Journal of Applied Horticulture, 28(3): 715-721, 2026
https://doi.org/10.37855/jah.2026.v28i03.109
Journal of Applied Horticulture
ISSN: 0972-1045

Effect of blanching on quality and shelf life of minimally processed moringa pulp shreds

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Abstract

Moringa (*Moringa oleifera* L.) is known as the "Miracle tree" for its medicinal and healing properties. It is a popular summer vegetable, adding distinct flavor and aroma to cuisine. However, during the off-season, its availability to consumers is low, driving up the price. Even though a few value-added products are available in the market in dry form, *i.e.*, powder, flakes, dried pods, etc., the availability of fresh, minimally processed moringa pulp shreds in the market is negligible. Utilization of simple and environmentally friendly preservation techniques such as blanching and refrigeration without chemical preservatives has not been evaluated for minimally processed moringa pulp shreds. In this study, freshly extracted moringa pulp shreds were blanched at 95°C for different durations, *i.e.*, 5 min (T1), 8 min (T2), 10 min (T3) and 12 min (T4), with non-blanched pulp as the control (T0), stored for 16 days under refrigeration and 2 days at room temperature, and evaluated for different nutrient and biochemical parameters at regular intervals. The results revealed that the moringa pulp shreds blanched at 95°C for 5 min (T1) retained higher TSS (8.66°B), total antioxidant capacity (76.84 mg/mL), total phenols (45.58 mg of gallic acid/mL), total flavonoids (6.15 mg of quercetin per mL), glucose (8.73°B) and vitamin C (16.97 mg/100 g), with a lower browning index (0.41). The blanched moringa pulp shreds could be stored in good condition for 16 days under refrigeration (4–7°C), followed by 2 days at room temperature (30 ± 4°C), with a low microbial count and good sensory attributes. Hence, minimally processed, blanched moringa pulp shreds can be utilised for ready-to-eat mixes, curry mixes, dried moringa pulp shreds, etc.

Key words: Nutrition, antioxidants, value-addition, minimally processed, browning

Introduction

The moringa plant, *Moringa oleifera* L., belongs to the family Moringaceae and is a promising food source known as the "Miracle Tree". It is cultivated all over the Indian subcontinent for its tender pods, leaves, and flowers, and almost every part of the plant is of value for food and medicine (Rani, 2021; Sandeep *et al*., 2023). The tree parts, such as tender pods and leaves, are used as a popular summer vegetable (culinary preparations) and are known for their distinct flavor and aroma (Indira and Peter, 1988). Moringa flowers have a wide range of medicinal properties, including curing inflammation and swelling and promoting milk production in nursing mothers. The moringa pods were used as medicine for diabetes, asthma, HIV, kidney stones, obesity, and other ailments (Gopalakrishnan, 2016). India is the largest producer of moringa pods, producing 2.2 million tons of tender fruits annually from an area of 43,600 hectares, resulting in a productivity of around 51 tons per ha. Andhra Pradesh leads in both area and production (15,665 ha), followed by Tamil Nadu (13,042 ha) and Karnataka (10,280 ha) (Sekhar, 2018). Driven by urban expansion and a heightened focus on managing lifestyle ailments, the market for moringa pods has seen significant growth. A survey by Market Research Future® (MRFR) predicted that by 2025, the worldwide demand for moringa products would be worth USD 7902.9 million, or 9.3 per cent of the total. In India, by 2025, the value of the global market for moringa products is likely to reach USD 10 billion, growing at a compound annual growth rate of 8.9% between 2019-25 (APEDA). It was anticipated that the moringa industry would expand dramatically worldwide. In the off-season, the surplus of moringa creates high demand in both local and international markets. About one-fourth of all moringa products harvested are thought to deteriorate before being eaten (Shunmugapriya, 2019). The only way to make use of this commodity is through the commercialization of various value-added moringa products. The pulp of the moringa pod is highly valued and is the most delicious part of the moringa plant. The scarcity of moringa pulp preservation techniques makes marketing and availability difficult both locally and internationally.

Preservation techniques such as chemical, thermal, biological, etc., help in the preservation of food. Among them, blanching is a thermal technique involving a low-temperature heat treatment used to denature enzymes in solid vegetables and fruit before freezing, drying or canning (Sahoo, 2022). Blanching also helps to preserve food color and is usually performed at atmospheric pressure using steam or hot water at temperatures ranging from 90 to 95°C for around 1 or 2 min (Smith and Smith, 2011). To retain the quality of the product, thermal blanching was frequently used before processing the product. Its main objectives are to inactivate the microbes and enzymes that cause deterioration and remove intracellular air to stop the oxidation of fresh/processed horticultural products (Deng *et al.,* 2019). Blanching has been used as a successful technique for preserving processed foods such as frozen peas (Lin and Brewer, 2005), potato (Mowafy and Liu, 2024), kale and spinach (Mugo *et al.,* 2024), leeks and Brussels sprouts (Vancoillie *et al.,* 2024), orange and lemon

(Ozdemirli and Kamiloglu, 2015) and yellow peaches (Xian *et al.,* 2024) for short periods.

Although it is a simple technique, blanching has not been studied for its influence on the quality and shelf-life of moringa pulp shreds. There is a great deal of scope for the value addition of moringa pulp in terms of developing value-added products while considering the health prospects of the moringa pulp and its market demand. The main obstacle facing the processed food sector is the creation of food items that meet customer requirements. Blanched moringa pulp shreds would become a raw material directly/indirectly in the preparation of value-added products such as ready-to-eat mix, curry mix, dried moringa pulp shreds, etc. This may help in creating a healthy lifestyle for the urban population where there are rapid shifts in the socio-economic landscape and food consumption. Also, processing and selling convenience foods would benefit entrepreneurs and farmers economically.

Materials and methods

Plant material: Freshly harvested moringa pods of the cultivar 'Andipatti' were collected from local fields in Tiruvarur, Tamil Nadu. The research was carried out in the Postharvest Technology Lab, Department of Horticulture, Central University of Tamil Nadu, Thiruvarur, TN, India (latitude: 10.8119244, longitude: 79.6154067).

Sample preparation and treatment details: The collected pods were washed with running water to remove adhering materials and shade-dried under a fan. The pods were cut into 3 pieces and blanched as follows. The water bath (model number ATI-134, Kanak Dhara Biotech Pvt. Ltd., Delhi) was pre-heated to 95°C, and the moringa pods were blanched at 95°C for different durations, *i.e.*, 5 min (T1), 8 min (T2), 10 min (T3) and 12 min (T4), with non-blanched pulp as the control (T0). The pulp shreds were extracted from each treated moringa pod using a clean scraper, with an average weight of 150 g per replication. The pulp shreds were transferred to sterilised PET bottles (150 g capacity) and stored for 16 days under refrigeration (4–7°C), followed by 2 days at room temperature (30 ± 4°C), simulating cold chain distribution followed by consumer handling at home. Biochemical quality parameters were evaluated at regular intervals.

TSS and glucose (°Brix): Moringa pulp shreds (1 g) were crushed using a pestle and mortar and squeezed through a muslin cloth. A drop of the filtrate was placed on the digital refractometer (HI96801, Hanna Instruments, Romania), and TSS and glucose readings were taken and expressed in °B.

Total phenols (mg/mL): The total phenol content of pre-treated moringa shreds was estimated by the Folin-Ciocalteu assay described by Singleton and Rossi (1965), with slight modifications. A methanol extract of moringa shreds was prepared by taking 1 g of moringa shreds and grinding them with 80% methanol in a pestle and mortar. The ground pulp liquid was centrifuged (5418R type, Eppendorf AG, Germany) at room temperature (27°C) at 10,000 rpm. The supernatant was collected and used for the phenol assay. A standard graph was prepared using gallic acid as the standard. Different concentrations of gallic acid (1 mg/mL) were used to prepare the standard graph. In a test tube, 0.5 mL of the methanol extract sample was mixed with 0.2 mL of Folin-Ciocalteu reagent (1 N), followed by 3.25 mL of distilled water and 1 mL of sodium carbonate (20%). The sample was incubated at room temperature for half an hour. After yellow color formation, the reading was taken using a UV spectrophotometer (Genesys^{TM}180, USA) at 700 nm.

Total flavonoids (mg/mL): The total flavonoid content of treated moringa shreds was estimated using the aluminum chloride colorimetric technique and reported as quercetin equivalents (QE) per gram of moringa pulp. The standard was prepared using quercetin in methanol at various concentrations (1 mg/mL). A methanol extract of moringa shreds was prepared by taking 1 g of moringa shreds and grinding them with 80% methanol in a pestle and mortar. The ground pulp liquid was centrifuged at room temperature (27°C) at 10,000 rpm, and the supernatant was collected for the assay. In a test tube, 1 mL of the sample methanol extract was mixed with 1.5 mL of methanol, 0.1 mL of 10% aluminum chloride, 0.1 mL of 1 M sodium acetate and 2.8 mL of distilled water. The mixture was incubated at room temperature for 30 min, and the optical density was then measured at 415 nm using a UV spectrophotometer (Genesys^{TM}180, USA) (Liaqat *et al.,* 2021).

Total antioxidant capacity (mg/mL): The total antioxidant capacity of moringa shreds was estimated by the Ferric Reducing Antioxidant Power (FRAP) assay as described by Rama Krishna *et al.* (2020), with slight modifications. The FRAP reagent was prepared in a 10:1:1 ratio using the following chemicals: 300 mM acetate buffer (pH 3.6), 10 mM TPTZ (2,4,6-tripyridyl-s-triazine) solution in 40 mM hydrochloric acid and 20 mM iron(III) chloride. Different concentrations of ascorbic acid (1 mg/mL) were used as a standard positive control. In a test tube, 0.5 mL of the methanol sample was mixed with 1.8 mL of FRAP reagent and 1.2 mL of distilled water. The mixture was incubated at room temperature for 30 min, and the developed blue color was measured at 593 nm using a UV spectrophotometer.

Browning index: The browning index of the moringa shred samples was determined by blanching moringa shreds (5.0 g) with 80% methanol (20.0 mL) at room temperature (30 ± 1°C) for 30 min, with occasional stirring at 5 min intervals, under dark conditions. The clear filtered supernatant was obtained by centrifugation to remove turbidity (Remi, CPR24 Plus, India) at 8,000 rpm for 10 min. The optical density of the colored filtered supernatant was immediately measured at 420 nm against a distilled water blank using a UV–Vis spectrophotometer (Joshi and Mehta, 2010).

Vitamin C (mg/mL): Ascorbic acid was estimated by the volumetric method described by Sadasivam and Balasubramanian (1987) and Ananth *et al*. (2025).

Microbial count: According to the U.S. Food and Drug Administration (2021), the standard total plate count of samples was determined with reference to Chapter 3, Aerobic Plate Count, of the Bacteriological Analytical Manual by Maturin and Peeler (2001), with slight modifications. The dilution buffer, Butterfield's phosphate-buffered solution, was prepared by dissolving 34 g of KH_2PO_4 in 500 mL of distilled water and making the volume up to one litre after adjusting the pH to 7.2 using 1 N NaOH. After sterilisation of the buffer solution at 121°C for 15 min, dilution blanks were prepared as 90 ± 1 mL. Dilution factors of 10^{-4} and 10^{-5} were prepared using the serial dilution method. The Petri plates were marked according to the sample, followed by the addition of 12–15 mL of plate count agar at 45 ± 1°C to each Petri plate, with an agar control plate and a water dilution control plate for each series of samples. The diluted sample and

agar were mixed uniformly using a back-and-forth motion. After solidification, the plates were inverted and incubated at 35°C for 48 ± 2 h. The total plate count (TPC) was determined using a colony counter.

Organoleptic evaluation: The organoleptic evaluation was performed with the help of 20 untrained and 10 semi-trained panellists using a 9-point hedonic scale. Each panellist was asked to rate the sensory attributes of the blanched moringa pulp shreds, such as color, firmness, odour, appearance and overall acceptability, on day 18 (16 + 2 days) (Liaqat *et al.,* 2021).

Statistical analysis: Each treatment was replicated 4 times, with 150 g per replication, and observations were recorded at regular intervals. Statistical analysis of the data was performed using the SPSS Statistics 17.0 software package (SPSS Inc., USA). Mean differences were compared using Duncan's multiple range test at $P \leq 0.05$. The significance of differences among the treatments was determined using one-way analysis of variance (ANOVA). In the figures, different letters indicate significant differences according to DMRT at $P \leq 0.05$. The error bars in the figures indicate standard deviation (SD).

Results and discussion

TSS and glucose: The TSS of all the moringa pulp shreds blanched for different durations decreased until the 16th day of refrigerated storage (4–7°C), followed by an increase in TSS on the 18th day, *i.e.*, after 2 days at room temperature, irrespective of treatment (Fig. 1). No significant difference in glucose levels was observed among the treatments, including the control, on the 16th day. However, on the 18th day, the control (T0) recorded lower glucose (7.86°B) than the blanched treatments (Fig. 2). The TSS of the moringa pulp shreds was influenced by the blanching time in all treatments. The TSS of moringa pulp blanched for 12 min (T4) (8.90°B) was significantly higher, followed by pulp blanched for 5 min (T1) and the control (T0) (8.36 and 8.30, respectively), on the 16th day of storage. Lower TSS was recorded for blanching periods of 8 min (T2) and 10 min (T3). On the 18th day, significantly lower TSS was recorded for a blanching period of 5 min (T1) (8.66°B), whereas all other treatments showed an increase in TSS. The reduction in TSS levels during refrigerated storage for 16 days could be due to the utilisation of sugars for the metabolic and repair activities of moringa pulp shreds. However, an increase in TSS during storage at room temperature might be due to the hydrolysis of insoluble starch into soluble sugars by enzymes or microbes. The present total microbial analysis also supports the increase

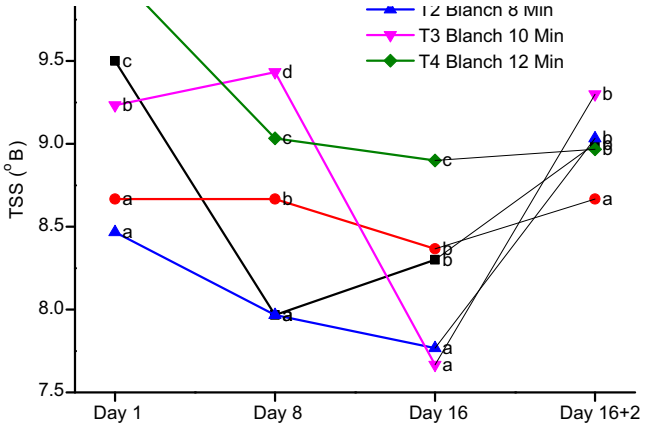


Fig. 1. Influence of blanching duration on TSS of moringa pulp shreds

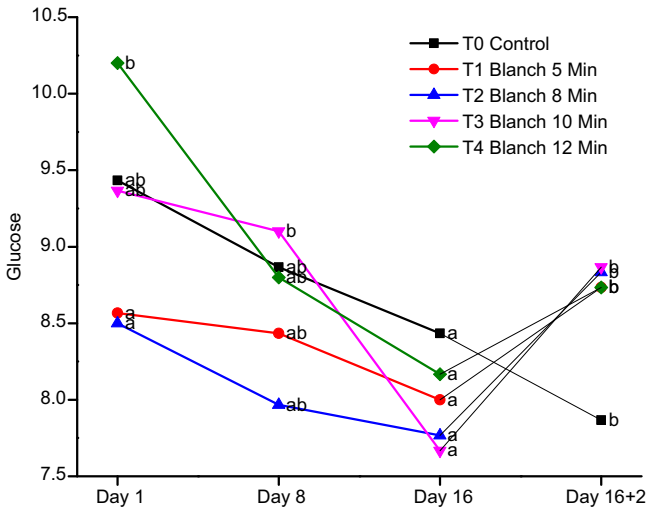


Fig. 2. Effect of blanching duration on glucose of moringa pulp shreds

in TSS due to the conversion and utilization of sugars at room temperature, or it may be due to the breakdown of complex sugars through catabolic enzymatic reactions that could have been activated during storage at room temperature (Nath *et al.,* 2013; Sharma *et al.,* 2015). The lower glucose levels in the control on the 18th day at room temperature might be due to the rapid utilisation of readily available simple sugars (glucose) for metabolic activity (Clemens *et al.,* 2016; Septembre-Malaterre *et al.,* 2018).

Vitamin C: During storage at both refrigeration temperature (16th day) and room temperature (18th day), higher vitamin C content was recorded in the control (29.06, 22.04), followed by T1 (22.04, 16.97) and T2 (28.00, 15.94), respectively, as shown in Fig. 3. As vitamin C is a heat-sensitive biomolecule, the reduction in all the blanched treatments was obvious, but among the treatments, T1 and T2 recorded higher retention of vitamin C. The reduction in vitamin C during storage might be due to its utilisation as an antioxidant to combat the free radicals produced by heat treatment (Giannakourou *et al.,* 2021; Mieszczakowska-Frąc *et al.,* 2021). Blanching of moringa shreds led to a loss of vitamin C. A similar loss was reported in tomatoes blanched at 88°C, which showed a decreasing trend in vitamin C as heating time increased (Wagner *et al.,* 1947). Similar results have also been reported in green leafy vegetables (Sikora *et al.,* 2008),

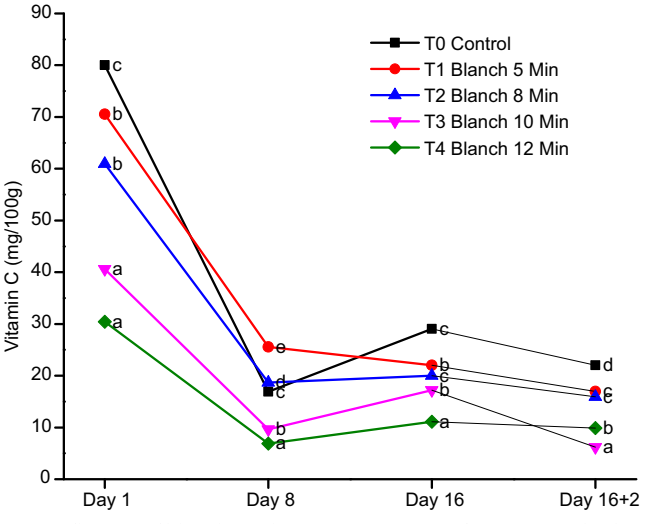


Fig. 3. Influence of blanching duration vitamin C of moringa pulp shreds

broccoli (Septembre-Malaterre *et al.,* 2018), kale and spinach (Mugo *et al.,* 2021), carrots and green beans (Patras *et al.,* 2011).

Total phenols, antioxidants and flavonoids: Irrespective of the treatment, the total phenols, antioxidants and flavonoids of the blanched moringa pulp shreds decreased during storage. The results depicted in Fig. 4 show that on the 16th day (48.76) and the 18th day (45.58) of storage, moringa pulp blanched for 5 min showed significantly greater retention of phenolic content than the other treatments. Similar results were also obtained for total antioxidant capacity: moringa pulp shreds blanched for 5 min (T1) had higher values on the 16th day (91.50) and the 18th day (76.84) than the control and other treatments (Fig. 5). The flavonoid content of the moringa pulp shreds showed no significant difference between the control and blanched treatments at the end of storage. However, there was a drastic reduction in the flavonoid content of the control (unblanched) by the end of storage compared with day one (Fig. 6). Up to the last day of refrigerated storage, there was a decreasing trend in total phenols, antioxidants and flavonoids; however, T1 showed the highest retention of phenolic and antioxidant content. This may be attributed to the reduction of native polyphenol oxidase activity, *i.e.*, enzyme-mediated polyphenol degradation, during blanching (Bamidele *et al.,* 2017). In other treatments, which were blanched at a higher temperature, the reduction in phenolic content might

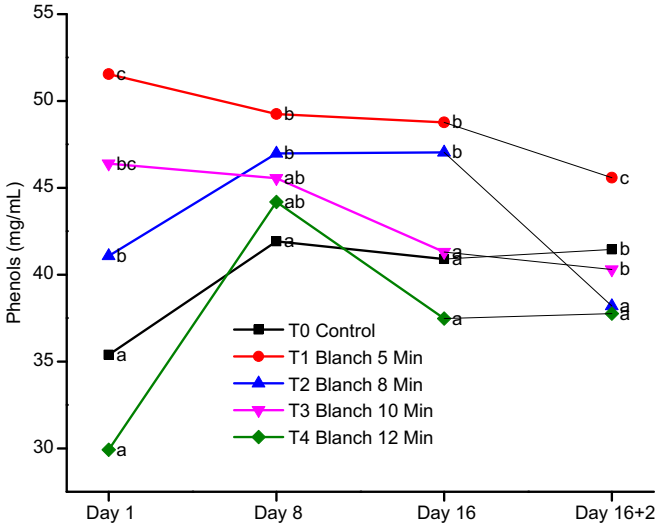


Fig. 4. Phenolic content of moringa pulp shreds after blanching

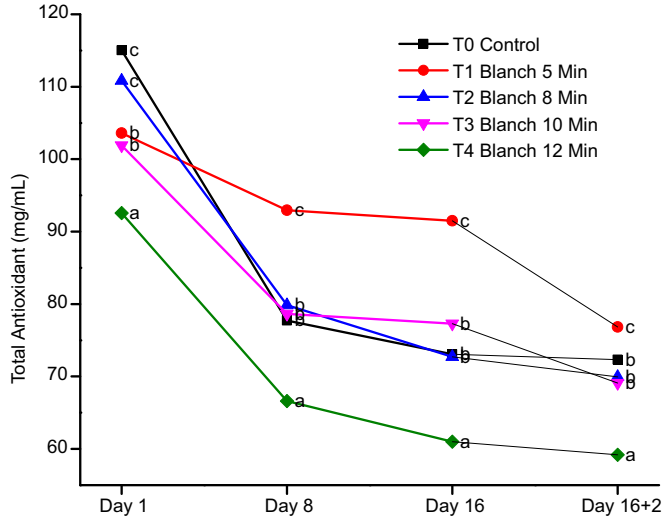


Fig. 5. Antioxidant activity of blanched moringa pulp shreds

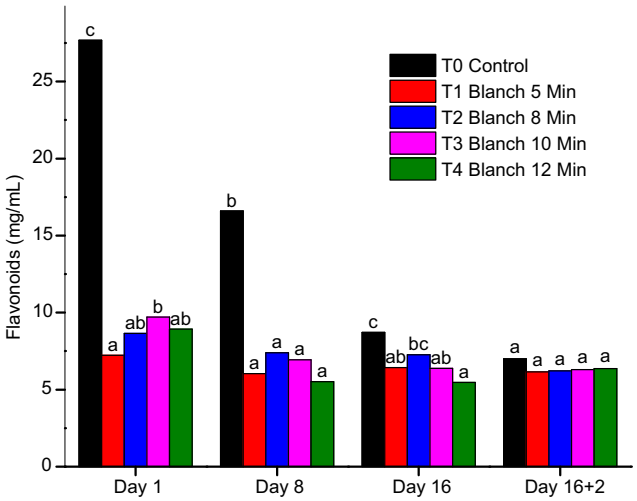


Fig. 6. Effect of blanching duration on flavonoids of moringa pulp shreds

be due to sensitivity to heat or the leaching of phenols into the blanching water through disruption of the cell wall (Francisco *et al.,* 2010). Similar reductions in phenolic compounds were reported in *Adansonia digitata* (Irondi *et al.,* 2017), cauliflower (Ahmed and Ali, 2013), cruciferous vegetables (Ismail *et al.,* 2004), squash, leek and peas (Turkmen *et al.,* 2022), and Brussels sprouts (Hwang, 2017). Also, antioxidant radical scavenging activity might have decreased with an increase in blanching duration. A similar trend of decreased radical scavenging power was reported in cruciferous vegetables (Sikora *et al.,* 2008). Flavonoids also contribute to the antioxidant capacity of the plant. They are also very important in giving a particular vegetable its characteristic aroma. There was a reduction in the flavonoid content of both the blanched moringa pulp shreds and the control. This might be due to the loss or structural degradation of flavonoids (quercetin, isorhamnetin, apigenin and kaempferol) during blanching (Limbaga and Castillo-Israel, 2020). In the control, the drastic reduction in flavonoid content could be due to the utilisation of flavonoid compounds as antioxidants for scavenging free radicals or for repair following cutting. A similar reduction in flavonoids during blanching was found in sweet potato leaves (Chu *et al.,* 2000).

Browning index: The browning index revealed discoloration of the pulp during storage. In the present study, Fig. 7 shows that a longer blanching duration caused greater discoloration (browning index). Among the treatments, moringa pulp shreds blanched for 5 min (T1) (0.41) had a lower browning index than the control (T0) (0.63) and other treatments at the end of storage, *i.e.*, on the 18th day at room temperature. This could be because the shorter blanching time inactivated polyphenol oxidase, an enzyme that causes discoloration of the pulp (Ndiaye *et al.,* 2009; Adetoro *et al.,* 2020). However, an increase in blanching duration might have led to disintegration of the cell structure, resulting in electrolyte leakage and oxidative discoloration (Queiroz *et al.,* 2008). In the control, *i.e.*, unblanched moringa pulp shreds, the cut surface was freely exposed to oxidation, and the lack of inactivation of polyphenol oxidase could have led to a higher browning index. This is supported by results obtained in radish (Goyeneche *et al.,* 2013), sweet potato (Manohan and Wai, 2012), mango (Ndiaye *et al.,* 2009) and pomegranate (Adetoro *et al.,* 2020).

Microbial count: The total microbial population in minimally processed foods is a critical factor that determines product safety and quality. During food processing, contamination of stored products might occur, which may lead to spoilage. Therefore,

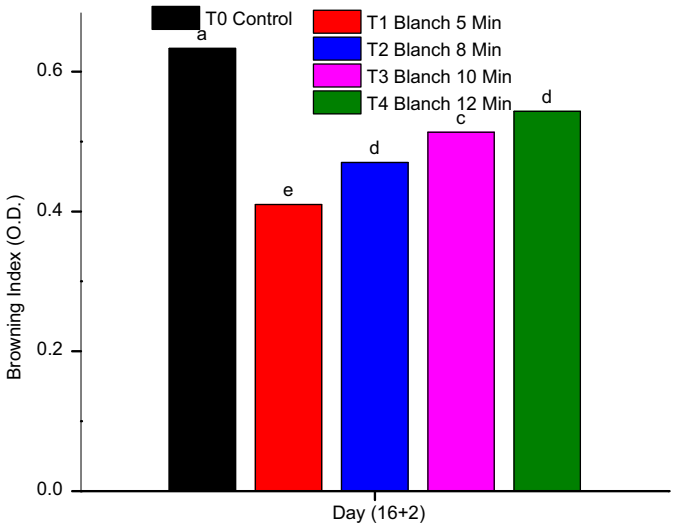


Fig. 7. Browning index of moringa pulp shreds after blanching duration

assessment of the total microbial population is a mandatory step in creating a new product line. Microbial analysis of blanched moringa shreds was carried out using the total plate count method on the 18th day. The results showed that the total microbial count was low in T1 (0.3 cfu/g), followed by T2 (0.5 cfu/g), compared with the control (0.7 cfu/g) (Fig. 8). Generally, heat treatment causes both enzyme inactivation and microorganism deactivation. This compound could have been utilized by microorganisms as a substrate for growth during storage. In this study, the longer blanching duration led to the liberation of intercellular matrices, such as sugar compounds, due to disintegration of the cell wall. The shorter blanching duration (5 min) may have maintained cell integrity, thereby restricting microbial growth. Low-temperature storage (4–7°C) could also have simultaneously delayed the growth of microorganisms. In support of the present finding, similarly low microbial growth was observed in blanched cowpea for up to 8 days of refrigerated storage (Tavares *et al.,* 2022).

Organoleptic evaluation: The sensory scores of blanched moringa shreds on the last day of storage showed that T1 had the highest scores for taste (8.22), flavour (7.5), texture (7.56) and colour (7.89) compared with the other treatments, as shown in Fig. 9 and Fig. 10. This might be due to several factors synergistically affecting the sensory attributes of moringa pulp shreds. Blanching could have led to uniform colour maintenance; similar findings were reported in whole yacon tubers (Limbaga and Castillo-Israel,

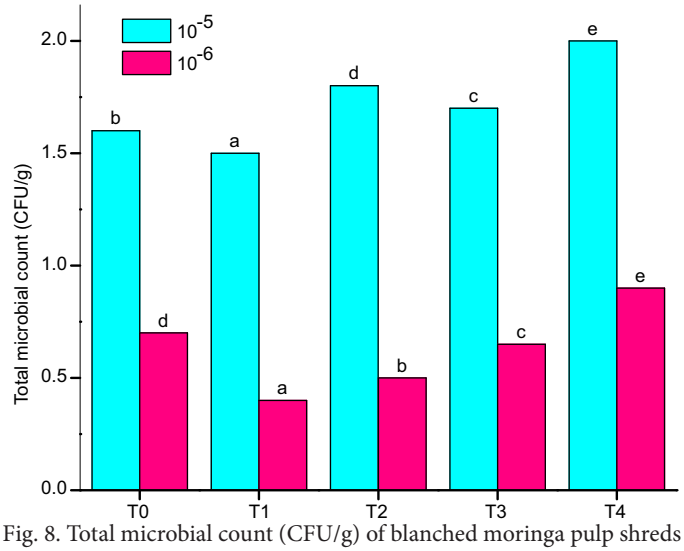


Fig. 8. Total microbial count (CFU/g) of blanched moringa pulp shreds

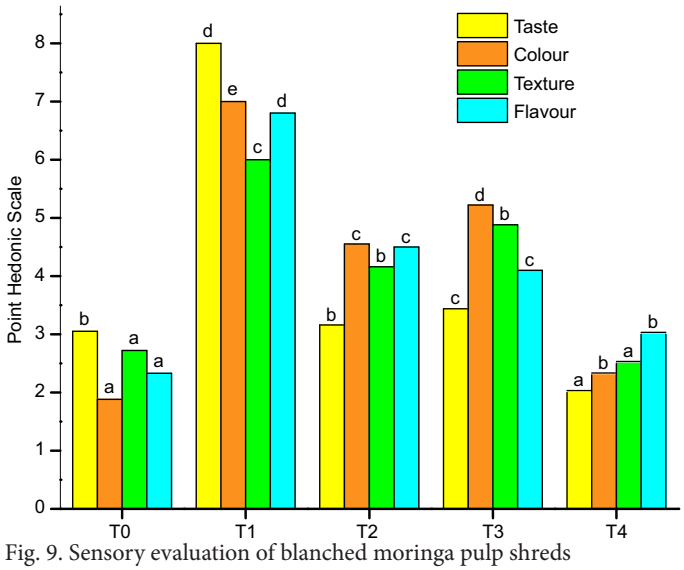


Fig. 9. Sensory evaluation of blanched moringa pulp shreds

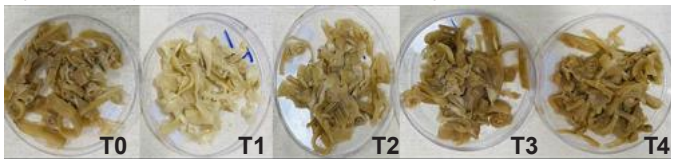


Fig. 10. Blanching duration influence on moringa pulp shreds

2020). A shorter blanching duration (5 min) could also have maintained higher cell integrity, with starch gelatinisation and cell wall rupture due to degradation of pectic substances, thereby resulting in a higher texture score (Singh and Ramaswamy, 2023). Blanching and storage at low temperatures could have released flavonoids slowly and maintained the texture, giving a better mouthfeel to the panellists. Overall, moringa pulp shreds blanched at 95°C for 5 min and stored at a low temperature (4–7°C) had better consumer acceptance (Richter, 2017; Agiriga *et al.,* 2015).

Moringa tree pods have been used as medicine for diabetes, asthma, HIV, kidney stones, obesity and other ailments, and have high national and international demand. This demand is reflected in the projected growth of their value-added products. The pulp, being the most delicious part of the moringa pod, also has high demand for domestic consumption and in the growing food and pharmaceutical industries. From the present study, it can be concluded that moringa pulp shreds blanched at 95°C for 5 min retained higher nutrient levels and biochemical attributes. The blanched moringa pulp shreds could be stored in good condition for 16 days under refrigeration (4–7°C), followed by 2 days at room temperature (30 ± 4°C), with a low microbial count and good sensory attributes. These minimally processed, blanched moringa shreds can be utilised for ready-to-eat mixes, curry mixes, dried moringa pulp shreds, etc. The availability of moringa pulp shreds during the off-season will benefit the urban population in the context of changing food habits, while processing and selling convenience foods will also benefit entrepreneurs and farmers economically.

Acknowledgements

The authors thank Dr. I. Arumuka Pravin (Plant Pathologist), Research Associate, Department of Horticulture, and Mr. Abishek (Ph.D. Scholar, Microbiology), Department of Microbiology, Central University of Tamil Nadu, for their assistance during the work.

Author contribution statement: MCD conducted the experiments and drafted the manuscript; KRK conceived the original research plan, designed the experiments, supervised the research and edited the manuscript; SSV analyzed the data and helped edit the manuscript; ARK facilitated and helped design the plan.

Funding Statement: This research received no specific grant from any funding agency in the public, commercial, or nonprofit sectors.

Conflict of interest: The authors declare that they do not have any conflicts of interest.

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Received: May, 2026; Revised: June, 2026; Accepted: July, 2026