# Exploring the Effects of Pre-treatments on the Quality and Shelf Life Attributes of Karonda (*Carissa carandas* L.) Fruit Powder

T. Lavanya[1], S. Parameshwari[1]

**10.18805/ajdfr.DR-2341**


## ABSTRACT

**Background:** Karonda (*Carissa carandas*) is valued for its nutritional and medicinal properties, but has a shorter shelf life. Therefore, this study aimed to enhance the functional qualities and extend the shelf life of Karonda fruits through the application of different pre-treatment methods prior to drying.

**Methods:** Mature green Karonda fruits were subjected to three different pre-treatments lemon immersion (LI), sugar immersion (SI) and honey immersion (HI) before being dehydrated in a cabinet tray dryer at 60°C. The dried fruits were then powdered, packed in polyethylene pouches and stored at -20°C for subsequent processes.

**Result:** The study demonstrated that Karonda fruit powder pre-treated with lemon immersion (LI) exhibited the most favourable results. Different pre-treatment methods significantly influenced the functional, physicochemical, colour, microstructural images (SEM), sensory and storage stability properties of the fruit powder. In terms of functional properties, lemon immersion enhanced the bulk density and foaming capacity of the powder, indicating improved structural and functional behaviour, despite slight reductions in water absorption capacity and swelling index. Among the physicochemical attributes, LI-treated samples showed the highest acidity, reduced water activity and lower sugar content. SI treated samples retained maximum colour values followed by LI, Control and HI samples. Sensory evaluation revealed that LI-treated powder received the highest overall acceptability scores from the panellists. Storage studies further indicated that lemon-immersed Karonda powder-maintained stability for up to six months, comparable to the untreated control. Overall, lemon immersion proved to be the most effective pre-treatment, significantly enhancing the quality, functionality and shelf life of Karonda fruit powder, making it suitable for potential commercial applications.


**Key words:** Karonda, Nutrients, Pre-treatments, Sensory, Shelf-life.

## INTRODUCTION

Karonda, scientifically named (*Carissa carandas* L.) is a resilient, perennial, neglected and thorny fruit shrub from the *Apocynaceae* family (Mahajan *et al.,* 2022) and Sawant *et al.,* 2018). According to Singh *et al.* (2020), the genus *Carissa* contains approximately twenty-five species, five of which are native to India. This species is primarily cultivated in various regions of India, mainly in Bihar, West Bengal, South India and the plains of Northern India (Singh and Saxena, 2020). It has the potential to significantly enhance food security, health and economic productivity (Meena *et al.,* 2020). The karonda fruit, a berry with multiple seeds, is generally round to broadly oblong in shape and grows in clusters of three to ten fruits (Hameed *et al.,* 2021). Each tree yields approximately 4 to 5 kilograms of berries and the fruit takes an average of 120 to 130 days to reach maturity. Karonda plants bloom during March and April, with their fruits ripening between June and September, depending on the variety (Meghwal *et al.,* 2022). Rich in vital nutrients and bioactive compounds, karonda fruit may help manage several health conditions, such as diabetes, cancer, obesity, constipation, anemia, wound healing and cardiovascular disease (Meichander *et al.,* 2024 and Misra *et al.,* 2016). However, due to its high moisture content, it is highly perishable. Storage and processing conditions significantly affect the stability, preservation and bioavailability of its nutrients and phytonutrients (Tomer and Kumar, 2024).

A major challenge with karonda fruit (Fig 1) is its rapid deterioration after harvest due to its high moisture content and delicate flesh. As a result, the postharvest shelf life of ripe fruit is limited to just two days, while that of unripe fruit extends to only five to seven days. Drying is widely recognized as one of the most efficient and cost-effective methods for fruit preservation, assisting to expand shelf life and ensure year-round availability (Mahajan *et al.,* 2022).

[1]Department of Nutrition and Dietetics, Periyar University, Salem-636 011, Tamil Nadu, India.

**Corresponding Author:** S. Parameshwari, Department of Nutrition and Dietetics, Periyar University, Salem-636 011, Tamil Nadu, India. Email: parameshwari@periyaruniversity.ac.in
ORCIDs: https://orcid.org/0009-0008-9372-613X, https://orcid.org/0000-0002-8053-9780

**How to cite this article:** Lavanya, T. and Parameshwari, S. (2025). Exploring the Effects of Pre-treatments on the Quality and Shelf Life Attributes of Karonda (*Carissa carandas* L.) Fruit Powder. *Asian Journal of Dairy and Food Research*. **44 (Special Issue):** 151-159. doi: 10.18805/ajdfr.DR-2341.

**Submitted:** 02-05-2025 **Accepted:** 22-07-2025 **Online:** 20-08-2025

The primary focus of the food industry is to preserve food products in a manner that ensures their safety, quality and shelf stability (Yadav and Singh, 2014). Consequently, pre-treatments have emerged as essential preservation techniques aimed at enhancing the organoleptic and nutritional qualities of food, while also improving its storage potential (Suhasini *et al.,* 2016 and Lydia and Osunde, 2017). Few studies have explored sugar and jaggery immersion as pre-treatment techniques before dehydration to ensure the quality of food products (Suhasini *et al.,* 2015). Moreover, no studies are currently available on the use of lemon juice and honey immersion as pre-treatment methods specifically for karonda fruits. Addressing this research gap is crucial for enhancing the nutritional quality of karonda and promoting overall nutritional security. This study introduces a novel approach by utilizing honey and lemon juice as osmotic pre-treatments for the dehydration of karonda fruits. The aim of the current study was to investigate the influence of various pre-treatments, including lemon, sugar and honey immersion, on the quality parameters and storage stability of dried karonda fruit powder.

## MATERIALS AND METHODS

### Preparation of raw materials

Mature green karonda fruits with a pink greenish (12 kg), along with other pre-treated ingredients including lemon, sugar and honey were procured from the local market in Salem district, Tamil Nadu, in the month of June for the study.

### Pre-treatment methods of karonda before dehydration

Fresh fruits, consistently sized and shaped, undamaged from transportation and bruise-free were chosen for further processing. The selected fruits were washed and sliced into four pieces using a stainless-steel knife. Once the seeds were removed, the fruits were divided into four equal portions for different pre-treatment methods with control. The karonda samples were split into 3 kg portions each and treated with sugar immersion, honey immersion and lemon immersion before drying; one sample remained untreated as a control.

### Lemon immersion (LI)

After preparing a lemon juice solution by mixing 1500 milliliters of lemon juice with 1500 milliliters of water (in a 1:1 ratio), the karonda slices were immersed in the solution for 15 minutes, according to Patel *et al.* (2019).

### Sugar immersion (SI)

The karonda slices were immersed in a 70-degree Brix sugar solution immediately after slicing and allowed to soak for 18 hours as described by Suhasini *et al.* (2016).

### Honey immersion (HI)

A honey immersion solution was prepared by mixing equal parts of honey and water and the fruit slices were immersed in the solution for 2 hours following the method of Roby *et al.* (2019).

### Dehydration of karonda slices

Once the dipping time was complete, the lemon, sugar and honey solutions were drained and the karonda slices were spread out on muslin cloth to remove excess moisture. The drying procedure was carried out at the Centre for post-harvest Technology Laboratory, TNAU, Coimbatore. Following the method described by Verma *et al.* (2023), karonda slices were dehydrated in a cabinet tray dryer at 60°C for three to four days. The fruits were heated and allowed to cool at room temperature. After cooling, the Karonda samples were ground into a powder, stored in airtight polyethylene bags and kept at -20°C for further analysis, following the procedure of Mahajan *et al.* (2022).

## RESULTS AND DISCUSSION

### Functional characteristics of karonda fruit powder

The functional characteristics of karonda powder are illustrated in (Table 1). Bulk density, an indicator of powder



**Fig 1:** Schematic diagram of mature Karonda fruits.

compactness, varied significantly among treatments. The lemon-immersed sample exhibited the highest bulk density (0.55 g/cm$^3$), likely attributable to structural compaction induced by acidic constituents. Conversely, sugar (0.31 g/cm$^3$) and honey (0.35 g/cm$^3$) pre-treatments resulted in notably lower bulk densities. The control sample displayed an intermediate bulk density (0.49 g/cm$^3$). When compared to previous studies, such as the 0.52 g/cm$^3$ bulk density of dried aonla fruit powder reported by Rathour *et al.* (2022), the present study demonstrates a lower bulk density for the karonda powder, except for the lemon immersion treatment. Honey immersion significantly increased the water absorption capacity (WAC) by 44.42%, which may be attributed to the high fructose content of honey, as reported by Anwar *et al.* (2025). The water absorption capacity (WAC) was further improved by sugar treatment, though to a lesser extent (34.44%). These results suggest that both treatments enhanced the hydrophilic properties of the matrix. In contrast, samples treated with LI and the control group exhibited lower WAC values (29.71% and 31.12%, respectively), indicating a relatively reduced moisture retention capacity. The WAC values observed in this study were significantly higher than those reported by Raju *et al.* (2023), who found that amla pomace powder had a WAC of only 12.30%. Additionally, oil absorption capacity (OAC) increased progressively across the treatments, rising from 22.36% in the control to 23.17%, 26.08% and 29.93% in the samples treated with lemon, sugar and honey, respectively. The improved OAC in the sugar- and honey-treated samples may be attributed to alterations in surface properties and increased structural porosity, which facilitated greater oil binding and retention. This is further underscored by Khatri and Jaiswal (2024), who reported an OAC of only 0.20 g/g (or 20%) for mulberry fruit juice powder, highlighting the comparatively higher values achieved in the present study. All treated samples exhibited a substantial decrease in swelling index compared to the control sample (2.08 mL/g). The lemon-treated sample showed the most pronounced reduction (0.67 mL/g), indicating a significantly diminished capacity to swell upon hydration. Samples treated with sugar and honey recorded slightly higher swelling indices (1.17 mL/g and 1.33 mL/g, respectively), though still lower than the untreated control. These values are considerably below the swelling index of 4.0 mL/g reported for *Carissa carandas* fruit powder by Singh *et al.* (2020). Conversely, all pre-treated samples demonstrated a slight increase in foaming index (1000/a), (333.30) compared to the control (310.19), with lemon, sugar and honey treatments yielding similar levels of improvement. This uniform enhancement suggests that the pre-treatments may have positively influenced protein surface activity or induced structural modifications in proteins, thereby promoting improved foam formation. The values of the pre-treated samples are similar to the foaming index value of 333 (1000/a) reported for the extract of fresh karonda fruits by Sharma *et al.* (2007).

**Physicochemical characteristics of karonda fruit powder**

Physicochemical attributes of dried karonda fruit powder outlined in (Table 2). The control sample displayed the

**Table 1:** Functional properties.

| Functional characteristics | Pre-treatments | | | |
|---|---|---|---|---|
| | Control | LI | SI | HI |
| Bulk density (g/cm$^3$) | 0.49±0.05$^b$ | 0.55±0.01$^c$ | 0.31±0.02$^a$ | 0.35±0.01$^a$ |
| Water absorption capacity (%) | 31.12±0.55$^a$ | 29.71±0.42$^a$ | 34.44±0.37$^b$ | 44.42±0.10$^c$ |
| Oil absorption capacity (%) | 22.36±0.18$^a$ | 23.17±0.33$^b$ | 26.08±0.15$^c$ | 29.93±0.36$^d$ |
| Swelling index (mL/g) | 2.08±0.03$^d$ | 0.67±0.01$^c$ | 1.17±0.02$^a$ | 1.33±0.01$^a$ |
| Foaming index (1000/a) | 310.19±0.06$^a$ | 333.30±0.00$^b$ | 333.30±0.00$^b$ | 333.30±0.00$^b$ |

(a-d) Different letters on the same line indicate significant differences (n=3) according to Duncan's test ($p<0.01$). (Control) -Without pre-treatment; (LI)-Lemon immersion; (SI)-Sugar immersion; (HI)-Honey immersion.

**Table 2:** Physicochemical analysis of dried karonda fruits.

| Physicochemical properties | Pre-treatments | | | |
|---|---|---|---|---|
| | Control | LI | SI | HI |
| pH | 4.21±0.04$^{bc}$ | 2.98±0.03$^a$ | 3.56±0.20$^b$ | 4.09±0.46$^c$ |
| Titratable acidity (g/L) | 5.25±0.37$^b$ | 3.70±0.05$^a$ | 3.41±0.01$^a$ | 3.63±0.08$^a$ |
| Acidity (%) | 3.42±0.02$^c$ | 2.18±0.27$^b$ | 0.91±0.04$^a$ | 1.08±0.16$^a$ |
| Water activity (aw) | 0.36±0.03$^a$ | 0.33±0.03$^{ab}$ | 0.42±0.02$^c$ | 0.41±0.02$^{bc}$ |
| TSS (°Brix) | 8.12±0.03$^d$ | 2.45±0.08$^a$ | 6.73±0.03$^c$ | 4.13±0.13$^b$ |
| Total sugar (%) | 14.22±0.09$^b$ | 4.82±0.44$^a$ | 45.63±0.31$^d$ | 37.53±0.13$^c$ |
| Reducing sugar (%) | 11.23±0.28$^b$ | 2.28±0.07$^a$ | 23.13±0.22$^d$ | 21.47±0.25$^c$ |
| Non-reducing sugar (%) | 5.20±0.09$^b$ | 2.54±0.03$^a$ | 22.5±0.11$^d$ | 16.06±0.17$^c$ |

highest pH value at 4.21, indicating low acidity, whereas the lemon pre-treatment significantly decreased the pH to 2.98, reflecting increased acidification. Samples treated with SI (3.56) and HI (4.09) exhibited moderate pH levels. These observations are similar with the results of Sabale *et al.* (2024), who stated the pH behaviour in karonda syrup formulations, where increasing citric acid concentration led to pH reductions from 4.08 to as low as 2.80, depending on the acid level used. The addition of lemon juice to the slices lowered the pH due to its acidic nature. pH plays a crucial role in preventing microbial spoilage and is one of the key factors contributing to shelf stability Owolade *et al.* (2017). Titratable acidity was the highest in the control sample (5.25 g/L), whereas all pre-treatment methods led to a notable reduction in acidity. Acidity was reduced most significantly by sugar immersion (3.41g/L), followed by honey (3.63 g/L) and lemon (3.70 g/L). The modest rise in acidity observed in the lemon-treated samples may be attributed to the additional organic acids naturally present in *Carissa carandas* fruit. Notably, the results for sugar and honey-treated samples are consistent with the results of Verma *et al.* (2023), who revealed similar outcomes in their study on osmotically dehydrated karonda fruits. The lowest acidity value (0.91%) was observed with sugar immersion, followed by honey immersion (1.08%), based on acidity measurements. Lemon immersion was also effective, although it resulted in a higher acidity level (2.18%), which was still considerably lower than that of the control (3.42%). The acidity values observed in this study are significantly higher than those reported by Purohit *et al.* (2019) for ash gourd and bottle gourd-karonda juice blends, which ranged from 0.26% to 0.30%.

The water activity (aw) value was lowest after the lemon treatment (0.33), which is advantageous for inhibiting microbial growth. In contrast, the sugar (0.42) and honey (0.41) immersion treatments exhibited higher water activity levels than the control (0.36), suggesting a potential reduction in long-term stability. These results align well with those of Mohammadi *et al.* (2020), who reported water activity values of 0.31 for air-dried and 0.36 for freeze-dried orange powders. The natural sweetness of the control sample was reflected in its maximum total soluble solids (TSS) level of 8.12°Brix. The TSS levels were slightly increased by sugar immersion (6.73) and honey immersion (4.13), likely due to the sugar infusion. In contrast, immersion in lemon resulted in a significant decrease in TSS (2.45). The TSS value of the control sample is consistent with the findings of (Meti and Sunita, 2023) in their study of dried karonda fruit. The total sugar content was the highest in the SI treatment (45.63%), followed by the HI treatment (37.53%), consistent with the sugar-rich nature of these substances. The findings marginally exceeded those reported by Verma *et al.* (2023), who investigated osmotically dehydrated karonda using a 50° Brix sugar syrup. LI dramatically decreased sugar levels (4.82%), perhaps as a result of the diluting effect of lemon juice, whereas the control sample had a moderate sugar content (14.22%). The analysis of sugar content showed significant differences in both reducing and non-reducing sugars across different pre-treatment methods. Sugar immersion treatment recorded the highest concentrations, with 23.13% reducing sugar and 22.5% non-reducing sugar, followed by honey immersion, with 21.47% reducing sugar and 16.06% non-reducing sugar. The control sample exhibited intermediate values of 11.23% and 5.20% for the reducing and non-reducing sugars, respectively. In contrast, lemon immersion resulted in the lowest sugar levels, with 2.28% reducing sugar and 2.54% non-reducing sugar. This study demonstrated a notable increase in reducing sugar content in comparison to the findings of Reshmi *et al.* (2018), who recorded reducing sugar levels between 6.11% and 6.25% in aonla fruits pre-treated with salt solutions. Additionally, the non-reducing sugar levels were lower than the 7.04% reported by Shaheel *et al.* (2015) for 100% Karonda juice, emphasizing the impact of various pre-treatments on altering the sugar profile of Karonda fruit. Lemon juice contains B-complex vitamins, carotenoids, potassium and dietary fiber. It is also a good source of phytochemicals such as ascorbic acid, citric acid, polyphenols and flavonoids, which act as natural antioxidants. These compounds help prevent oxidative damage, protect sensitive nutrients and maintain the visual and nutritional quality of fruits (Kour *et al.,* 2019).

**Colour attributes of karonda fruit powder**

The color of the dried karonda powders is significantly impacted by pretreatments ($p<0.05$). The colour characteristics (L*, a*, b*) of Karonda fruit powder, affected by various pre-treatments, are shown in (Fig 2). A scale of 0 to 100, where 0 is black and 100 is white, is used to determine the samples, L* value, which indicates the amount of lightness or darkness. The red-green chromaticity is shown by a* value. Likewise, the yellow-blue chromaticity is represented by the b* value stated by Li *et al.* (2023). In comparison to the pre-treated samples, the control sample exhibited the lowest L* value (34.28), indicating a darker appearance. LI pre-treatment samples

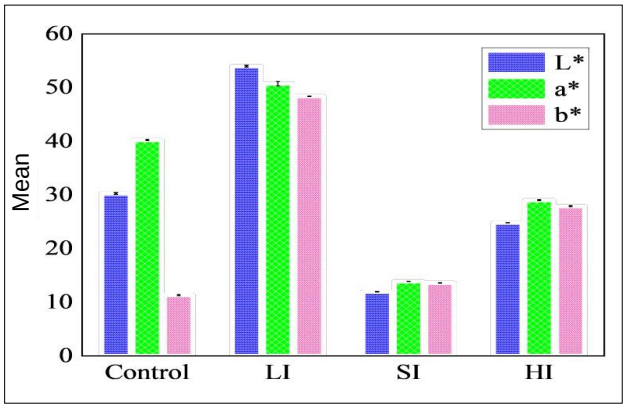
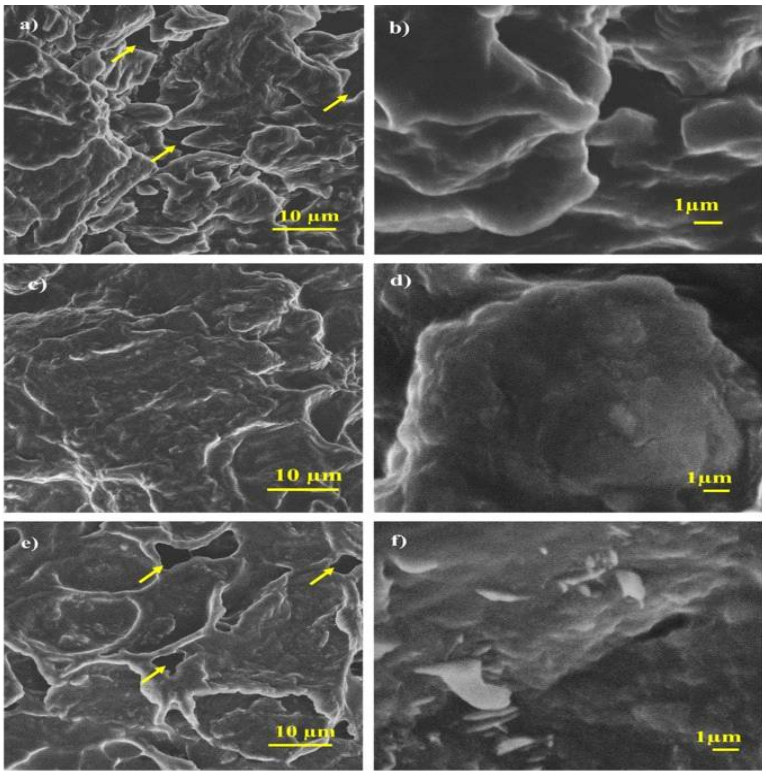



**Fig 2:** Color attributes of different pre-treated *Carissa carandas* fruit powder.

resulted in the highest lightness (53.99), followed by SI (50.73) and HI (48.39), indicating that these pre-treatments significantly enhanced the brightness of the fruit powders. The control sample, which retained the strong red-green chromaticity and deep red colour characteristic of fresh *karonda* fruits rich in anthocyanins, shown the highest a* value (37.24). Redness was significantly reduced in all pre-treated samples, with a* values ranging from 11.98 to 13.92. Compared to the control, the pre-treated samples showed a notable increase in b* values, the control sample had the lowest b* value (13.21), while the SI treatment resulted in the highest yellowness (29.04), followed by HI (27.92) and LI (24.83). Lemon juice helps prevent enzymatic browning by inhibiting enzymes like polyphenol oxidase, a property attributed to its citric acid and ascorbic acid content, as demonstrated in various studies (Moon *et al.*, 2020). In comparison to the untreated control, the pre-treated powders were generally lighter and more yellow, but less red. These changes emphasize how processing significantly affects the visual quality and pigment stability of *karonda* fruit powder. Among the pre-treatment methods, sugar immersion (SI) demonstrated the highest overall colour quality, preserving an ideal level of brightness (L*), moderate redness (a*) and enhanced yellowness (b*), compared to LI, HI and the untreated control. This suggests improved pigment stability and greater visual appeal. Consistent findings were reported by Wojtys *et al.* (2024) in their study on the osmotic dehydration of Japanese quince fruits.

**SEM images for the pre-treated karonda fruit powder**

The microstructures of the pretreated powders at different magnifications are presented in (Fig 3). The SEM micrographs allow for the analysis of particle shape, surface uniformity and structural characteristics. The images reveal irregularly shaped particles. Non-uniformity in particle size is observed, which may be attributed to grinding or agglomeration of the samples after drying, indicating a lack of particle size control. In the SEM images (a, b, e and f), corresponding to LI and HI treatment, a highly irregular surface morphology with sharp, angular features and a porous texture is evident. Furthermore, in images (a) and (e), the presence of pores, as indicated by arrows, suggests that fractures likely occurred during the processing period. By contrast, images (c) and (d) shows the smoother surfaces with minimal and irregularly distributed pores of varying sizes. So, the SEM analysis demonstrated that pre-treatment methods significantly influenced the microstructure of karonda fruit powders. Similar results were recorded by Ahmad *et al.* (2022) in their study on *Carissa carandas* fruit polysaccharides.




(a,b - Lemon Immersion sample); (c,d - Sugar immersion sample); (e,f -Honey immersion sample)

**Fig 3:** Scanning electron microscope images of LI, SI and HI pre-treated karonda fruit powder.

### Organoleptic evaluation of karonda fruit powders

The pre-treatments significantly influenced the sensory attributes of karonda fruit powder and it was revealed in (Table 3). The maximum colour score was observed in SI treatment (7.83), whereas HI recorded the lowest (6.27). Texture scores were highest for LI (8.00) and HI (7.60), while SI exhibited the lowest texture value (5.17). In terms of flavour, LI achieved the highest score (7.60) and HI the lowest (6.43). Mouthfeel was rated higher for LI (6.93) and HI (6.87), with the control sample receiving the lowest score (5.27). Taste was valued highest in HI (7.23) and LI (7.20), whereas SI and the control both showed the lowest taste scores (6.17). Overall acceptability was highest for LI (7.23), followed by HI (7.01), SI (6.55) and the control (6.47). The higher overall acceptability of lemon immersion (LI) karonda fruit powder could be attributed to the enhancement of flavour, better texture, pleasant mouthfeel and the balancing effect of natural lemon acidity on the inherent taste of karonda.

### Storage stability of karonda fruit powder

Pre-treated karonda fruit powder was analyzed for bacterial, fungal and mold growth at monthly intervals, with the results summarized in (Table 4). The findings indicated that the control sample exhibited no microbial growth throughout the six-month study period (Fig 4) illustrates the progression of visual changes in Karonda powder during storage. In contrast, the sugar immersion (SI) showed bacterial growth by the third month, while the honey immersion (HI) treatment exhibited bacterial growth in the fourth month. The lemon immersion (LI) sample delayed bacterial growth until sixth month. Notably, the LI-treated karonda powder demonstrated an extended shelf life comparable to that of the control samples.

**Table 3:** Organoleptic evaluation of pre-treated karonda fruit powder.

| Parameters | Pre-treatments | | | |
|---|---|---|---|---|
| | Control | LI | SI | HI |
| Color | 7.27±0.94$^{b}$ | 6.90±1.09$^{b}$ | 7.83±0.79$^{c}$ | 6.27±1.23$^{a}$ |
| Texture | 7.52±0.96$^{b}$ | 8.00±0.74$^{c}$ | 5.17±0.95$^{a}$ | 7.60±0.77$^{bc}$ |
| Flavour | 6.67±1.09$^{a}$ | 7.60±0.93$^{b}$ | 6.97±1.00$^{a}$ | 6.43±1.10$^{a}$ |
| Mouthfeel | 5.27±1.14$^{a}$ | 6.93±0.98$^{b}$ | 6.47±0.97$^{b}$ | 6.87±0.90$^{b}$ |
| Taste | 6.17±1.04$^{a}$ | 7.20±1.10$^{b}$ | 6.27±0.83$^{a}$ | 7.23±1.14$^{b}$ |
| Overall acceptability | 6.47±0.79$^{a}$ | 7.23±1.04$^{b}$ | 6.55±0.86$^{a}$ | 7.01±1.00$^{ab}$ |




(LD/LI- Lemon dipping/Lemon immersion; SD/SI- Sugar dipping/Sugar immersion; HD/HI- Honey dipping/ Honey immersion)

**Fig 4:** Visual changes in Karonda powder during the storage study.

**Table 4:** Storage stability of karonda fruit powder.

| Time | Microbial load (Bacteria) | | | Microbial load (Fungi) | | | Microbial load (Mold) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dilution | Number of colony | Total plate count (TPC) | Time dilution | Number of colony | Total plate count (TPC) | Timed ilution | Number of colony | Total plate count (TPC) |
| | | | | | **Control** | | | | |
| 1st Month to 4th Month | 10-6 | Nil | Nil | 10-3 | Nil | Nil | 10-3 | Nil | Nil |
| | 10-7 | Nil | Nil | 10-4 | Nil | Nil | 10-4 | Nil | Nil |
| 5th Month and 6th Month | 10-6 | Nil | Nil | 10-6 | Nil | Nil | 10-6 | Nil | Nil |
| | 10-7 | Nil | Nil | 10-7 | Nil | Nil | 10-7 | Nil | Nil |
| | | | | | **Lemon immersion** | | | | |
| 1st Month 2nd Month 3rd Month | 10-6 | Nil | Nil | 10-3 | Nil | Nil | 10-3 | Nil | Nil |
| | 10-7 | Nil | Nil | 10-4 | Nil | Nil | 10-4 | Nil | Nil |
| 4th Month 5th Month | 10-6 | Nil | Nil | 10-6 | Nil | Nil | 10-6 | Nil | Nil |
| | 10-7 | Nil | Nil | 10-7 | Nil | Nil | 10-7 | Nil | Nil |
| 6th Month | 10-6 | 4 | 4 × 10-6 | 10-6 | Nil | Nil | 10-6 | Nil | Nil |
| | 10-7 | 3 | 3 × 10-7 | 10-7 | Nil | Nil | 10-7 | Nil | Nil |
| | | | | | **Sugar immersion** | | | | |
| 1st Month 2nd Month | 10-6 | Nil | Nil | 10-3 | Nil | Nil | 10-3 | Nil | Nil |
| | 10-7 | Nil | Nil | 10-4 | Nil | Nil | 10-4 | Nil | Nil |
| 3rd Month | 10-6 | 6 | 6 × 10-6 | 10-3 | Nil | Nil | 10-3 | Nil | Nil |
| | 10-7 | 4 | 4 × 10-7 | 10-3 | Nil | Nil | 10-4 | Nil | Nil |
| | | | | | **Honey immersion** | | | | |
| 1st Month 2nd Month 3rd Month | 10-6 | Nil | Nil | 10-3 | Nil | Nil | 10-3 | Nil | Nil |
| | 10-7 | Nil | Nil | 10-4 | Nil | Nil | 10-4 | Nil | Nil |
| 4th Month | 10-6 | 5 | 5 × 10-6 | 10-6 | Nil | Nil | 10-6 | Nil | Nil |
| | 10-7 | 3 | 3 × 10-7 | 10-7 | Nil | Nil | 10-7 | Nil | Nil |

## CONCLUSION

Among the various pre-treatments applied to karonda (*Carissa carandas*) fruit prior to drying, lemon immersion (LI) proved to be the most effective. It significantly enhanced functional properties such as bulk density (0.55 g/cm$^3$) and foaming capacity (333.30), while also reducing water activity (0.33) and sugar content (4.82%). The elevated acidity of LI-treated samples corresponded with the naturally acidic nature of the fruit. In terms of colour retention, both SI and LI treatments preserved maximum colour values, followed by control and honey immersion (HI). Sensory evaluation further confirmed the superiority of lemon immersion, with LI samples receiving the highest scores for most organoleptic parameters, followed by HI, SI and control. These findings indicate that lemon immersion not only improves product quality but also enhances storage stability up to 6 months, making it a promising technique for post-harvest handling of karonda and similar perishable fruits. Incorporating such pre-treatments can play a crucial role in minimizing post-harvest losses and developing value-added products with extended shelf life and consumer appeal.

## ACKNOWLEDGEMENT

We express our gratitude to the University Grants Commission for funding support through the National Eligibility Test- Junior Research Fellowship (NET-JRF) and to the Centre for Post-Harvest Technology (TNAU) Laboratory, Coimbatore and the Department of Food Science, Periyar University, Salem, for their assistance in conducting the drying and analysis processes.

### Conflict of interest

The authors declare that there is no conflict of interest.

## REFERENCES

Ahmad, M.M., Chatha, S.A.S., Hussain, A.I. and Khan, I. (2023). Chemical modification and antioxidant activities of *Carissa carandas* fruit polysaccharides. *Journal of Food Measurement and Characterization*. **17(2):** 1175-1185.

Anwar, A., Faiz, M.A. and Hou, J. (2025). Effect of honey concentration on the quality and antioxidant properties of probiotic yogurt beverages from different milk sources. *Applied Sciences*. **15(4):** 2210.

Hameed, F., Gupta, N., Rahman, R. and Rai, G.K. (2021). Bioactive potential of Karonda (*Carissa carandas* L.). *Indian Journal of Agricultural Biochemistry*. **34(1):** 24-32.

Khatri, B. and Jaiswal, A.K. (2024). Optimizing foaming agents for shelf-stable foam-mat-dried black mulberry juice powder. *LWT*. 205: 116512.

Kour, P., Gupta, N. and Kour., M. (2019). Nutritional value, uses and benefits of lemon. *Hind Agricultural Research and Training Institute*. **14(1):** 99-100.

Li, S., Mao, X., Guo, L. and Zhou, Z. (2023). Comparative analysis of the impact of three drying methods on the properties of *Citrus reticulata* blanco cv. dahongpao powder and solid drinks. *Foods*. **12(13):** 2514.

Lydia, A.A. and Delebo Osunde, Z. (2017). Effect of pretreatments and drying methods on some qualities of dried mango (*Mangifera indica*) fruit. Agric EngInt: *CIGR Journal*. **19(1):** 187-194.

Mahajan, M., Bons, H.K., Dhillon, G.K. and Sachdeva, P.A. (2022). Unlocking the impact of drying methods on quality attributes of an unexploited fruit, karonda (*Carissa carandas* L.): A step towards food and nutritional security. *South African Journal of Botany*. **145:** 473-480.

Meena, V.S., Pratap, B., Bhatt, K.C., Pradeep, K., Meena, N.L., Kumar, A. and Singh, K. (2020). Physico-chemical studies on maroon coloured Karonda (*Carissa carandus*) collected from Uttar Pradesh, India. *International Journal of Economic Plants*. **7(1):** 034-037.

Meghwal, P.R., Singh, A. and Singh, D. (2022). Underutilized fruits and vegetables in hot arid regions of India: Status and prospects: A Review. *Agricultural Reviews*. **43(1):** 38-45.

Meichander, P., Ranjani, M., Nandhini, S., Kavipriya, S. and Pavithiraa D. (2024). Karonda (*Carissa carandas* L.): A potent medicinal and nutritious fruit. *Vigyan Varta an International E-Magazine for Science Enthusiasts*. **5(1):** 249-253.

Meti, R. and Sunita, B. (2023). Physico-chemical properties and proximate analysis of fresh and dried karonda (*Carrisa carandas*). *Journal of Postharvest Technology*. **11(2):** 29-35.

Misra, K.K., Singh, S. and Singh, O. (2016). Response of cultivars, picking dates and storage period on quality characteristics of imitation cherry of Karonda (*Carissa carandas* L.) fruits. *Agricultural Science Digest-A Research Journal*. **36(3):** 165-171. doi: 10.18805/asd.v36i3.11441.

Mohammadi, X., Deng, Y., Matinfar, G., Singh, A., Mandal, R. and Pratap-Singh, A. (2020). Impact of three different dehydration methods on nutritional values and sensory quality of dried broccoli, oranges and carrots. *Foods*. **9(10):** 1464.

Moon, K.M., Kwon, E.B., Lee, B. and Kim, C.Y. (2020). Recent trends in controlling the enzymatic browning of fruit and vegetable prod ucts. *Molecules*. **25(12):** 2754.

Owolade, S.O., Akinrinola, A.O., Popoola, F.O., Aderibigbe, O.R., Ademoyegun, O.T. and Olabode, I.A. (2017). Study on physico-chemical properties, antioxidant activity and shelf stability of carrot (*Daucus carota*) and pineapple (*Ananas comosus*) juice blend. *Int. Food Res. J*. **24:** 534-540.

Patel, D.P., Ramani, M.L. and Burbade, R.G. (2019). Effect of various pre-treatments on drying behavior of banana. *Multilogic in Science*. **VIII(A):** 50-53.

Purohit, P., Palamthodi, S. and Lele, S.S. (2019). Effect of karwanda (Carissa congesta Wight) and sugar addition on physicochemical characteristics of ash gourd (*Benincasa hispida*) and bottle gourd (*Langenaria siceraria*) based beverages. *Journal of Food Science and Technology*. **56:** 1037-1045.

Raju, S. Shamshad Begum, B. Kalpana, A. Sathish. (2023). Processing and nutritional evaluation of amla (*Phyllanthus emblica*) pomace. *Asian Journal of Dairy and Food Research*. 1-6. doi: 10.18805/ajdfr.DR-2068.

Rathour, S.S., Gurjar, P.K.S., Lekhi, R. and Bimal, S.S. (2022). Effect of different drying methods on physico-biochemical aspects of aonla fruit pulp powder. *International Journal of Plant and Soil Science*. **34(21):** 428-434.

Reshmi, N.P., Mandal, G. and Thokchom, R. (2018). Effect of pre-treatment of salt solution and drying methods on the quality of processed aonla (*Emblica officinalis Gaertn*). *International Journal of Current Microbiology and Applied Sciences*. **7(8):** 1438-1446.

Roby, M., Abd-Eltawab, S. and Abu El-Hassan, A. (2019). Effect of different pre-drying treatments on the quality of dried apple slices. *Egyptian Journal of Food Science*. **47(1):** 131-138.

Sabale, P.A., Lohakare, A.S., Joshi, A.A., Naik, K.M and Deshmukh, A.A (2024). Standardization and quality evaluation of syrup from karonda (*Carissa carandas* L.). *International Journal of Advanced Biochemistry Research.* **8(12):** 851-857.

Sawant, P.J., Rai, D.C. and Yadav, S.P. (2018). Assessment of impact of feeding fermented karonda (*Carissa carandas*) whey beverage on biochemical parameters of albino rats. *Indian Journal of Animal Research*. **52(8):** 1162-1166. doi: 10.18805/ijar.B-3336.

Shaheel, S.K., Swami, D.V., Kumar, B.P. and Krishna, K.U. (2015). Effect of storage period on chemical properties of RTS prepared from karonda (*Carissa carandas* L.) blended juices. *Plant Archives*. **15(1):** 35-40.

Sharma, A., Tiwari, R. K., Kaushik, A., Tyagi, L.K., Shankar, K., Virmani, T. and Parvez, N. (2007). Standardisation of *Carissa carandas* Linn: A drug used in Indian system of medicine as per WHO Guidelines. *Cont. J. Pharm Sci*. **1(1):** 9-14.

Singh, A.K., Singh, S., Saroj, P.L., Mishra, D. S., Yadav, V. and Kumar, R. (2020). Cultivation of underutilized fruit crops in hot semi-arid regions: Developments and challenges-A review. *Current Horticulture*. **8(1):** 12-23.

Singh, S. and Saxena, A.K. (2020). Effect of picking dates on physico-chemical characteristics of Karonda (*Carissa Carandas* L.) cultivars. *Indian Journal of Agricultural Research*. **54(1):** 43-50. doi: 10.18805/IJARe.A-5296.

Singh, S., Bajpai, M. and Mishra, P. (2020). Pharmacognostical evaluation of indigenous herbal drug: *Carissa carandas* Linn. fruit. *Annals of Phytomedicine-An International Journal*. **9(2):** 263-270.

Suhasini, L., Vanajalatha, K., Padmavathamma, A.S. and Rao, P.V. (2016). Effect of different osmotic pretretments on moisture loss, weight loss and yield in osmotically dehydrated Karonda (*Carissa carandas* L.). *Environment and Ecology*. **34(1A):** 267-270.

Suhasini, L., Vanajalatha, K., Padmavathamma, A.S. and Rao, P.V. (2015). Studies on sensory evaluation and microbial count of osmodried karonda (*Carissa carandas* L.). *Asian Journal of Dairy and Food Research.* **34(2):** 141-145. doi: 10.59 58/0976-0563.2015.00028.7.

Tomer, V. and Kumar, A. (2024). Karonda (*Carissa carandas* L.): A miracle fruit with multifaceted potential. *Journal of Agriculture and Food Research*. pp. 101417.

Verma, S., Bhat, A., Gupta, N. and Kumar, A. (2023). Physio-chemical characteristics of osmotically dehydrated Karonda (*Carissa carandas* L.) with different pre-treatments during storage. *J. Pharm Innov*. **12(1):** 1396-1401.

Wojtys, A., Pietrzyk, S., Bogacz, S. and Witkowicz, R. (2024). Osmotic dehydration of Japanese quince (*Chaenomeles japonica*) fruits in erythritol solutions: Impact of processing conditions on the kinetic parameters and on physicochemical and antioxidant properties of the fruits. *Molecules*. **29(23):** 5524.

Yadav, A.K. and Singh, S.V. (2014). Osmotic dehydration of fruits and vegetables: A review. *Journal of Food Science and Technology*. **51:** 1654-1673.