moringa Pod Powder (MPP) into buttermilk. Response Surface Methodology (RSM) was used to optimize the product formulation, and a blend of 0.04% pectin and 0.015% carrageenan was found to be the most suitable stabilizer. Addition of salt, sugar, and spice blend was also found to be acceptable. The proximate chemical composition of Moringa Pod Buttermilk (MPBM) showed 11.77% total solids, 1.51% protein, 1.84% fat, and 0.89% ash. MPBM was found to be an "excellent source of calcium" and "a good source of Vitamin A, calcium, and iron." The developed product is rich in fiber and iron, conventionally deficient in milk, and has a shelf-life of 20 days under refrigeration.

2. Patel *et al.*, incorporated Moringa pod powder into curd, consequently showing higher levels of vitamins A and C, iron, fiber and potassium than the control sample.

- **Moringa Roots**

Small trees of about 60 cm in height can be harvested and ground followed by mixing with vinegar and salt can be used as substitute of horseradish. Roots of moringa contain alkaloids pterygospermin and spirachin a nerve-paralyzing agent so large amount of root consumption at once or consumption of roots on daily basis should be avoided. The roots and root bark of the young moringa tree are rubefacient and vesicant in nature (Anwar & Bhangar, 2003). The Ayurvedic

Pharmacopoeia of India stated that dried moringa root bark can be used in goitre, glycosuria, and lipid disorders (Khare, 2007).

- **Moringa Flowers**

Moringa tree starts flowering after 8 to 12 months and continues year-round. Moringa flowers are such a good source of calcium and potassium, and contain 9 amino acids along with sucrose, glucose, wax, kaempferol and quercetin. Antioxidant properties of moringa flowers along with potent anti-inflammatory activity make them special. Moringa flowers can be used for treatment of ascites, rheumatism, and venomous bites. Moringa flowers possess cardiac and circulatory stimulants which explain their use in folk remedies (Alhakmani *et al.*, 2013). Various uses of moringa flowers in dairy products:

1. Pontual *et al.*, 2012 investigated the caseinolytic and milk-clotting activities of *Moringa oleifera* flowers. Proteins extracted from the flowers were precipitated and assessed for their enzymatic activities. The results showed that the highest caseinolytic activity was observed after incubation of the precipitated protein fraction at pH 4.0 and heating at 50°C. Milk-clotting activity was detected only in the presence of CaCl₂ and was highest at incubation of the precipitated protein fraction at pH 3.0. Aspartic proteases were found to be the main enzymes involved in milk-clotting activity. The study suggests that *Moringa oleifera* flowers could be used in the dairy industry.
2. Zhao *et al.*, 2022 isolated and identified two milk-clotting proteases (MoFP 12 and MoFP 13) from *Moringa oleifera* flowers using LC-MS/MS. These proteases were primarily involved in hydrolase activity and catabolic process, exhibited hydrophilicity, and were stable in the pH range of 5.0 to 8.0 and showed their maximum MCA at 70°C. The proteases preferentially hydrolyzed κ -casein, followed by α -CN, and to a lesser extent β -CN. The study suggests that *M. oleifera* flowers have potential for application in the dairy and food sectors, especially in the cheese-making industry.
3. Chikkara *et al.*, 2021 used *Moringa oleifera* leaves to enhance milk production and for cheese and yogurt preparation. Chemicals and enzymes are commonly used to coagulate milk in the dairy industry, but *Moringa* flowers have gained attention as a natural coagulant with potential health benefits. The milk-clotting activity of *Moringa* flower protein was evaluated and found to be highest at pH 3 and in the presence of calcium chloride. Aspartic protease was identified as the main enzyme involved in milk clotting activity, making *M. oleifera* flowers a potential alternative to traditional coagulants in the dairy industry.

Therapeutic Value of Moringa

- **Antioxidant Activity**

Pari *et al.* (2007) mentioned that phenolic acids (derivatives of caffeic, p-cumaric or ferulic acids) were the major phenolic components of *Moringa oleifera* leaves extract. Due to the presence of free radical scavenging and reducing power extract also exhibited strong antioxidant properties.

Paliwal *et al.* (2011) analysed the phytochemical profile and antioxidant activity of *Moringa oleifera* pods against free radicals using specific in vitro standard procedures. Hydro-ethanolic and aqueous extracts of moringa pods were able to scavenge peroxy and superoxy radicals during in vitro studies. Similar scavenging activities for different solvent extracts of every collection were found for the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical and other reactive oxygen species. This study expressed moringa pods as good anti-oxidant.

Hossain *et al.* (2012) investigated the free radical scavenging ability of five extracts (methanol, ethanol, petroleum ether, n-hexane and chloroform) of the *Moringa oleifera* leaves by observing its potential for scavenging DPPH radical, hydrogen peroxide radical, nitric oxide radical. It was reported that chloroform extract of *Moringa* leaves possess the highest total antioxidant capacity followed by ethanol and methanol extracts respectively.

Raghavendra *et al.* (2015) analysed moringa leaf and pod extract for their antioxidant potential and reported that *Moringa oleifera* leaf extract was superior to the moringa pod extract in terms of antioxidant potential. The IC₅₀ values for DPPH radical scavenging activity were 150, 240 and 14 μ g/ml for leaf, pod and standard respectively.

Abdulkadir *et al.* (2015) determined antioxidant activity of different parts of *Moringa* in terms of total phenolic content and total flavonoid content. Antioxidant activity evaluated by DPPH radical scavenging assay. Methanolic extract of a bark, stem and leaf expressed high potential for free radical scavenging activity. Methanolic extract of various parts were superior to hexane extracts in terms of total phenolics and total flavonoids content. The highest phenolic content was observed in methanolic bark, leaf and pods with 44.03 \pm 1.21, 32.83 \pm 0.38 and 32.07 \pm 1.01 (mg Gallic acid equivalent/g) respectively.

○ **Antimicrobial Activity**

A niaziridin-rich extract fraction of moringa pods enhanced the bioactivity of several antibiotics (rifampicin, tetracycline and ampicillin) against gram positive and gram negative bacteria and facilitated drugs, vitamins and nutrients absorption through the gastrointestinal membrane (Khanuja *et al.*, 2005). The aqueous extracts of *Moringa oleifera* was found to be inhibitory against many pathogenic bacteria, including *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, and *Pseudomonas aeruginosa* in dose dependent manner (Saadabi and Zaid, 2011). Fresh leaf juice and aqueous extracts from the seeds inhibit the growth of *pseudomonas aeruginosa* and *Staphylococcus aureus* (Rahman *et al.*, 2009). Seed extracts of moringa were evaluated for their antimicrobial activity against four types of bacteria namely *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli* and *Pseudomonas aeruginosa* and two species of fungi i.e. *Aspergillus niger* and *Candida albicans* (Saadabi and Abu, 2011). Aqueous extract showed strong and superior antibacterial activity against all bacterial strains. Less or no activity was observed against *Aspergillus niger* and *Candida albicans*. Nwosu and Okafor, (1995) studied antifungal properties of medicinal plants and found that Moringa extract inhibit the growth of *Bacidiobolus haptosporus*, *basidiobolus ranarum*, *trichophyton rubrum*, and *trichophyton mentagrophyies* but could not inhibit the growth *Aspergillus fumigatus*, *Geotrichum candidum*, and *Candida albicans*. They concluded that this extract can be used in treatment of subcutaneous phycomycosis in humans and animals.

○ **Antiasthmatic Activity**

Agrawal and Mehta, (2008) carried out studies to investigate the efficacy and safety of moringa seed kernels in treatment of bronchial asthma and they observed that significant increase in haemoglobin values (Hb) whereas Erythrocyte sedimentation rate was decreased significantly in most of patients. In end of study it was reported that moringa seed kernel can be used for patients of bronchial asthma because of presence of alkaloid moringine in kernels of moringa seeds.

○ **Anti-hypertensive activity**

Bioassay guided fractionation of the active ethanol extract of Moringa leaves was caused out by (Gilani *et al.*, 1994a) and he isolated four pure compounds, niazinin A [1], niazinin [1] B, niazimicin [4] and niazinin A + B, and it was reported that these compounds are responsible for blood pressure reducing effect of moringa by calcium antagonist mechanism. Faizi *et al.*, 1995 isolated thiocarbamate, carbamate or nitrile groups from moringa leaves and found that these are fully acetylated glycosides, which are very rare in nature, and reported that these glycosides play role to reduce blood pressure.

○ **Cholesterol lowering activity**

The crude extract of Moringa leaves has a significant cholesterol lowering action in the serum of high fat diet fed rats which might be attributed to the presence of a bioactive phytoconstituent, i.e. β -sitosterol (Ghasi *et al.*, 2000). Moringa fruit has been found to lower the serum cholesterol, phospholipids, triglycerides, low density lipoprotein (LDL), very low density lipoprotein (VLDL) cholesterol to phospholipid ratio, atherogenic index lipid and reduced the lipid profile of liver, heart and aorta in hypercholesteremic rabbits and increased the excretion of faecal cholesterol (Mehta *et al.*, 2003).

○ **Antiulcer activity**

Pal *et al.*, 1995 conducted studies on antiulcer activity of Moringa and found that methanolic extract of moringa leaves possess significant protective action against gastric lesions of experimental rats induced by action acetylsalicylic acid, serotonin and indomethacin. A significant increase in healing process of acetic acid induced chronic gastric lesions was also observed in the extract-treated animals.

○ **Antiurothiatic Activity**

Antiurothiatic activity revealed by the moringa pods extract was studied by Vijayalakshmi *et al.*, (2010). An aqueous extract administered orally in albino rats of Wistar strains @ 400 mg/kg and 800 mg/kg to evaluate the antiurothiatic potential of moringa pods extract. In both groups, the oral administration of the pod extract has resulted in significant decrease in the bladder stones weight compared to the control group.

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