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Moringa oleifera pods: Bibliometric analysis, properties, and food technology applications

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ABSTRACT

This study examines the bibliometric analysis, properties, and food technology applications of *Moringa oleifera. Moringa oleifera* is a multifunctional plant with few agronomic requirements and high yields. It is well adapted to climate change, and all its parts are edible with high quality nutritional properties. There are many studies on the properties and uses of the leaves, but fewer on the pods. Consequently, the aim of this review is to carry out a bibliometric analysis that provides information regarding both the research into pods that do exist and in which areas that research is categorized, in addition to where the highest quantity of scientific groups working in the characterization of the pods may be found. This review will also highlight the primary parameters under investigation and the methods used for the analysis. From these published studies, a compilation of the compositional values (fiber, proteins, fats, amino acids, fatty acids, vitamins, minerals, and antioxidants) is shown, bearing their ripening stage in mind. Additionally, we outline the potential technological uses for the pods, aiming to improve their utilization, particularly in developed nations where this plant remains unfamiliar. Extractions of their pectin, the addition of pod powder to different foods, and their properties as low-cost adsorbents for the removal of drugs from water are some of the most remarkable uses of these pods.

Contribution/Originality: Moringa is a little-known plant in Europe, and its leaves, pods, flowers, seeds, and oil can be consumed. Little information is available on the pods. Therefore, this review will give a broad view of the nutritional and technological properties of moringa pods to assess their incorporation in food matrices.

1. INTRODUCTION

Moringa oleifera (MO) is a species belonging to the Moringaceae family's genus Moringa. Among the 13 species within the family, *Moringa oleifera* is by far the most studied and exploited (Leone et al., 2015). Because of its numerous applications, its ease of multiplication, and its tolerance to different soils and climates, MO has become highly popular all around the world (Kasolo, Bimenya, Ojok, Ochieng, & Ogwal-Okeng, 2010). Additionally, Moringa is a gold mine for agropreneurs seeking a crop to invest in where they can make a significant return on their investment with no risk (Arumugam, Allirani, & Premalakshmi, 2023).

Studies into the moringa tree, originally a native of the southern Himalayan foothills and known as far back as 150 B.C., have shown evidence of moringa consumption in eighty countries, as well as its translation into 200 languages (Haldar & Kosankar, 2017). According to Trigo, Castello, Ortola, Garcia-Mares, & Soriano, (2020) the trees are grown around the Red Sea and other parts of Asia and Africa, including Madagascar, indicating its global spread. Although *Moringa oleifera* has been used ancestrally as a remedy or palliative for a wide range of diseases and a great variety of research has been carried out demonstrating its effects on the organism, studies into the benefits of moringa as a food ingredient are still scarce (Asensi, Villadiego, & Berruezo, 2017).

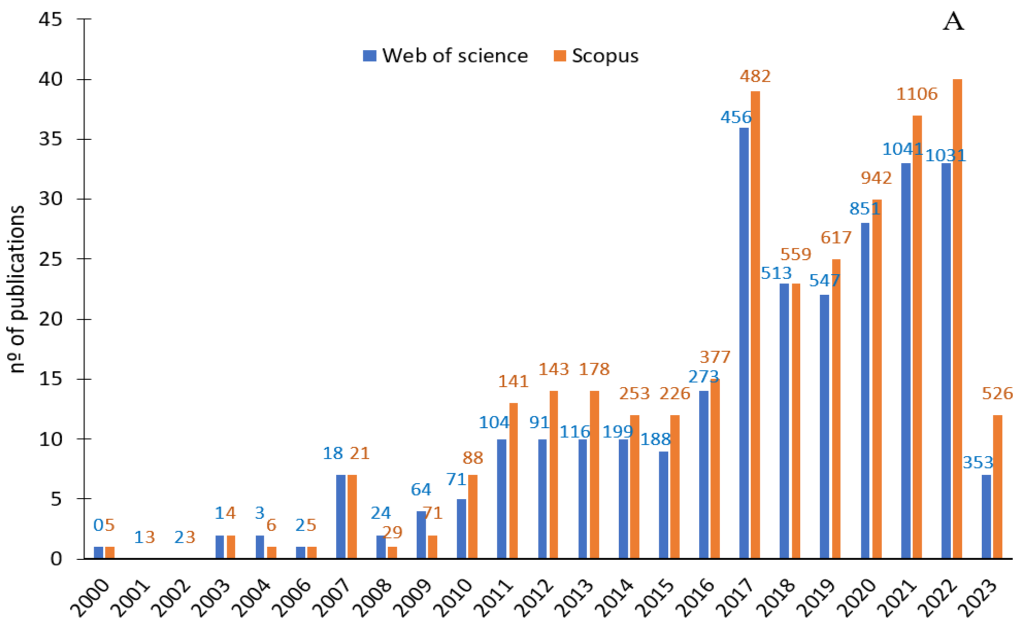
Four edible parts can be found in the *Moringa oleifera* tree: the leaves, flowers, pods, and roots. Basically, every part of the tree, except the bark, can be eaten. Of these parts, the immature pods are extremely nutritious, containing all the essential amino acids along with many vitamins and other nutrients (Joshi & Jain, 2011). Also, although the pods represent a valuable source of dietary fibre, they are poor in lipids when compared with the leaves and flowers (Sánchez-Machado, Núñez-Gastélum, Reyes-Moreno, Ramírez-Wong, & López-Cervantes, 2010).

This review aims to provide a general view of how advanced and complete the scientific literature is regarding *Moringa oleifera* and specifically its pods. To that end, the study has been divided into 3 parts: (i) the bibliometric analysis, (ii) the compositional and physicochemical analysis and (iii) the food technology applications. The bibliometric analysis has been performed by searching both Scopus® and Web of Science using the keywords "Moringa pod," whereas the rest of the document has been compiled by consulting the bibliography from these 2 databases in addition to Google Scholar.

2. THE BIBLIOMETRIC ANALYSIS OF THE RESEARCH INTO *MORINGA OLEIFERA* PODS

When carrying out a bibliometric analysis, the results obtained via Scopus® search (Figure 1) using the keywords "Moringa pod" showed that interest in *Moringa oleifera* pods, as defined by citation overview, has increased over the past 23 years (2000 –2023), and especially over the past 6 years. However, the number of document results for this search is still scarce when compared with that for other parts of the tree, such as the leaves or simply the tree itself (5680 document results using the keyword "Moringa"). Furthermore, the number of articles per year (Figure 1) also shows that interest is following the same upward trend.

We found the countries that have published articles related to moringa pod research by filtering Scopus results by country, as shown in Figure 2. The top 10 countries in terms of moringa pod research were, in decreasing order: India (96), Pakistan (35), Saudi Arabia (22), Egypt (21), Nigeria (18), Brazil (17), Malaysia (16), China (15), Thailand (13), the United States (12), and. Spanish research, however, is a long way behind, with only 6 articles. As can be seen (Figure 2), the top 20 affiliations correspond to countries with a high level of article production.



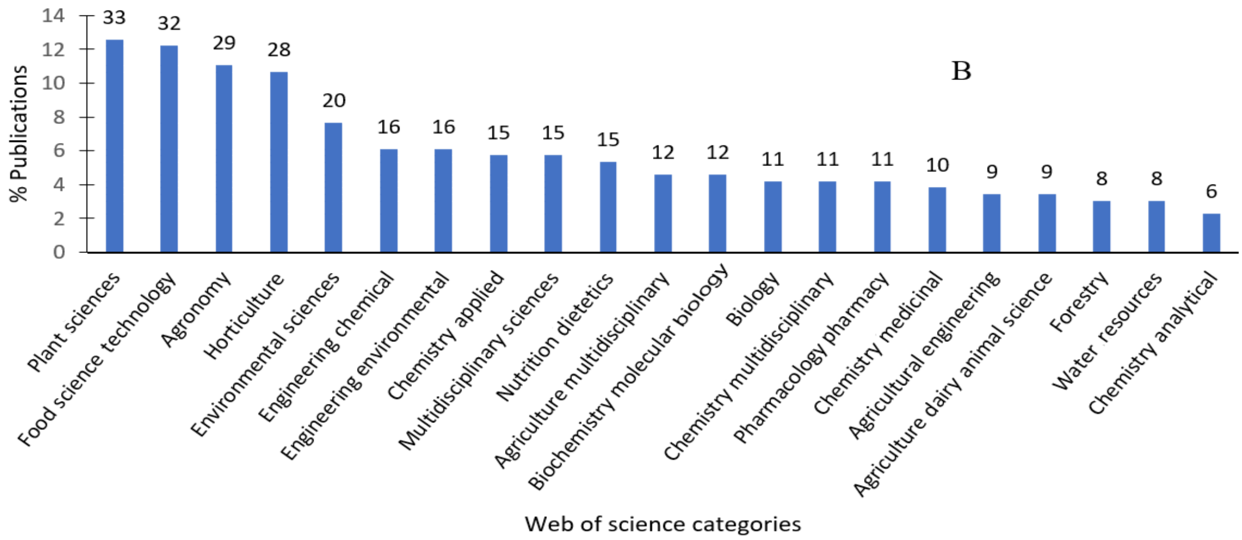


Figure 1. Bibliometric analysis. A: Bars represent the number of articles over the years obtained via web of science or Scopus® using the keywords "moringa pod". The rise in citations is above each bar. B: Bars represent the percentage of publications on each web of science category using the same keywords. Number of articles in each category is above the bar.

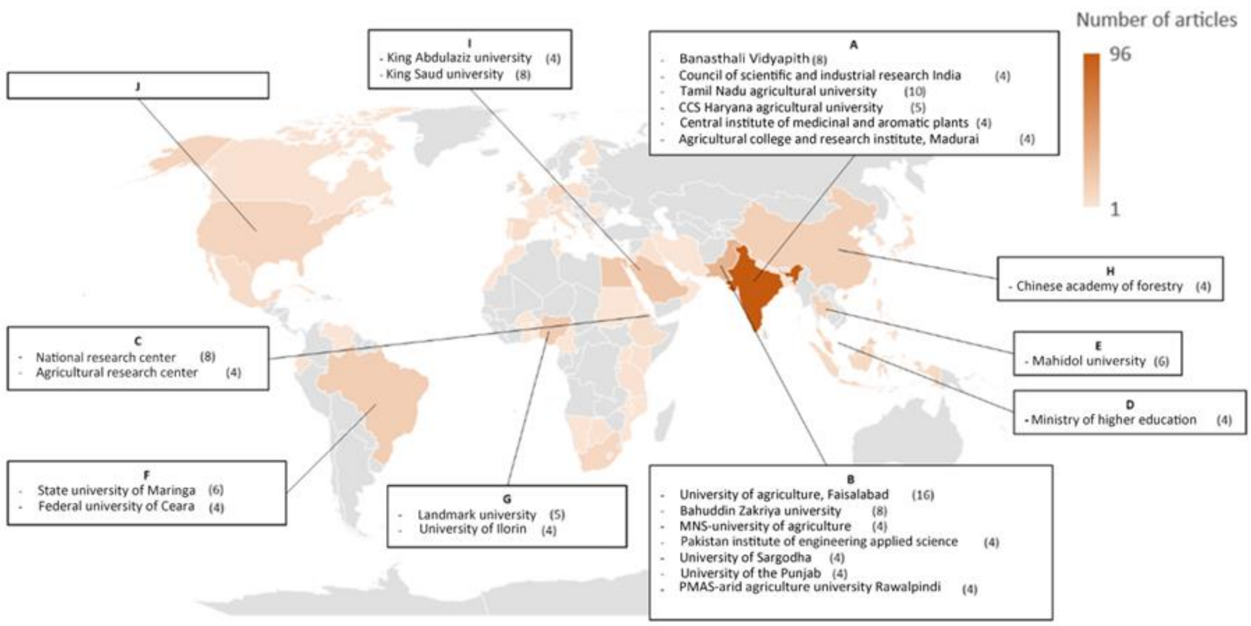


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Figure 2. Choropleth map of moringa pod related articles per region from 2000-2023 (Results obtained via Scopus® and graph designed using Excel). The top 10 countries article producers (A: India, B: Pakistan, C: Egypt, D: Malaysia, E: Thailand, F: Brazil, G: Nigeria, H: China and I: Saudi Arabi, J: United States) are marked on the map with the number of articles higher or equal to 4 in parentheses for the 1st author's affiliation.

3. COMPOSITIONAL AND PHYSICOCHEMICAL ANALYSIS OF MORINGA PODS

3.1. Fibre Content

Proper dietary fibre quantification is crucial, given its importance for health and well-being. For instance, through the intake of dietary fibre it is possible to reduce the risk of developing several diseases, such as diabetes or hypertension (Anderson et al., 2009). In fact, since *Moringa oleifera* pods are fibrous, they are useful when treating digestive problems (Punia, Singh, Kumari, & Pandit, 2017). However, even though the crude fibre procedure fails to quantify fibre properly, it still remains a legal measuring method. The conditions used to separate protein in the crude fibre method also solubilize some lignin and a great deal of the hemicellulose, underestimating the true fibre content by 30-50%. In contrast, detergent analyses and total dietary fibre methods represent far more accurate measurement methods (Fahey, Novotny, Layton, & Mertens, 2019). The quantification of both crude fibre and total dietary fibre (Table 1) was carried out following the gravimetric enzymatic method and the official AOAC method, respectively. It can be observed that the total dietary fibre content is very similar despite the different factors, whereas there is a huge variability in terms of the crude fibre the values are lower than those of the total dietary fibre. These results are consistent with what was stated before about the crude fibre not being an appropriate method that underestimates total dietary fibre content.

Table 1. Crude and total dietary fibre content in different moringa pods.

Ripening stage	Origin	Crude fibre (g/100 g)	Total dietary fibre† (g/100 g)	References
Immature pods (2 weeks old)	Sonora, Mexico	ND	46.8 ± 2.2 (DW)	Sánchez-Machado et al. (2010)
Immature pods	Anand, Gujarat, India	2.31 ± 0.57 (DW)	ND	Ravani, Prasad, Dumle, and Joshi (2018)
NS	Giza	34.96 ± 0.3 (DW)	ND	Massry, Fatma, and Mossa (2013)
Mature pods	Sakha, Kafrelsheikh, Egypt)	ND	≈ 46 ± 1	Owon, Osman, Ibrahim, Salama, and Matthäus (2021)
Immature pods (1-2 weeks old)	Tanzania	26.77 (DW)	ND	Gidamis, Panga, Sarwatt, Chove, and Shayo (2003)
NS	NS	4.8	ND	Uphadek, Shinkar, Patil, and Saudagar (2018)

Note: ND = Not determined.
NS = Not specified.
DW: Respect to dry weight.
†Total dietary fibre refers to the sum of the soluble dietary fibre (SDF) and the insoluble dietary fibre (IDF).
Source: Ahmad and Khalid (2018).

3.2. Protein and Amino acid Content

Leaves, pods, and other parts of *Moringa oleifera* trees contain higher levels of crude proteins and amino acids when compared with other plants, such as soybeans. Therefore, they are well known as a complement with which to overcome protein deficiency in developing countries (Dhakar et al., 2011). The published protein quantification studies (Table 2) were carried out using the Kjeldahl method, according to AOAC (2010) Method No. 920. The protein content varies from 4.0 ± 0.6 to 20.66 g/100g among immature pod samples, while it is 10.1 g/100g in a mature pod sample; this indicates that the ripening stage does not seem to be a very determinant factor for fixing standard protein content values. Overall, these results indicate a much higher protein content than the standard average amount of 1.04g/100g (US Department of Agriculture, 2022) making moringa pods a very interesting source of protein.

Table 2. Protein content in different moringa pods.

Ripening stage	Origin	Protein (g/100 g dried weight)	Reference
Immature pods (2 weeks old)	Sonora, Mexico	19.3 ± 0.2	Sánchez-Machado et al. (2010)
Immature pods (1-2 weeks old)	Tanzania	20.66	Gidamis et al. (2003)
Immature pods	Anand, Gujarat, India	4.0 ± 0.6	Ravani et al. (2018)
Mature pods	Sakha, Kafrelsheikh, Egypt	10.1	Owon et al. (2021)
NS	Agric. Res. Center, Giza	17.2 ± 0.7	Massry et al. (2013)
NS	NS	2.5 (g/100 of total weight)	Uphadek et al. (2018)

Note: NS = Not specified.

Table 3. Amino acid composition in different *Moringa oleifera pods* (mg/g dry weight).

Reference	Amino acid (mg/g dry weight)																
	Asp	**Glu**	**Ser**	**His**[a]	**Gly**	**Thr**[a]	**Ala**	**Pro**	**Tyr**[a]	**Arg**	**Val**[a]	**Met**[a]	**Ile**[a]	**Leu**[a]	**Phe**[a]	**Lys**[a]	**Cys**	**Trp**[a]
Sánchez-Machado et al. (2010)	7.4 (0.3)	14.6 (2.3)	7.5 (1.8)	2.0 (0.3)	4.3 (0.5)	3.3 (0.5)	4.2 (0.7)	4.0 (0.6)	0.4 (0.1)	8.1 (2.5)	4.3 (1.0)	0.9 (0.2)	3.1 (0.4)	5.6 (0.5)	2.3 (0.4)	2.5 (0.6)	ND	ND
Massry et al. (2013) [a]	2.1	9.9	1.4	1.2	2.5	1.1	1.9	2.8	0.8	5.9	1.8	1.0	1.6	2.8	2.0	0.8	2.2	0.4
Nouman et al. (2014) [b]	ND	ND	ND	1.1	ND	3.9	ND	ND	ND	3.6	5.4	1.4	4.4	6.5	4.3	1.5	ND	0.8
Arumugam et al. (2023)*	ND	ND	ND	27.5	ND	98	ND	ND	ND	90	135	35	110	163	108	37.5	ND	20

Note: ND = Not determined.
Standard deviation is given in parentheses when the source provides it.
[a]Essential amino acid.
[a] Original data from Massry et al. (2013) in (g aa/16g N) was converted into (mg/g dry weight) in order to compare both experiments. This conversion was done considering the total quantity of protein in the samples as well as the equivalence of 6.25 grams of protein per gram of nitrogen.
[b] Expressed in mg g–1 N *mg/100 of edible protein.

As regards the amino acidic content (Table 3), the first 2 samples can be observed to vary, probably because Sánchez-Machado et al. (2010) sample comes from Mexico and is analyzed through HPLC, whereas the Massry et al. (2013) sample is from Egypt and has been analyzed through an amino acid analyzer (LC 3000). However, despite that, very similar values are found in the amino acids of methionine, tyrosine, and phenylalanine. Furthermore, in both cases, it can be observed that glutamate is the most abundant amino acid in *Moringa oleifera* pods. However, there are other quantifications that show leucine as the most abundant amino acid, very close to valine (Dhakar et al., 2011). In addition, it is interesting that despite the inter-sample variability, the milligram quantity proportion of essential amino acids from the total of amino acids is quite similar (32.75% and 31.99%).

3.3. Content of Fats and Fatty Acids

Whereas a high value of protein is decisive for the purposes of animal and human nutrition, a high fat amount is of interest for oil processing applications (Owon et al., 2021). As expected, the experiments (Table 4) show that there are very low levels of fat in moringa pods. Nevertheless, fatty acids (Table 5) are also essential for optimal cellular health; there are also good fats that actively help body health, such as the well-known omega-3 and omega-6 fatty acids (Dhakar et al., 2011).

Although there are studies into *Moringa oleifera* seeds in which the lipids are extracted with hexane (Bale et al., 2015; Díaz-Domínguez et al., 2017) it is not so common for *Moringa oleifera* pods; in all likelihood, this is because there is less interest in oil pods since they are scarce and extraction with ether is a much more standardized method.

Table 4. Lipid content (mg/g dry weight) in different moringa pods.

Ripening stage	Origen	Lipid (mg/g dry weight)	Solvent	Method	Reference
Immature pods (2 weeks old)	Sonora, Mexico	1.3 ± 0.1	2:1 chloroform-methanol	Extraction, filtration, and concentration Folch, Lees, and Stanley (1957)	Sánchez-Machado et al. (2010)
Tender pods	Anand, Gujarat, India	1.4 ± 0.7	NS	AOAC (2012)	Ravani et al. (2018)
Mature pods	Sakha, Kafrelsheikh, Egypt	1.0	Petroleum ether	Soxhlet extraction method	Owon et al. (2021)
Fresh pods	Agric. Res. Center, Giza	0.4 ± 0.2	Ether	AOAC (2000)	Massry et al. (2013)
Immature pods (1-2 weeks old)	Tanzania	2.54	Ether	AOAC (1995)	Gidamis et al. (2003)
NS	NS	0.1	NS	NS	Uphadek et al. (2018)

Note: NS = Not specified.

As regards fatty acid composition (Table 5), the samples from Mexico (Sánchez-Machado et al., 2010) Ghana (Amaglo et al., 2010) and India (Saini, Shetty, & Giridhar, 2014) were analyzed through GC-FID. The results showed that hexadecanoic acid, octadecanoic acid, oleic acid, linoleic acid, and α-Linolenic acid represented a considerable fraction of the total fatty acid composition of at least one of the 3 samples.

Table 5. Fatty acid composition (g/100 g total fatty acids) in different moringa pods.

Reference					
Fatty acid		Sánchez-Machado et al. (2010) [a]	Amaglo et al. (2010) [b]	Amaglo et al. (2010) [c]	Saini et al. (2014) [d]
C8:0	Octanoic acid	0.24 ± 0.06	ND	ND	0.12
C10:0	Decanoic acid	ND	ND	ND	0.02
C12:0	Dodecanoic acid	0.11 ± 0.02	ND	ND	0.17
C13:0	Tridecanoic acid	ND	ND	ND	0.17
C14:0	Tetradecanoic acid	0.26 ± 0.04	0.34	0.1	1.93
C14:1w5	Myristoleic acid	0.15 ± 0.03	ND	ND	ND
C16:0	Hexadecanoic acid	26.5 ± 0.5	48.0	9.16	24.33
C16:1w7	Palmitoleic acid	ND	0.97	1.44	1.49
C17:0	Heptadecanoic acid	ND	0.97	0.1	ND
C17:1	Heptadecenoic acid	ND	0.00	0.03	ND
C18:0	Octadecanoic acid	3.10 ± 0.13	13.4	5.32	6.23
C18:1w7	Vaccenic acid	1.0 ± 0.2	ND	ND	ND
C18:1w9	Oleic acid	17.0 ± 1.3	34.6	78.9	9.81
C18:2w6	Linoleic acid	23.5 ± 1.0	0.02	1.16	16.91
C18:3w3	α-Linolenic acid	26.15 ± 0.74	0.02	0.50	30.42
C20:0	Arachidic acid	0.39 ± 0.02	1.54	3.02	0.47
C20:1w9	Eicosenoic acid	0.24 ± 0.03	0.03	0.17	ND
C20:4w6	Arachidonic acid	0.24 ± 0.03	ND	ND	ND
C22:0	Docosanoic acid	1.06 ± 0.10	0.03	0.03	0.54
C22:1	Erucic acid	ND	ND	ND	5.68
C24:0	Tetracosanoic acid	ND	0.03	0.03	1.72

Note: ND = Not determined.
[a] Immature pods (2 weeks old).
[b] Whole young green pods.
[c] Whole mature green pods.
[d] Tender pods.

3.4. Ash, Mineral and Vitamin Contents

Ash content (Table 6) from different experiments was measured after incinerating the samples in a muffle furnace at 550 °C, following AOAC (2010) (Method No. 923.03).

Table 6. Ash content (g/100 g dry weight) in different moringa pods.

Stage	Origin	Ash (g/100 g dry weight)	Reference
Immature pods (2 weeks old)	Sonora, Mexico	7.6 ± 0.3	Sánchez-Machado et al. (2010)
Immature pods (1-2 weeks old)	Tanzania	8.25	Gidamis et al. (2003)
Immature pods	Anand, Gujarat, India	1.74 ± 0.11	Ravani et al. (2018)
Mature pods	Sakha, Kafrelsheikh, Egypt	13.1	Owon et al. (2021)
NS	Agric. Res. Center, Giza	12.3 ± 0.2	Massry et al. (2013)

Note: NS = Not specified.

Mineral composition (Table 7) analysis methodology consisted of either emission flame photometry Massry et al. (2013) or ionic liquid chromatography (Amaglo et al., 2010). The samples came from different locations, including India (Gujarat), Egypt (Giza), the USA (Florida), and Tanzania. The results point to a significant variation in the mineral content of Moringa oleifera pods. Even analyzing pods in Pakistan a wide range in the mineral content can be seen (Aslam et al., 2005).

Table 7. Mineral (mg/100 g dry weight) and vitamin (mg/100 g dry basis) in different moringa pods.

Reference										
Minerals and vitamins	Ravani et al. (2018)	Massry et al. (2013)	Amaglo et al. (2010)[a]	Amaglo et al. (2010)[b]	Gidamis et al. (2003)	Nouman et al. (2014)	Uphadek et al. (2018)	Aslam et al. (2005)[c]	Aslam et al. (2005)[d]	Aslam et al. (2005)[e]
Calcium	37.96 ± 2.46	29 ± 0.4	100	180	254.82	124.8	30	156.30 ± 0.13	129.2 ± 1.1	183.7 ± 0.6
Potassium	ND	263.45 ± 0.17	2740	4450	4599.15	1.54	259	2097.2 ± 0.8	1973.5 ± 0.9	1836.9 ± 0.5
Phosphorus	136.2± 1.6	112.3 ± 0.3	ND	ND	41.74	175.7	110	194.3 ± 0.7	212.5 ± 0.7	186 ± 0.7
Iron	3.3 ± 0.6	5.3 ± 2.3	ND	ND	7.66	23.12	5.3	15.52 ± 0.16	28.1 ± 0.3	43.59 ± 0.25
Magnesium	ND	25.2 ± 0.1	<DL	<DL	270.96	13.35	24	9.6 ± 0.14	9.39 ± 0.13	10.39 ± 0.19
Zinc	ND	0.3 ± 3.4	<DL	<DL	2.43	2.19	ND	2.14 ± 0.05	1.53 ± 0.03	2.9 ± 0.07
Copper	ND	3.24 ± 0.19	ND	ND	0.66	2.767	3.1	2.67 ± 0.05	3.21 ± 0.07	2.09 ± 0.01
Sodium	ND	15.34 ± 0.14	290	860	993.55	17.09	ND	210.5 ± 0.5	199 ± 0.4	103.2 ± 0.4
Manganese	ND	8.4 ± 2.7	ND	ND	ND	5.77	ND	4.02±0.08	7.2 ± 0.1	6.1 ± 0.07
Sulphur	ND	ND	ND	ND	ND	114.7	ND	ND	ND	ND
β-carotene	0.12 ± 1.62	0.97±0.43	ND	ND	-	ND	ND	ND	ND	ND
Vitamin C	118 ± 6	871.28±0.32	ND	ND	34.33 ± 0.08	ND	120	ND	ND	ND

Note: ND = Not detected. DL = Detection limit. [a] Whole young green pods. [b] Whole mature green pods. [c] M. oleifera pods from Bahawalnager, Punjab, Pakistan. [d] M. oleifera pods from Sadiqabad, Punjab, Pakistan. [e] M. oleifera pods from Chenabnager, Punjab, Pakistan.

Calcium, potassium, phosphorus, and sodium were, overall, the predominant minerals in the samples, with a mean of 122.575 mg/100g dry weight, 2024.53 mg/100g dry weight, 146.09 mg/100g dry weight, and 328.59 mg/100g dry weight, respectively. The average amount of each of those in green beans is 36 mg/100g dry weight, 97 mg/100g dry weight, 23 mg/100g dry weight and 282 mg/100g dry weight for calcium, potassium, phosphorus, and sodium, respectively (US Department of Agriculture, 2022) which makes *Moringa oleifera* pods a reliable source of those essential minerals. Those four minerals play a very important role in human metabolism.

Adequate calcium intake is essential for both bone mass development during childhood and for maintaining an adequate bone mineral density, thus reducing the risk of the elderly suffering from osteoporosis (Picciano & McDonald, 2013). Dietary potassium is an essential nutrient that acts on many cellular functions, including muscle contraction, fluid homeostasis, nerve impulses (by maintaining the membrane potential for electrical excitation), and reducing blood pressure (McLean & Wang, 2021). Phosphorus constitutes an essential micronutrient with a role in several critical biological processes, such as intracellular signaling and bone metabolism (Gutiérrez, 2020). Sodium plays an important role in cellular homeostasis and physiological functions, as well as the interaction between systolic blood pressure and albuminuria (Farquhar, Edwards, Jurkovitz, & Weintraub, 2015; Hosohata, 2021).

According to the European Union legislation, the average daily recommended intakes of calcium, potassium and phosphorus are 800-1000 mg/day, 2000 mg/day and 700 mg/day, respectively, whereas the average daily intake of sodium has not been determined (Hosp et al., 2017). Therefore, 100g dry weight of *Moringa oleifera* pods represents 12.26-15.32% of the average daily calcium intake, 101.23% of the average daily potassium intake, and 20.87% of the average daily phosphorus intake. When compared with the same weight of green beans, the percentages are 3.6-4.5%, 4.85%, and 3.29% respectively. Therefore, *Moringa oleifera* pods can be considered very nutritious foods.

In these studies, the vitamin content (Table 7) was measured using official AOAC methods. The vitamin C levels detected by Ravani et al. (2018) (118.00 ± 6.24 mg/100g) coincide closely with the results obtained by Uphadek et al. (2018) (120 mg/100g), indicating that *Moringa oleifera* pods can be a good source of this vitamin. The presence of vitamins B1, B2, and B3 has also been detected with values of 0.05 mg/100 g, 0.07 mg/100 g and 0.2 mg/100 g, respectively (Uphadek et al., 2018).

When analyzing cooked pods, it was found that cooking (in distilled boiling water for 15 minutes) caused significant reductions ($p \leq 0.05$) in the vitamin C contents in pods. However, despite its significance, the loss represented only 17.1% of the loss with respect to the value of the raw pods (Gidamis et al., 2003). Therefore, the pods remain a good source of vitamins even if cooked.

3.5. Antioxidants

Studies have proven that *Moringa oleifera* pods constitute a rich source of secondary metabolites, such as natural antioxidants, including phenolics, triterpenoids, cardiac glycosides, steroids, alkaloids, and saponin (Sharma & Paliwal, 2013). The antioxidants, together with the antioxidant activity (Table 8) in moringa pods, show variability. The antioxidant activity is considerably affected by the solvent of extraction; for instance, in the Malaysian pod sample, 2 solvent extracts were used, and the methanolic extract (represented in the table) showed greater scavenging activity than the hexane extract (Abdulkadir, Zawawi, & Jahan, 2015). Solvent polarity plays an important role in increasing phenolic solubility and, therefore, influences the extraction of the phenol/flavonoid content responsible for the antioxidant activity (Ravani et al., 2018).

Further quantification results are available from Owon et al. (2021) however, despite their recentness, they are not comparable with the rest of the experiments due to the fact that they follow different experimental procedures as they express DPPH in terms of ED50.

Table 8. Antioxidants and antioxidant activity in different moringa pods.

Ripening stage	Origin	Total capacity (DPPH, % absorbance reduction)	Total phenols (Folin-Ciocalteu)	Total flavonoids	Reference
Immature pods	Anand, Gujarat, India	45.1 ± 0.5	11 ± 0.5 mg GAE/g extract	3.42 ± 0.12 mg QAE/g extract	Ravani et al. (2018)
NS	Agric. Res. Center, Giza	-	13.7 ± 0.5 mg/100g	69 ± 0.5 mg/100g	Massry et al. (2013)
NS	Rajasthan, India	50.6 ± 0.2	0.6 ± 0.2 mg gallic acid/g of dry plant material	1.89 ± 0.16 mg rutin/g of dry plant material†	Sharma, Paliwal, and Sharma (2011)
NS	Terrengganu, Malaysia	38.1 ± 1.4	32.1 ± 1.1 mg GAE/g	3 ± 1.4 mg QAE/g	Abdulkadir et al. (2015)

Note: NS = Not specified.
†Proanthocyanidins (Type of bioflavonoid).
GAE= Gallic acid equivalents.
QAE=Quercetin equivalents.

4. FOOD TECHNOLOGY APPLICATIONS

Together with their numerous medicinal applications, *Moringa oleifera* leaves have many other potential applications, such as their use in soups, weaning foods, moringa paneer, herbal biscuits, bread, or cakes, among many others (Sahay, Yadav, & Srinivasamurthy, 2017). This, though, was not the case for *Moringa oleifera* pods, the applications of which were much more limited.

Pods can be boiled and eaten like beans, as the fibre content in the pod increases as it grows, but they should be consumed when they can be easily broken (Makkar & Becker, 1996). You can either eat the immature pod raw or prepare it like green peas or green beans, while you usually fry the mature pod (Ramachandran, Peter, & Gopalakrishnan, 1980). The traditional method of cooking most pods is to boil them in water for 15 minutes (Gidamis et al., 2003). Even after longer (30 minutes) of thermal treatment (at 100°C), *Moringa oleifera* Lam. pods showed high nutritional content (Razzak, Roy, Sadia, & Zzaman, 2022).

Some applications for moringa pods have been found:

1) High purity pectin extracted from the pods by means of the acid hydrolysis method is used for strawberry jam production and shows good sensory acceptance. The extract has low methoxyl pectin, slow gelation, and low ash content. The gelling power and degree of esterification of the extract validate its suitability for use in the production of jams, dietary products, compotes, jellies, and other similar products, as they exhibit a favourable gel formation behavior. The jam made can also be sold on the food market as it meets the main requirements for consumer acceptance (Moreno Quintero, Crespo Zafra, & Quintero Ramírez, 2018).
2) Pod powder (obtained by drying the pods in an oven, powdering in a blender, or grinding and sieving through a mesh) has been studied as an enrichment component for both baked products (biscuits) and fried products (the North Indian snack mathri), as well as pasta. As a result of the enrichment, both foods contain all the essential micronutrients crucial for growth and development and provide a good amount of vitamin C, iron, and potassium along with a fair amount of other nutrients (Joshi & Jain, 2011). Pasta has also incorporated Moringa oleifera pod powder, replacing durum wheat semolina, demonstrating acceptable cooking, textural, and sensory properties up to a 15% incorporation level. The blending of 15% *Moringa oleifera* pod powder with durum wheat semolina leads to an improvement in the nutrient composition, phenol content, and antioxidant activity while maintaining acceptable cooking and sensory quality (Kamble, Bashir, Singh, & Rani, 2022).
3) Dried moringa pods used as livestock fodder: although protein levels are low in pods in comparison to the seeds and leaves, they are still suitable for use as high-fibre raw materials for supplementing animal feeds

(Owon et al., 2021). Moreover, this powder can be used for the development of immunity boosting instant soup mixes (Ansari et al., 2022).

Moringa oleifera pods are a low-cost adsorbent for the removal of drugs from water by adsorption. This is because they have a complex surface, are highly heterogeneous and have a wide variety of functional groups (Viotti et al., 2019).

5. CONCLUSION

In conclusion, its compositional and physicochemical properties mean that underdeveloped countries could benefit from the cultivation of *Moringa oleifera* (more specifically the pods) in order to combat malnutrition and its associated diseases. Those same properties also make the pods suitable for livestock fodder, while other applications include their use as an adsorbent for the water treatment. However, a lack of knowledge about these pods in many other parts of the world necessitates further scientific dissemination, enabling various companies and organizations to enhance their use of this plant component.

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