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RESEARCH ARTICLE

Optimization of water blanching and cabinet drying conditions for preservation of nutritional and phytochemical properties of moringa leaves

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Abstract

The perishable nature of moringa leaves leads to its limited shelf life. Drying methods reduce water activity and help extend the shelf life of dried leaves. In this study, the moringa leaves were subjected to water blanching at 50, 60, 70 and 80 °C for 1, 2 and 3 min, followed by drying. Water blanching at 50 °C for 3 min resulted in the highest retention of total carotenoids (24.65 mg/100 g), iron (21.50 mg/100 g), calcium (1413.10 mg/100 g) and colour of dried moringa leaves. To assess their impact on nutrient retention, the water-blanched moringa leaves were then subjected to three different drying methods: cabinet drying, sun drying and shade drying. The drying methods significantly influenced the retention of nutrients, with varying degrees of effectiveness across methods in moringa leaves. The moringa leaves blanched in water at 50°C for 3 min and dried in a cabinet drier retained the higher total carotenoids (24.65 mg/100 g), iron (21.50 mg/100 g) and calcium (1413.10 mg/100 g).

Keywords

blanching; calcium; drying; iron; moringa; total carotenoids

Introduction

Moringa, *Moringa oleifera* Lam. is also known as Drumstick and Horseradish trees. In India, it is cultivated in 43,600 hectares (1). Andhra Pradesh ranks first in cultivation of moringa with cultivation area of 15, 655 hectares followed by Karnataka with 10,280 hectares and Tamil Nadu with 7,408 hectares. In Tamil Nadu, Theni, Madurai, Dindigul, Toothukudi, Ariyalur, Tiruppur and Karur districts were declared as Export zones of Moringa. It is an essential perennial leafy vegetable cultivated for its nutritious leaves, pods and seeds. Moringa leaves, pods, seeds and flowers are used in various food preparations. They contain good nutritional and medicinal values (2). Moringa leaves are an excellent source of protein (6.7 g/100 g), calcium (440 mg/100 g), iron (4 mg/100 g), vitamin A (378 µg/100 g) and folic acid. The iron content in moringa leaves makes them a valuable dietary supplement for individuals with anaemia (3).

Despite its enormous potential uses, Moringa remains underexplored, primarily due to its perishable nature. Moringa leaves have a short shelf life of one day, primarily due to leaf yellowing and senescence. Drying and dehydration techniques are commonly employed to preserve the nutritional and physicochemical properties and extend the shelf life of moringa leaves. Drying is an effective method of preservation that reduces water activity and minimizes the enzymatic and chemical reactions in the dried leaves. To improve the quality of dried leaves, selecting appropriate blanching methods as pretreatment and method of drying are essential. Blanching is a heat treatment where vegetables are heated in boiling water or steam for 2 to 5 min, then cooling the vegetables to prevent further cooking. Blanching helps destroy microorganisms, halts enzymatic activity, removes gases from the vegetables and reduces saponin content in moringa leaves (4). Blanching influences the quality, nutritional content and digestibility of vegetables (5-7). After blanching, drying can be performed using solar or mechanical methods, each offering distinct advantages for nutrient preservation. Dried moringa leaves can be stored for extended periods and utilized to develop value-added products.

There is an excellent scope for moringa leaf-based products such as soups, cookies, biscuits, bread, moringa paneer, moringa chocolates, idli powder, dhal powder and halwa to make them available throughout the year. The need for nutrient-rich, value-added products is ever-increasing with increasing malnutrition. Ready-to-use moringa leaf powder has the potential to become an essential product for changing lifestyles. Moisture content, protein, vitamin A, calcium and iron in the dried leaves are the most critical parameters that must be retained during storage. Water blanching and drying of moringa leaves were carried out to study the nutritional and phytochemical parameters in dried moringa leaves.

Materials and Methods

Water blanching

The present work on water blanching and drying techniques for retaining nutritional profile in dried moringa leaves (*Moringa oleifera* Lam.) was conducted at the Horticultural College and Research Institute for Women, Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu during 2018-19. The first experiment, conducted with three replications, aimed to study the effect of water blanching on the nutritional quality of dried Moringa leaves. The freshly harvested PKM 1 moringa leaves were procured from Thanjavur, Tamil Nadu. The cleaned, washed leaves were subjected to water blanching at 50°C, 60°C, 70°C and 80 °C for one, two and three min and then dried in a cabinet drier at 50 °C.

The nutrient analysis was done to standardize the blanching method for better retention of nutritional quality in dehydrated leaves. The following parameters were measured for all the blanched, dried Moringa leaves: moisture content, drying ratio, rehydration ratio, total carotenoids, ascorbic acid, calcium, iron and non-enzymatic browning. The sensory evaluation also calculated the overall quality of the leaves. Based on biochemical analysis (nutrient retention) and sensory evaluation (overall quality), the blanching method that yielded the highest nutritional retention and best sensory scores was selected for the second experiment.

Treatments	Treatment details
T_0	Without blanching
T_1	Water blanching at 50 °C for 1 min
T_2	Water blanching at 50 °C for 2 min
T_3	Water blanching at 50 °C for 3 min
T_4	Water blanching at 60 °C for 1 min
T_5	Water blanching at 60 °C °C for 2 min
T_6	Water blanching at 60 °C for 3 min
T_7	Water blanching at 70 °C for 1 min
T_8	Water blanching at 70 °C for 2 min
T_9	Water blanching at 70 °C for 3 min
T_{10}	Water blanching at 80 °C for 1 min
T_{11}	Water blanching at 80 °C for 2 min
T_{12}	Water blanching at 80 °C for 3 min

Drying methods

The experiment was conducted with 5 replications to evaluate the effect of drying on the nutritional quality of dried moringa leaves. The unblanched and best water-blanched (Water blanching at 50°C for 3 min) leaves were dried by the sun, shade and cabinet drying.

Treatments	Treatment details
D_1	Control (Without blanching) + Sun drying
D_2	Control (Without blanching) + Shade drying
D_3	Control (Without blanching) + Cabinet drying
D_4	Water blanching (50°C for 3 min) + Sun drying
D_5	Water blanching (50°C for 3 min) + Shade drying
D_6	Water blanching (50°C for 3 min) + Cabinet drying

The cleaned moringa leaves were spread in the food-grade trays and dried under sunlight for drying with frequent turning. Shade drying was done in insect- and rodent-proof, dust-proof and well-ventilated rooms. In cabinet drying, the cleaned moringa leaves were spread in a thin layer in clean trays and dried at 50 °C for eight hours. In all the drying methods, leaves were turned over frequently for uniform drying. As detailed below, moisture content, drying ratio, rehydration ratio, total carotenoids, ascorbic acid, calcium, iron, non-enzymatic browning and sensory evaluation were calculated for all the dried moringa leaves.

Physical and nutritional parameters

Drying ratio

The drying ratio was determined by dividing the fresh weight of moringa leaves by the net dry weight of moringa leaves obtained after drying and the formula is given in Equation 1.

$$\text{Drying ratio} = \frac{\text{Fresh weight of the material}}{\text{Net dry weight obtained}} \qquad \text{(Eqn. 1)}$$

Moisture content

The moisture content of dried moringa leaves was estimated using the hot air oven method (8). One gram of moringa leaves was taken into an aluminium can and dried in a hot air oven at 60-65 °C. The dry weight of samples was recorded at an interval of 24 hours until two consecutive readings became the same. The percentage of moisture content was calculated using the following formula in Equation 2.

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight - Dry weight}}{\text{Fresh weight}} \times 100 \quad \text{(Eqn. 2)}$$

Total carotenoids

Five grams of dried sample was ground in a pestle and mortar with acetone. The extracts were decanted into a conical flask. The extraction continued till the entire pigments were extracted and the residue became colourless. This extract was transferred to a separating funnel. 10-15 ml of petroleum ether: acetone (3:2) and water containing 5 % anhydrous sodium sulphate solution was added into a funnel and separated clear solution. Extraction of acetone phases was repeated with a small volume of petroleum ether until no more colour was extracted. Then, a small amount of anhydrous sodium sulphate was added to absorb the excess water and the volume was made up of eluent (3 % acetone in petroleum ether). The spectrophotometer measured the colour at 452 nm using eluent as blank. Results were expressed as mg/ 100 g using the formula in Equation 3.

$$\text{Total carotenoids (mg/ 100 g)} = \frac{3.857 \times \text{Optical density} \times \text{Volume made up} \times 100}{\text{Weight of sample (g)}} \quad \text{(Eqn. 3)}$$

Ascorbic acid

Ascorbic acid was estimated by titrating five grams of leaf sample against 2,6-dichlorophenol indophenol dye (9). Five grams of sample was extracted with 3 % metaphosphoric acid and then 10 ml of aliquot was titrated against 2, 6 dichlorophenol indophenol dye to faint pink colour, which persisted for 15 seconds. Ascorbic acid was expressed in mg/100 g using the following formula in Equation 4.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{volume made up} \times 100}{\text{Aliquot of sample} \times \text{weight of sample}} \quad \text{(Eqn. 4)}$$

Iron

The ash solution prepared from wet digestion was used to develop colour. Wet digestion was done using a triple acid mixture *viz*., sulphuric acid, nitric acid and perchloric acid at 1:2:1. Samples were digested until the digest on cooling became pale yellow or light brown. Then, the samples were heated to fuming in a sand bath until the residue became colourless. The solution was cooled and poured into separate stoppered cylinders. The volume was made up of 15 ml of water. The colour was measured at 480 nm by transmitting the blank at 100 %. Iron content was expressed as mg/100 g and the formula is given in Equation 5.

$$\text{Iron (mg/100 g)} = \frac{\text{OD of sample} \times 0.1 \times \text{Total sample volume} \times 100}{\text{OD of standard} \times 5 \times \text{weight of sample taken}} \quad \text{(Eqn. 5)}$$

Calcium

About 20 ml of the sample was taken into a conical flask obtained by wet digestion. Wet digestion was done using a triple acid mixture viz., sulphuric acid, nitric acid and perchloric acid at 1:2:1. Samples were digested until the digest on cooling was pale yellow or light brown. Then, the samples were heated to fuming by keeping them in a sand bath until the residue was colourless. 10 ml of saturated ammonium oxalate solution and two drops of methyl red indicator were added to the ash solution. Then, the solution was made slightly alkaline by adding dilute ammonia and slightly acidic by adding a few drops of acetic acid until the colour became faintly pink. Then, the solution was heated to the boiling point and allowed to stand at room temperature for 4 hours. The solution was filtered through Whatman No. 42 filter paper and washed with water until the filtrate was oxalate-free (the test for absence of chloride using $AgNO_3$). The precipitate and filter paper was washed using sulphuric acid into a beaker in which calcium was precipitated and then titrated with 0.01 N $KMnO_4$ to the first permanent pink colour. The calcium content was expressed as mg/ 100 g and the formula was given as Equation 6.

$$\text{Calcium (mg/100g)} = \frac{\text{Titre} \times 0.2 \times \text{total volume of ash solution} \times 100}{\text{Volume taken for estimation} \times \text{weight of sample taken}} \quad \text{(Eqn. 6)}$$

Rehydration ratio

Five grams of the dehydrated moringa leaves were taken into a beaker and 50 ml of warm water (60°C) was added. After 2 hours, the drained weight of the rehydrated material was taken. The rehydration ratio was estimated by dividing the weight of the rehydrated leaves by the weight of the dried leaves.

Non-enzymatic browning

Non-enzymatic browning was measured by soaking two grams of dried moringa leaves after grinding in 50 ml of 60 % alcohol. The samples were kept overnight and filtered through Whatman No.1 and the OD was recorded at 420 nm using 60 % alcohol as blank in a spectrophotometer (9).

Sensory evaluation

A panel of seven judges conducted the sensory evaluation to assess the colour, flavour and texture of dried moringa leaves. The scoring was done using the nine-point hedonic scale (10). A score of 5.5 and above was valued as acceptable.

Statistical analysis

These laboratory experiments were conducted completely randomized and subjected to statistical analysis (11). Data were analyzed using the ANOVA technique with a significance test at p=0.05.

Results and Discussion

Comparison of water blanching temperature

The moringa underwent initial processing, which included cleaning and washing before further treatment. During primary processing, the loss was recorded as 58 % with an edible to non-edible ratio of 0.92:1. The fresh leaves contain 70 % moisture, 420 mg/100 g calcium, 3.2 mg/100 g iron, 220 mg/100 g ascorbic acid and 4 mg/100 g total carotenoids. The blanching temperature significantly influenced drying, vitamins and colour (Table 1). Among 12

Table 1. Effect of blanching methods on moisture content, drying ratio, rehydration ratio, total carotenoids, ascorbic acid and non-enzymatic browning of dried moringa leaves

Treatments	Moisture content (%)	Drying ratio	Rehydration ratio	Total carotenoids (mg/100 g)	Ascorbic acid (mg/100 g)	Non-enzymaticbrowning (OD)
T_0	4.95^a	5.50^a	1.91^a	23.04^a	133.48^a	1.92^a
T_1	5.10^a	5.33^a	1.93^a	23.61^b	85.67^a	1.80^b
T_2	5.14^a	5.33^a	1.93^a	23.81^b	80.79^a	1.70^b
T_3	5.17^a	5.00^a	1.94^a	24.65^b	77.25^a	1.00^b
T_4	5.20^a	6.67^b	1.92^a	23.21^a	69.26^a	1.80^b
T_5	5.37^a	6.00^a	1.92^a	23.70^b	60.11^a	1.91^a
T_6	5.47^a	6.67^b	1.92^a	23.26^a	52.67^a	1.84^b
T_7	5.50^a	6.17^a	1.91^a	23.64^b	49.33^a	1.63^b
T_8	5.52^a	6.33^a	1.91^a	23.44^b	43.67^a	1.67^b
T_9	5.56^a	6.00^a	1.91^a	23.31^b	35.24^a	1.73^b
T_{10}	5.56^a	6.83^b	1.91^a	23.07^a	30.10^a	1.83^b
T_{11}	5.59^a	6.83^b	1.91^a	23.50^b	27.33^b	1.90^a
T_{12}	5.60^a	6.83^b	1.90^a	23.00^a	22.59^b	1.81^b
CD(0.05)	0.65	0.44	0.03	0.29	5.34	0.07
SEd	0.32	0.22	0.01	0.14	2.65	0.03

treatments, T_9 recorded a better drying ratio (6.00) than other treatments. The rehydration ratio was slightly higher (1.94) in T_3. This might be due to better water absorption, the increased porousness of the cell wall in dehydrated leaves and the difference in the number of imbibing materials. A similar report of enhanced rehydration due to blanching was observed in cabbage (12). The blanched moringa leaves recorded higher moisture content than unblanched, dried moringa leaves (4.95 %) due to the gel formation on pectin substances of the cell membrane, which hindered the water removal from the cell.

The retention of total carotenoids (24.65 mg/100 g) was better in the dried moringa leaves when blanched in water at 50 °C for 3 min, followed by water blanching at 60 °C for 1 minute. There was a noticeable difference in the retention of total carotenoids in the dried moringa leaves, possibly due to the concentration of total carotenoids during blanching. Though thermal degradation of ascorbic acid occurs, the remarkable stability could probably be due to the inactivation of the ascorbic acid oxidase enzyme during blanching. Water blanching increases cell damage and membrane permeability, facilitating the release and leaching of water-soluble nutrients. The leaching loss of ascorbic acid increased rapidly as the cell walls broke and the cell membrane turned permeable. The loss of ascorbic acid during the blanching of vegetables has been reported (5). Non -enzymatic browning was the least (1.00) in dried moringa leaves (T_3-Water blanching at 50 °C for 3 min) compared to other treatments. This is likely due to sugar inversion and ascorbic acid degradation, which both contribute to browning. Moisture in the dried moringa leaves would also have formed browning compounds.

The variation in iron and calcium content of dried moringa leaves might be due to the difference in blanching temperature, maturity of leaves and growing conditions (13). The highest iron (21.50 mg/100 g) and calcium content (1413.10 mg/100 g) were recorded in dried moringa leaves (T_3-Water blanching at 50 °C for 3 min) which might be due to the concentration of nutrients during drying (Fig. 1). Water blanching might have heavily ruptured the cells and high permeability of the membrane through which nutrients might have leached out. Sensory evaluation indicated that the treatments significantly influenced the sensory quality of

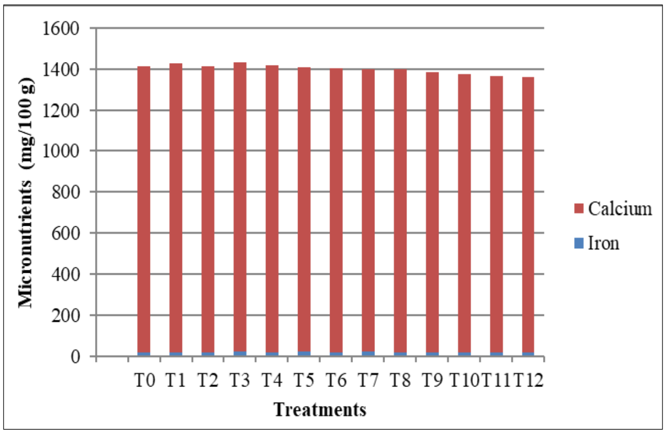

Fig. 1. Effect of drying methods on calcium and iron in dried moringa leaves. The data presented as means of 3 replicates ±SE; CD(p=0.05).

Moringa leaves, including attributes such as taste, texture and colour (Table 2). The overall sensory score is higher (8.7) in moringa leaf soup (T_3-Water blanching at 50 °C for 3 min) followed by moringa leaf soup (T_2-Water blanching at 50 °C for 2 min), which might be due to the reduction in saponin content during blanching (4). At 50 °C, the biochemical reaction rate is slower and helps maintain better colour and texture of dried moringa leaves. T_3 (Water blanching at 50 °C for 3 min) was determined to be the best blanching treatment

Table 2. Sensory evaluation of moringa soup made from dried moringa leaves

Treatments	Colour	Flavour	Taste	Overall Sensory score
T_0	7.3	6.9	7.5	7.2
T_1	7.0	7.5	7.0	7.2
T_2	8.0	8.0	8.5	8.2
T_3	8.5	8.5	9.0	8.7
T_4	7.0	7.5	7.1	7.2
T_5	7.3	7.5	7.4	7.4
T_6	7.3	7.6	7.5	7.5
T_7	7.5	7.6	6.0	7.0
T_8	7.7	7.7	6.3	7.2
T_9	7.8	7.7	6.5	7.3
T_{10}	7.8	7.8	6.3	7.3
T_{11}	7.8	7.8	6.6	7.4
T_{12}	7.8	7.8	6.7	7.4
Mean	7.6	7.7	7.1	7.5

T_0:Without blanching, T_1:Water blanching at 50 °C for 1 min, T_2:Water blanching at 50 °C for 2 min, T_3:Water blanching at 50 °C for 3 min, T_4:Water blanching at 60 °C for 1 min, T_5:Water blanching at 60 °C for 2 min, T_6:Water blanching at 60 °C for 3 min, T_7:Water blanching at 70°C for 1 min, T_8:Water blanching at 70 °C for 2 min, T_9:Water blanching at 70 °C for 3 min, T_{10}:Water blanching at 80 °C for 1 min, T_{11}:Water blanching at 80 °C for 2 min,T_{12}:Water blanching at 80 °C for 3 min.

based on its superior retention of total carotenoids, iron and calcium and its high sensory score.

Comparison of drying methods

The water-blanched (50 °C for 3 min) and unblanched moringa leaves (PKM 1) were dried under different conditions such as cabinet, sun and shade. The drying methods significantly influenced the drying efficiency, nutrient retention (vitamins) and colour (Table 3). Treatment D_6 recorded the best drying ratio (4.90) compared to the other treatments. The higher drying ratio in blanched Moringa leaves is likely due to water leakage from the cells during blanching, which facilitates more efficient water removal during drying. The moisture content of dried moringa leaves ranged from 4.52 to 6.12 %. Moisture content was lower (4.52 %) in sun dried moringa leaves (D_1) than shade and cabinet-dried moringa leaves. Compared to sun and shade-dried moringa leaves, a rehydration ratio was higher (1.93) in cabinet dried moringa leaves (D_3).

The optimum drying temperature was 50 °C for maximum retention of nutrients and colour (14). There was a significant difference among the drying methods in the retention of total carotenoids and ascorbic acid content. Total carotenoid content was found to be significantly higher (24.65 mg/100 g) in cabinet-dried moringa leaves (D_6), followed by D_5, shade-dried moringa leaves (24.40 mg/100 g). Total carotenoid retention was high in blanched, cabinet-dried moringa leaves. This might be due to the concentration of total carotenoids during blanching and uniform temperature during drying. In addition to blanching, sulphiting effectively retained beta-carotene in the dehydrated moringa leaves (15). The retention of ascorbic acid was significantly higher (67.25 mg/100 g) in cabinet-dried moringa leaves (D_6), followed by D_5, shade-dried moringa leaves (63.53 mg/100 g). Thermal degradation is the main reason for the decrease in ascorbic acid content. The loss of ascorbic acid was recorded in solar-dried and cabinet-dried amaranthus leaves (16). The retention of ascorbic acid and total iron was higher in cabinet-dried fenugreek, cabbage and spinach than in sun-dried and shade-dried fenugreek, cabbage and spinach (17). The colour change of leaves occurs during drying due to the conversion of chlorophyll to pyropheophytin and pheophytin (18). Non-enzymatic browning of dried leaves varies with drying methods. Non-enzymatic browning was found to be significantly lower (1.03 OD) in cabinet-dried moringa leaves (D_6), followed by D_5, shade-dried moringa leaves (1.72 OD).

No significant difference was found in the retention of iron and calcium content in all the dried moringa leaves (Fig. 2). Studies conducted by various scientists showed that different drying conditions did not significantly change the mineral content of vegetables (19). Iron content was found to be higher (21.50 mg/100 g) in cabinet-dried moringa leaves (D_6), followed by D_3, cabinet-dried moringa leaves without blanching (21.48 mg/100 g). The blanched, cabinet-dried moringa leaves showed high iron content due to the concentration of iron during blanching. The retention of calcium content was found to be higher (1498.08 mg/100 g) in shade-dried moringa leaves (D_5), followed by D_6, cabinet-dried moringa leaves (1413.10 mg/100 g). The higher calcium content was observed in blanched, dried moringa leaves due to the concentration of nutrients during drying. The variation in iron and calcium content of dried moringa leaves might be due to the difference in blanching, drying, maturity of leaves and growing ecology (13). The higher nutrient contents were recorded in blanched and shade-dried moringa leaves (20). The retention of calcium and iron was good in the dehydrated green leafy vegetable powder (21). The sensory evaluation showed that the treatments influenced the sensory quality of moringa leaves (Table 4). The sensory score was higher (8.8) in cabinet-dried moringa leaves (D_6), followed by D_3 cabinet-dried moringa leaves without blanching (8.3).

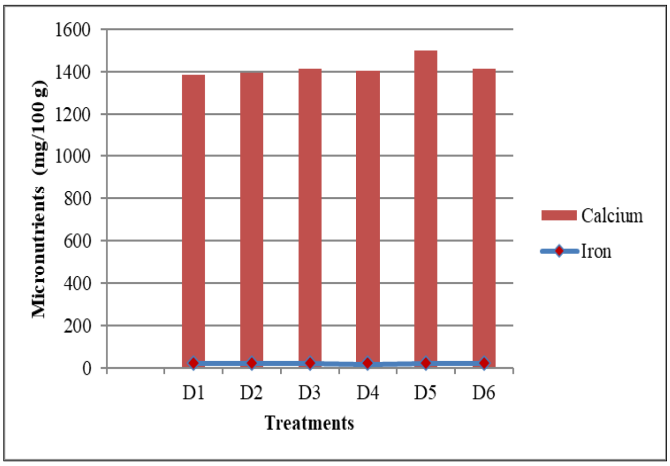

Fig. 2. Effect of drying methods on calcium and iron content in dried moringa leaves. The data presented as means of 5 replicates ±SE; CD(p=0.05)

Table 3. Effect of drying methods on moisture content, drying ratio, rehydration ratio, total carotenoids, ascorbic acid and non-enzymatic browning of dried moringa leaves

Treatments	Moisture content (%)	Drying ratio	Rehydration ratio	Total carotenoids (mg/100 g)	Ascorbic acid (mg/100 g)	Non- enzymatic browning (OD)
D_1	4.52^a	5.50^a	1.89^a	23.05^a	43.25^a	2.25^a
D_2	4.62^a	5.12^b	1.92^a	23.61^a	62.27^b	2.05^b
D_3	4.75^a	5.50^a	1.93^a	23.32^a	53.45^b	1.75^b
D_4	4.65^a	5.37^a	1.88^a	22.32^b	54.75^b	1.80^b
D_5	4.75^a	5.25^b	1.90^a	24.40^b	63.53^b	1.72^b
D_6	5.12^a	4.90^b	1.92^a	24.65^b	67.25^b	1.03^b
CD (0.05)	0.59	0.23	0.04	1.18	6.02	0.07
SEd	0.24	0.11	0.02	0.58	3.09	0.03

D_1:Control (Without blanching) + Sun drying, D_2:Control (Without blanching) + Shade drying, D_3: Control (Without blanching) + Cabinet drying, D_4: Water blanching (50 °C for 3 min) + Sun drying, D_5:Water blanching (50 °C for 3 min) + Shade drying, D_6:Water blanching (50 °C for 3 min) + cabinet drying.

Table 4. Sensory evaluation of moringa soup made from dried moringa leaves

Treatments	Colour	Flavour	Taste	Consistency	Overall Sensory score
D_1	7.0	7.0	7.0	7.0	7.0
D_2	8.0	7.5	7.5	7.5	7.6
D_3	8.0	8.0	8.0	8.0	8.2
D_4	8.0	7.0	8.0	8.0	7.7
D_5	8.5	8.1	8.5	8.5	8.4
D_6	9.0	8.5	9.0	9.0	8.8
Mean	8.1	7.7	8.0	8.0	8.0

D_1:Control (Without blanching) + Sun drying, D_2:Control (Without blanching) + Shade drying, D_3: Control (Without blanching) + Cabinet drying,D_4: Water blanching (50 °C for 3 min) + Sun drying, D_5:Water blanching (50 °C for 3 min) + Shade drying, D_6:Water blanching (50 °C for 3 min) + cabinet drying.

Conclusion

The effect of the blanching temperature and drying methods led to variations in the retention of nutrients and colour of the dried moringa leaves. Water blanching at 50 °C for 3 min, followed by cabinet drying, retained nutritional and sensory quality in dehydrated moringa leaves better.

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Authors' contributions

RN carried out all the treatment works, contributed to interpreting the results, and drafted the manuscript. CI contributed to the manuscript correction. AT contributed to the manuscript correction. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

While preparing this work, the authors used Chatgpt–4 to improve their language skills. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

References

1. Samsai T. A study on moringa production and marketing in the southern region of Tamil Nadu. Pharma Innov. 2023;12(11):1947–52.
2. Farooq F, Rai M, Tiwari A, Khan AA, Farooq S. Medicinal properties of *Moringa oleifera*: An overview of promising healer. J Med Plant Res. 2012;6(27):4368–74. https://doi.org/10.5897/jmpr12.279
3. Chandramouli P, Divya VS, Bharathi, Sivakami A, Bharathiraja B, Jayamuthunagai J. Standardisation and nutritional analysis of soup powder prepared from *Moringa oleifera, Solanum trilobatum* and *Centella asiatica*. Int J Future Biotechnol. 2012;1(1):1–16.
4. Indriasari Y, Wignyanto W, Sri Kumalaningsih. Effect of blanching on saponins and nutritional content of moringa leaves extract. J Food Res. 2016;5(3):55–60. https://doi.org/10.5539/jfr.v5n3p55
5. Neelavathi R, Pal RK, Sangita Sen, Kumar P. Effect of blanching on the quality of dehydrated cauliflower. Ind J Hortic. 2013;70(2):313–17.
6. Wickramasinghe YWH, Wickramasinghe I, Wijesekara I. Effect of steam blanching, dehydration temperature and time, on the sensory and nutritional properties of a herbal tea developed from *Moringa oleifera* leaves. Int J Food Sci. 2020;1:5376280. https://doi.org/10.1155/2020/5376280
7. Mutiara KT, Estiasih HT, Endang S. Effect of blanching treatments against protein content and amino acid drumstick leaves (*Moringa oleifera*). J Food Res. 2013;2(1):101–08. https://doi.org/10.5539/jfr.v2n1p101
8. AOAC.Official methods of analysis of the association of official analytical chemists. Association of Official Analytical Chemists: AOAC; 2016
9. Ranganna S. Handbook of analysis and quality control for fruits and vegetable products. New Delhi: McGraw Hill Education (India) Ltd; 2014
10. Amerine MA, Pangborn RM, Roessler EB. Principles of sensory evaluation of food. In: Food science technology. New York: Academic Press; 1965
11. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. Fourth Enlarged Edition, New Delhi ICAR publications; 1985
12. Mulay SV, Pawar VN, Thorat SS, Ghatge UM, Ingle UM. Effect of pretreatments on quality of dehydrated cabbage. Indian Food Packer. 1994;48:11–13.
13. Bikila AM, Tola Y, Eshi TB, Forsido SF. Effect of pre-drying treatment and drying temperature on proximate composition, mineral contents and thermophysical properties of anchote (*Coccinia abyssinica* (Lam.) Cogn.) flour. Food Sci Nutr. 2020;8(10):5532–44. https://doi.org/10.1002/fsn3.1860
14. Ali MA, Yusof YA, Chin NL, Ibrahim MN. Processing of moringa leaves and natural source of nutrients by optimization of drying and grinding mechanism. J Food Process Eng. 2017;40(6):e12583. https://doi.org/10.1111/jfpe.12583
15. Subadra S, Monica J, Dhabhai D. Retention and storage stability of beta-carotene in dehydrated drumstick leaves (*Moringa oleifera*). Int J Food Sci Nutr 1997;48(6):373–79. https://doi.org/10.3109/09637489709028585
16. Negi PS, Roy SK. Effect of drying conditions on quality of green leaves during long term storage. Food Res Int. 2001;34(4):283–87. https://doi.org/10.1016/S0963-9969(00)00165-4
17. Bharati B, Asha A. Effect of drying on iron and vitamin C content of selected vegetables. Food Sci Res J. 2010;1(2):157–61.
18. Buchaillot A, Caffin N, Bhandari B. Drying of lemon myrtle (*Backhousia citriodora*) leaves: retention of volatiles colour. Dry Technol. 2009;27(3):445–50. https://doi.org/10.1080/07373930802683740
19. Gothwal PP, Setty RG, Mookerji KK. Effect of processing steps for dehydration of mango, pineapple, carrot and drumstick on the retention of nutrients. Beverage and Food World. 1998;25(4):31–35.
20. Parvathi S, Nithya M, Priya DJ, Yogeshwari R. Effects of different drying methods and value addition of versatile food mix with moringa dry leaves. Int J Home Sci Extension Comm Management. 2015;2(1):8–12. https://doi.org/10.15740/HAS/IJHSECM/2.1/8-12
21. Lakshmi B, Vimala V. Nutritive value of dehydrated green leafy vegetable powders. J Food Sci Technol. 2000;37(5):465–79.