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Effect of Packaging Materials and Treatments on Biochemical quality characteristics of Indian Blackberry (*Syzygium cumini* L.) Fruit Pulp during Storage

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ABSTRACT: Indian blackberry (*Syzygium cumini* L.) fruit is seasonal and highly perishable in nature owing to its delicate texture and high moisture content. It is required to store the pulp in the harvesting season to prepare different value added products from it in the lean season. The present investigation was carried out to preserve the fruit pulp using different chemical preservatives such as ascorbic acid (25mg/100g), sodium benzoate (300 ppm) and potassium sorbate (300 ppm) under ambient condition in metalized polyester poly (MPP) and high-density polyethylene (HDPE) packaging materials. Quality parameters of stored pulp were analyzed at 0, 30, 60 and 90 days of storage. The total phenolic content, total anthocyanin content, antioxidant and sensory score reduced with increase in storage period whereas change in colour and microbial load showed an increasing trend. Among all treatments, pulp treated 300 ppm sodium benzoate (T_3) gave best result with respect to highest sensory score (7.25±0.28), highest total anthocyanin content (32.93±3.29 mg/100g) with lowest colour change value (15.47±0.29) and microbial load ($5.90\pm0.05\times10^4$cfu/g) within acceptable limit in HDPE packaging at 90 days of storage. HDPE packaging was found to be better in terms of total anthocyanin content, total phenolic content and antioxidant activity of stored pulp as compared to MPP packaging. The fruit pulp heated at 90˚C for 5 min and treated with 300 ppm sodium benzoate can be stored for 90 days under ambient condition for further value addition.

Keywords: Jamun pulp, total anthocyanin content, total phenolic content, antioxidant activity, microbial load, sensory, MPP and HDPE packaging.

INTRODUCTION

Indian blackberry (*Syzygium cumini* L.), a potentially tropical indigenous minor fruit crop in India and it belongs to the family myrtaceae. It is native to the Indian subcontinent and southeast Asian countries, eastern Africa and Australia, grown several tropical and sub-tropical countries region (Oliveria *et al.*, 2016). This fruit crop is known by several different names in India, such as Jamun, Jambul, and Jamoon, however it is also known by other names internationally, including Indian blackberry, Java Plum, black Plum, Portuguese plum, Jambolana plum, Jambolana, and Jamblang (Kannan and Puraikalan 2013).

Indian blackberry fruit has been used as a therapeutic and nutraceutical in nature due to extensive diversity of health-promoting components. It has rich source of antioxidant activity and various phytochemicals present in it such as glycoside, anthocyanin content, jamboline, jambosine, ellagic acid, tannins and mineral content (Qamar *et al.*, 2022). It is generally used a traditional medicinal crop, whose parts havebeen pharmacologically proven to possess hypoglycemic, neuropsycho-pharmacological, free radical scavenging, anti-bacterial, anti-fungal, anti-fertility, anti-inflammatory, gastro-protective, anti-ulcerogenic, anti-pyratic, anti-diarrheal, anti-diabetic, anti-HIV, radio-protective activities (Chhikara *et al*., 2018). It plays a significant role in the management of diabetes by lowering the blood sugar level (Qamar *et al*., 2022). Several traditional medical systems have utilised its various plant components, such as bark, leaves, fruit, pomace and seeds. Recently, the extraction, encapsulation and storage stability of anthocyanin content from Jamun fruit pomace was experimented and found better result for preserving its bioactive component (Panda *et al*., 2022).

As Jamun is seasonally available and highly perishable in nature, it is wasted during harvesting, rainstorms or during sorting and grading. Its harvesting season lasts around 30 to 40 days. After harvesting, mature fruits ripen fast at room temperature and become unsuitable for consumption. Between its harvest to use, the quality and shelf life of fruit significantly declines. Despite being the second largest producer of jamun in the world, India's production mainly remains unorganised with significant post-harvest loss of this fruit every year. External and internal conditions of fruits are responsible for post-harvest losses and affect the shelf life and quality parameters of fruit such as pH, total soluble solids, weight loss, juice contents and firmness etc. (Randhawa *et al.*, 2018). Also, it is possible to transform the fruit into value-added products like jam, jelly, Squash, ready to drink (RTD) and fresh pulp etc. to reduce post-harvest loss and accessible throughout the year (Shahnawaz *et al*., 2012). The Mango Loquat blended pulp was stored up to six months by different chemical preservatives under ambient condition (Ali and Muhammad, 2021). For conserving the shelf life of peach pulp natural preservative like tamarind extract was used (Ahmad *et al.*, 2022). Preservation of fruit pulp is very important so that the preserved pulp can be further used for the preparation of juice-based beverages throughout the year (Bagkar *et al.*, 2016). The Jamun fruit cannot be stored for more than 2 to 3 days under ordinary conditions due to its high metabolism rate and respires very fast i.e., the fruit consumes oxygen and ejects carbon dioxide, water & heat, decays only after one day at ambient condition. To prevent the wastage of fruit, days short harvest periods and to make available round the year, it is quite necessary to store the ripe fresh fruit for production of value-added products. Therefore, the present research work was aimed to evaluate the quality characteristics of jamun pulp and its effect on storage under ambient conditions using two types of packaging materials.

MATERIALS AND METHODS

Raw materials collection. The ripe jamun fruits (Large variety) were procured from the local market of Bhubaneswar (20° 17' 45.8124" N and 85° 49' 28.3404" E), Odisha, India in the second week of June, 2022. The damaged one and undesired materials were sorted out manually. The experiments were conducted in the department of Agricultural Processing and Food Engineering at CAET, OUAT.

Preparation of jamun pulp. Immediately after receiving fruits were washed with 100 ppm chlorinated water and then drained followed by surface drying for 3 hours under open shed on perforated metal plates. Jamun pulp was extracted by passing the cleaned jamun fruits through a pulper machine of 50 kg/h capacity. The pulp was collected at one outlet whereas rest pomace and seed were collected at another outlet. These operations were done taking 10 kg of fresh weight of jamun in three lots. Jamun pulp obtained from each lot was 5.475±0.65 kg. Then the extracted jamun pulp was mild heat treated at 90°C for 5 minutes. Then preservatives of different proportions (ascorbic acid (25 mg/100g), sodium benzoate (300 ppm) and potassium sorbate (300 ppm) were added and hygienically packed with two different types of presterilized packaging materials i.e., metalized polyester poly (MPP) pouches of 50 ml and high density poly ethylene (HDPE) bottles of 100 ml. The packed jamun pulp thus collected was stored under ambient condition (30 ± 2°C) for further analysis. The biochemical quality parameters, colour, microbial load and sensory evaluation of the pulp were measured intermittently after every 30 days interval.

Treatments details:

T1: Control (without any preservative)

T2: Pulp + 0.025% ascorbic acid

T3: Pulp + 300 ppm sodium benzoate

T4: Pulp + 300 ppm potassium sorbate

T5: Pulp + 0.025% ascorbic acid + 300 ppm sodium benzoate

T6: Pulp + 0.025% ascorbic acid + 300 ppm potassium sorbate

T7: Pulp + 300 ppm sodium benzoate + 300 ppm potassium sorbate

T8: Pulp + 0.025% ascorbic acid + 300 ppm sodium benzoate + 300 ppm potassium sorbate

Biochemical quality evaluation of pulp. Quality of treated and stored jamun pulp was analyzed in terms of total phenolic content, total anthocyanin content, antioxidant activity, colour change, microbial load and sensory evaluation.

Total phenolic content. Total phenolic content of sample was measured by spectrophotometric method by using Folin-Ciocalteu (F.C.) reagent. The procedure followed were 1.5 ml Folin-Ciocalteu's reagent was added to pulp extract supernatant (1 ml diluted to 10 ml with distilled water) and allowed to incubate at room temperature for 5 min. 1 ml of 20% (w/w) Na_2CO_3 was added, adjusted with distilled water up to the mark of 25 ml, agitated and left to stand for 45 min at room temperature. Then, TPC, was found out following the method explained by Abd El-Salam and Morsy (2019) and the results were expressed as mg Gallic acid equivalents (GAE)/100g.

Total anthocyanin content. Total anthocyanin content (TAC) of stored jamun pulp was estimated by pH-differential spectrophotometry methods as describe by Ghosh *et al.* (2017).

Antioxidant activity. The antioxidant activity of stored jamun pulp was determined by DPPH (2,2-diphenyl-1-picrylhydrazyl) method as described by Ghosh *et al.* (2017).

Change in colour. The colour of jamun fruit was analyzed using CR-20 (Konica, Milonta, INC, Japan) Colorimeter. Prior to analysing the sample, a white coloured tile was used to calibrate the instrument. Obtained results were expressed in the form of L^*, a^* and b^* where L^* value represents the lightness coefficient of colour (0= black, 100= white), a^* value represents greenness to redness and b^* value represents yellowness to blueness. The values of L, a and b were chosen to represent the colour of fruits (Ghose *et al.*, 2017).

Triplicate samples were analysed and the average value was reported. The change in colour of pulp was calculated by the following formula.

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

Where, ΔE is the change in colour from the standard, ΔL, Δa and Δb are the differences in the respective colour values of the sample at initial stage.

Microbial load. Microbial load of Jamun pulp was recorded using standard plate count method (Kaddumukasa *et al.*, 2017). Petri plates, test tubes, conical flask, measuring cylinder and the prepared media (nutrient agar) was also autoclaved at 121° C at 15 psi pressure for 45 min. For the serial dilution, the test tubes were filled with 9 mL NaCl solution and autoclaved at 121° C at 15 psi pressure for 30 min. one g of Jamun pulp was taken from each sample under aseptic condition and placed in a sterile test tube. A 10-fold serial dilution for each sample was made up to 10-5 dilution. One mL of dilution sample was transferred to each of two plates to enumerate bacteria. Then the plates were incubated at incubation oven at 37°C for 24 hours. The number of colonies was counted per plate and recorded in next days.

Sensory evaluation. The sensory evaluation was done using a 9-point hedonic scale following the procedure of Amerine *et al.* (1965). The 9-point hedonic scale used the descriptive scoring i.e., like extremely 9, like very much 8, like moderately 7, like slightly 6, neither like nor dislike 5, dislike slightly 4, dislike moderately 3, dislike very much 2 and dislike extremely 1. The attributes for the product under study considered were colour, aroma, taste and overall acceptability. However, the overall acceptability was estimated by composite scoring. The investigation attributes were given some weightage based on the judge's opinion regarding the importance given to a particular investigating attribute. The weightages given to a particular subjective attribute was in such a way that the sum of the weightages for all the investigating attributes was 1. In composite scoring the scores allotted to each investigating attributes was multiplied by corresponding weightage and then the average of all the cumulative summation was considered to be the score of overall acceptability.

Statistical analysis. Statistical analysis of data was carried out by using Minitab software (version 17). Collected data were analysed using two-way analysis of variance (ANOVA) and the means were corelated at the $p<0.05$ level of significance by employing Tukey's test. Results were expressed as mean ± standard deviation.

RESULTS AND DISCUSSION

The effects of different preservative treatments, packaging materials and storage period on the biochemical, microbial and sensory quality of pulp are analysed and discussed hereunder.

A. Effect of different treatments, packaging material and storage periods on Total phenolic content

The total phenolic content (TPC) of jamun pulp stored in MPP and HDPE packaging during storage is given in Table 1. TPC of the pulp decreased in all the treatments with storage periods. Maximum decrease in total phenolic content was observed in control sample followed by sample treated with ascorbic acid only. The total phenolic content of control sample decrease from an initial value of 289.41±3.89 mg GAE/100g to 164.21±3.00 mg GAE/100g in MPP and to 205.45±4.18 mg GAE/100g in HDPE packaging after 90 days of storage. The retention of TPC in HDPE packaging was found to be significantly higher than MPP packaging for all the treatments after 90 days. Similar findings of decreasing TPC throughout the storage periods was reported by Ali and Muhammad (2021) for mango loquat blended pulp and Randhawa *et al.* (2018) for jamun fruit pulp juices. The retention of TPC was observed to be highest for T5 sample in HDPE (258.77±4.25 mg GAE/100g) and MPP (235.15±4.01 mg GAE/100g) packaging after 90 days of storage. Walkowiak-Tomczak (2007) reported also declination of TPC due to an increment in temperature and oxygen during storage period. The higher oxygen permeability of MPP pouch as compared to HDPE might be responsible for the oxidation and reduction of total phenolic content of jamun pulp stored in MPP. The treatment of 300 ppm sodium benzoate and potassium sorbate with 0.025% ascorbic acid retained maximum TPC compared to any other treatment.

Table 1: Effect of treatments and storage periods on total phenolic content (mg GAE/100g) of jamun pulp.

Treatments	Fresh	MPP			HDPE		
	0 days	30 days	60 days	90 days	30 days	60 days	90 days
T1	289.41±3.89	219.22±6.00^{e}	202.15±7.00^{c}	164.21±3.00^{d}	238.49±5.01^{d}	221.57±4.35^{f}	205.45±4.18^{c}
T2		251.24±3.88^{abc}	221.24±5.32^{b}	199.14±4.74^{c}	274.13±4.61^{b}	268.99±4.22^{ab}	248.60±3.89^{a}
T3		235.57±7.02^{cde}	215.30±2.01^{bc}	201.17±5.01^{bc}	276.87±5.31^{ab}	259.42±2.05^{bc}	247.28±7.26^{a}
T4		226.63±4.01^{de}	204.29±1.89^{c}	195.22±3.02^{c}	243.20±4.06^{cd}	234.55±2.98^{e}	224.60±4.84^{b}
T5		268.57±5.11^{a}	248.18±4.00^{a}	235.15±4.01^{a}	290.35±5.11^{a}	272.64±3.55^{a}	258.77±4.25^{a}
T6		246.67±4.99^{bcd}	220.19±6.01^{b}	214.32±4.02^{b}	254.21±4.82^{c}	247.85±5.20^{d}	219.42±4.89^{b}
T7		255.42±13.00^{abc}	225.23±8.19^{b}	202.19±6.02^{bc}	284.49±4.28^{ab}	254.61±5.08^{cd}	244.64±7.05^{a}
T8		262.36±8.99^{ab}	225.54±4.99^{b}	202.61±7.05^{bc}	253.81±5.05^{c}	231.25±4.39^{e}	212.61±6.59^{b}

Values represents mean ± standard deviation; Values with different letters within the same column are significantly different by Tukey's test at $P < 0.05$

B. Effect of different treatments, packaging material and storage periods on Total anthocyanin content (TAC)

The values of total anthocyanin content during storage up to 90 days is given in Table 2. It was found that the TAC of the pulp drastically decreased with respect to storage period for all the treatments and packaging materials under study. However, sudden decrease was observed during the first 30 days of storage irrespective of treatments and packaging materials. The decrease in anthocyanin content during storage was probably due to hydrolysis of unstable aglycones, degradation of intermediaries, formation of co-pigment complexes with flavonoids and degradation due to polyphenol-oxidase as reported by (Wesche-Ebeling and Montgomery 1990) for juice storage. Similar results of degradation in anthocyanin content with respect to storage period were also reported for strawberry juice (Garzon and Wrolstad 2006), strawberry pulp (Bishnoi *et al.*, 2016) and blood orange juice concentrate (Kirca and Cemeroglu 2003). The reduction in TAC was found to be maximum in control sample which decreased from an initial value of 134.72±3.03 mg/100g to 10.47±4.0 mg/100g in MPP and 20.52±2.78 mg/100g in HDPE packaging. The TAC of jamun pulp stored in HDPE was significantly higher than MPP for all the treatments. Highest retention of TAC was observed for T3 and T6 treatment stored in HDPE packaging after 90 days storage period. The total anthocyanin content of jamun pulp stored in HDPE packaging was more than that of MPP probably due to higher oxygen permeability of MPP in comparison with HDPE.

Table 2: Effect of treatments and storage periods on total anthocyanin content (mg/100g) of jamun pulp.

Treatments	Fresh	MPP			HDPE		
	0 days	30 days	60 days	90 days	30 days	60 days	90 days
T1	134.72±3.03	35.20±1.99^{c}	20.16±4.99^{de}	10.47±4.00^{de}	72.17±2.89^{ab}	51.35±4.28^{b}	20.52±2.78^{c}
T2		29.37±2.99^{c}	28.48±3.98^{cd}	14.51±2.02^{cd}	58.38±2.52^{cd}	44.28±3.22^{c}	21.36±3.18^{c}
T3		72.41±3.03^{a}	55.14±1.99^{a}	24.40±3.04^{ab}	76.89±3.23^{a}	61.28±2.28^{ab}	32.93±3.29^{ab}
T4		15.13±4.99^{d}	12.47±6.98^{e}	19.38±3.01^{de}	55.23±4.59^{cd}	49.27±6.58^{bc}	27.59±3.46^{abc}
T5		32.41±3.03^{c}	24.33±5.01^{de}	15.34±4.00^{bcd}	53.49±3.63^{d}	43.88±4.86^{c}	23.14±4.20^{bc}
T6		30.80±3.00^{c}	19.46±3.01^{de}	4.79±3.50^{e}	69.16±3.08^{ab}	62.46±4.23^{a}	36.49±3.27^{a}
T7		52.47±3.00^{b}	40.18±4.99^{bc}	20.17±2.99^{bc}	68.19±3.06^{ab}	53.23±4.68^{abc}	30.26±3.09^{abc}
T8		55.15±2.99^{b}	45.65±5.00^{ab}	23.34±4.01^{a}	62.90±2.78^{bc}	49.13±4.75^{bc}	23.14±4.34^{bc}

Values represents mean ± standard deviation; Values with different letters within the same column are significantly different by Tukey's test at $P < 0.05$

C. Effect of different treatments, packaging material and storage periods on antioxidant activity

The antioxidant activity of jamun pulp during storage is given in Table 3. Antioxidant activity of the pulp decreased with storage periods for all the treatments and samples stored in HDPE showed higher antioxidant activity as compared to MPP after 90 days of storage. The antioxidant activity was observed to be lowest in control sample after 90 days of storage which decreased from an initial value of 90.32% to 78.74% in MPP and to 79.26% in HDPE packaging. The effects of different preservatives treatments on jamun pulp during storage was negligible and non-significant ($p<0.05$), indicates preservatives had very little effect on the change of antioxidant activity of jamun pulp and remained stable up to 90 days storage. Similar findings of decrease in antioxidant activity were reported for mango loquat blended pulp (Ali and Muhammad 2021) and blended fruit pulp (Hoffmann *et al.*, 2017) under ambient storage conditions.

Table 3: Effect of treatments and storage periods on antioxidant activity (%) of jamun pulp.

Treatments	Fresh	MPP			HDPE		
	0 days	30 days	60 days	90 days	30 days	60 days	90 days
T1	90.32±0.36	88.09±0.24^{d}	83.15±0.23^{f}	78.74±0.79^{d}	89.85±0.53^{bc}	84.52±0.48^{e}	79.26±0.38^{c}
T2		89.80±0.66^{b}	86.32±0.16^{d}	83.80±0.24^{b}	90.00±0.48^{abc}	89.227±0.37^{bc}	88.081±0.42^{a}
T3		89.38±0.23^{bc}	86.91±0.11^{cd}	84.68±0.23^{ab}	89.28±0.52^{c}	88.69±0.19^{c}	88.27±0.75^{a}
T4		88.44±0.23^{cd}	87.08±0.52^{cd}	85.28±0.70^{a}	90.62±0.25^{ab}	89.40±0.28^{abc}	86.13±0.26^{b}
T5		91.21±0.35^{a}	88.71±0.35^{a}	85.83±0.32^{a}	89.41±0.38^{c}	87.31±0.24^{d}	86.24±0.65^{b}
T6		90.32±0.58^{ab}	89.15±0.58^{ab}	84.65±0.38^{ab}	91.01±0.37^{a}	89.92±0.48^{ab}	88.69±0.58^{a}
T7		90.42±0.49^{ab}	87.63±0.39^{bc}	84.55±0.51^{ab}	90.22±0.32^{abc}	89.52±0.35^{abc}	88.37±0.45^{a}
T8		89.65±0.46^{bc}	84.19±0.23^{e}	81.57±0.23^{c}	91.00±0.21^{a}	90.28±0.38^{a}	88.98±0.29^{a}

Values represents mean ± standard deviation; Values with different letters within the same column are significantly different by Tukey's test at $P < 0.05$

D. Effect of different treatments, packaging material and storage periods on Change in colour (ΔE)

The change in colour of jamun pulp during storage up to 90 days is given in Table 4**.** There was steep increase in colour change value of the pulp in the first 30 days of storage after which it significantly increased up to 90 days in both the packaging materials. Highest colour change was observed in control sample (T1) in both MPP and HDPE packaging. The change in colour value of control sample were found to be 18.93±0.16 in MPP and 19.94±0.34 in HDPE packaging after 90 days of storage. However, lowest colour change values were observed in samples treated with sodium benzoate only (T3) followed by samples treated withs odium benzoate plus potassium sorbate plus ascorbic acid(T8) in both the packaging materials after 90 days. The samples treated with ascorbic acid showed higher colour change as compared to the other treatments which might be due to increase in acidity of the pulp. Higher colour change was observed in samples packed in HDPE as compared to that in MPP packaging. This may be due to the higher opaqueness of MPP to light as compared to HDPE.

E. Effect of different treatments, packaging material and storage periods on Microbial load

The effect of different preservative treatments, storage periods and packaging material on microbial load (bacterial count) in jamun pulp stored under ambient condition are presented in Table 5. The total bacterial count in jamun pulp increased with storage periods in both MPP and HDPE packaging. However, results also indicated that bacterial load increased suddenly in control (T_1) sample as no chemical preservatives were used. Maximum load of 155×10^4 cfu/g in MPP and 211×10^4 cfu/g in HDPE packaging were found in control sample after 30 days of storage. With increase of storage period beyond 30 days in control sample, the samples got spoiled and the packaging materials were swelled with gas generated due to high microbial load. As the microbial load in control samples were more than the safety limit of 1×10^6cfu/ml (Kornacki, 2017) in both the packaging materials, the samples were not acceptable to use at 30 days of storage.

The microbial load of jamun pulp stored in MPP were significantly lower than that of HDPE packaging for all the treatments under study. The total bacterial load of pulp ranged from 2.51×10^4 to 6.80×10^4cfu/g in MPP and 4.10×10^4 to 7.7×10^4cfu/g in HDPE after 90 days of storage which were within the acceptable limit. Lowest microbial load was observed in T5 sample where sodium benzoate and ascorbic acid preservatives were used, while T8 showed highest microbial load in both the packaging materials (Table 5). After 90 days of stored jamun pulp, the microbial load was minimum in T5 (2.51×10^4cfu/g) treatment packed in MPP packaging. The use of ascorbic acid and sodium benzoate significantly influenced the microbial load of jamun pulp. Similar findings were also reported by Adeola and Aworh (2014) in the shelf-life study of tamarind juice. Stephen *et al.* (2018) also noticed that sodium benzoate had a good preservative effect against colonizing microorganisms in orange juice.

Table 4: Effect of treatments and storage periods on change in colour of jamun pulp.

Treatments	MPP			HDPE		
	30 days	60 days	90 days	30 days	60 days	90 days
T1	5.11±0.46^{d}	11.52±0.16^{b}	18.93±0.16^{a}	13.03±0.82^{ab}	16.48±0.55^{a}	19.94±0.34^{a}
T2	12.92±0.56^{b}	15.69±0.39^{a}	18.09±0.46^{ab}	12.38±0.46^{d}	16.24±0.89^{c}	18.57±0.52^{b}
T3	5.06±1.17^{d}	6.93±0.31^{c}	11.30±0.34^{c}	8.23±1.17^{cd}	12.01±0.31^{c}	15.23±0.26^{d}
T4	15.35±0.22^{a}	16.31±0.29^{a}	18.52±0.16^{ab}	14.82±0.22^{a}	15.97±0.29^{a}	18.95±0.18^{b}
T5	14.42±2.64^{ab}	15.55±0.65^{a}	17.68±0.37^{b}	13.12±2.64^{ab}	15.94±0.65^{a}	19.06±0.18^{b}
T6	13.07±0.71^{ab}	16.67±0.62^{a}	18.74±0.11^{a}	12.41±0.71^{ab}	15.62±0.62^{a}	18.84±0.22^{b}
T7	8.68±0.38^{c}	10.24±0.26^{b}	11.71±0.30^{c}	10.99±0.38^{bc}	13.80±0.26^{b}	16.01±0.23^{c}
T8	4.82±0.61^{d}	7.48±0.37^{c}	11.63±0.32^{d}	8.88±0.61^{cd}	12.23±0.37^{c}	15.47±0.29^{cd}

Values represents mean ± standard deviation; Values with different letters within the same column are significantly different by Tukey's test at $P < 0.05$

Table 5: Effect of treatments and storage periods on microbial load ($\times 10^4$cfu/g) of jamun pulp.

Treatments	MPP			HDPE		
	30 days	60 days	90 days	30 days	60 days	90 days
T1	155.00±1.00^{a}	-	-	211.00±1.00^{a}	-	-
T2	0.29±0.03^{b}	1.94±0.08^{d}	3.40±0.08^{f}	0.27±0.05^{b}	2.15±0.04^{de}	4.50±0.07^{e}
T3	0.32±0.05^{b}	2.77±0.05^{b}	5.80±0.05^{b}	0.42±0.02^{b}	2.96±0.04^{b}	5.90±0.05^{c}
T4	0.29±0.03^{b}	2.01±0.03^{d}	4.20±0.06^{e}	0.28±0.03^{b}	2.42±0.05^{c}	5.10±0.07^{d}
T5	0.27±0.04^{b}	1.26±0.08^{e}	2.51±0.03^{g}	0.25±0.02^{b}	2.06±0.04^{e}	4.10±0.07^{f}
T6	0.28±0.04^{b}	2.32±0.05^{c}	5.30±0.06^{c}	0.28±0.05^{b}	2.23±0.05^{d}	5.80±0.05^{c}
T7	0.42±0.06^{b}	2.33±0.10^{c}	5.10±0.07^{d}	0.32±0.04^{b}	2.47±0.03^{c}	6.10±0.04^{b}
T8	0.56±0.07^{b}	3.50±0.06^{a}	6.80±0.06^{a}	0.45±0.04^{b}	3.70±0.03^{a}	7.70±0.04^{a}

Values represents mean ± standard deviation; Values with different letters within the same column are significantly different by Tukey's test at $P < 0.05$

F. Effect of different treatments, packaging material and storage periods on Sensory quality

The sensory evaluation of jamun pulp treated with different preservatives and stored in HDPE and MPP was carried out for different attributes *viz.* colour, aroma, taste and overall acceptability by 15 panel lists of different age groups using 9-point hedonic scale. The sensory scores of the samples are presented in Fig. 1 and 2. It was observed that, mean scores of colour, aroma, taste and overall acceptability of jamun pulp varied significantly with storage period, treatments and packaging materials. All the sensory scores decreased with storage period which might be due to slight browning, acidity and fermentation process owing to ambient storage temperature. Similar results were also reported by Khurdiya and Roy (1984) for jamun juice and Shakoor *et al.* (2013) for strawberry juice during storage.

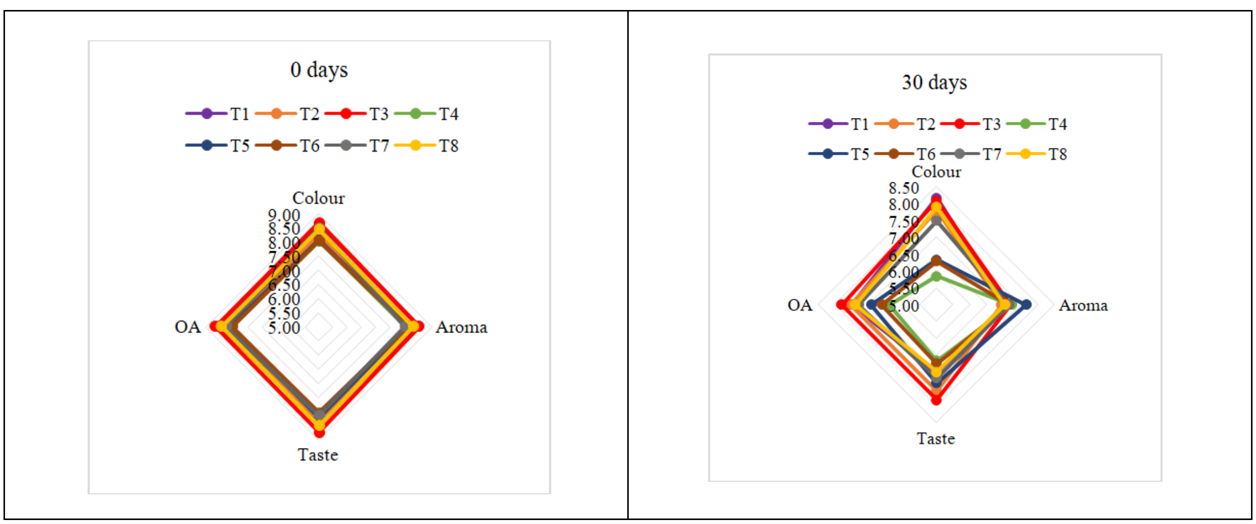
Colour. The colour score decreased significantly with storage period in both the packaging material. The sensory colour score highest in T_3 sample in both the packaging materials after 90 days storage of the pulp. The sensory colour score of samples packed in MPP were significantly ($p<0.05$) higher than that packed in HDPE. Similar results were also observed during the objective colour measurement of the pulp using Hunter lab colourimeter. Samples treated with ascorbic acid got lower colour score as compared to other treatments.

Aroma. The aroma score decreased with storage period in both the packaging material. The reduction was found to be sharp during the initial period of storage up to 30 days. The sensory aroma score was found to be highest in T_3 sample followed by T_5 sample in both the packaging materials. Samples T_2 and T_7 scored lower aroma score. However, aroma score of jamun pulp packed in MPP were higher than that packed in HDPE.

Taste. The taste score decreased with storage period in both the packaging material. The sensory taste scores were found to be highest in T_3 sample followed by T_5 sample in both the packaging materials. Samples T_4 scored lowest taste score as compared to other treatments. Taste score of jamun pulp packed in MPP were found to be higher than that packed in HDPE. After 90 days, the sensory taste score decreased from an initial value of 8.75 to 7.33 for T_3 sample in MPP pack and from 8.15 to 5.95 for T_4 sample packed in HDPE. These research findings are similar to Hayat *et al.* (2005); Mehmood *et al.* (2008) who reported consecutively decreasing trend of taste and flavour of mango and apple pulp during storage at room temperature and humidity of 25-32°C and 70-75%, respectively.

Overall acceptability. The overall acceptability score decreased with storage period in both the packaging material. The overall acceptability score was found to be highest in T_3 sample whereas, T_4 sample scored lowest score as compared to other treatments. Jamun pulp packed in MPP showed higher overall acceptability score than that packed in HDPE packaging. The overall acceptability score decreased from an initial value of 8.68 to 7.21 for T_7 sample in MPP pack and from 8.08 to 5.72 for T_8 sample packed in HDPE after 90 days of storage. Similar results were reported by Shahnawaz *et al.* (2012) who found out decrease in overall acceptability score of mango sea buckthorn blended pulp during storage study.

From the above sensory study, it could be concluded that jamun pulp treated with sodium benzoate (T_3) got higher sensory score for all the attributes and accepted by consumers after 90 days of storage under ambient condition. Shakoor *et al.* (2013) also reported that the colour, flavour and overall acceptability of strawberry juice decreased with increase in storage periods due to browning and loss of acids or effect of temperature and storage quality of juice.



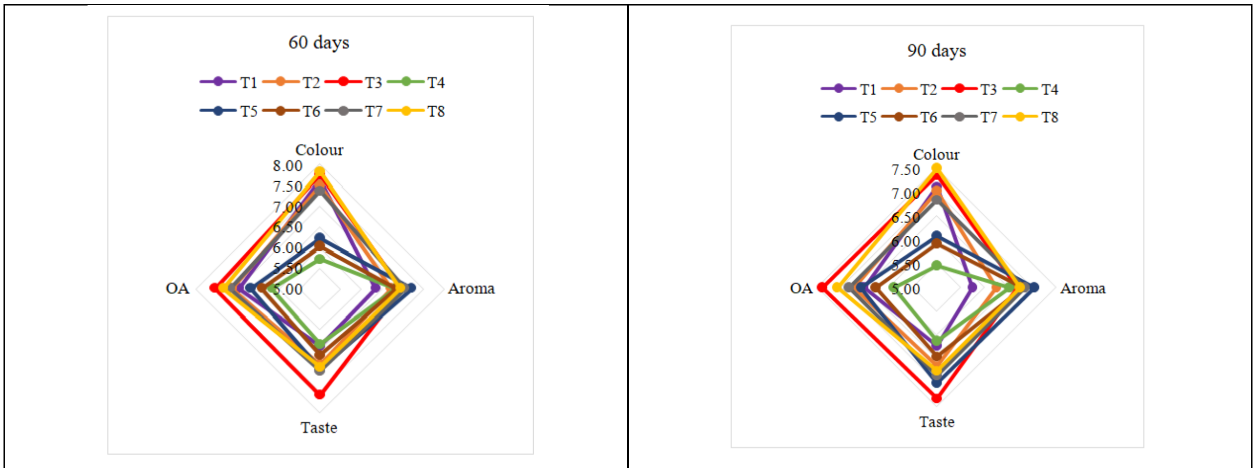


Fig. 1. Sensory evaluation of jamun pulp in MPP packaging with storage.

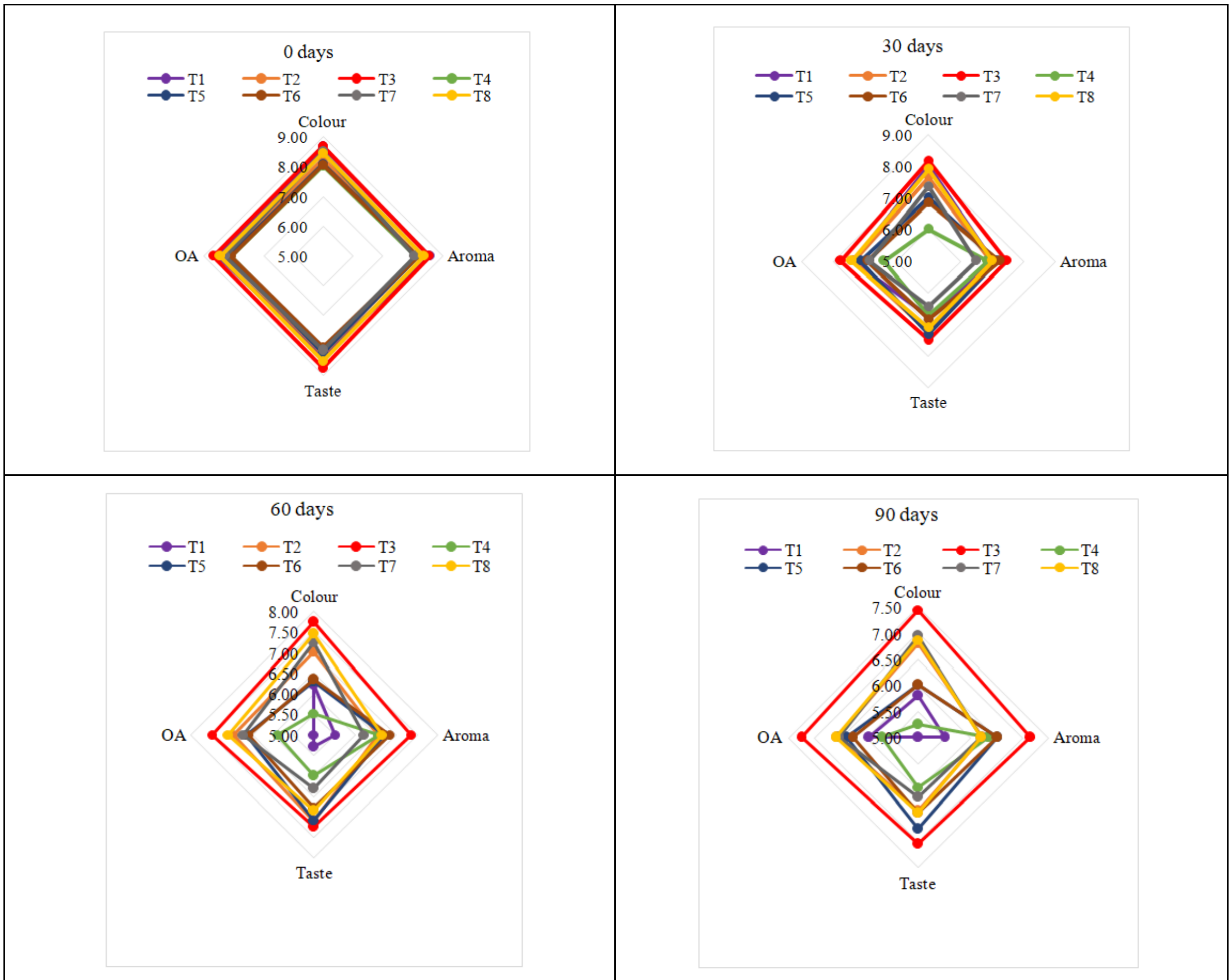


Fig. 2. Sensory evaluation of jamun pulp in HDPE packaging with storage.

Optimization of treatments for bulk packaging of jamun pulp. The jamun pulp treated with 300 ppm sodium benzoate (T_3) showed highest sensory score and total anthocyanin content, lowest colour change value and microbial load within acceptable limit. So, this treatment was recommended for shelf-life enhancement of jamun pulp during storage followed by T_8 (0.025% ascorbic acid + 300 ppm sodium benzoate + 300 ppm potassium sorbate) treatment. Bagkar *et al.* (2016) also reported similar results during storage of jamun juice up to 4 months using different concentration of sodium benzoate. However, sample treated with 300 ppm sodium benzoate and ascorbic acid (T_5) was also better in terms of sensory acceptability, highest total phenolic content and lowest microbial load. Though sample T_5 was having lowest microbial load due to the synergistic effect of preservatives (300 ppm sodium benzoate plus ascorbic acid), it was not acceptable because of low sensory score, total anthocyanin content and higher colour change value.

Comparison of packaging material. Jamun pulp stored in MPP pouch packaging was better in terms of lower microbial load and colour change value with higher sensory score as compared to that stored in HDPE packaging (Fig. 3). However, the total phenolic content, total anthocyanin content and antioxidant activity retained well in samples stored in HDPE packaging materials. There is negligible difference observed between HDPE and MPP packaging in terms of microbial load, colour change and sensory score. So, packaging of jamun pulp was recommended in HDPE packaging for storage up to 90 days under ambient condition.

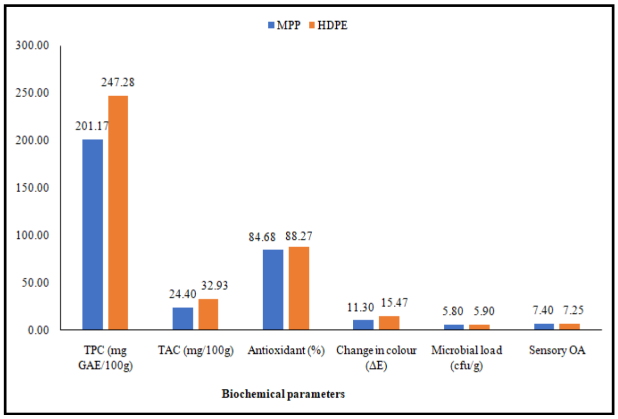


Fig. 3. Comparison of packaging materials on different biochemical parameters of jamun pulp after 90 days of storage.

CONCLUSIONS

The present study concluded that jamun pulp treated with different preservatives significantly influence the quality characteristics during storage. Since jamun is highly perishable fruit which cannot be stored for longer period, it could be stored in pulp form for its availability in off-season to prepare different value-added products. Among different treatments use of sodium benzoate at 300 ppm concentration (T_3) showed best results followed by T_8 (0.025% ascorbic acid + 300 ppm sodium benzoate + 300 ppm potassium sorbate) for storage of jamun pulp up to 90 days under ambient conditionwith respect to biochemical properties, microbial load and sensory score. HDPE packaging was found to be better in terms of total anthocyanin content, total phenolic content and antioxidant activity.

FUTURE SCOPE

Since Jamun fruit is seasonally available, it has great opportunity to develop different value-added products like Jam, Jelly, Squash, RTS drinks, candy and fruit bar etc. from its stored pulp. This research work may be extended under refrigerated storage condition for further improve in quality and shelf-life of Jamun pulp.

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Conflict of Interest. None.

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