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Effect of packaging materials on quality parameters of guava (*Psidium guajava* L.) cv. Hisar Safeda during storage after transportation

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Abstract
An experiment was conducted in Post-harvest Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar to find the effect of nine packaging materials *viz*., sealed and perforated poly bags, wooden boxes with no cushioning, wooden boxes lined with newspaper lining, wooden boxes with paddy straw, wooden boxes lined with newspaper cuttings, corrugated fibreboard boxes lined with newspaper cuttings, corrugated fibreboard boxes without newspaper cuttings and plastic crates without cushioning used during transportation, on physiological parameters of guava cv. Hisar Safeda stored at room temperature during rainy season of 2017. The total distance covered by road for the transportation of packed guava fruits was 200 km (Hisar to Charkhi Dadri and back to Hisar). The data were recorded on total soluble solids, titratable acidity, ascorbic acid content, total soluble solids to acid ratio, reducing sugars, non-reducing sugar, total sugars, pectin content and organoleptic rating during storage. The results reveal that guava fruits packed in corrugated fibreboard box lined with newspaper cuttings had maximum total soluble solids, total soluble solids to acid ratio, ascorbic acid content, total sugars, reducing sugars and organoleptic rating and minimum acidity, while guava fruits packed in wooden box lined with paddy straw and wooden box lined with newspaper lining had maximum non-reducing sugar and pectin content respectively. The results of the experiment indicate that corrugated fibreboard boxes had a significantly overall positive influence on most of the recorded parameters.

Keywords: Guava, *Psidium guajava*, packaging, transportation, quality parameters

Introduction
Guava (*Psidium guajava* L.), popularly known as Apple of Tropics or Poor Man's Apple, belongs to the family Myrtaceae and is considered to be originated in the Southern part of Mexico and Central America, where from it was introduced to Asian countries in the 17th century. Guava owing to its hardy nature can be grown successfully in tropical and subtropical regions up to a height of 1500 m *amsl* and on a wide range of soils from heavy clay to sandy with pH of 4.5-8.2 (Chadha, 2001) [6]. Guava is cultivated in more than 60 countries of the world. The countries where it is cultivated commercially are India, Brazil, Mexico, Florida, Hawaii, California, Peru, Egypt, South Africa, Algeria, Columbia, West Indies, China and Malaysia. In terms of area and production, it is the fifth most important fruit crop, as it occupies an area of 262 thousand hectare with annual production and productivity of 3648000 and 13.9 tonnes per hectare, respectively. In Haryana, the total area under fruit crops is 64000 hectare with a production of 900000 tonnes, out of which, guava is cultivated on 12030 hectare area with a production and productivity of 185630 and 15.44 tonnes, respectively (Anonymous, 2017) [2]. Guava being a climacteric and extremely perishable fruit under ambient room conditions becomes overripe within a week, thus, its share in export market is not enough but it can be boosted by increasing its storability (Tandon *et al*., 1989) [36]. Due to the adoption of inappropriate packinghouse operations, packaging material and transport vehicle, 20-25% of the total produce is going waste every year before reaching the consumer (Chandra *et al.*, 2011) [8]. Therefore, guava fruits are required to be managed appropriately in order to get a regulated market supply, which can be attained with judicious use of post-harvest treatments followed by storage at appropriate temperature and relative humidity. Packaging of fruits is one of the most commonly used post-harvest practices that put them into unitized volumes, which are easy to handle and protect them from transportation and storage hazards. Use of proper packaging and cushioning material free from any harmful residual

effects on human health is always preferred for the storage of guava since they help in prolonging the shelf life to a great extent. Therefore, an experiment was planned to study the effect of packaging materials on physiological parameters of guava cv. Hisar Safeda during storage after transportation.

Materials and Methods

The experiment was conducted during rainy season of 2017 in Post-harvest Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar situated at 215.2 m *amsl* with 29º10′ N latitude and 75º46′ E longitudes. The fruits of Hisar Safeda cultivar were harvested at green mature stage from the experimental orchard from rainy season crop. Diseased, undesirable and damaged fruits were sorted out from the samples. Healthy fruits of uniform size were taken for conducting the experiment and packed in different packaging materials *viz*, sealed and perforated poly bags, wooden boxes with no cushioning, wooden boxes lined with newspaper lining, wooden boxes with paddy straw, wooden boxes lined with newspaper cuttings, corrugated fibreboard boxes lined with newspaper cuttings, corrugated fibreboard boxes without newspaper cuttings and plastic crates without cushioning each of 10 kg capacity. The total distance covered by road for the transportation of guava was 200 km (Hisar to Charkhi Dadri and back to Hisar). The treatments were laid out in completely randomized design with three replications and various physiological parameters were studied during experimentation. The total soluble solids (TSS) of the fruits was recorded using fruit juice through digital hand refractometer. Titratable acidity and ascorbic acid was estimated by using the method given in AOAC (2000) [4]. The total soluble solids: acid ratio was calculated by dividing the total soluble solids with acidity. Total sugars, reducing sugars and non-reducing sugar were estimated as per the method described by Hulme and Narain (1931) [16]. The total pectin as calcium pectate in fresh fruits was estimated by using the method of Ranganna (1979) [27]. The fruits were organoleptically evaluated by a nine point hedonic scale (Amerine *et al*., 1965) [2]. The data were tabulated in excel sheet and statistically analysed with the procedures described by Gomez and Gomez (1984) [13].

Results and Discussion

The perusal of data in Table 1 indicates that packaging materials had significant effect on total soluble solids (%) after transportation during storage. The maximum total soluble solids (%) was recorded in fruits packed in corrugated fibreboard box lined with newspaper cuttings (11.34%) followed by the fruits packed in corrugated fibreboard box with no newspaper cuttings (11.21%). The maximum retention of total soluble solids in fruit might be due to the hydrolysis of polysaccharides and slow rate of sugar utilization in the process of respiration because of modified atmosphere in corrugated fibreboard box lined with newspaper cuttings during storage of fruits. The minimum total soluble solids (%) was observed in fruits packed in wooden box with no cushioning (10.50%), which was at par with the fruits packed in wooden box lined with newspaper (10.58%).

Table 1: Effect of different packaging materials on total soluble solids (%) during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		10.36	11.27	11.21	10.30	11.00
Poly bags	Sealed	10.35	11.14	11.07	10.36	10.85
	Perforated	10.33	11.17	11.11	10.39	10.90
CFB box	Newspaper cuttings	10.31	11.32	11.25	10.35	11.34
	No cuttings	10.38	11.30	11.24	10.34	11.21
Wooden box	No cushioning	10.37	10.62	10.58	10.32	10.50
	Newspaper lining	10.28	10.73	10.67	10.35	10.58
	Paddy straw	10.40	11.04	11.00	10.31	10.79
	Newspaper cuttings	10.34	10.88	10.83	10.33	10.68
Mean		10.34	11.07	11.01	10.33	10.90

CD at 5% level of significance
Packaging material = 0.12
Storage period = 0.27
Packaging material x Storage period = NS

No significant results were obtained with the interaction between the packaging material and storage period. Similar findings were reported by Sharma *et al.* (2002) [31] who also found that the newspaper packed fruits of guava cv. Sardar recorded the maximum increase in total soluble solids, Ramesh and Pal (2006) [25]. who recommended that litchi fruits packed in corrugated fibreboard box showed the maximum retention of total soluble solids and Goutam *et al.* (2010) [14]. who reported in guava that the total soluble solids of fruits increased for few days in storage but later it declined.

The titratable acidity (%) of guava fruits packed in different packaging materials went on decreasing with the advancement of storage period (Table 2). The minimum acidity (0.44%) was noted in fruits packed in corrugated fibreboard box lined with newspaper cuttings, which was at par with fruits packed in wooden box lined with newspaper cuttings and plastic crates. Such reduction in acidity might be due to the utilization of different organic acids present in the vacuole of cells during various metabolic processes like respiration (Panda *et al.*, 2017) [23]. Whereas, the maximum acidity (0.47%) was recorded in fruits packed in wooden box with no cushioning, which was at par with fruits packed in sealed and perforated poly bags, wooden box lined with newspaper and paddy straw. No significant results were obtained with the interaction between the packaging material and storage period.

Table 2: Effect of different packaging materials on titratable acidity (%) during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		0.46	0.44	0.45	0.46	0.44
Poly bags	Sealed	0.46	0.43	0.45	0.46	0.46
	Perforated	0.47	0.45	0.46	0.47	0.46
CFB box	Newspaper cuttings	0.47	0.43	0.44	0.46	0.44
	No cuttings	0.45	0.44	0.45	0.48	0.45
Wooden box	No cushioning	0.46	0.45	0.47	0.48	0.47
	Newspaper lining	0.47	0.45	0.46	0.45	0.46
	Paddy straw	0.47	0.43	0.46	0.48	0.46
	Newspaper cuttings	0.46	0.46	0.47	0.46	0.45
Mean		0.46	0.44	0.45	0.46	0.45

CD at 5% level of significance
Packaging material = 0.01
Storage period = 0.01
Packaging material x Storage period = NS

The results of present study are in conformation with the findings of Goutam *et al.* (2010) [14]. who also reported a decrease in acidity of guava fruits with the advancement of storage period and a higher acidity in film wrapped guava fruits as compared to control fruits, Sharma *et al*. (2010) [32] who also reported that in apple, the acids decreased with time during storage and due to inverse relation between acids and total soluble solids, the acids decreased as the total soluble solids increased and Salomao *et al*. (2012) [29] who reported minimum acidity in fruits of litchi cv. Bengal immersed in different concentrations of hydrochloric acid and packed in polystyrene trays covered with polyvinyl chloride film.

The perusal of data in Table 3 indicates significant effect of storage period on transported guava packed in different packaging materials. The maximum ascorbic acid was recorded on 2nd day of storage with maximum value (198.0 mg/100 g pulp) for fruits packed in corrugated fibreboard box lined with newspaper cuttings, which might be due to the greater accumulation of carbon dioxide and lesser accumulation of ethylene causing the destruction of ascorbic acid, which reduced the oxidation of ascorbic acid (Isherwood and Mapson, 1962) [18]. The minimum value (190.0 mg/100 g pulp) was recorded for fruits packed in perforated poly bags, which was at par with the fruits packed in wooden box lined with newspaper cuttings. There was non-significant interaction between the packaging materials and storage. The results of present study are in line with the findings of Srivastava *et al*. (1962) [34]. who reported a decreasing trend in ascorbic acid during storage of guava fruits under ordinary conditions, Fassema *et al*. (2011) [11]. who also reported that in sweet orange, high rate of transpiration and respiration reduced the ascorbic acid and Rana *et al*. (2018) [26]. who suggested that wrapping of individual guava fruits helped in retention of higher ascorbic acid during storage, while the vacuum packed fruits retained maximum ascorbic acid.

Table 3: Effect of different packaging materials on Ascorbic acid content (mg/100 g pulp) during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		203.3	197.3	195.7	191.0	194.4
Poly bags	Sealed	203.3	196.6	195.3	191.3	194.4
	Perforated	201.6	197.0	195.6	190.0	194.2
CFB box	Newspaper cuttings	199.0	198.0	195.7	192.0	195.2
	No cuttings	202.3	197.7	195.0	190.6	194.4
Wooden box	No cushioning	202.0	195.3	194.7	190.6	193.5
	Newspaper lining	202.6	195.7	194.0	190.3	193.3
	Paddy straw	202.6	196.3	195.7	191.7	194.6
	Newspaper cuttings	201.6	196.0	195.6	190.0	193.9
Mean		201.9	196.6	195.2	190.8	194.2

CD at 5% level of significance
Packaging material = NS
Storage period = 1.5
Packaging material x Storage period = NS

The data in Table 4 indicate significant influence of different packaging materials on transported guava during storage. The total soluble solids to acid ratio (24.77) was noted maximum in fruits packed in corrugated fibreboard box lined with newspaper cuttings, which might be due to the increase in total soluble solids because of the hydrolysis of polysaccharides and decrease in acidity because of the utilization of organic acid in respiration during storage. The total soluble solids to acid ratio (23.10) was noticed minimum in fruits packed in wooden box with no cushioning followed by wooden box lined with newspaper (23.34). Significant interaction was found between different packaging materials and storage. The above study corroborate the findings of Subedi *et al*. (2017) [35]. who reported higher ratio of total soluble solids to acid (74.4) in apple packed in 3 Ply Beer cartons.

Table 4: Effect of different packaging materials on total soluble solids to acid ratio during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		22.52	25.97	24.91	22.39	24.42
Poly bags	Sealed	22.50	26.43	24.00	22.52	24.31
	Perforated	21.97	24.10	24.37	22.10	23.52
CFB box	Newspaper cuttings	21.93	26.25	25.57	22.50	24.77
	No cuttings	23.06	24.67	24.98	21.54	23.73
Wooden box	No cushioning	22.53	23.82	23.04	22.45	23.10
	Newspaper lining	21.88	23.99	23.21	22.83	23.34
	Paddy straw	22.12	24.87	25.01	21.48	23.79
	Newspaper cuttings	22.48	24.30	23.51	22.43	23.41
Mean		22.33	24.93	24.51	22.25	23.90

CD at 5% level of significance
Packaging material = 0.23
Storage period = 0.49
Packaging material x Storage period = 0.69

The packaging materials affected the reducing sugars of guava fruits during storage after transportation (Table 5). The maximum reducing sugars (3.50%) was noted in fruits packed in corrugated fibreboard box lined with newspaper cuttings, which might be due to the hydrolysis of insoluble polysaccharides to simple sugars or hydrolysis of sucrose during storage (Venkatesh *et al*., 2016) [16]. The minimum reducing sugars (2.66%) was observed in fruits packed in wooden box with no cushioning, which was at par with reducing sugars of fruits packed in sealed poly bags, perforated poly bags and wooden box lined with paddy straw as well as wooden box lined with newspaper cuttings. Interaction between different packaging materials and storage length significantly influenced the reducing sugars in guava fruits. The experimental results of the present study are in conformity with the reports of Ingle *et al*. (1982) [17]. who reported that the sapota fruits packed in LDPE bags showed an increase in reducing sugars during ripening as compared to other treatments, Garg *et al*. (2018) [12] who recommended that pomegranate fruits packed in corrugated fibreboard box had the maximum reducing sugars at room temperature up to 6th day of storage and Shalini *et al*. (2018) [30]. who also reported that the kiwi fruits packed in LDPE + 5 g KMnO4 retained maximum reducing sugars after seven months of refrigerated storage (2±1ºC).

Table 5: Effect of different packaging materials on reducing sugars (%) during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		3.12	3.43	3.28	3.01	3.24
Poly bags	Sealed	2.70	2.98	2.87	2.43	2.76
	Perforated	2.68	2.93	2.81	2.79	2.84
CFB box	Newspaper cuttings	3.72	3.70	3.59	3.23	3.50
	No cuttings	3.30	3.43	3.30	2.98	3.23
Wooden box	No cushioning	2.65	2.84	2.71	2.44	2.66
	Newspaper lining	2.64	2.79	2.65	2.33	2.59
	Paddy straw	2.51	2.75	2.63	2.65	2.68
	Newspaper cuttings	2.67	2.89	2.74	2.72	2.78
Mean		2.89	3.08	2.95	2.73	2.92

CD at 5% level of significance
Packaging material = 0.28
Storage period = 0.08
Packaging material x Storage period = 0.11

The accumulation of non-reducing sugar (%) showed an increasing trend with the increase in storage period and it slightly declined at over ripe stage (Table 6), being significantly highest(2.85%) in fruits packed in wooden box lined with paddy straw, which might be due to the hydrolysis of starch and conversion of pectin substances from water insoluble to water soluble fractions. The minimum non-reducing sugar (2.01%) was observed in fruits packed in corrugated fibreboard box lined with newspaper cuttings.

Table 6: Effect of different packaging materials on non-reducing sugar (%) during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		2.06	2.20	2.30	2.23	2.24
Poly bags	Sealed	2.53	2.52	2.60	2.77	2.63
	Perforated	2.51	2.71	2.69	2.44	2.61
CFB box	Newspaper cuttings	1.47	1.96	2.05	2.02	2.01
	No cuttings	1.90	2.21	2.30	2.24	2.25
Wooden box	No cushioning	2.56	2.46	2.56	2.75	2.59
	Newspaper lining	2.53	2.56	2.66	2.87	2.70

	Paddy straw	2.77	2.79	2.87	2.89	2.85
	Newspaper cuttings	2.54	2.57	2.69	2.56	2.61
Mean		2.31	2.44	2.52	2.53	2.50

CD at 5% level of significance
Packaging material = 0.09
Storage period = 0.18
Packaging material x Storage period = NS

Interaction between the packaging materials and storage period had no significant effect on non-reducing sugars of guava fruits. These results are in accordance with the findings of Hiwale and Singh *et al*. (2003) [15]. Who reported that guava fruits packed in 5% perforated LDPE had the maximum non-reducing sugar and Garg *et al*. (2018) [12]. who recommended that pomegranate fruits packed in corrugated fibreboard box had the maximum non-reducing sugar at room temperature up to 9th day of storage as compared to zero day of storage. The packaging materials influenced the guava fruits total sugars significantly during storage after transportation (Table 7). The guava fruits packed in corrugated fibreboard box lined with newspaper cuttings had the maximum total sugars (5.51%), which was at par with the fruits packed in plastic crates and fruits packed in corrugated fibreboard box with no newspaper cuttings. The higher retention of total sugars might be due to the reduced rate of respiration and slow conversion of starch and polysaccharides in sugars (Chandra *et al*., 2011) [8]. The fruits packed in wooden box with no cushioning had the minimum total sugars (5.25%), which were at par with the total sugars of fruits packed in wooden box lined with newspaper. Interaction between different packaging materials and storage length significantly influenced the total sugars in guava fruits. These results are in close conformity with the findings of Parihar and Kumar (2007) [24]. who reported that the total sugars in guava increased with the increase in storage period, (Mahajan *et al*., 2015) [14]. Who also suggested that plum fruits packed in 5% perforated LDPE increased the total sugars during storage, Garg *et al*. (2018) [12]. who recommended that pomegranate fruits packed in corrugated fibreboard box retained maximum total sugars at room temperature and Shalini *et al*. (2018) [30]. who also reported that the kiwi fruits packed in LDPE + 5 g KMnO4 retained maximum total sugars after seven months of refrigerated storage (2±1ºC).

Table 7: Effect of different packaging materials on total sugars (%) during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		5.18	5.63	5.58	5.24	5.48
Poly bags	Sealed	5.23	5.50	5.47	5.20	5.40
	Perforated	5.19	5.54	5.50	5.23	5.42
CFB box	Newspaper cuttings	5.19	5.66	5.64	5.25	5.51
	No cuttings	5.20	5.64	5.60	5.22	5.49
Wooden box	No cushioning	5.21	5.30	5.27	5.19	5.25
	Newspaper lining	5.17	5.35	5.31	5.20	5.29
	Paddy straw	5.22	5.54	5.50	5.17	5.40
	Newspaper cuttings	5.21	5.46	5.43	5.21	5.37
Mean		5.20	5.51	5.48	5.21	5.40

CD at 5% level of significance
Packaging material = 0.04
Storage period = 0.08
Packaging material x Storage period = 0.11

A significant decrease in pectin content (%) was observed with the advancement of storage period (Table 8). The maximum pectin content (0.46%) was noted in fruits packed in wooden box lined with newspaper. The reduction in pectin content during storage might be due to degradation of insoluble protopectin to soluble pectin by pectin methyl esterase (PME) enzyme, activity of which increased with the advancement in ripening of guava (Chandra *et al*., 2011) [8]. The minimum pectin content (0.33%) was observed in guava fruits packed in wooden box lined with newspaper cuttings. Interaction between different packaging materials and storage length had no significant influence on pectin content in guava fruits. These findings are in accordance with the results of Chaitanya (1984) [7] who reported minimum retention of pectin in unwrapped guava fruits and Wijewardane and Guleria (2009) [38] who also reported that the apple fruits treated with 2% *Neem* oil and packed in shrink wrapped tray had the maximum pectin content.

Table 8: Effect of different packaging materials on pectin content (%) during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		0.51	0.47	0.42	0.36	0.41
Poly bags	Sealed	0.54	0.49	0.43	0.38	0.43
	Perforated	0.51	0.46	0.40	0.34	0.39
CFB box	Newspaper cuttings	0.48	0.44	0.39	0.35	0.39
	No cuttings	0.46	0.42	0.36	0.32	0.36
Wooden box	No cushioning	0.47	0.43	0.39	0.34	0.38
	Newspaper lining	0.55	0.51	0.46	0.41	0.46
	Paddy straw	0.52	0.47	0.43	0.37	0.42

	Newspaper cuttings	0.42	0.38	0.33	0.29	0.33
Mean		0.50	0.45	0.40	0.35	0.40

CD at 5% level of significance
Packaging material = 0.01
Storage period = 0.04
Packaging material x Storage period = NS

The organoleptic rating of guava fruits show a gradual increase up to 2nd days of storage and thereafter it declined (Table 9). Taste, flavour and visual quality decreased with the increase in duration of storage**.** The maximum organoleptic rating (7.94) was noticed for guava fruits packed in corrugated fibreboard box lined with newspaper cuttings, whereas, the minimum organoleptic rating (7.07) was recorded for guava fruits packed in sealed poly bags. Organoleptic rating varied significantly due to interaction between different packaging materials and storage length.

Table 9: Effect of different packaging materials on organoleptic rating during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		7.1	8.3	8.1	6.4	7.61
Poly bags	Sealed	7.2	7.6	7.5	6.1	7.07
	Perforated	7.3	8.3	8.1	6.2	7.54
CFB box	Newspaper cuttings	7.1	8.6	8.5	6.7	7.94
	No cuttings	7.2	8.5	8.4	6.5	7.80
Wooden box	No cushioning	7.2	7.8	7.7	6.1	7.20
	Newspaper lining	7.1	8.1	7.9	6.3	7.43
	Paddy straw	7.3	8.2	8.1	6.4	7.57
	Newspaper cuttings	7.2	8.1	7.9	6.3	7.43
Mean		7.19	8.17	8.02	6.33	7.51

CD at 5% level of significance
Packaging material = 0.07
Storage period = 0.16
Packaging material x Storage period = 0.20

These findings are in accordance with the results of Jain and Chauhan (1993) [19] and Fassema *et al*. (2011) [11] who reported that organoleptic rating decreased with time, however, corrugated fibreboard box and wooden box were found the best to maintain organoleptic rating in kinnow mandarin and sweet orange, respectively, Kaur *et al*. (2014) [21] who reported that guava fruits packed in five percent perforated LDPE film and kept in corrugated fibreboard boxes can be stored for 14 days with good organoleptic quality at 6-8°C temperature and 90-95% relative humidity and Singh *et al.* (2014) [1] who reported that in guava fruits, different cushioning materials play a vital role in improving the organoleptic quality.

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