Blanching and Vacuum Drying of Jamun Leaves: A Study on Nutritional Preservation and Quality Enhancement

---

ABSTRACT

This study investigates the effects of blanching and vacuum drying on the physico-chemical and nutritional properties of *Paras* variety jamun (*Syzygium cumini* L.) leaves. Blanching treatments, including hot water and steam blanching at various temperatures and durations, were evaluated for residual enzymatic activity. Optimal enzyme inactivation was achieved with hot water blanching at 70°C for 1 minute, effectively preserving enzymatic activity. The vacuum drying process was evaluated across temperatures (50-70°C) and pressures (300, 400 and 500 mm Hg). Vacuum drying at 70°C and 300 mm Hg for 245 minutes yielded leaves with 6.50 % moisture content, 0.363 water activity, 25.782 % carbohydrate content, 37.646 mg/100 g phenolic concentration, and 5.95 % antioxidant content. Higher drying temperatures reduced moisture content and increased color values, while phenolic content and antioxidant activity peaked at higher temperatures. These findings underscore the potential of vacuum-dried jamun leaves as a valuable ingredient in nutraceutical and pharmaceutical applications.

Keywords: *Jamun Leaves, Characteristics, Hot Water Blanching, Steam Blanching, Vacuum Drying*

INTRODUCTION

Jamun (*Syzygium cumini* L.) is a tropical fruit known for its medicinal and therapeutic properties, yet remains underutilized. Globally, the production of jamun is approximately 13.5 million tons per year, with India contributing 15.4% of this amount, making it the second-

largest producer in the world. In Ayurvedic medicine, Jamun leaves are highly valued for treating digestive disorders. They are beneficial in preventing liver diseases such as necrosis and fibrosis due to their biochemical and phytochemical compounds, like polyphenols, which exhibit anti-cancer properties.

Jamun leaves are traditionally used to treat dysentery, and their ash is effective for mouth ulcers. Leaf extracts show moderate activity against Escherichia coli, highlighting their natural antibiotic properties, which aid in the rapid healing of injuries. These leaves contain various phytochemicals, including phytosterols like β-sitosterol, alkanes such as n-heptacosane and n-nonacosane, terpenoids like betulinic acid and α-pinene, and flavonoids including quercetin and myricetin. Additionally, they are rich in minerals like sodium, calcium, iron, zinc, potassium, magnesium, copper, manganese, chromium, and lead. The leaves are also used in Ayurvedic preparations (Qamar *et al*., 2022). One of the most important agriculture operations is to properly manage weeds. Weed management is a tedious task (Balas et al., 2022). A study was conducted to assess the microbial load on lemon fruits at different postharvest handling stages (Makavana et al., 2018a).

Chewing Jamun leaves helps treat diarrhea and ulcers, while their antibacterial properties strengthen teeth and gums. As an astringent, the leaves are beneficial for throat problems. Powdered Jamun leaves, obtained through drying, can be used as tooth powder to prevent gum infections and bleeding (Patil *et al.*, 2012). They also have potential applications in treating skin wounds and typhoid, especially when combined with other medicinal plants containing phenolic compounds and tannins. Topical antimicrobials derived from these leaves deliver high local concentrations of antibiotics, avoiding adverse systemic effects and resistance (Gowri and Vasantha, 2010).

Drying is essential for preserving agricultural products by removing water to slow microbial growth and chemical reactions, thereby extending shelf life. It also reduces the cost and difficulty of packaging, handling, storage, and transport by converting raw food into a dry solid. This process affects the food's palatability, flavor, aroma, viscosity, hardness, and resistance to microbial spoilage and enzymatic activity (Orikasa *et al*., 2014).

Maintaining the nutritional and physico-chemical integrity of Jamun leaves during processing is vital for maximizing their health benefits and shelf life. Vacuum drying is particularly effective in retaining nutritional quality and minimizing the degradation of sensitive bioactive compounds. This method operates under reduced pressure, lowering the boiling point of water and allowing dehydration at lower temperatures, thereby preserving the

structural integrity and nutritional components of the leaves. Density was increased by 3.91 times and calorific value was increased by 1.19 times (Makavana et al., 2020).

This study aims to evaluate the impact of vacuum drying on the physico-chemical and nutritional properties of Jamun leaves. By assessing parameters such as moisture content, color, texture, and the concentration of key bioactive compounds, this research seeks to provide insights into the effectiveness of vacuum drying in maintaining the quality of Jamun leaves. These findings will contribute to developing optimal processing techniques that preserve the health-promoting properties of Jamun leaves, enhancing their potential use in nutraceutical and pharmaceutical applications.

MATERIALS AND METHODS

Fresh jamun leaves of *Paras* variety were procured from the Horticulture farm at Anand Agricultural University, Anand, Gujarat, in August. The leaves were sorted, washed, and surface-dried before being stored at 4°C (Nobosse *et al*., 2017). This research focuses on standardizing pre-treatments, including hot water and steam blanching, and examining the vacuum drying behavior of jamun leaves powder. Potato slices ware subjected to various pre-drying treatment viz., blanching in hot water at temperature, i.e., 60, 70, 80, 90 and 100˚C and blanching time, i.e., 2.0, 3.0, 4.0 and 5.0 min.(Kapadiya at al., 2018).

Pre-treatments Prior to Drying of Jamun Leaves

After sorting of jamun leaves, pre-treatments prior to drying (Table 1) were carried out with some modifications for catalase and peroxidase analysis. Pre-treatments of fresh jamun leaves were carried out through hot water blanching for temperature-time combinations of 50℃ for 3 minutes, 60℃ for 2 minutes and 70℃ for 1 minute as well as steam blanching for 2.5, 5.0 and 7.50 minutes prior to drying. Hot water blanching and steam blanching was procured by using the method described in Ranganna (2007).

Peroxidase and Catalase Activity

The effectiveness of blanching was estimated using peroxidase activity as an indicator of enzymatic activity. A small portion of the sample was taken in a test tube to depth of about 1 inch. 10 ml of Guaiacol (0.5 %) and 10 ml of Hydrogen peroxide (0.08 %) were added. The test tube was shaken and kept for 3 min and colour was noted after 3 minutes.

Colour of the mixtures changing from colourless to brick red indicated incomplete enzyme inactivation. The substrate solution was transferred into a cuvette and check absorbance 720 nm in spectrophotometer (M/s Microprocessor UV-VIS Spectrophotometer - 2371, Electronics India) (Meher *et al.*, 2018). The residual activity was estimated using the following equation:

Residual activity (%) = Absorbance of fresh sample – Absorbance after blanching x 100 … (3.1)
Absorbance of fresh sample

Table 1: Peroxidase reaction

Colour	Test	Enzyme activity
No discolouration	Negative	Peroxidase inactivated
Light brown colour	Light positive	Peroxidase slightly active
Reddish brown colour	Positive	Peroxidase active

Two or three pieces of jamun leaves were occupied. A test tube of 25 mm in diameter and 25 mm depth was filled with 10 ml water and equal volume of 40 % hydrogen peroxide was added and mixed the contents by shaking them gently. The test was considered;

Positive - oxygen bubble, indicating that catalase is active.

Negative - If no oxygen bubble indicating inactivation of catalase (Gandhi, 2023).

Vacuum Drying

The vacuum dryer used in this study, manufactured by Kalptaru Engivation in Anand, Gujarat, can achieve up to 750 mm Hg (0.1 Mbar) vacuum pressure. It features a high-temperature-resistant silicon food-grade seal, a 50 mm insulated SS 316 vacuum chamber, and six removable, non-perforated trays. The dryer uses a 30-litre, 4 kW hot water generator with an automatic temperature controller and a circulation pump. Its automatic control panel includes a digital display, MCB protection, and a condenser with a 20-litre receiver chamber. Operating under vacuum conditions, it efficiently removes air and humidity, increasing the drying rate while preventing contamination. The dryer was set to various temperatures (50-70℃) and vacuum pressures (300-500 mm Hg), with sample weights measured hourly until constant.

Determination of Physico-chemical Properties

Moisture content

The moisture content was determined using the method described in AOAC (2012) with a hot air oven (Make: NOVA Instruments Pvt. Ltd., Ahmedabad, Gujarat). A metallic dish was dried at 110°C for one hour, cooled in a desiccator, and weighed (W_1). A 5 g sample was placed on the dish and weighed (W_2). The sample was dried in the oven at 100 ± 5 °C until a constant weight was obtained (W_3). Moisture content was calculated using:

$$\text{Moisture content (\% w.b.)} = \frac{W_1 - W_2}{W_1} \times 100 \quad \ldots (3.2)$$

Where,

W_1= Initial mass of sample (g) and

W_2 = Mass of sample after drying (g)

Water activity

Water activity of any food may be defined as the ratio of vapour pressure of the food when in equilibrium with the surrounding to the vapour pressure of water under same conditions. Wateractivity of jamun leaves powder were determined using a water activity meter (Make: Novasina LabSwift - aw).

Carbohydrate content

Carbohydrate content of the sample was calculated by difference. It was calculated by using the following formula:

Carbohydrate (%) = 100 % (moisture + ash + crude fiber + crude fat + protein) ...(3.3**)**

Colour value determination

The color of the Jamun leaves and fine Jamun leaf powder was determined using a Lovibond tintometer (Type: Lovibond®RT850i) on the CIELAB scale (L*, a*, b*). The tintometer was initially calibrated, and the samples were analyzed for their L* (lightness), a* (red/green), and b* (yellow/blue) values. Three replications were taken for each sample.

Total phenolic content

Total phenolic content was determined using the method described by Balaji *et al.* (2014). A 100 g sample was extracted with 500 ml methanol using a Soxhlet extractor for 8-10 hours. The extract was filtered, and the total phenolic content was determined using the Folin-Ciocalteu assay. For every 1 ml of extract, 1 ml of Folin-Ciocalteu reagent and 2 ml of 2.5% sodium carbonate were added, mixed, and allowed to stand for two hours in the dark. Absorbance was measured at 750 nm. Quantification was done using a standard curve of gallic acid, expressed as mg gallic acid per gram of sample.

Antioxidant activity

Antioxidant activity was measured using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method (Joshi *et al.*, 2019). A 2 g sample was extracted with 0.5 ml methanol, centrifuged, and 0.1 ml of extract was added to 3 ml of absolute ethanol. The mixture was incubated for 60 minutes in the dark, and absorbance was measured at 517 nm. Inhibition (%) was calculated using:

$$\text{Inhibition (\%)} = \frac{(\text{AB} - \text{AA}) \times 100}{\text{AB}} \quad \ldots (3.4)$$

Where,

AB = Absorbance of control

AA = Absorbance of sample

RESULTS AND DISCUSSION

Standardization of Pre-treatment

Pre-treatments are necessary for horticultural crops before processing in order to retain colour, inactivation of enzymes and boost drying rate process. The ultimate aim of pre-treatments is to improve quality parameters of final product and reduce processing cost. The pre-treatments differ from product to product. Blanching helps to improve powder physical properties and preserving the phenolic contents and ascorbic acid (Raja, 2019).

After sorting, preliminary trials were carried out by using hot water blanching at different temperature-time combinations (50℃ for 3 minutes, 60℃ for 2 minutes, 70℃ for 1 minute) as well as steam blanching (2.50, 5.0 and 7.50 minutes) for enzymatic inactivation of catalyst and peroxidase. Details for peroxidase & catalase enzymes are given in the Table 1(a) & (b).

Table 1(a): Hot water and steam blanching of jamun leaves for peroxidase enzyme

Blanching	Temperature (°C)	Time of blanching (min)	Enzyme activity (Peroxidase)	Observations
Hot water	50	3	Present	Reddish brown colour
	60	2	Light positive	Light brown colour
	70	1	Absent	No discolouration
Steam	-	2.50	Present	Reddish brown colour
		5	Light positive	Light brown colour
		7.50	Light positive	Light brown colour

Table 1(b): Hot water and steam blanching of jamun leaves for catalase enzyme

Blanching	Temperature (°C)	Time of blanching (min)	Enzyme activity (Catalase)	Observations
Hot water	50	3	Present	Oxygen bubbles
	60	2	Present	Oxygen bubbles
	70	1	Absent	No oxygen bubble
Steam	-	2.50	Present	Oxygen bubbles

		5	Present	Oxygen bubbles
		7.50	Present	Oxygen bubbles

It can be observed in Fig.1(a) the residual activity of jamun leaves after various blanching treatments compared to a control group. The x-axis shows blanching conditions, including hot water and steam blanching at different temperatures and durations, while the y-axis indicates residual activity percentage, with 10% as the threshold for good preservation of enzymatic activity. The data reveals that blanching at 70℃ for 1 minute effectively meets this threshold, indicating optimal enzyme preservation. Both catalase and peroxidase were successfully inactivated at this temperature-time combination, making it the standardized condition for hot water blanching. This finding is consistent with Parmar (2022) results for papaya leaves.

VACUUM DRYING

Drying Time

The Fig. 1(b) depicting the drying time of vacuum dried jamun leaves as influenced by temperature and vacuum pressure showcases a complex relationship between these variables. At higher temperatures, such as 70°C, drying time decreases significantly across all vacuum pressure levels, with drying times of 245, 220 and 215 minutes observed at vacuum pressures of 300, 400 and 500 mm Hg, respectively. Conversely, lower temperatures, like 50°C, result in longer drying times, with values of 360, 335 and 325 minutes observed at the same respective pressure levels. This trend suggests a strong inverse correlation between temperature and drying time, highlighting the importance of temperature control in the vacuum drying process. Moreover, varying vacuum pressure levels exhibit nuanced effects on drying time, with higher pressures generally associated with shorter drying time at each temperature level.

From Table 2 the ANOVA results for drying time during vacuum drying, with vacuum pressure and temperature as factors of interest. Vacuum pressure shows significant effect on drying time, with an F-value (59.2) and a p-value (1.606×10^{-05}). Similarly, temperature demonstrates a significant impact, with an F value of 351 and a p-value of 5.126×10^{-09}. These findings suggest that both vacuum pressure and temperature play crucial roles in determining drying time. Bulk density of rice husk and rice straw was 331.59 kg/m^3 and 380.54 kg/m^3 respectively (Makavana et al., 2018). The efficiency of the catalyst was investigated in relation to temperature, gas hourly space velocity, the ratio of steam to carbon monoxide, hydrogen sulfide (H 2 S) loading, and tar concentration (Makavana et. at., 2024).

Moisture content

The Fig. 1(c) illustrates the moisture content of jamun leaves during vacuum drying at temperatures ranging from 50 to 70°C under three different vacuum pressures: 300, 400 and 500 mm Hg. Each line on the graph represents a specific vacuum pressure, with points indicating the moisture content at each temperature-pressure combination. The data reveals how moisture content varies with temperature and vacuum pressure, providing insights into the effectiveness of vacuum drying in reducing moisture content at different operating conditions. The visualization allows for a clear comparison between the effects of temperature and vacuum pressure on the moisture content of jamun leaves, aiding in the understanding of optimal drying conditions for this process. The average pod-vine ratio for groundnut varietyGG-22 was observed as 0.3353 having moisture content of pods and vine as 11.73 and 11.53% (d.b.) respectively (Amrutiya et al., 2019).

From the ANOVA in Table 2 presents results for moisture content during vacuum drying, showing significant effects of both vacuum pressure ($F=32.168$, $p< 0.001$) and temperature ($F=8.536$, $p<0.001$). However, the interaction between these factors is not significant ($F=0.007$, $p=1.00$). These conclusions are drawn from the analysis of variance, where vacuum pressure and temperature contribute significantly to the observed variability, while their interaction does not.

Water activity

The water activity of vacuum dried jamun leaves powder was analyzed across various temperatures and vacuum pressures. The data obtained from the experiments revealed distinct trends in water activity as influenced by temperature and vacuum pressure. At 50°C, the water activity ranged from 0.393 at 300 mm Hg to 0.349 at 500 mm Hg. From Fig. 1(d), the temperature increased to 70°C, the water activity decreased consistently across all vacuum pressures, with values ranging from 0.344 to 0.320. Notably, at each temperature, a lower vacuum pressure corresponded to higher water activity values, indicating the influence of pressure on the moisture content of the jamun leaves. These observations underscore the importance of both temperature and vacuum pressure in controlling the water activity of vacuum dried jamun leaves.

Table 2 presents the results of an analysis of variance (ANOVA) for water activity during vacuum drying. The Table indicates that vacuum pressure has a statistically significant effect on water activity ($F=16.848$, $p<0.05$). Similarly, temperature also shows a significant impact ($F=2.995$, $p<0.05$) on water activity. However, the interaction between vacuum pressure and temperature does not significantly influence water activity ($F=0.004$, $p=0.999$).

Carbohydrate content

The Fig. 1(e) depicts the influence of temperature and vacuum pressure on the carbohydrate content of vacuum dried jamun leaves. It features three lines representing vacuum pressures of 300, 400 and 500 mm Hg. The x-axis displays temperatures ranging from 50 to 70℃, while the y-axis denotes carbohydrate content (%). Each line illustrates the trend of carbohydrate content across varying temperatures under different vacuum pressures. For instance, at 50℃, carbohydrate content under 300 mm Hg is 28.14 %, under 400 mm Hg is 26.17 %, and under 500 mm Hg is 24.81 %. Similarly, this pattern continues for other temperatures, offering insights into the impact of temperature and vacuum pressure on carbohydrate levels in dried jamun leaves.

Table 2 presents the results of ANOVA for carbohydrate content during vacuum drying. The analysis reveals significant effects of vacuum pressure ($p<0.05$) and temperature ($p<0.05$) on carbohydrate levels. Specifically, vacuum pressure demonstrates a substantial impact, with a p-value of 3.45×10^{-6}, while temperature also shows significance, with a p-value of 0.028. However, there is no significant interaction between these factors.

Colour L*

The colour L* values of vacuum dried jamun leaves were analyzed at various temperatures (50, 55, 60, 65 and 70℃) and vacuum pressures (300, 400 and 500 mm Hg). A line graph Fig. 1(f) was constructed with temperature (℃) on x-axis and colour L* values on y-axis. Each line on the graph represents a different pressure level, with colours distinguishing between them. The data showed that as temperature increased, the colour L* values generally exhibited an upward trend across all pressure levels. For instance, at 50℃, the colour L* values ranged from approximately 75.32 to 77.76 at different pressure levels. Similarly, at 70℃, the values ranged from about 77.35 to 80.02.

The ANOVA results from Table 2 reveal significant effects on colour value L* during vacuum drying. Vacuum pressure demonstrates a substantial impact ($p<0.05$), as does temperature ($p<0.05$). Interaction effects are not significant ($p > 0.05$). These findings suggest that variations in vacuum pressure and temperature significantly influence the colour value L* during vacuum drying, with no significant interaction effect observed.

Colour a*

The Fig. 1(g) depicts the impact of temperature and vacuum level on the colour a* values of vacuum dried jamun leaves. Three vacuum levels (300, 400 and 500 mm Hg) were examined across temperatures ranging from 50 to 70°C. As temperature rises, a consistent upward trend in colour a* values is observed across all vacuum levels. Moreover, higher

vacuum levels exhibit slightly elevated colour a* values compared to lower vacuum levels at equivalent temperatures. This underscores the significant influence of both temperature and vacuum level on the colour characteristics of vacuum-dried jamun leaves. For instance, at 65°C, the colour a* values for vacuum levels of 300, 400 and 500 mm Hg are 0.961, 0.977, and 0.993, respectively.

Table 2 presents the results of an ANOVA for colour value a* during vacuum drying. Vacuum Pressure and Temperature show significant effects on colour a* ($p<0.05$), with F-values of 32.168 and 8.536, respectively. The Interaction term, however, is not significant ($p=1$). These results indicate that vacuum pressure and temperature have a no impact on colour value a* during vacuum drying, while their interaction does not significantly affect the outcome.

Colour b*

The Fig. 1(h) illustrates the variation in colour b* values of vacuum dried jamun leaves across different temperatures and pressures. Temperature, ranging from 50 to 70°C, is plotted on x-axis, while y-axis represents colour b* values. Three vacuum pressure conditions (300, 400 and 500 mm Hg) are depicted with distinct lines on the graph. Each line connects data points corresponding to specific temperature-pressure combinations. For instance, at 50°C, the b* values at 300, 400 and 500 mm Hg are 7.532, 7.654 and 7.776, respectively. Similarly, at 70°C, the b* values for the above same pressure conditions are 7.735, 7.869 and 8.002, respectively.

Table 2 presents the ANOVA results for colour value b* during vacuum drying. Vacuum pressure and temperature show significant effects on colour value b* ($p<0.05$). However, the interaction between vacuum pressure and temperature does not significantly affect colour value b* ($p=1$). Overall, vacuum pressure and temperature exert considerable influence on colour value b* during the process.

Total phenolic content

The Fig. 1(i) illustrates the impact of temperature on the total phenolic content (TPC) of vacuum dried jamun leaves under different vacuum pressure conditions (300, 400 and 500 mm Hg). Across temperatures ranging from 50 to 70°C, TPC generally decreases as temperature increases. Notably, at 50°C, TPC ranges from approximately 36.23 to 41.09 mg/100 g, with the highest TPC observed at 300 mm Hg. Conversely, at 70°C, TPC ranges from approximately 33.19 to 37.65 mg/100g, with the lowest TPC observed at 500 mm Hg.

Table 2 presents the results of an analysis of variance (ANOVA) for the total phenolic content during vacuum drying. Significant effects are observed for vacuum pressure ($p<0.05$)

and temperature ($p<0.05$), with vacuum pressure having the most substantial impact. However, the interaction term ($p=1$) is not significant. These findings suggest that both vacuum pressure and temperature influence total phenolic content during vacuum drying.

Antioxidant activity

The antioxidant activity of vacuum dried jamun leaves was examined across temperatures ranging from 50 to 70°C at pressures of 300, 400 and 500 mm Hg. The Fig. 1(j) illustrates the relationship between temperature and antioxidant activity at each pressure level. Overall, as temperature increases, there is a tendency for antioxidant activity to rise. Notably, at 65 and 70°C, the highest antioxidant activity was observed across all pressure levels, with values ranging from approximately 6.11 to 6.16 %. This suggests that higher temperatures may enhance antioxidant properties of jamun leaves. The data reveals variations in antioxidant activity between different pressure levels, indicating potential pressure-dependent effects on antioxidant activity of vacuum dried jamun leaves.

Table 2 presents the ANOVA results for antioxidant activity during vacuum drying. Vacuum pressure and temperature both show significant effects on antioxidant activity ($p<0.05$). The Interaction term, however, is not significant ($p=1$). The F-values for vacuum pressure and temperature are 32.168 and 8.536, respectively, indicating their strong influence.

Standardization of Vacuum Drying

The standardization of drying jamun leaves was analyzed to assess quality, nutrition, and health benefits. The jamun leaves were vacuum dried at 70°C with 300 mm Hg vacuum pressure for 245 minutes, achieving a moisture content of 6.50 % and water activity of 0.363, both indicating good preservation and microbial stability. The nutritional analysis showed a carbohydrate content of 25.782 %, while the phenol concentration, known for antioxidant benefits, was 37.646 mg/100 g. The antioxidant content was 5.95 % by mass. The effective drying process and the nutritional value of dried jamun leaves, make them a beneficial ingredient with potential health applications.

CONCLUSIONS

The study demonstrated that vacuum drying significantly affects the physico-chemical and nutritional properties of jamun (*Syzygium cumini* L.) leaves. Optimal pre-treatment with hot water blanching at 70°C for 1 minute effectively inactivated enzymes, retaining the phenolic content and ascorbic acid. The drying time was shortest at 70°C and 300 mm Hg (215 minutes), and moisture content decreased with increasing temperature and vacuum pressure. Water activity ranged from 0.393 to 0.320, and carbohydrate content decreased from 28.81% to 24.14% as temperature increased from 50 to 70°C. Higher temperatures also resulted in

lighter leaves, with increased color values (L*, a*, b*). The total phenolic content was highest at 50°C (36.23 to 41.09 mg/100 g) and lowest at 70°C (33.19 to 37.65 mg/100 g), while antioxidant activity peaked at 65 and 70°C (6.11 to 6.16 %). These results highlight the efficacy of vacuum drying at 70°C and 300 mm Hg in preserving the quality of Jamun leaves, supporting their use in nutraceutical and pharmaceutical applications.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

REFERENCE

Qamar, M., Akhtar, S., Ismail, T., Wahid, M., Abbas, M., Mubarak, Y., Barnard, R., Ziora, Z., & Esatbeyoglu, T. (2022). Phytochemical profile, biological properties, and food applications of the medicinal plant *Syzygium cumini*. *Foods*, 11 (3), 378.

Amrutiya, M. D., Makavana, J. M., Kachhot, A. R., Chauhan, P. M., & Tiwari, V. K. (2020). Performance evaluation of tractor operated groundnut thresher. Current Journal of Applied Science and Technology, 38(6), 1-15.

Balas, P. R., Makavana, J. M., Mohnot, P., Jhala, K. B., & Yadav, R. (2022). Inter and intra row Weeders: A review. Current Journal of Applied Science and Technology, 41(28), 1-9.

Patil, S., Thorat, R., & Rajasekaran, P. (2012). Utilization of jamun fruit (*Syzygium cumini*) for production of red wine. *Journal of Advanced Laboratory Research in Biology*, 3 (3), 200-203.

Gowri, S.S., & Vasantha, K. (2010). Phytochemical screening and antibacterial activity of *Syzyguim cumini* L. (Myrtaceae) leaves extracts. *International Journal of PharmTech Research*, 2(2), 1569-1573.

Kapadiya, D. C., Makavana, J. M., & Kathiria, M. K. (2018). Effect of hot water blanching treatment on quality of dried potato slices. Int. J. Curr. Microbiol. Appl. Sci, 7(7), 2754-2764.

Orikasa, T., Koide, S., Okamoto, S., Imaizumi, T., Muramatsu, Y., Takeda, J., & Tagawa, A. (2014). Impacts of hot air and vacuum drying on the quality attributes of kiwi fruit slices. *Journal of Food Engineering*, 125, 51-58.

Makavana, J. M., Makwana, P. J., Kukadiya, V. D., & Joshi, A. M. (2018a). Post-harvest losses of lemon fruits: An assessment of microbial floral strength during post-harvest handling. International Journal of Current Microbiology and Applied Sciences, 7(5), 1184-1188.

Ranganna, S. (2007). *Handbook of analysis and quality control for fruit and vegetable products*, 2nd ed. McGraw-Hill Publications, New Delhi.

Meher, J., Keshav, A., Mazumdar, B., & Keshav, S. (2018). Effect of blanching and thermal preservation on rheology of curry leaf puree. *Journal of Food Measurement and* Characterization, 12 (1), 105-117.

Makavana, J. M., Agravat, V. V., Balas, P. R., Makwana, P. J., & Vyas, V. G. (2018). Engineering properties of various agricultural residue. Int J Curr Microbiol App. Sci, 7(6), 2362-2367.

Makavana, J. M., Sarsavadia, P. N., & Chauhan, P. M. (2020). Effect of pyrolysis temperature and residence time on bio-char obtained from pyrolysis of shredded cotton stalk. International Research Journal of Pure and Applied Chemistry, 21(13), 10-28.

Gandhi, R., Kumar, N., & Mistry, A. (2023). Physicochemical characterization of steam blanched parijat (Nyctanthes arbor-tristis L.) leaves. Pharma Innovation 2023;12(8):2261-2269.

Makavana, J. M., Chauhan, P. M., & Dulawat, M. S. (2024). A study on the production of hydrogen-enriched fuel through a water gas shift reactor integrated with a biomass gasifier.

AOAC (2012). Official Methods of Analysis, 19th Edition, *Association of Official Analytical Chemists*, Washington DC.

Balaji, K., Hean, K., Ravinchandran, K., & Sikarwar, M. (2014). In-Vitro evaluation of antioxidant activity and total phenolic content of methanolic extract of *Convolvulus pluricaulis*. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 5, 959-964.

Joshi, N., Bains, K., & Kaur, H. (2019). Optimization of drying time and temperature for preparation of antioxidant rich vegetable powders from unconventional leafy greens. *Chemical Science Review and Letters*, 8(29), 70-78.

Raja, K.S., Taip, F.S., Azmi, M.Z., & Shishir, M.I. (2019). Effect of pre-treatment and different drying methods on the physicochemical properties of *Carica papaya* L. laef powder. *Journal of the Saudi Society of Agricultural Sciences*, 18, 150-156.

Parmar, M.R., Kumpavat, M.T., Doshi, J.S., & Kapdi, S.S. (2017). A comparative study on drying of basil leaves. *Agricultural Engineering International: CIGR Journal*, 19 (1), 169-177.

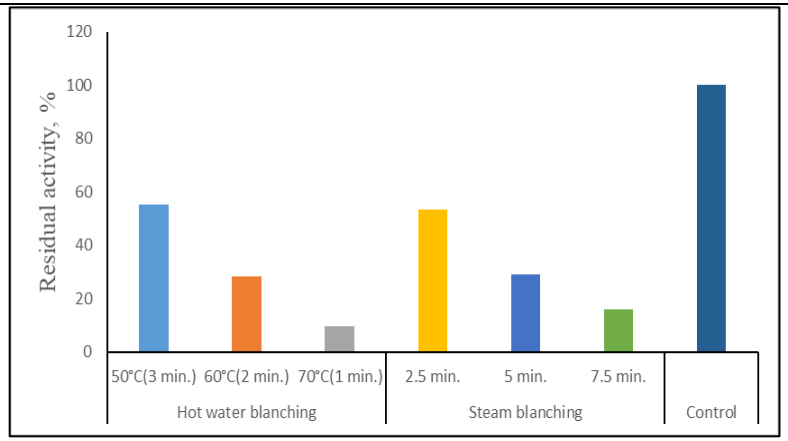

Fig. 1(a): Effect on Residual activity during blanching

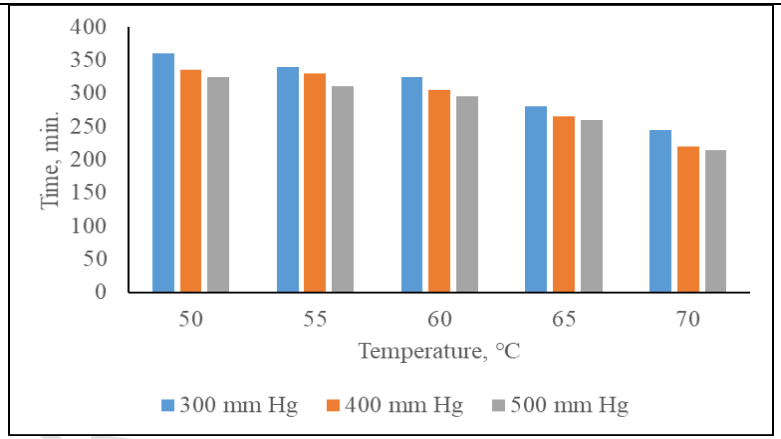

Fig. 1(b): Effect on drying time duirng vacuum drying

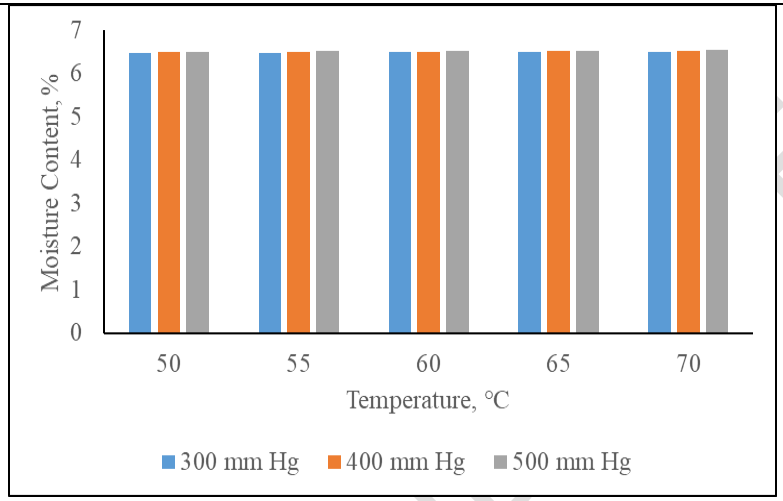

Fig. 1(c): Effect on moisture content during vacuum drying

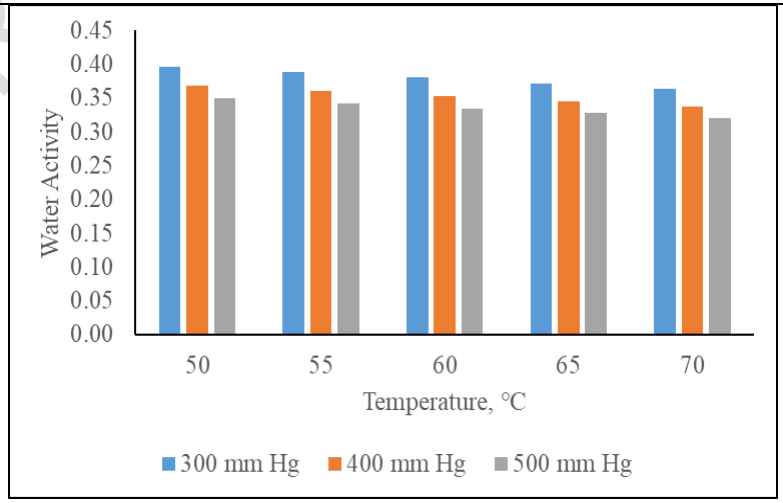

Fig. 1(d): Effect on water activity during vacuum drying

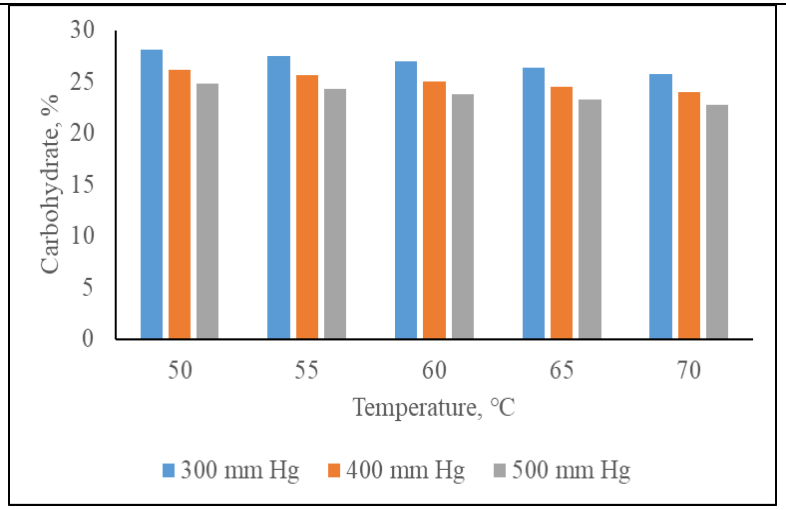

Fig. 1(e): Effect on carbohydrate content during vacuum drying

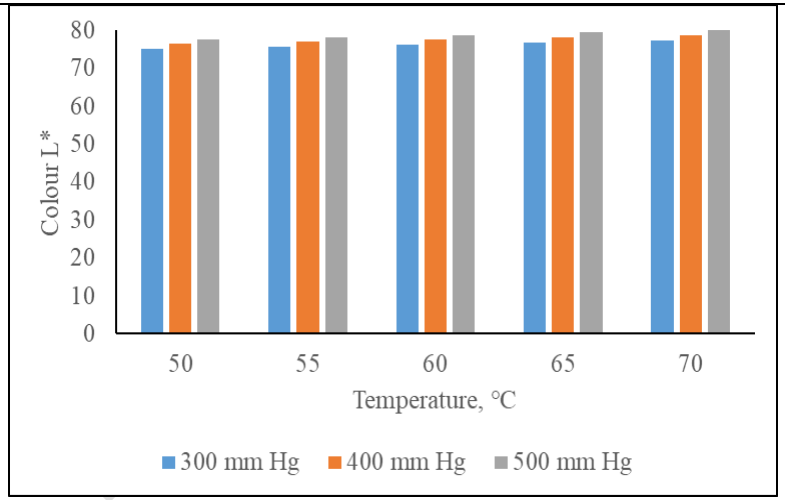

Fig. 1(f): Effect on colour L* value using vacuum drying

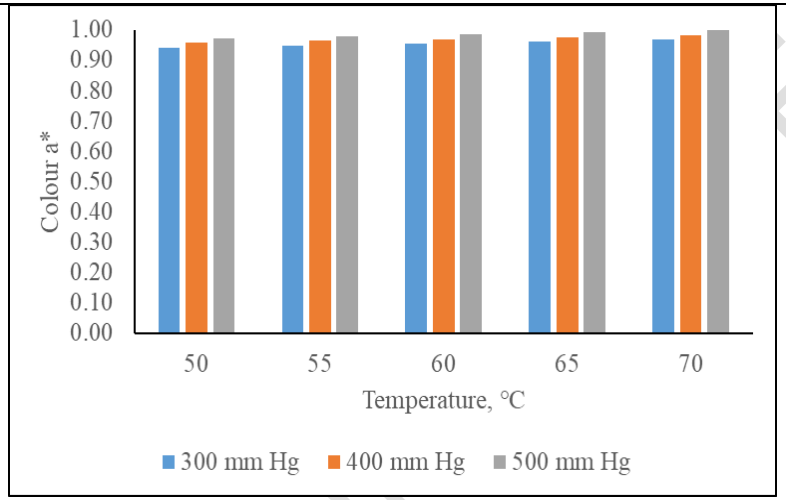

Fig. 1(g): Effect on colour a* value using vacuum drying

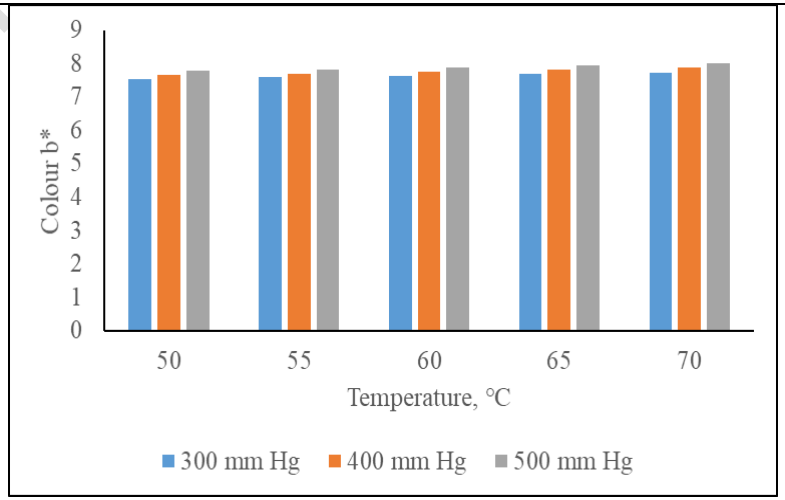

Fig. 1(h): Effect on colour b* value using vacuum drying

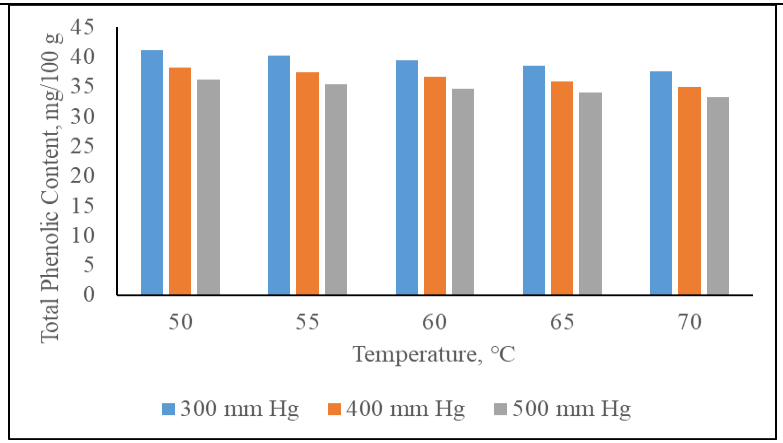

Fig. 1(i): Effect on total phenolic content duirng vacuum drying

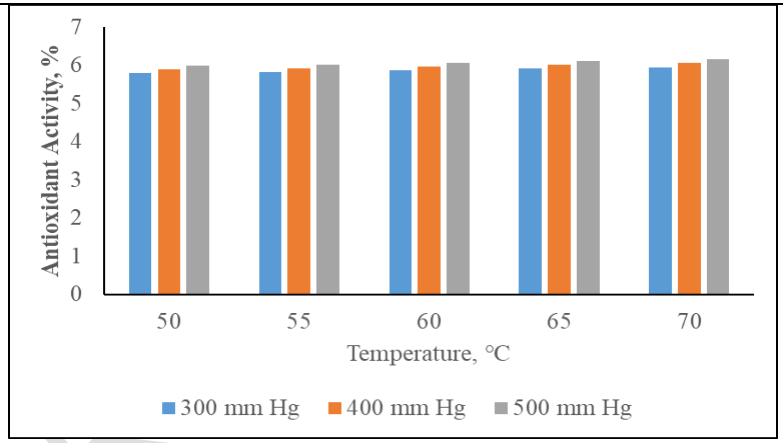

Fig. 1(j): Effect on antioxidant activity duirng vacuum drying

Table 2: ANOVA for biochemical properties during vacuum drying

Drying time							***Moisture content***						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***	***Source of Variation***	***df***	***MS***	***F***	***P-value***	***F crit***	
Vacuum Pressure	2170	2	1085	59.2	1.606×10^{-05}	4.459	**Vacuum Pressure**	0.010	2	0.005	32.168	2.11×10^{-09}	3.204
Temperature	25743.33	4	6435.833	351	5.126×10^{-09}	3.838	**Temperature**	0.005	4	0.001	8.536	3.25×10^{-05}	2.579
Error	146.667	8	18.333				**Interaction**	9.74×10^{-06}	8	1.22×10^{-06}	0.007	1	2.152
Total	28060	14					**Error**	0.007	45	0.0001			
							Total	0.023	59				
Water activity							**Carbohydrate**						
Vacuum Pressure	0.020	2	0.010	16.848	3.45×10^{-06}	3.204	**Vacuum Pressure**	102.940	2	51.470	16.848	3.45×10^{-06}	3.204
Temperature	0.007	4	0.002	2.995	0.028	2.579	**Temperature**	36.604	4	9.151	2.996	0.028	2.579
Interaction	1.95×10^{-05}	8	2.44×10^{-06}	0.004	0.999	2.152	**Interaction**	0.0983	8	0.012	0.004	1	2.152
Within	0.027	45	0.001				**Error**	137.470	45	3.055			
Total	0.055	59					**Total**	277.111	59				

Colour L*						
Vacuum Pressure	65.259	2	32.629	32.168	2.11×10^{-09}	3.204
Temperature	34.635	4	8.659	8.536	3.25×10^{-05}	2.579
Interaction	0.062	8	0.008	0.008	1	2.152
Within	45.645	45	1.014			
Total	145.602	59				

Colour a*						
	0.010	2	0.005	32.168	2.11×10^{-09}	3.204
	0.005	4	0.001	8.536	3.25×10^{-05}	2.579
	9.74×10^{-06}	8	1.22×10^{-06}	0.008	1	2.152
	0.007	45	0.0001			
	0.023	59				

Colour b*						
Vacuum Pressure	0.653	2	0.326	32.168	2.11×10^{-09}	3.204
Temperature	0.346	4	0.086	8.536	3.25×10^{-05}	2.579
Interaction	0.007	8	7.79×10^{-05}	0.008	1	2.152
Within	0.456	45	0.010			
Total	1.456	59				

Total phenolic content						
Vacuum Pressure	219.483	2	109.742	16.849	3.45×10^{-06}	3.204
Temperature	78.046	4	19.511	2.996	0.028	2.579
Interaction	0.210	8	0.026	0.004	1	2.152
Within	293.105	45	6.513			
Total	590.844	59				

Antioxidant activity						
Vacuum Pressure	0.386	2	0.1930	32.168	2.11×10^{-09}	3.2043
Temperature	0.205	4	0.0512	8.536	3.25×10^{-05}	2.579
Interaction	0.0003	8	4.61×10^{-05}	0.008	1	2.152
Within	0.270	45	0.006			
Total	0.862	59				