

Effect of drying condition on physicochemical and antioxidant properties of dried *Moringa* leaf powder

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Abstract

Profile of physicochemical and antioxidant activity of dried *Moringa* leaves from Bangladesh are presented. *Moringa* is beneficial for health because it has a lot of nutritional and medicinal values. The leaves were collected and washed with distilled water at different temperatures in an oven dryer, and then the fine powder is taken as a sample by grinding and sieving method. This research was done to compare the changes in physicochemical and antioxidant elements at different temperatures (60°C, 70°C and 80°C) and to find the right temperature at which the nutrient loss will be the lowest. This study showed that as the drying temperature changed, so did the nutrient component of *Moringa* leaves. Physicochemical parameters (moisture, ash, protein, carbohydrate, fat, color) and antioxidant activity (Total phenol content, DPPH free radical scavenging activity, vitamin C, and β-carotene) were extracted using a variety of methods. The protein content, carbohydrate content was estimated by the Kjeldahl and phenol sulfuric acid method respectively. Total phenol content (38.30 mg/100g), DPPH (77.79%), and β-carotene (22.71mg/100g) were measured by the spectrophotometric method. And the colorimeter instrument is used for determining the optical properties. It can be seen that the moisture, ash, protein, carbohydrate, Total phenol content, Vitamin C, DPPH free radical scavenging activity, β-carotene contents decrease significantly with increasing drying temperature, whereas fat content increases. At 60°C drying temperature the nutrient loss was lowest compared to 70°C and 80°C drying temperature, so it can be concluded that 60°C is the most suitable temperature for drying *Moringa* leaves.

1. Introduction

Moringa oleifera is residential principally in India, Bangladesh, Afghanistan, Pakistan, Brazil, Southeast Asia, West Asia, Sri Lanka, East and West Africa, Southern Florida, West Indies, and from Mexico to Peru and Paraguay (Chaudhary and Chaurasia, 2017). *Moringa oleifera* Lam. tree flourishes in numerous tropical and subtropical regions. *Moringa oleifera* tree has a place with the group of Moringaceae. In some countries, *Moringa* is called a “drumstick tree” or horseradish tree and is privately called “zogale” in Hausa, Nigeria. It is familiar for its multipurpose qualities (Bashir *et al.*, 2016). *Moringa oleifera* is familiar with its excellent quality such as fast-growing even in impoverished soil, drought tolerant, deciduous

tree (Ferreira *et al.*, 2008). It develops excellent in hot, semi-dry, and moist regions and the suitable soil is sandy or loamy soils. The seed must be moderately new to give decent germination. Warm temperatures are significant for germination. Someone called *Moringa* “Miracle Tree” or “Mother’s best friend” also for its high nutritional quality (Daba, 2016). *Moringa* has multipurpose use like medicinal uses, industrial uses, nutritional uses, economic uses, which can be used for water conservation and green manure also (Daba, 2016). *Moringa* plant has importance for human beings because almost all parts of *Moringa* (seed, pods, flower, and leaf) are edible (Daba, 2016). *Moringa* leaves are exceptionally perishable and require processing to protect against losses during postharvest. The best way of preserving *Moringa* leaves is drying. After the drying

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process, dry leaves require to convert into leaf powder and store (Emelike and Ebere, 2016; Affandi et al., 2017).

Traditionally, *Moringa oleifera* is utilized to treat numerous maladies all around the world and a large number of them are experimentally demonstrated, which for the most part incorporate, antiasthmatic, antihypertensive, antibiotic, antiulcer, CNS-depressant, anthelmintic, anti-inflammatory (Isitua et al., 2015). In many developing countries, many people cannot get the opportunity of medical services, they suffer from many kinds of diseases. Therapeutic plants offer possible cures with huge chances (Kumbhare et al., 2012). As a medicinal plant, *Moringa* is a blessing for many countries, especially those who are suffering from poor health conditions and poverty. For the water purification method, the watery extract of kernels of *Moringa* is used (Makkar and Becker, 1997).

Moringa is wealthy in numerous nutrients. It has more than 90 nutrient components. It has many antioxidant components and all eight vital amino acids with good proportions (Offor et al., 2014). The leaves of *Moringa* have high nutritional components. It contains vitamin C, β -carotene, protein, minerals such as iron, potassium, and calcium, also. *Moringa* has flavonoid components that help to prevent diseases such as heart diseases and give protection against chronic degenerative diseases (Coppin et al., 2013). The iron substance of the leaves is high and they are recommended for iron deficiency and are utilized in the treatment of scurvy skin maladies (Abbas et al., 2018). During pregnancy, if a woman takes 6 teaspoons of dried *Moringa* leaves powder regularly they can meet iron and calcium demand (Gopalakrishnan et al., 2016). *Moringa oleifera* leaves are additionally great resources of phytonutrients, for example, tocopherols and carotenoids. These supplements are known to scavenge free radicals at the point when joined with a reasonable eating regimen and may have immunosuppressive impacts (Oyeyinka and Oyeyinka, 2018). *Moringa oleifera* leaves act as an anti-diabetic agent (Gopalakrishnan et al., 2016). *Moringa* leaves have Vitamin A content more than carrots, Vitamin C content more than oranges, calcium more than milk, potassium more than bananas, and iron more than spinach (Fahey, 2005). The moisture content of a product plays a pivotal role in determining the shelf life of the product. Drying can reduce the moisture content of *Moringa* leaf but it also causes different nutrient losses. Thus, an optimum temperature is needed for drying to minimize the nutritional loss and moisture content (Olabode et al., 2015). The present study aimed to evaluate the impact of drying conditions on the physicochemical and antioxidant properties of dried

Moringa leaves powder.

2. Materials and methods

2.1 Sample handling and preparation

Fresh *Moringa* leaves were collected from the Sunamganj district of Bangladesh. The stalk and branches of the leaves were removed followed by washing with distilled water. Then the leaves were dried in an oven dryer at different temperatures: 60°C, 70°C and 80°C for 2 hrs. The dried *Moringa* leaves were then ground into powder form and sieved in a 100 mesh to obtain fine particles. The powder found from *Moringa* leaves dried at different drying temperatures was stored in a different airtight vessel.

2.2 Moisture content determination

The moisture content of the dried *Moringa* leaf powder was determined according to a method described by (Rajput et al., 2017; Moazzem et al., 2019). Firstly, the powder was taken into a crucible and weighed (W_1). Then it was dried at 105°C for 24 hrs in an oven drier and weighed again (W_2). The moisture content of the sample was calculated according to the following equation:

$$\text{Moisture content} = ((W_1 - W_2) / W_1) \times 100$$

2.3 Ash content determination

A method described by (Akubugwo et al., 2007) was followed to determine the ash content of the dried *Moringa* leaf powder. Approximately 3 g of *Moringa* leaf powder was taken into a crucible. The sample was then heated at 550°C for 8 hrs in a muffle furnace and residue was determined.

2.4 Fat content determination

The fat content of the dried *Moringa* leaf powder was determined according to a method described by (Ravichandran and Parthiban, 2000). Firstly, 5 g of dried *Moringa* leaf powder was mixed with 25 mL methanol and chloroform mixture (2:1) in a separating funnel. Then 5 mL of 0.9% sodium chloride was added. Three layers were seen in the separating funnel. The lowest layer was collected in a pre-weighed beaker and heated at 80°C in a water bath. The residue amount was then measured.

2.5 Protein content determination

According to the Kjeldahl method described by (Offor et al., 2014) protein content of the dried *Moringa* leaf powder was estimated. Firstly, the digestion of the powder was done with a digestion mixture and sulfuric acid. After digestion, the distillation of the digested sample was carried out in a distillation chamber. The

titrate value was then measured by HCl. The percentage of nitrogen content was found by this method. To determine the protein content, nitrogen percentage was multiplied by a conversion factor.

2.6 Carbohydrate content determination

Carbohydrate content was estimated according to Phenol sulfuric acid method described by (Agrawal *et al.*, 2015). Firstly, 0.1 g dried *Moringa* leaf powder was boiled in a water bath for 3 hrs. The sample was then neutralized by adding solid sodium carbonate. The volume of the sample was made 100 mL by adding distilled water and centrifuging. The supernatant was used as the sample for further process. 0.2 mL sample was made 1 mL by adding distilled water. After that, 1 mL of 5% phenol and 5 mL of 96% sulfuric acid were incorporated into the sample and the absorbance of the sample was taken at 490 nm wavelength by spectrophotometer. The percentage of carbohydrate content was determined by using Glucose standard curve.

2.7 Optical properties

The optical properties of dried *Moringa* leaf powder were evaluated by a colorimeter. A standard plate (L^* : 89.87, a^* : 2.52 and b^* : -3.36) was used to measure the L^* , a^* and b^* values of the dried *Moringa* leaf powder (Zzaman *et al.*, 2014).

2.8 Total phenol content

Total phenol content was determined according to a method described by (Amorim *et al.*, 2008; Shin *et al.*, 2015). At first extract, the solution was prepared by adding 80% methanol to 0.5 g dried *Moringa* leaf powder. Then, 0.5 mL extract was mixed with 8.5 mL distilled water and 0.5 mL Folin-Ciocalteu and kept for a few minutes. 1 mL of 35% sodium carbonate solution was then added to the mixture and absorbance was taken at 765 nm wavelength. Total phenol content was determined by the Gallic acid standard curve.

2.9 Determination of DPPH free radical scavenging activity

DPPH free radical scavenging activity was determined according to the method described by Chang *et al.* (2001). At first extract, the solution was prepared. Then, 2 mL extract sample incorporated into 2 mL DPPH (0.16 mM) methanol solution and kept in dark condition. The absorbance of the mixture was measured at 517 nm wavelength by spectrophotometer.

2.10 Determination of vitamin C content

According to a method described by (Ranganna,

1986), vitamin C content was determined. At first 5 mL standard ascorbic acid and 5 mL Meta phosphoric acid was taken into a conical flask. The dye solution was put into a burette for titration of the sample. Dye factor was obtained by this process. Then titration of the 5 g sample was done by adding 3% of HPO_3 .

2.11 Determination of β -carotene

β -Carotene content was determined by using a method described by (Biswas *et al.*, 2011; Hossain *et al.*, 2021). Approximately 5 g of chilled acetone and 1 g of sample was taken in a test tube. The mixture was then centrifuged and the supernatant was taken into another test tube. After making the standard β -Carotene content absorbance of extract and standard β -Carotene solution was taken at 421 nm wavelength by spectrophotometer.

2.12 Statistical analysis

The SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA) was used with one-way analysis of variance (ANOVA). Duncan multiple range tests ($p < 0.05$) was performed to statistically analyze the mean values. All experiments were repeated at least 3 times and the data were represented as mean \pm standard deviation.

3. Results and discussion

3.1 Physicochemical properties of dried *Moringa* leaf powder

The moisture content of the *Moringa* leaf powder dried at 60°C samples, 70°C samples and 80°C samples were found 4.96%, 2.89% and 2.57% respectively (Table 1). Different drying temperature affects the moisture content of dried *Moringa* leaf powder. (Alakali *et al.*, 2015) reported that increasing drying temperature reduces the moisture content of *Moringa* leaves. According to Sanni *et al.* (2006) sample containing lower moisture content has a longer shelf life. Singh and Prasad (2013) reported that unblanched *Moringa* leaf dried at 60°C contain 5.67% moisture content. Rajput *et al.* (2017) showed fresh and dried *Moringa* leaves contain 72.83% and 7.43% moisture content respectively.

Ash content for the sample dried at 60°C, 70°C and 80°C were found 10.3%, 9.81% and 9.39% respectively. A significant decrease in ash content was found with increasing drying temperature. Oluduro (2012) reported similar results and found 10.64 % ash content in dried *Moringa* leaf powder. According to Alakali *et al.* (2015), the ash content of *Moringa* leaf powder dried at 60°C and 70°C were 5.22% and 5.20% respectively which illustrates a similar decrease in ash content with

Table 1. Moisture, ash, fat, protein and carbohydrate content of *Moringa* leaf powder.

Drying Temperature	Moisture	Ash	Fat	Protein	Carbohydrate
60°C	4.96 ± 0.16 ^b	10.30±0.44 ^c	4.96±0.16 ^a	24.67±0.03 ^c	45.57±0.30 ^c
70°C	2.89±0.09 ^a	9.81±0.70 ^b	5.19±0.13 ^b	21.65±0.02 ^b	43.40±0.14 ^b
80°C	2.57±0.08 ^a	9.39±0.02 ^a	5.33±0.25 ^c	19.89±0.03 ^a	41.57±0.03 ^a

Values are presented as mean±SD, n = 5. Values with different superscripts within the same column are significantly different (p < 0.05) by Duncan's multiple range tests.

increasing drying temperature.

Fat content for the *Moringa* leaf powder dried at 60°C, 70°C and 80°C were found 4.96%, 5.19% and 5.33% respectively. The change in fat content is significant but very small which may be due to inherent variation of the composition of natural products. Ilyas *et al.* (2015) found 2.89% of fat content in dried *Moringa* leaf. A similar result for fat content was reported by Sengev *et al.* (2013).

A significant difference was found for the protein content of *Moringa* leaf powder dried at different temperatures. *Moringa* leaf dried at 60°C, 70°C and 80°C contained 24.67%, 21.65% and 19.89% protein respectively. The significant decrease in protein content of the *Moringa* leaf powder with increasing drying temperature was due to increased protein denaturalization (Alakali *et al.*, 2015). The protein content of *Moringa* leaf powder dried at 60°C and 70°C were found 20.75% and 19.89% respectively (Alakali *et al.*, 2015). Chinwe *et al.* (2015) reported that dried *Moringa* leaf powder contains 24.31% protein.

The carbohydrate content of *Moringa* leaf powder dried at 60°C, 70°C and 80°C were found 45.57%, 43.4%, and 41.57% respectively. Carbohydrate content decreased with increasing drying temperature. A decrease in carbohydrate content may be the result of the thermal degradation of carbohydrates during drying (Lemus-Mondaca *et al.*, 2016). Oluduro (2012) found 45.43% carbohydrate in dried *Moringa* leaf powder

which is similar to this study.

3.2 Optical properties

From Table 2, the L^* value of the powder increased continuously from 42.38 to 43.24 with the increased drying temperature of *Moringa* leaf powder. A significant increase in lightness is indicated by the increase in the L^* value of the powder. The b^* value of the powder decreased from 32.63 to 28.24 with the increase of drying temperature which indicates a decrease in yellowness of the *Moringa* leaf powder. The increase in lightness and decrease in yellowness of the dried powder may be due to the breakdown of chlorophyll with increasing drying temperature (Sejali and Anuar, 2011).

3.3 Antioxidant properties of dried *Moringa* leaf powder

Total phenol content of the sample dried at 60°C samples, 70°C samples and 80°C samples are found 38.30 mg/100 g, 27.77 mg/100 g and 16.39 mg/100 g respectively (Table 3). Total phenol content decreased with the increasing drying temperature of the dried *Moringa* leaf powder. Potisate and Phoungchandang (2015) reported that reduction in drying time helps to retain higher total phenol content.

DPPH free radical scavenging activity of the dried *Moringa* leaves powder decreased from 77.79% to 56.42% with the increase in drying temperature from 60°C to 80°C. *Moringa* leaf powder dried at 70°C possessed 63.30% DPPH free radical scavenging activity. Ilyas *et*

Table 2. Optical properties of dried *Moringa* leaf powder

Drying Temperature	L^*	a^*	b^*	c^*	d^*
60°C	42.38±0.17 ^b	3.16±0.02 ^a	32.63±0.10 ^c	32.44±0.35 ^c	95.54±0.03 ^c
70°C	43.24±0.57 ^b	0.60±0.68 ^b	29.54±0.76 ^b	28.34±0.36 ^b	88.86±1.44 ^b
80°C	46.00±1.70 ^c	2.33±0.20 ^c	28.24±0.71 ^c	28.34±0.76 ^b	84.61±0.89 ^a

Values are presented as mean±SD, n = 5. Values with different superscripts within the same column are significantly different (p < 0.05) by Duncan's multiple range tests.

Table 3. Antioxidant properties of dried *Moringa* leaf powder

Drying Temperature	Total phenol content (mg/100 g)	Vitamin C content (mg/100 g)	β -carotene content (mg/100 g)	DPPH (%)
60°C	38.30±0.77 ^c	21.45±0.12 ^b	22.71±0.03 ^c	56.42±0.38 ^a
70°C	27.77±0.19 ^b	17.81±0.14 ^a	21.14±0.60 ^b	63.30±0.08 ^b
80°C	16.39±0.40 ^a	17.00±0.04 ^a	19.87±0.06 ^a	77.79±0.12 ^c

Values are presented as mean±SD, n = 5. Values with different superscripts within the same column are significantly different (p < 0.05) by Duncan's multiple range tests.

al. (2015) found 87.02% DPPH free radical scavenging activity for dried *Moringa* leaf powder.

Vitamin C content for the sample dried at 60°C samples, 70°C samples and 80°C samples were found 21.45 mg/100 g, 17.81 mg/100 g and 17 mg/100 g respectively. Vitamin C is heat sensitive and thus reduced with increasing drying temperature (Igwemmar et al., 2013). 19.3 mg of vitamin C content per 100 g of dried *Moringa* leaf powder was collected from Nigeria (Mensah et al., 2012)

Beta-carotene content of the *Moringa* leaf powder dried at 60°C, 70°C and 80°C were found 21.45 mg/100 g, 17.81 mg/100 g and 17. mg/100 g respectively. β -carotene content decreased with increasing drying temperature of *Moringa* leaf. Subadra et al. (1997) found 17.4 mg of β -carotene content per 100 g of fresh *Moringa* leaves and found that β -carotene reduces after drying.

4. Conclusion

From this study, the drying temperature affects the nutrient component of *Moringa* leaves. And from this, the sample dried at 60°C temperature has higher amount of antioxidant and physicochemical content than another sample. And with the increasing of temperature, the loss of nutrient component occurs at most. Thus, the temperature of the sample in oven drying should maintain not more than 60°C temperature to get desirable product. Further studies needed to be carried out to analyse the stability of developed product from dried *Moringa* leaves and how many grams of dried powder should be given to pregnant women as an alternative to iron tablet.

References

- Abbas, R., Elsharbasy, F. and Fadlelmula, A. (2018). Nutritional Values of *Moringa oleifera*, Total Protein, Amino Acid, Vitamins, Minerals, Carbohydrates, Total Fat and Crude Fiber, under the Semi-Arid Conditions of Sudan. *Journal of Microbial Biochemical Technology*, 10(2), 56-58. <https://doi.org/10.4172/1948-5948.1000396>
- Affandi, N., Zzaman, W., Yang, T.A. and Easa, A.M. (2017). Production of *Nigella sativa* Beverage Powder under Foam Mat Drying Using Egg Albumen as a Foaming Agent. *Beverages*, 3(1), 9. <https://doi.org/10.3390/beverages3010009>
- Agarwal, N., Minj, D. and Rani, K. (2015). Estimation of total carbohydrate present in dry fruits. *Journal of Environmental Science, Toxicology and Food Technology*, 1(6), 24-27.
- Akubugwo, I., Obasi, A. and Ginika, S. (2007). Nutritional potential of the leaves and seeds of black nightshade-*Solanum nigrum* L. Var *virginicum* from Afikpo-Nigeria. *Pakistan Journal of Nutrition*, 6(4), 323-326. <https://doi.org/10.3923/pjn.2007.323.326>
- Alakali, J., Kucha, C. and Rabi, I. (2015). Effect of drying temperature on the nutritional quality of *Moringa oleifera* leaves. *African Journal of Food Science*, 9(7), 395-399. <https://doi.org/10.5897/AJFS2014.1145>
- Amorim, E.L., Nascimento, J.E., Monteiro, J.M., Peixoto Sobrinho, T., Araújo, T.A. and Albuquerque, U.P. (2008). A simple and accurate procedure for the determination of tannin and flavonoid levels and some applications in ethnobotany and ethnopharmacology. *Functional Ecosystems and Communities*, 2(1), 88-94.
- Bashir, K., Waziri, A. and Musa, D. (2016). *Moringa oleifera*, a potential miracle tree: a review. *Journal of Pharmaceutical and Biological Science*, 11(6), 25-30.
- Biswas, A., Sahoo, J. and Chatli, M. (2011). A simple UV-Vis spectrophotometric method for determination of β -carotene content in raw carrot, sweet potato and supplemented chicken meat nuggets. *LWT-Food Science and Technology*, 44(8), 1809-1813. <https://doi.org/10.1016/j.lwt.2011.03.017>
- Chang, S.T., Wu, J.H., Wang, S.Y., Kang, P.L., Yang, N.S. and Shyur, L.F. (2001). Antioxidant activity of extracts from *Acacia confusa* bark and heartwood. *Journal of Agricultural and Food Chemistry*, 49(7), 3420-3424. <https://doi.org/10.1021/jf0100907>
- Chaudhary, K. and Chaurasia, S. (2017). Nutraceutical properties of *Moringa oleifera*: a review. *European Journal of Pharmaceutical and Medical Research*, 4 (4), 646-655. <https://doi.org/10.1007/s13596-020-00468-0>
- Coppin, J.P., Xu, Y., Chen, H., Pan, M.H., Ho, C.T., Juliani, R., Simon, J.E. and Wu, Q. (2013). Determination of flavonoids by LC/MS and anti-inflammatory activity in *Moringa oleifera*. *Journal of Functional Foods*, 5(4), 1892-1899. <https://doi.org/10.1016/j.jff.2013.09.010>
- Daba, M.H. (2016). Miracle tree: A review on multi-purposes of *Moringa oleifera* and its implication for climate change mitigation. *Journal of Earth Science and Climate Change*, 7(8). <https://doi:10.4172/2157-7617.1000366>
- Emelike, N. and Eber, C. (2016). Effect of Drying Techniques of *Moringa* Leaf on the Quality of Chin-Chin Enriched with *Moringa* Leaf Powder. *Journal*

- of *Environmental Science, Toxicology and Food Technology*, 10(4), 65-70. <https://doi.org/10.9790/2402-1004016570>
- Fahey, J.W. (2005). *Moringa oleifera*: A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. *Trees for life Journal*, 1(5), 21205-22185.
- Ferreira, P.M.P., Farias, D.F., Oliveira, J.T.D.A. and Carvalho, A.D.F.U. (2008). *Moringa oleifera*: bioactive compounds and nutritional potential. *Revista de Nutrição*, 21(4), 431-437. <https://doi.org/10.3390/antiox6040091>
- Gopalakrishnan, L., Doriya, K. and Kumar, D.S. (2016). *Moringa oleifera*: A review on nutritive importance and its medicinal application. *Food Science and Human Wellness*, 5(2), 49-56. <https://doi.org/10.1016/j.fshw.2016.04.001>
- Hossain, M.A., Mitra, S., Belal, M. and Zzaman, W. (2021). Effect of foaming agent concentration and drying temperature on biochemical properties of foam mat dried tomato powder. *Food Research*, 5 (1), 291 – 297. [https://doi.org/10.26656/fr.2017.5\(1\).372](https://doi.org/10.26656/fr.2017.5(1).372)
- Igwemmar, N., Kolawole, S. and Imran, I. (2013). Effect of heating on vitamin C content of some selected vegetables. *International Journal of Scientific and Technology Research*, 2(11), 209-212.
- Ilyas, M., Arshad, M., Saeed, F. and Iqbal, M. (2015). Antioxidant potential and nutritional comparison of *Moringa* leaf and seed powders and their tea infusions. *Journal of Animal and Plant Sciences*, 25 (1), 226-233.
- Isitua, C.C., Lozano, M., Jaramillo, C. and Dutan, F. (2015). Phytochemical and nutritional properties of dried leaf powder of *Moringa oleifera* Lam. from Machala El Oro province of Ecuador. *Asian Journal Plant Science Research*, 5(2), 8-16.
- Kumbhare, M., Guleha, V. and Sivakumar, T. (2012). Estimation of total phenolic content, cytotoxicity and in-vitro antioxidant activity of stem bark of *Moringa oleifera*. *Asian Pacific Journal of Tropical Disease*, 2(2), 144-150. [https://doi.org/10.1016/S2222-1808\(12\)60033-4](https://doi.org/10.1016/S2222-1808(12)60033-4)
- Makkar, H. and Becker, K. (1997). Nutrients and anti-quality factors in different morphological parts of the *Moringa oleifera* tree. *The Journal of Agricultural Science*, 128(3), 311-322. <https://doi.org/10.1017/S0021859697004292>
- Mensah, J., Ikhajagbe, B., Edema, N. and Emokhor, J. (2012). Phytochemical, nutritional and antibacterial properties of dried leaf powder of *Moringa oleifera* (Lam.) from Edo Central Province. *Journal of Natural Products and Plant Resources*, 2(1), 107-112.
- Moazzem, M.S., Sikder, M.B.H. and Zzaman, W. (2019). Shelf-Life Extension of Wood Apple Beverages Maintaining Consumption-Safe Parameters and Sensory Qualities. *Beverages*, 5, 25. <https://doi.org/10.3390/beverages5010025>
- Offor, I., Ehiri, R. and Njoku, C. (2014). Proximate nutritional analysis and heavy metal composition of dried *Moringa oleifera* leaves from OshiriOnicha LGA, Ebonyi State, Nigeria. *Journal of Environmental Science, Toxicology and Food Technology*, 8(1), 57-62. <https://doi.org/10.9790/2402-08115762>
- Olabode, Z., Akanbi, C.T., Olunlade, B. and Adeola, A.A. (2015). Effects of drying temperature on the nutrients of *Moringa (Moringa oleifera)* leaves and sensory attributes of dried leaves infusion. *Direct Research Journal of Agriculture and Food Science*, 3(5), 177-122. <https://doi.org/10.1155/2020/5376280>
- Oluduro, A.O. (2012). Evaluation of antimicrobial properties and nutritional potentials of *Moringa oleifera* Lam. leaf in South-Western Nigeria. *Malaysian Journal of Microbiology*, 8(2), 59-67. <https://doi.org/10.21161/mjm.02912>
- Oyeyinka, A.T. and Oyeyinka, S.A. (2018). *Moringa oleifera* as a food fortificant: Recent trends and prospects. *Journal of the Saudi Society of Agricultural Sciences*, 17(2), 127-136. <https://doi.org/10.1016/j.jssas.2016.02.002>
- Potisate, Y. and Phoungchandang, S. (2015). Microwave drying of *Moringa oleifera* (Lam.) leaves: drying characteristics and quality aspects. *Asia-Pacific Journal of Science and Technology*, 20(1), 12-25. <https://doi.org/10.14456/kkurj.2015.2>
- Rajput, H., Prasad, S., Srivastav, P., Singh, N., Suraj, L. and Chandra, R. (2017). Chemical and Phytochemical Properties of Fresh and Dried *Moringa oleifera* (PKM-1) Leaf Powder. *Chemical Science Review and Letters*, 6(22), 1004-1009.
- Ranganna, S. (1986). Handbook of analysis and quality control for fruit and vegetable products. New York, USA: Tata McGraw-Hill Education.
- Ravichandran, R. and Parthiban, R. (2000). Lipid occurrence, distribution and degradation to flavour volatiles during tea processing. *Food Chemistry*, 68 (1), 7-13. [https://doi.org/10.1016/S0308-8146\(99\)00143-0](https://doi.org/10.1016/S0308-8146(99)00143-0)
- Sanni, L., Adebowale, A. and Tafa, S. (2006). Proximate, functional, pasting and sensory qualities of instant yam flour, presented at the 14 ISTRC

- Symposium. Trivandrum, Kerala State, India:
Central Tuber Crops the Research Institute
- Sejali, S. and Anuar, M. (2011). Effect of drying methods on phenolic contents of neem (*Azadirachta indica*) leaf powder. *Journal of Herbs, Spices and Medicinal Plants*, 17(2), 119-131. <https://doi.org/10.1080/10496475.2011.584293>
- Sengev, A.I., Abu, J.O. and Gernah, D.I. (2013). Effect of *Moringa oleifera* leaf powder supplementation on some quality characteristics of wheat bread. *Food and Nutrition Sciences*, 4(3), 270. <https://doi.org/10.4236/fns.2013.43036>.
- Shin, L.E.R., Zzaman, W. and Bhat, R. (2015). Influence of dehydration techniques on physicochemical, antioxidant and microbial qualities of *Ipomoea aquatica* forsk., an underutilized green leafy vegetable. *Journal of Food Processing and Preservation*, 39(6), 1118–1124. <https://doi.org/10.1111/jfpp.12326>
- Singh, Y. and Prasad, K. (2013). *Moringa oleifera* leaf as functional food powder: Characterization and uses. *International Journal of Agriculture and Food Science Technology*, 4(4), 317-324.
- Subadra, S., Monica, J. and Dhabhai, D. (1997). Retention and storage stability of beta-carotene in dehydrated drumstick leaves (*Moringa oleifera*). *International Journal of Food Sciences and Nutrition*, 48(6), 373-379. <https://doi.org/10.3109/09637489709028585>
- Zzaman, W., Silvia, D., Abdullah, W.N.W. and Yang, T.A. (2014). Physicochemical and Quality Characteristics of Cold and Hot Press of *Nigella sativa* L Seed Oil Using Screw Press. *Journal of Applied Sciences Research*, 10(12), 36-45.