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Avesh,
Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana, India

Surender Singh
Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana, India

MK Rana
Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana, India

JR Sharma
Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana, India

Correspondence
Avesh,
Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana, India

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

Avesh, Surender Singh, MK Rana and JR Sharma

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 physiological loss in weight, decay loss or spoilage, fruit firmness, change in colour and injury during storage. The results reveal that the guava fruits packed in sealed poly bags had minimum physiological and decay loss, while the fruits packed in corrugated fibreboard box with newspaper cuttings retained maximum firmness with minimum injury. However, the guava fruits packed in perforated poly bags, wooden box lined with paddy straw and corrugated fibreboard boxes lined with newspaper cuttings maintained their colour in acceptable limit at the end of storage. 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, physiological 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) [5]. 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) [26]. 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) [6]. 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 physiological loss in weight (PLW) of the fruit was recorded using the formula given by Srivastava and Tandon (1968) [24] based on initial weight of the fruit and loss in weight that occurred. Spoilage was assayed by counting the number of spoiled fruits displaying fungal mycelia. The fruit firmness was measured with the help of a penetrometer using 4 mm cylindrical plunger probe. Change in colour of fruits was recorded on alternate days by visual observations. The injury was calculated by counting the number of injured fruits in different packaging materials after transportation. The data were tabulated in excel sheet and statistically analysed with the procedures described by Gomez and Gomez (1984) [10].

Results and Discussion

The perusal of data in Table 1 indicates that the physiological loss in weight (%) increased with the increase in storage period. After 6 days of storage, the fruits packed in sealed poly bags showed minimum physiological loss in weight (0.32%) followed by the fruits packed in corrugated fibreboard boxes with newspaper cuttings lining (1.03%), while the maximum physiological loss in weight was recorded in fruits packed in wooden box with no cushioning (5.69%) followed by wooden box with paddy straw cushioning (4.62%). The minimum physiological loss in weight of guava fruits packed in sealed poly bags might be due to the development of high humidity inside the bags, which reduced the rate of water loss from the fruit surface through a process of transpiration. Bhardwaj and Sen (2003) [4] also reported that the decreased physiological loss in mandarin might be due to the reduction of metabolism rate and prevention of water loss.

Table 1: Effect of different packaging materials on physiological loss in weight (%) during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage		
			2	4	6
Plastic crates		-	2.02	2.81	4.05
Poly bags	Sealed	-	0.16	0.22	0.32
	Perforated	-	0.31	0.43	0.62
CFB box	Newspaper cuttings	-	0.55	0.76	1.03
	No cuttings	-	0.62	0.86	1.32
Wooden box	No cushioning	-	2.84	3.95	5.69
	Newspaper lining	-	2.05	2.85	4.10
	Paddy straw	-	2.31	3.21	4.62
	Newspaper cuttings	-	2.10	2.92	4.20
Mean		-	1.44	2.00	2.88
CD at 5% level of significance			0.19	0.25	0.28

These results are in close conformity with the finding of Usushizaki *et al*. (1987) [28] who reported that apple fruits packed in different postures did not affect the physiological loss in weight, Jain and Chauhan (1993) [12] who reported minimum physiological loss in weight in Kinnow mandarin packed in corrugated fibreboard box, Baviskar *et al*. (1995) [3] who reported maximum physiological loss in weight of control fruits, while it was found minimum in guava fruits packed in polyethylene, Sharma and Singh (2010) [1] who also reported an increase in physiological loss in weight of apple fruits with the increase in storage period and Rana *et al*. (2018) [17] who recommended that the individual packing of guava fruits in polyethylene films reduced the physiological loss in weight.

The decay loss increased significantly with the increase in storage period (Table 2). This increasing trend in decay loss might be related to the spoilage of fruit caused by various fungal diseases like stem end rot, side rots, *etc*. during extended storage (Jeffries *et al*., 1990; Crane and Campbell, 1991; Eckert *et al*., 1996) [13, 7, 9]. On 2nd day of storage, the minimum decay loss (%) was observed in fruits packed in sealed poly bags, which was at par with decay loss in fruits packed in corrugated fibreboard box with newspaper cuttings lining followed by perforated poly bags. The minimum decay loss (%) in sealed poly bags might be due to low concentration of oxygen and high concentration of carbon dioxide, which suppressed the multiplication of spoilage causing microorganisms. The maximum decay loss (%) was noted in fruits packed in plastic crates (50.37%) followed by wooden box with no cushioning. However, after 6th day of storage, the decay loss or spoilage was noticed significantly minimum (31.75%) in fruits packed in corrugated fibreboard box with newspaper cuttings lining. The significant check in fruits spoilage in corrugated fibreboard box lined with newspaper cuttings might be due to the capability of newspaper cuttings to slow down the rate of respiration, ethylene evolution, oxidative metabolism and pectin hydrolysis, resulting in retention of firmness for longer

period, which in turn might have imparted some resistance against the growth of pathogens on fruits (Alam *et al*., 2014) [1]. The findings of present experiment are in line with the findings of Yadav *et al*. (2005) [31] who observed minimum decay loss in *Ber* fruits packed in corrugated fibreboard boxes since corrugated fibreboard boxes remained intact without any structural damage (Deka *et al*., 2008) [8], Sharma *et al*. (2009) [21] who also reported that the decay loss in apples increased with time during storage and Subedi *et al.* (2017) [25] who reported minimum spoilage (2.0%) in apple fruits packed in 7 Ply 180 PSI corrugated fibreboard boxes.

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

Treatment		Before transportation	Days of storage		
			2	4	6
Plastic crates		-	22.22	37.62	50.37
Poly bags	Sealed	-	09.25	20.05	34.77
	Perforated	-	10.36	19.35	29.15
CFB box	Newspaper cuttings	-	9.65	20.75	31.75
	No cuttings	-	10.45	22.15	33.79
Wooden box	No cushioning	-	16.29	28.78	40.81
	Newspaper lining	-	14.81	27.87	36.13
	Paddy straw	-	12.96	27.28	34.51
	Newspaper cuttings	-	11.85	25.64	33.96
Mean		-	14.90	25.50	36.14
CD at 5% level of significance			0.78	1.30	2.01

The packaging materials affected the firmness of guava fruits during storage after transportation (Table 3) and it declined sharply with increasing storage period. The guava packed in corrugated fibreboard box lined with newspaper cuttings retained maximum firmness (14.50 LBF), which was at par with the firmness of fruits packed in sealed poly bags (14.47 LBF) irrespective of storage period, which might be due to the higher concentration of carbon dioxide and low concentration of oxygen inside the package, which led to slow ripening and respiration rate, *per se* the fruits retained their firmness (Kaur *et al*., 2014) [16], while the minimum firmness was observed in fruits packed in wooden box with no cushioning (13.55 LBF) followed by wooden box lined with newspaper cuttings (13.62 LBF). The declined firmness might be due to the loss of water from the fruits and their ripening (Rokaya *et al*., 2015) [18]. The results of present investigation are in agreement with the findings of Thakur *et al.* (2005) [27] who reported that the fruit firmness decreased due to metabolic activities during post-harvest handling and distribution, Kaur *et al*. (2013) [15] who claimed that pear firmness declined with time during storage and found the corrugate fibreboard and wooden boxes better for the packaging of pear fruits, Rose *et al*. (2016) [19] who also suggested that mango fruits packed in polypropylene bags of 150 gauge with 1% ventilation had the highest firmness throughout the storage period and Rana *et al*. (2018) [17] who found that the vacuum packed guava fruits retained maximum firmness on 21st day of storage.

Table 3: Effect of different packaging materials on firmness (LBF) during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage			
			2	4	6	Mean
Plastic crates		15.66	15.40	13.65	12.82	13.97
Poly bags	Sealed	15.89	15.55	14.68	13.15	14.47
	Perforated	15.62	15.33	14.30	13.00	14.21
CFB box	Newspaper cuttings	15.71	15.57	14.66	13.28	14.50
	No cuttings	14.66	15.37	14.40	13.11	14.29
Wooden box	No cushioning	15.60	15.10	13.45	12.10	13.55
	Newspaper lining	15.81	15.32	13.73	12.35	13.80
	Paddy straw	14.94	15.38	13.76	12.44	13.87
	Newspaper cuttings	15.00	15.17	13.50	12.21	13.62
Mean		15.43	15.35	14.01	12.71	14.30

CD at 5% level of significance
Packaging material = 0.3
Storage = NS
Packaging material x Storage = NS

The packaging materials influenced the guava fruits colour significantly during storage after transportation (Table 4). The colour of fruits in all packing materials was yellowish green before transportation, but after transportation on 2nd day of storage, it changed to greenish yellow except in corrugated fibreboard box lined with newspaper cuttings. Change in colour during the storage might be due to the breakdown of chlorophyll and synthesis of carotenoid pigment because of some enzymatic reaction.

Table 4: Effect of different packaging materials on change in colour during storage of transported guava cv. Hisar Safeda

Treatment		Before transportation	Days of storage		
			2	4	6
Plastic crates		YG	GY	LY	Y
Poly bags	Sealed	YG	GY	LY	Y
	Perforated	YG	GY	GY	LY
CFB box	Newspaper cuttings	YG	YG	GY	LY
	No cuttings	YG	GY	LY	Y
Wooden box	No cushioning	YG	GY	LY	Y
	Newspaper lining	YG	GY	LY	Y
	Paddy straw	YG	GY	GY	LY
	Newspaper cuttings	YG	GY	LY	Y

YG= Yellowish green, GY= Greenish yellow, LY= Light yellow, Y= Yellow

In the end of storage, all fruits turned yellow except the fruits packed in perforated poly bags, wooden box lined with paddy straw and corrugated fibreboard box lined with newspaper cuttings, which might be due to higher concentration of carbon dioxide and low concentration of oxygen inside the packages, which reduced the activities of enzymes involved in breakdown and constructive processes. The findings of present experiment corroborate the findings of Somboonkaew and Terry (2011) [23] who reported positive results in the maintenance of colouration in litchi fruits stored in Propa Fresh™ PFAM at 5ºC temperature, Kaur *et al*. (2014) [16] who reported that the guava fruits packed in non-perforated polypropylene film retained green colour as compared to perforated polypropylene film and Hailu *et al.*, (2014) [11] who also reported maximum retention of greenness in banana fruits packed in 300 gauge LDPE bags for 30 days under ambient room conditions.

The different packaging materials had significant effect on percent injury during transportation (Table 5). The minimum injury (%) was observed in fruits packed in corrugated fibreboard box lined with newspaper cuttings (0.99%) followed by the fruits packed in corrugated fibreboard box without newspaper cuttings (1.92%), while the maximum injury (%) was noticed in fruits packed in wooden box without cushioning (6.71%) followed by fruits packed in wooden box lined with newspaper (5.50%). The minimum injury in corrugated fibreboard box might be due to the newspaper cuttings as cushioning with enough strength and high shock bearing capacity, reducing the development of abrasion and bruises during long distance transportation on rough roads. The results obtained are in conformity with the results of Joshi *et al*. (1988) [14] who suggested the use of corrugated fibreboard boxes to reduce the bruising losses of Red Delicious apples, Vursavus and Ozguven (2004) [29] who also recommended the use of cushioning materials to reduce fruit injury during transportation, Singh *et al.* (2014) [1] also recommended that corrugated fibreboard box was found most effective for reducing the mechanical injury in guava and Wasala *et al.* (2015) [30] who reported that the packaging of banana in Styrofoam sheets under simulated transport conditions significantly reduced the injury.

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

Treatment		Before transportation	After transportation
Plastic crates		-	4.87
Poly bags	Sealed	-	3.89
	Perforated	-	4.81
CFB box	Newspaper cuttings	-	0.99
	No cuttings	-	1.92
Wooden box	No cushioning	-	6.71
	Newspaper lining	-	5.50
	Paddy straw	-	4.68
	Newspaper cuttings	-	5.27
CD at 5% level significance		-	0.24

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