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Optimisation of packaging and storage of jamun (*Syzygium cumini* L.) fruits

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Abstract
An experiment has been carried out to evaluate the suitability of packaging materials for extending the shelf life of jamun fruit which is highly perishable in nature. The fruits were packed in the packaging materials LDPE, HDPE, PP and stored at ambient (28 to 42 °C), 3 °C, 6 °C and 9 °C temperatures for 0, 2, 4, 6 and 8 days after harvest with 3 replications and the control being that without packaging.
The best suited packaging material depending on the biochemical, microbial and physiological changes observed at different days of storage and different temperatures was found to be LDPE at 3 °C for 6 days after harvest. The fate of vitamin C among all the treatments decreased continuously during storage where at 3 °C in LDPE it had minimal loss. Also the rotting and weight loss were lower in LDPE upto 6 DAH. Due to low gas (GTR) and water vapor transmission rates (WVTR) in LDPE, the losses were lower than in HDPE and PP.
The fruits were not suitable to be stored at 6 or 9 °C due to their high degree of susceptibility to infection by Botrytis cineria and Saccharomyces sps. Hence, the best storage temperature for jamun was 3 °C with LDPE (50 µ) as packaging material.

Keywords: LDPE, HDPE, PP, storage temperature

Introduction
Indian blackberry, commonly known as jamun (*Syzygium cuminii* L.) is a minor and underutilized tropical fruit. It is rich in tannins, flavonoids, essential oils, anthocyanins, and other phenolic constituents (Sharma *et al.* 2003; Reynertson *et al.* 2008) [17, 15]. The purple coloured fruits are available abundantly during summer season for a short span of time, causing a seasonal glut. The fruits and seeds are sweet, acrid and sour and they are used for the treatment and control of diabetes, diarrhea and blood pressure in unani/ayurvedic system of medicine. Jamun trees are available around parks, on roadsides on avenues. On account of its unorganized farming, consolidated information regarding its area and production in India is not available. The fruits are highly perishable and are sold by road side vendors, under unhygienic environment, which cuts short its shelf life drastically.
Packaging protects the produce from mechanical injury, and contamination during marketing. Packing can greatly influence air flow rates around the commodity, thereby affecting temperature and relative humidity management of produce while in storage or in transit. In India proper packaging is inadequate which a major cause of post-harvest losses. Packaging materials have significant impact on the quality and storage life of fruits (Neeraj and Kumar, 2004; Kumar *et al.*, 2005) [12, 10]. Studies related to post harvest physiological behavior of this fruit negligible or nil. Also, there are no standard methods for storage of jamun fruit. The shelf life of the fruit is not more than a day at room temperature. The information an optimum storage temperature of jamun is either scanty or not available. Although this fruit has been considered as a powerhouse of nutraceuticals yet, its use in the processing industry is limited due to lack of information on packaging of appropriate storage of this delicate fruit.
Keeping in view the above facts, the present study was undertaken with the objective to study the effect of various packaging materials at different temperatures on the shelf life of jamun fruit during storage.

Materials and Methods

The materials and method followed for conducting the experiment is detailed in the following.

a) Packing of the fruits for storage

Fully mature and healthy fruits of *jamun* (*desi* variety) of uniform size, free from pest and diseases were collected. They were washed in potable water and packed in 20 × 17 cm polyethylene pouches (containing 200 gm fruits) made up of low density poly ethylene (LDPE) of 50 μ, high density poly ethylene (HDPE) of 50 μ and poly propylene (PP) of 30 μ. The fruits without packing were treated as the control. The packed fruits and the control were kept at ambient (29 to 42 °C and 70-75% RH), 3 °C, 6 °C and 9 °C temperature for storage and were analysed for their physiological, physico-chemical and microbial quality and shelf life at 0,2,4,6,8 days after harvest (DAH). The experiment was analyzed statistically using completely randomized design with 3 replications in a factorial layout using SAS 9.2 package developed by SAS Institute (2000) and were subjected to Duncan's multiple range comparisons test (DMRT) procedure using least significant difference at 5% level.

The detail properties of packaging materials with respect to CO_2, O_2 and water-vapor transmission rates were measured using package testing equipment (Labthink® VAC-VBS Gas Permeability Tester and PERME™ W3/030 Water Vapor Transmission Rate Tester respectively) as per ASTM Standard E 96.

Table 1: Properties of packaging materials

Packaging Material	O_2 GTR ($cm^3/m^2/24h$)	CO_2 GTR ($cm^3/m^2/24h$)	WVTR ($g/m^2.24h$)
LDPE	1870.03	8872.65	16
HDPE	10082.78	4974.5	7.8
PP	2701.73	1663.58	9.3

b) Evaluation of the quality of the fruits

For determining the keeping quality of the fruits in various packages stored at different temperatures certain observations were made as mentioned in the following.

i. Assessment of physiological quality

Respiration rate: By using head space gas analysis technique with the help of CO_2/O_2 analyzer (Model: Checkmate 9900 O_2/CO_2, PBI Dan sensor, Denmark) the respiration rate was measured and expressed as mL CO_2 kg^{-1} h^{-1}. Rate of respiration was calculated on the basis of rate of evolution of CO_2 from the sample per unit weight per unit time using the following formula.

$$\text{Respiration rate (ml } CO_2 \text{ kg/H)} = \frac{CO_2\ (\%) * \text{Head space (ml)}}{100 * \text{Weight (kg)} * \text{Time (H)}}$$

Ethylene evolution: Rate of ethylene evolution was measured using gas chromatograph technique.

Physiological loss in weight: The fruit were weighed during storage at regular intervals with the help of an electronic balance. Physiological loss in weight was calculated by using the following formula and data were expressed in percentage.

$$\text{PLW}(\%) = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{ x } 100$$

Rotting (%): The percentage fruits decay was calculated by using the following formula:

$$\text{Rotting } (\%) = \frac{\text{Number of decayed fruits}}{\text{Number of total fruits}} \text{ x } 100$$

ii. Assessment of physico-chemical quality

Total soluble solids: The total soluble solids of the fruit were determined using ERMA hand refractometer by placing a drop of the juice on the refractometer prism (AOAC 2001) [1].

Total sugars, reducing sugars and non-reducing sugars were determined by AOAC (2001) [1] method.

Titrable acidity was determined by titrating a known weight of sample with 0.1N NaOH solution using a few drops of phenolphthalein as indicator (AOAC, 2001) [1]. Acidity of sample was expressed as percent citric acid.

$$\text{Acidity } (\%) = \frac{\text{T.V} * \text{N} * \text{Total vol.} * \text{Eq. wt. of acid} * 100}{\text{Vol. of sample taken for estimation} * \text{Wt. of sample taken} * 1000}$$

Ascorbic acid: By titrating the sample with 2, 6-dichlorophenol indophenol dye using metaphosphoric acid as stabilizing agent (AOAC, 2001) [1] the ascorbic acid content was determined and was expressed as mg of ascorbic acid per 100 g or ml.

$$\text{Ascorbic acid (mg/100 g or ml} = \frac{\text{T.V} * \text{D.F} * \text{Vol. made up}}{\text{Aliquot of extract x vol. of sample taken}} \text{ x } 100$$

Anthocyanin content: The total monomeric anthocyanin content was determined by a UV-visible spectrophotometer using pH-differential method (Wrolstad *et al.*, 2005) [21] of two buffer systems viz. potassium chloride buffer, pH 1 (0.025 M) and sodium acetate buffer, pH 4.5 (0.4 M). Samples were diluted in pH 1 and pH 4.5 buffers, and absorbance was recorded at 510 and 700 nm using 1 cm path length cuvette.

$$\text{Monomeric anthocyanin content} \left(\frac{\text{mg}}{\text{l}}\right) = \text{A} * \text{MW} * \text{DF} * 1000/(\varepsilon \text{ x } 1)$$

Where,

A (Absorbance) = ($A_{510\ nm}$-$A_{700\ nm}$) pH 1.0-($A_{510\ nm}$-$A_{700\ nm}$) pH 4.5

MW (molecular weight) = 449.2 g/mol for caynidin-3-glucoside & 493.5 g/mol for malvidin-3-o-glucoside

DF = dilution factor; ε = 26,900 & 28,000 molar extinction coefficient in l/mol/cm for caynidin-3-glucoside & malvidin-3-o-glucoside respectively

l = path length in cm 1000 = conversion from g to mg.

Total phenolic content: The total phenolic content was determined by the Singleton and Rossi method (1965) and was expressed in mg of gallic acid equivalents (GAE)/100 mL of the extract.

Moisture content: The moisture content of the fruits was determined by gravimetric method. The moisture content was expressed in percentage.

$$\text{Moisture content}(\%) = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{ x } 100$$

Results

i. Physiological quality of *jamun* fruits

Respiration rate (mg CO_2 $kg^{-1}h^{-1}$)

Rate of respiration gradually increased during storage in all the treatments irrespective of the storage temperatures and packages that ranged from 23.03 to 36.39 mg CO_2 kg-^{1} h-^{1}, 23.03 to 30.32 mg CO_2 kg-^{1} h-^{1}, 23.03 to 31.97 mg CO_2 kg-^{1} h-^{1} and 23.03 to 35.16 mg CO_2 kg-^{1} h-^{1} in control, LDPE, HDPE and PP respectively as depicted in Fig 1 and Table 1. Whereas, the control sample showed the highest respiratory rate at ambient temperature irrespective of the packaging materials due to the direct interaction with the atmosphere where the chances of gaseous exchange is more.

Ethylene evolution rate

No sign of ethylene evolution was found in all the treatments at all the storage periods. This could be due to non-climacteric nature of the fruit.

PLW (%)

The PLW was found to increase gradually throughout the storage period in all the treatments irrespective of the storage temperatures and packaging. A sharp increase in PLW was observed in control at all the temperatures except at 3 °C, where considerably losses were less. Similar trend was followed HDPE and PP packaging materials.

Rotting (%)

As there was no ventilation in the packages, the heat liberated during the respiration remained in the packages and so it caused spoilage upon storage irrespective of the packaging materials and temperatures. It is evident from the properties of packaging materials that LDPE had high WVTR compared to HDPE and PP. Hence, more exchange of water vapor in LDPE probably resulted in maintaining a low water activity leading to less incidence of rotting (Fig. 3).

ii. Physico chemical quality of *jamun* fruits

Total soluble solids (°Brix)

The T.S.S of the fruits decreased in all the treatments during storage irrespective of the storage conditions. At 3 °C, the unpacked fruits and fruits packed in LDPE were non-significant and fruits packed in HDPE were at par to them. The TSS of *jamun* fruits exhibited least changes at 3 °C but a decreasing trend was observed at higher temperatures. With the advancement of storage days also, the TSS followed a declining trend. On 8 DAH, fruits stored at 3 °C in LDPE showed maximum retention of T.S.S followed by the unpacked fruits, HDPE and PP which were found to be non-significant. The superiority of LDPE could be observed at all the temperatures during the whole period of storage (Table 2).

Reducing sugars (%)

Similar to that of TSS there was a rapid reduction in reducing sugars at ambient temperature. However, the reduction in reducing sugars at low temperature was very low up to 2 DAH at all the storage temperature. On 4th day there was a rapid decline in reducing sugars at 9 °C which was at par with 3 °C on 8th day. In general no significant difference in the reducing sugars could be observed among the packaging materials and control throughout the storage (Table 2).

Total sugars (%)

Similar to the fate of TSS and reducing sugars the total sugar content also followed a declining trend with the advancement in storage and rise in temperature. At 3 °C, there was minimal reduction in all the packaging materials and they were at par to each other except for LDPE where there was lower reduction. Similar trend was followed throughout the storage period.

Non Reducing sugars (%)

The non-reducing sugars also showed a similar trend to that of TSS, total sugars and reducing sugars with rapid reduction in non-reducing sugars at ambient temperature. With the reduction in total sugars, and reducing sugars, non reducing sugars also decreased as they are a portion of the total sugars.

Titrable acidity (%)

No significant difference in the titrable acidity was found among the treatments throughout the storage.

Ascorbic acid (mg/100 mL)

The ascorbic acid content of fruits decreased progressively during storage in all the treatments (55.5 to 45.2 mg/100 g). However, maximum ascorbic acid content was retained in fruits packed in LDPE at 3 °C (55.5 to 51.6 mg/100 g) followed by control (55.5 to 50.3 mg/100 g). The maximum retention of ascorbic acid was observed at 3 °C followed by 6 °C. The decrease in ascorbic acid was non-significantly different in all the packages and at all the temperatures except in LDPE the losses were lower than other packaging materials (Table 2).

Anthocyanins content (mg/100 g)

The anthocyanins in the *jamun* fruit decreased upon storage in all the storage conditions. A drastic change was visible at ambient temperature which ranged from 7.25 to 4.32 mg/100 g. Among the temperatures, retention was higher at 3 °C followed by 6 °C and 9 °C. Among the packages fruits packed in LDPE were found to have higher amount of anthocyanins followed by control, HDPE and PP. In LDPE, the maximum retention was observed as it had low oxygen and water vapor transmission rates compared to HDPE and PP (Table 2).

Total phenols (mg/100 mL) and Total antioxidants (µg mL^{-1} Trolox)

The total phenols and antioxidants have reduced during storage at all storage conditions from the day of harvest to 8 days after harvest (Table 2). In LDPE the retention of phenols and antioxidants is higher among all the packaging materials at 3 °C with LDPE being the better followed by HDPE and PP.

Moisture content (%)

A Continuous decrease in moisture was observed among all the temperatures where at
9 °C the losses were low compared to other temperature. Maximum loss was observed at ambient temperature among all the packaging materials. And all the observations were significantly different. The maximum reduction in moisture content at ambient temperature in all the packages and in control might be due to prevalence of high temperatures (29 to 42 °C) which caused dehydration of the fruits leading to decrease in moisture.

Discussion

i. Physiological quality of *jamun* fruits

Fruits packed in LDPE bags exhibited a slow and gradual rise in respiratory rate during the storage period up to 8 DAH which might be due to its lower oxygen transmission rate. And the gradual increase in PLW during storage is primarily due to high transpiration rate of the fruit. The loss in weight in fruits packed in LDPE was lower than HDPE and PP could be attributed to low water vapor transmission rate (Table 1) of LDPE. This is also evident from the high retention of moisture content packed in LDPE bags (Fig. 2). Similar such observations were reported by Baviskar *et al.* (1995). In control, the high PLW at all the temperatures might be due to the direct exposure of the fruit to the atmosphere which has further led to the high transpiration rate. It was higher at ambient temperature as the temperature was higher and kept fluctuating from 29 to 42 °C at each storage interval.

It is evident from the data presented in fig. 3 that rotting of *jamun* fruits was directly proportional to the increase in storage temperature. Tomkins and Cumming (1988) also reported similar finding. In PP higher percentage of rotting was probably due to poor CO_2 transmission rate compared to LDPE and HDPE.

ii. Physico chemical quality of *jamun* fruits

Our finding on reduction in TSS with the advancement in storage period is contradictory to other climacteric fruits. It might be due to the microbial utilisation of sugars for their nutrition. An alcoholic smell was observed as the fruits lost their initial freshness which supports the fact that the microorganisms have utilized the solids. Presence of *Saccharomyces sps.* and *Botrytis cineria* supports this result. Yeasts have a slightly higher growth rate than moulds, which ferment sugars into alcohols, and are responsible for off-flavors and off-odors. Yeast growth has been responsible for shelf life failure shredded chicory endives packed in high oxygen atmosphere with barrier film at 4 ℃ (Jacxsens *et al.*, 2001).

Loss of reducing sugars during storage could be attributed towards microbial utilization of high respiratory activity of the fruits as evident from fig 3. With the advancement in storage, the total sugars also reduced like that of T.S.S due to their consumption by the yeast in PP and HDPE and further in LDPE also. Whereas in control, though the decrease in total sugars was observed the incidence of the unwanted fermentation and accumulation of water was not present. It might be due to the micro climate created in the packages that allowed the accumulation of water inside the packages which further caused spoilage to the fruits that ultimately led to the reduction of total sugars. The decline of non-reducing sugars during storage could be attributed to the utilization of sugars by microbes during respiration.

The decrease in acidity might be associated with their utilisation as a substrate during respiration (Fig. 2). Similar decrease in organic acids was reported by Weichman (1986) [20]. Bhattarai and Gautam (2006) [3] stated that the fruit might utilise the acids during storage resulting in decrease in the acidity. Ramana *et al.* (1979) [14] substantiated the same that the change in total titrable acids during storage was mainly due to metabolic activities of the living tissues which further depletes the organic acids.

There was sharp decrease in vitamin C with the progress of storage which is in agreement with the observation reported by Gil *et al.* (1995) [6] in fruits and vegetables. It also indicates that the fruits are developing senescence. Tissue damage due to rotting might have led to the depletion of ascorbic acid. This fact is in accordance with Klein (1987) and Loewus. (1987) [9, 11] who have reported that on account of water loss and due to exposure to oxidation the ascorbic acid have decreased in *jamun*.

With the advancement in storage, there was reduction in anthocyanin content which might be due to the variable properties of the packaging materials with respect to gas and water vapor transmission rates.

The reduction in total phenols of the fruit during storage might be attack of microorganisms which have utilised the phenols. In LDPE the retention is more due to the low O_2 and high CO_2 property of LDPE which played a significant role in the retention of total phenols during storage.

Irrespective of the storage conditions and temperature of storage; a decrease in the antioxidant content was observed which might be attributed to the fact that as on oxidation there is reduction in the ascorbic acid and anthocyanin pigment, the antioxidants also reduced as ascorbic acid, anthocyanins and phenols contribute to the total antioxidant activity. Deepak *et al.* (2011) [4] and Rahman *et al.* (2007) [13] also reported that the antioxidant capacity of fruits and vegetables largely depends upon a plethora of individual or due to combined effect of individual antioxidants.

Among the packaging materials also the reduction in moisture was observed which might be due to the permeability of the packaging materials used to the atmospheric gases and differential water vapor transmission rates of the packages. In LDPE, the lower rate of moisture loss might be due to its low oxygen and water vapor transmission rates. These results are in agreement with Farooqi *et al.* (1975) [5] and Hussain *et al.* (2004) [7] who has reported increasing effect of packaging on retention of moisture content.

Table 2: Physico chemical quality of *jamun* fruits upon storage at different storage conditions

	2 DAH				4 DAH				6 DAH				8 DAH			
	AT	3 °C	6 °C	9 °C	AT	3 °C	6 °C	9 °C	AT	3 °C	6 °C	9 °C	AT	3 °C	6 °C	9°C
TSS (°B) at harvest =13.70^{a}																
CONTROL	11.00^{c}	13.00^{a}	12.40^{b}	12.30^{b}	-	12.20^{b}	12.00^{b}	11.30^{c}	-	10.40^{d}	10.00^{d}	9.60^{e}	-	9.60^{e}	-	-
LDPE	11.60^{c}	13.30^{a}	12.80^{b}	12.60^{b}	-	12.70^{b}	12.30^{b}	11.90^{c}	-	11.00^{c}	10.70^{d}	10.50^{d}	-	10.40^{d}	-	-
HDPE	11.70^{c}	12.90^{ba}	12.40^{b}	12.20^{b}	-	11.80^{c}	11.50^{c}	11.00^{c}	-	9.80^{e}	9.10^{e}	8.60^{f}	-	9.40^{e}	-	-
PP	11.40^{c}	12.80^{b}	12.20^{b}	12.00^{b}	-	11.30^{c}	11.10^{c}	10.60^{d}	-	9.50^{e}	8.80^{f}	8.10^{f}	-	9.00^{e}	-	-
Reducing sugars (%) at harvest =3.70																
CONTROL	2.72^{b}	3.56^{a}	3.08^{a}	3.04^{a}	-	3.08^{a}	3.00^{a}	2.80^{b}	-	2.56^{b}	2.40^{b}	2.36^{b}	-	2.28^{b}	-	-
LDPE	2.92^{b}	3.66^{a}	3.24^{a}	3.16^{a}	-	3.28^{a}	3.12^{a}	3.00^{a}	-	2.76^{b}	2.68^{b}	2.60^{b}	-	2.56^{b}	-	-
HDPE	2.96^{b}	3.40^{a}	3.16^{a}	3.08^{a}	-	3.00^{a}	2.92^{b}	2.76^{b}	-	2.40^{b}	2.28^{b}	2.16^{b}	-	2.18^{b}	-	-
PP	2.88	3.32^{a}	3.08^{a}	3.00^{a}	-	2.92^{b}	2.84^{b}	2.60^{b}	-	2.32^{b}	2.24^{b}	2.12^{b}	-	2.05^{b}	-	-
Total sugars (%) at harvest = 9.25^{a}																
CONTROL	6.80^{d}	8.90^{b}	7.70^{c}	7.60^{c}	-	7.70^{c}	7.50^{c}	7.00^{c}	-	6.40^{d}	6.00^{d}	5.90^{e}	-	5.70^{e}	-	-

LDPE	7.30^{c}	9.15^{a}	8.10^{b}	7.90^{c}	-	8.20^{b}	7.80^{c}	7.50^{c}	-	6.90^{d}	6.70^{d}	6.50^{e}	-	6.40^{d}	-	-
HDPE	7.40^{c}	8.50^{b}	7.90^{c}	7.70^{c}	-	7.50^{c}	7.30^{c}	6.90^{d}	-	6.00^{d}	5.70^{e}	5.40^{e}	-	5.40^{e}	-	-
PP	7.20^{c}	8.30^{b}	7.70^{c}	7.50^{c}	-	7.30^{c}	7.10^{c}	6.50^{d}	-	5.80^{e}	5.60^{e}	5.30^{e}	-	5.10^{e}	-	-
Titrable acidity (%) at harvest = 0.68^{a}																
CONTROL	0.43^{c}	0.65^{a}	0.64^{a}	0.61^{a}	-	0.60^{a}	0.57^{b}	0.53^{b}	-	0.53^{b}	0.51^{b}	0.49^{c}	-	0.48^{c}	-	-
LDPE	0.46^{c}	0.66^{a}	0.66^{a}	0.64^{a}	-	0.62^{a}	0.61^{a}	0.57^{b}	-	0.59^{b}	0.56^{b}	0.52^{b}	-	0.52^{b}	-	-
HDPE	0.45^{c}	0.63^{a}	0.62^{a}	0.60^{a}	-	0.58^{b}	0.55^{b}	0.51^{b}	-	0.50^{b}	0.47^{c}	0.44^{c}	-	0.46^{c}	-	-
PP	0.44^{c}	0.62^{a}	0.60^{a}	0.58^{b}	-	0.56^{b}	0.52^{b}	0.48^{c}	-	0.48^{c}	0.42^{c}	0.38^{d}	-	0.42^{c}	-	-
Ascorbic acid (mg / 100mL) at harvest = 55.5^{a}																
CONTROL	43.6^{j}	53.0^{b}	51.7^{c}	51.8^{c}	-	51.8^{c}	50.3^{c}	51.8^{c}	-	50.3^{c}	47.5^{e}	49.8^{d}	-	46.3^{e}	-	-
LDPE	42.5^{k}	53.8^{b}	52.0^{b}	52.2^{b}	-	53.0^{b}	50.7^{c}	52.2^{b}	-	51.6^{c}	48.7^{d}	50.2^{c}	-	47.9^{f}	-	-
HDPE	42.7^{k}	52.9^{b}	51.1^{c}	50.8^{c}	-	50.6^{c}	49.6^{d}	50.8^{c}	-	48.8^{d}	46.6^{e}	48.6^{d}	-	45.8^{g}	-	-
PP	42.1^{k}	52.8^{b}	50.9^{c}	50.7^{c}	-	50.3^{c}	49.1^{d}	50.7^{c}	-	48.2^{d}	45.9^{f}	48.7^{d}	-	45.2^{g}	-	-
Anthocyanin content (mg / 100g) at harvest =7.25^{a}																
CONTROL	4.32^{v}	7.10^{b}	7.14^{b}	7.00^{c}	-	6.82^{e}	6.74^{f}	6.60^{h}	-	6.20^{l}	5.94^{n}	5.67^{r}	-	6.00^{n}	-	-
LDPE	4.38^{u}	7.18^{b}	7.15^{b}	7.10^{b}	-	6.95^{c}	6.80^{f}	6.67^{g}	-	6.40^{j}	6.00^{n}	5.73^{r}	-	6.32^{k}	-	-
HDPE	4.35^{u}	6.90^{d}	6.60^{h}	6.50^{i}	-	6.60^{h}	6.46^{i}	6.39^{j}	-	6.15^{l}	5.82^{p}	5.51^{s}	-	5.93^{n}	-	-
PP	4.34^{v}	6.86^{d}	6.30^{j}	6.10^{l}	-	6.40^{j}	6.32^{j}	6.24^{k}	-	6.09^{m}	5.76^{q}	5.46^{t}	-	5.87^{o}	-	-
Total phenols (mg / 100g) at harvest = 215^{a}																
CONTROL	198.^{e}	214^{a}	212^{b}	210^{b}	-	210^{b}	208^{c}	207^{c}	-	205^{c}	202^{d}	199^{e}	-	202^{d}	-	-
LDPE	202.^{d}	215^{a}	214^{a}	212^{b}	-	212^{b}	210^{b}	208^{c}	-	208^{c}	206^{c}	203^{d}	-	204^{d}	-	-
HDPE	200^{e}	213^{a}	212^{b}	211^{b}	-	208^{c}	206^{c}	204^{d}	-	203^{d}	200^{d}	196^{f}	-	200^{e}	-	-
PP	201^{d}	213^{a}	213^{a}	211^{b}	-	206^{c}	203^{d}	201^{d}	-	202^{d}	198^{e}	194^{f}	-	199^{e}	-	-
Total antioxidants (µg mL^{-1} Trolox) at harvest =1275.1^{a}																
CONTROL	1172.3^{k}	1266.2^{a}	1256.3^{b}	1246.0^{c}	-	1245.0^{c}	1233.9^{e}	1227.2^{e}	-	1218.2^{f}	1199.6^{h}	1182.4^{c}	-	1198.0^{h}	-	-
LDPE	1196.0^{h}	1272.1^{a}	1270.1^{a}	1257.5^{b}	-	1258.1^{b}	1245.8^{c}	1233.9^{e}	-	1235.8^{e}	1223.8^{f}	1205.9^{g}	-	1211.8^{g}	-	-
HDPE	1184.2^{j}	1260.3^{b}	1255.3^{b}	1251.6^{c}	-	1236.5^{d}	1220.7^{f}	1210.0^{g}	-	1236.5^{e}	1220.7^{f}	1210.0^{g}	-	1187.7^{i}	-	-
PP	1188.1^{i}	1264.2^{b}	1262.2^{b}	1250.0^{c}	-	1222.5^{f}	1205.9^{g}	1193.0^{h}	-	1200.0^{h}	1176.2^{j}	1153.1^{l}	-	1180.6^{j}	-	-
Moisture (%) at harvest = 83.70^{a}																
CONTROL	78.40^{f}	82.00^{b}	82.30^{b}	82.60^{b}	-	79.10^{e}	80.20^{d}	81.90^{c}	-	76.40^{h}	78.30^{f}	80.10^{d}	-	78.60^{f}	-	-
LDPE	79.60^{e}	82.40^{b}	82.80^{b}	83.20^{a}	-	79.70^{e}	80.60^{d}	82.30^{b}	-	77.39^{g}	78.60^{f}	80.90^{d}	-	79.20^{e}	-	-
HDPE	79.00^{e}	80.70^{d}	81.60^{c}	82.10^{b}	-	78.80^{f}	79.50^{e}	81.20^{c}	-	74.50^{j}	75.90^{i}	78.70^{f}	-	76.80^{h}	-	-
PP	78.90^{f}	80.30^{d}	81.10^{c}	82.00^{b}	-	78.30^{f}	79.00^{e}	80.70^{d}	-	73.80^{b}	75.43^{i}	77.70^{g}	-	75.40^{i}	-	-

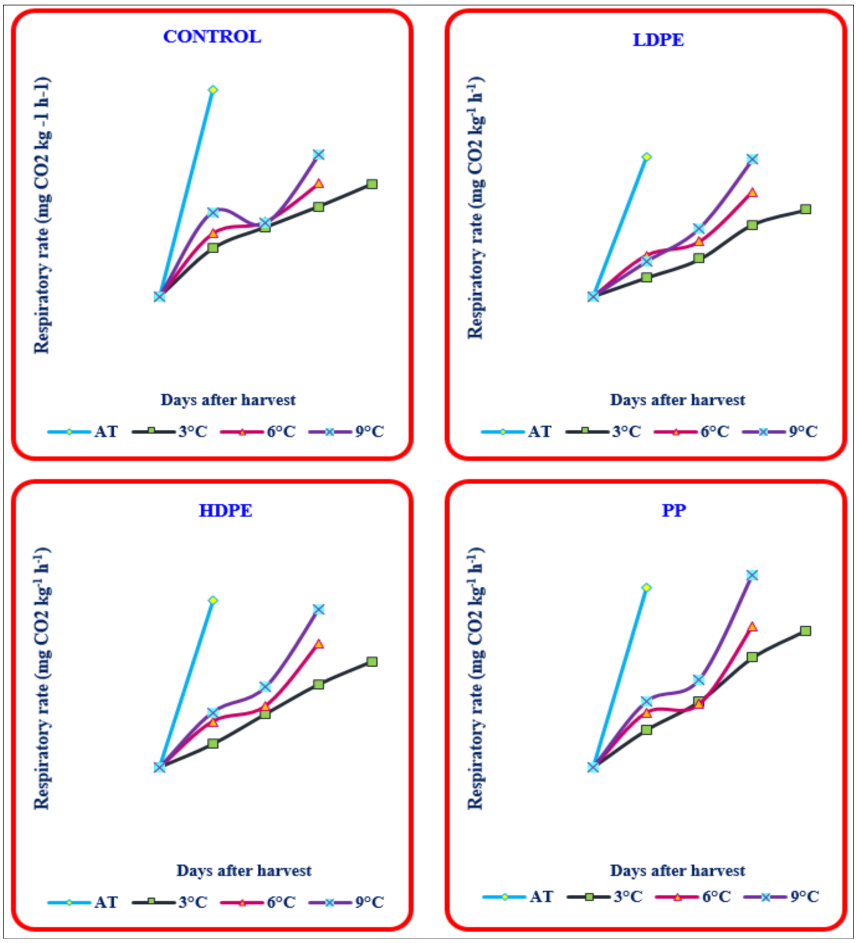

Fig 1: Respiratory rate (mg CO_2 kg^{-1}h^{-1}) of *jamun* fruits at different storage conditions

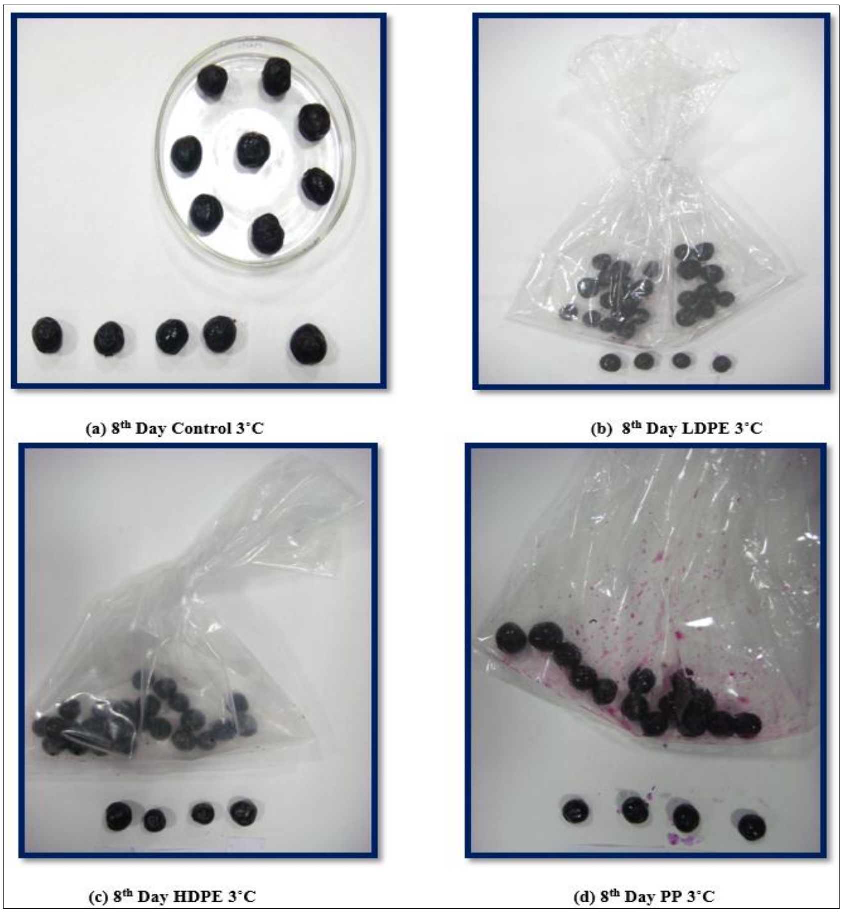

Fig 2: Jamun fruits at 8th day after harvest at different storage conditions

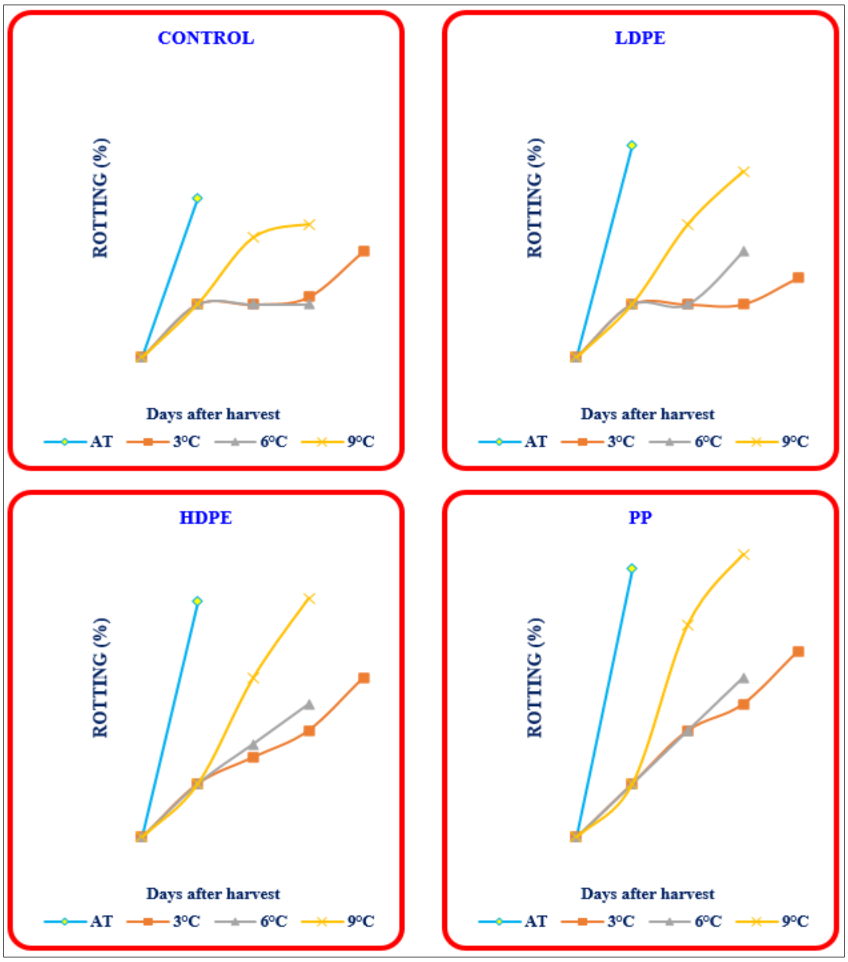

Fig 3: Rotting (%) of *jamun* fruits at different storage conditions

Conclusion
Packaging and storage at appropriate low temperatures increases the longevity of perishable fruits and vegetables. In our study, it was observed that the storage temperature and packaging had greatly affected the quality of *jamun* fruits. Although packaging in LDPE bags and control had close walk with each other throughout the storage period in various physic-chemical attributes. Yet, LDPE was found to be the best suitable package for *jamun* fruits as the retention of bioactive compounds like ascorbic acid, anthocyanins and phenols was higher than at control with low spoilage. Temperature and packaging material played an important role at 3 °C in protecting the fruit from spoilage due to better GTR and WVTR properties in LDPE bags as compared to HDPE and PP bags. Since, there was no systematic and scientifically sound method of harvesting of *jamun*, the inevitable skin injury coupled with highly favourable environmental conditions during harvest are the potential threats of storage of *jamun* fruits. Even with the best temperature management and packaging the storage life of these fruits could not be extended beyond 8 days after harvest. Evolving a suitable mechanism of fruit harvesting of *jamun* with least injury and hygienic collection would be the future research thrust for extending the storability of these important fruit considered to be the powerhouse of nutraceuticals.

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Declaration
Authors have declared that no competing interests exist.related to the work.

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