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Effect of packaging materials on physical parameters of banana (*Musa paradisiaca* L.) *cv*. Grand Naine under Ambient conditions

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Abstract
This study investigated Effect of Packaging Materials on Physical parameters of Banana (*Musa paradisiaca* L.) *cv*. Grand Naine under Ambient Conditions. The experiment, conducted at the Processing Laboratory of the Department of Fruit Science, College of Agriculture, IGKV, Raipur, evaluated 13 packaging treatments, including low-density polyethylene bags (LDPE), high-density polyethylene bags (HDPE), cling film, shrink film, banana leaves, corrugated fiberboard (CFB), and others, compared to a control (no packaging). Results revealed that LDPE bags (T_7) significantly extended shelf-life to 18.67 days, minimized physiological weight loss (3.20-23.05%), and maintained superior fruit weight and firmness. HDPE bags (T_5) and cling film (T_2) also performed well, while unpackaged fruits deteriorated fastest, lasting only 9.33 days. The findings highlight LDPE as the most effective packaging material for reducing post-harvest losses and preserving banana quality, offering practical benefits for farmers and the supply chain.

Keywords: Banana, Grand Naine, packaging materials, shelf life, post-harvest, LDPE, quality parameters

Introduction
Bananas (*Musa paradisiaca* L.) belongs to family Musaceae and it is one of the most significant tropical fruits in the world market. A popular fruit among people of all ages, bananas can be as eaten fresh or dried and are considered to be delicious. It is also a rich source of energy and the most affordable and nutritious fruit. Banana is easily digestible compared to other fruits. Banana is very popular because they are easy to peel and eat and they smell good. The banana plants can reach heights of 6 to 8 meters, with their spiral-shaped leaves (Rahman *et al*. 2006) [8].

One of the most significant and ancient fruit crops in the world, bananas have been grown by mankind since ancient times. Vedic literature makes reference to their use in religious ceremonies, frequently associating the fruit with India. The easy and great nutritional value of bananas are high in vitamins and carbohydrates have made them very popular. Banana is known as the "Plant of Virtues" (Kalpataru), every part of the banana plant serves a purpose. Two species, *Musa acuminata* and *Musa balbisiana*, are the ancestors of modern edible banana variants. The most popular tropical fruit in the world today is the banana, which has a well-established and organized industry (Patel *et al.*, 2018) [6].

Bananas are known to be a delicious and healthy fruit that is a great source of fiber, potassium, carbohydrates and other important minerals. The 100 g of bananas contain around 89 kcal of energy, 74 g of water, 1.1 g of protein, 0.3 g of lipids, 21.8 g of starch and 2 g of fiber. In addition, it has 0.4 mg of iron, 22 mg of phosphorus 8 mg of calcium, 30 mg of magnesium, 385 mg of potassium and 1 mg of sodium. Bananas contain ascorbic acid (11.7 mg), thiamine (40 µg), riboflavin (70 µg), niacin (610 µg), pantothenic acid (80,600 µg), pyridoxine (470 µg) and folic acid (23 µg). (Rahman *et al.*, 2020) [7].

Grand Naine, a tall mutant has recently been widely grown for commercial use, it is a highly productive variety that produces large bunches of well-developed fruits and is famous for its

early maturity, delicious flesh, pleasant flavor, and appealing color, which makes it a great choice for dessert fruit and also meets export standards.

Bananas are high having water content and susceptibility to multiple diseases, especially fungal infections, bananas are highly perishable. As a climacteric fruit, bananas produce a significant amount of ethylene, which speeds up changes in their physical and chemical characteristics, such as color, texture, aroma, chemical composition, respiration rate and aging. During the climacteric phase, ethylene production increases along with higher oxygen consumption, starch conversion to sugar, chlorophyll breakdown and the redistribution of micro and macronutrients between the pulp and other parts of the plant (Marriott *et al.*, 1981) [4].

The nutrition value of banana has highly decreased in many regions due to result of poor post-harvest management practices, which result in large economic losses. By applying many post-harvest management practices keeping quality of banana can be methods that are presently used world-wide to increase the shelf-life of bananas may result in lowered post-production losses.

Fresh banana must be marketed effectively, taking into account the use of the ideal humidity and temperature as well as adequate handling and packaging techniques, in order for them to reach the consumer in the best possible condition. When harvesting, proper handling can limit mechanical damage and minimize waste from microbial attack later on. By using various locally available packaging materials and optimizing post-harvest handling practices, the post-harvest loss of banana can be minimized.

Packaging plays a crucial role in connecting growers, processors and consumers. It is a crucial part of food processing, making it easier to assemble product and protecting it from mechanical, physiological and pathological deterioration during the marketing process. Packaging also acts as a barrier against environmental influences and improves the aesthetics of the product. In addition to controlling light exposure, heat transfer, moisture content and gas exchange, it guards against insect or microbe contamination. Additionally, packaging protects the integrity of processed and fresh foods, while they are being stored and helps reduce distribution costs. It prolongs the shelf-life of fresh food by delaying senescence through a slowdown in respiration and metabolic activities (Antala *et al.*, 2014) [1]

Banana is frequently packed in plastic boxes, aluminum foil, Low density poly bags packaging or gunny sacks to increase the shelf life. The strong respiratory activity and ethylene generation that occurs during ripening make bananas climacteric fruits and highly perishable. In ordinary circumstances, they are only fresh for seven to eight days after harvest. Banana fruits continue their physiological changes after being harvested. On the other hand, we can successfully extend the storage life of mature fruits by minimizing these alterations (Manikpuri *et al.*, 2023) [3].

Banana is being grown in almost all district of Chhattisgarh but due to perishable nature of fruit farmers can not store for long period of time. By packaging of banana fruits, farmer/grower of Chhattisgarh can not only increase the shelf life of banana but also they may get good price for their produce.

Materials and Methods

Location: Processing Laboratory, Department of Fruit Science, College of Agriculture, IGKV, Raipur (C.G.), 2024-25

Design: Completely Randomized Design (CRD) with 13 treatments and 3 replications, using 12 fruits per treatment.

Packaging materials: Banana leaves, cling film, corrugated fiberboard, dried palash leaves, low density poly bags and High density poly bags (LDPE and HDPE), Jute and Nylon bags, Newspaper, Paddy straw, Paper bags, and Shrink film

Treatments details: T_0-Control (No packaging), T_1 banana leaves, T_2 cling film, T_3 corrugated fiberboard, T_4 Dried Palash leaves, T_5 High-density poly bag, T_6 Jute bag, T_7 low density poly bags, T_8 Nylon bags,T_9 Newspaper, T_{10} Paddy straw, T_{11} Paper bags, and T_{12} Shrink film.

Results and Discussion

Physical parameters of banana fruits

1. Physical parameters of fresh banana fruits before storage

The data registered in Table 1 revealed the fruit weight, fruit diameter, physiological loss in weight, fruit firmness were 2294.34 g, 14.82 mm, 0%, 9.60 kg/cm2, respectively under the present investigation.

2. Physical parameters of banana fruits during storage

The physical parameters of banana fruits were recorded for the following variables *i.e*. fruit weight (g), fruit diameter (mm), physiological loss in weight (%), fruit firmness (kg/cm2), shelf life (Days), respectively.

2.1 Fruit weight (g)

There was decreasing trend of fruit weight with the increasing storage period in all the treatments. Among the various treatments of packaging materials, the maximum fruit weight (2260.12, 2223.57, 2169.67, 2090.66, 1985.34 and 1865.41 g) at 3rd, 6th, 9th, 12th, 15th and 18th days of storage was registered under the treatment T_7 (Low density polybags), while the minimum fruit weight (1770.98, 1669.73 and 1499 g) was marked under T_0 (control) during 3rd, 6th and 9th days of observation, respectively, whereas no fruits were found to be retained under control at 12th, 15th and 18th days of observation. The results of the present study are similar with the findings reported by Hailu *et al.* (2012) [2] in banana fruits and Miri *et al.* (2018) [5] in kinnow and Manikpuri *et al.* (2023) [3] in banana fruits

2.2 Fruit diameter (mm)

At 18 DAS, the fruit diameter was found decreased under the various treatments. The maximum diameter of banana (14.52, 14.39, 14.27, 14.08, 13.85 and 13.55 mm) was registered under the supremacy of treatment T_7 (Low density poly bag) at 3rd, 6th, 9th, 12th, 15th and 18th days of storage, respectively, which was followed by the treatment T_5, while the minimum fruit diameter of banana (13.20, 13.10 and 12.78) was perceived under control (No packaging) during 3rd, 6th and 9th days of observation, respectively, whereas no any fruits were found to be retained under control at 12th, 15th and 18th days of observation. The results of the present study are similar with the findings reported by Hailu *et al.* (2012) [2] in banana

fruits and Miri *et al.* (2018) [5] in kinnow and Manikpuri *et al.* (2023) [3] in banana fruits

2.3 Physiological loss in weight (%)

Significant variation was observed in respect to physiological loss in weight under the various treatments. It is noticed that the mean physiological loss in weight percentage of banana fruits kept under various packaging materials increased with the advancement of storage period. The preeminence of treatment T_7 (Low density poly bags) was exhibited, the minimum physiological loss in weight (3.20, 6.43, 10.23, 14.32, 18.42 and 23.05%), at 3rd, 6th, 9th, 12th, 15th and 18th days of storage, respectively, while the maximum physiological loss in weight (8.01, 11.37 and 16.92%) of banana fruit was recorded under T_0 (control) during 3rd, 6th and 9th days of observation. Whereas no any fruits were found to be retained under control at 12th, 15th and 18th days of observation during storage period. The results of the present study are similar with the findings reported by Hailu *et al.* (2012) [2] in banana fruits and Miri *et al.* (2018) [5] in kinnow and Manikpuri *et al.* (2023) [3] in banana fruits

2.4 Fruit firmness (kg/cm2)

Under the present investigation it has been noticed that, the fruit firmness of banana fruit was significantly decreased with the advancement in storage period under ambient condition. The maximum fruit firmness (9.34, 8.66, 7.69, 6.70, 4.42 and 2.87 kg/cm2) was obtained under the treatment T_7 (Low density poly bag) and the value is *at par* with the treatment T_5 (High density poly bags) with firmness of 9.30, 8.60, 7.62, 6.59, 4.21 and 2.11kg/cm2 at 3rd, 6th, 9th, 12th 15th and 18th days of storage, respectively However, the minimum fruit firmness (8.62, 8.10 and 7.02) was declared under the treatment control (No packaging) during 3rd, 6th and 9th days of observation. The results of the present study are similar with the findings reported by Hailu *et al.* (2012) [2] in banana fruits and Miri *et al.* (2018) [5] in kinnow and Manikpuri *et al.* (2023) [3] in banana fruits

2.5 Shelf life (days)

Among various treatments of packed fruits, the fruits under the treatment T_7 (Low density poly bags) was recorded maximum shelf life of 18.67 days with better acceptability than other treatments which is followed by the shelf life of T_5 (High density poly bags) *i.e.* 18.33 days. Whereas, the banana which are without any packaging materials control (No packaging) found significantly minimum shelf life of 9.33 days. The results of the present study are similar with the findings reported by Hailu *et al.* (2012) [2] in banana fruits and Miri *et al.* (2018) [5] in kinnow and Manikpuri *et al.* (2023) [3] in banana fruits

Table 1: Physical parameters of banana fruits before storage

Physical parameters	Mean value
Fruit weight (g)	2294.34 g
Fruit diameter (mm)	14.82 mm
Physiological loss in weight (%)	0%
Fruit firmness(kg/cm2)	9.60 kg/ cm2

Table 2.1: Effect of different packaging materials on fruit weight (g) of Banana *cv*. Grand Naine during storage under ambient condition

Notations	Treatments	Fruit Weight (g)						
		3 DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	Mean
T_0	Control (No packaging)	1770.98^{a}	1669.73^{a}	1499.00^{a}	0.00*	0.00*	0.00*	823.28
T_1	Banana Leaves	1904.76^{bc}	1819.01^{de}	1690.10^{cd}	1510.74^{a}	0.00*	0.00*	1154.2.10
T_2	Cling Film	2186.59^{hi}	2137.43^{h}	2067.43^{g}	1968.52^{e}	1833.32^{b}	1683.32^{a}	1979.43
T_3	Corrugated Fiber Board (CFB)	2079.45^{fg}	2011.78^{fg}	1911.74^{f}	1795.00^{d}	0.00*	0.00*	1299.66
T_4	Dried Palash Leaves	1925.35^{cd}	1842.42^{def}	1717.56^{d}	1557.8^{a}	0.00*	0.00*	1173.85
T_5	High Density Poly Bags	2231.67^{hi}	2188.96^{hi}	2128.76^{h}	2043.89^{f}	1922.67^{c}	1787.53^{b}	2050.58
T_6	Jute Bags	1830.54^{ab}	1738.52^{abc}	1593.38^{b}	0.00*	0.00*	0.00*	860.40
T_7	Low Density Poly Bags	2260.12^{i}	2223.57^{i}	2169.67^{h}	2090.66^{f}	1985.34^{d}	1865.41^{c}	2099.12
T_8	Newspaper	1882.69^{bc}	1792.46^{bcd}	1654.72^{c}	0.00*	0.00*	0.00*	888.31
T_9	Nylon Bags	1989.43^{de}	1908.52^{fe}	1787.43^{e}	1642.94^{b}	0.00*	0.00*	1221.38
T_{10}	Paddy Straw	1822.39^{ab}	1727^{ab}	1577.04^{b}	0.00*	0.00*	0.00*	854.40
T_{11}	Paper Bags	2022.89^{ef}	1950.95^{ef}	1840.9^{e}	1715.84^{c}	0.00*	0.00*	1255.09
T_{12}	Shrink Film	2105.00^{gh}	2050.56^{g}	1968.54^{f}	1863.06^{d}	1727.9^{a}	0.00*	1619.17
	SE (m)±	28.80	26.08	20.21	24.04	14.2.16	19.92	
	C.D. at 5%	84.20	76.25	59.09	70.27	41.41	58.17	

(1) DAS:-Days after storage.
(2) Value marked as * indicates fruit gets spoiled.
(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 2.2: Effect of different packaging materials on fruit diameter (mm) of Banana *cv*. Grand Naine during storage under ambient condition

Notations	Treatments	Fruit Diameter (mm)						
		3 DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	Mean
T_0	Control (No packaging)	13.20^{a}	13.10^{a}	12.78^{a}	0.00^{*}	0.00^{*}	0.00^{*}	6.51
T_1	Banana Leaves	13.32^{abc}	13.21^{a}	13.00^{ab}	12.45^{a}	0.00^{*}	0.00^{*}	8.66
T_2	Cling Film	$14.2.15^{efg}$	14.04^{bcd}	13.85^{def}	13.62^{efg}	13.44^{ab}	13.29^{a}	13.73
T_3	Corrugated Fiber Board (CFB)	13.89^{cdef}	13.65^{abc}	13.49^{bcd}	13.22^{cde}	0.00	0.00	9.04
T_4	Dried Palash Leaves	13.52^{abcd}	13.40^{ab}	13.10^{ab}	12.60^{ab}	0.00^{*}	0.00^{*}	6.53
T_5	High Density Poly Bags	14.32^{fg}	14.20^{cd}	14.08^{ef}	13.82^{fg}	13.60^{bc}	13.43^{a}	13.90
T_6	Jute Bags	13.24^{ab}	13.14^{a}	12.90^{a}	0.00^{*}	0.00^{*}	0.00^{*}	6.54
T_7	Low Density Poly Bags	14.52^{g}	14.39^{d}	14.27^{f}	14.08^{g}	13.85^{c}	13.55^{a}	14.2.11
T_8	Newspaper	13.29^{ab}	13.18^{a}	12.92^{a}	0.00^{*}	0.00^{*}	0.00^{*}	6.56
T_9	Nylon Bags	13.62^{abcde}	13.55^{a}	13.18^{abc}	12.81^{abc}	0.00^{*}	0.00^{*}	8.86
T_{10}	Paddy Straw	13.23^{a}	13.12^{a}	12.81^{a}	0.00^{*}	0.00^{*}	0.00^{*}	6.52
T_{11}	Paper Bags	13.82^{bcde}	13.60^{ab}c	13.29^{abcd}	13.05^{bcd}	0.00^{*}	0.00^{*}	8.96
T_{12}	Shrink Film	14.06^{defg}	13.89^{bcd}	13.70^{cde}	13.41^{def}	13.30^{a}	0.00^{*}	11.39
	SE (m)±	0.20	0.22	0.19	0.16	0.09	0.02	
	C.D. at 5%	0.58	0.65	0.56	0.48	0.27	0.04	

(1) DAS:-Days after storage.
(2) Value marked as * indicates fruit gets spoiled.
(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 2.3: Effect of different packaging materials on Physiological loss in weight (%) of Banana *cv*. Grand Naine during storage under ambient condition

Notations	Treatments	Physiological loss in weight (%)						
		3 DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	Mean
T_0	Control (No packaging)	8.01^{h}	11.37^{m}	16.92^{m}	0.00^{*}	0.00^{*}	0.00^{*}	9.92
T_1	Banana Leaves	5.92^{f}	8.79^{i}	14.59^{i}	19.21^{d}	0.00^{*}	0.00^{*}	10.24
T_2	Cling Film	3.43^{b}	6.93^{c}	10.69^{c}	15.20^{b}	19.00^{b}	$24.2.10^{c}$	9.81
T_3	Corrugated Fiber Board (CFB)	$4.2.19^{d}$	7.54^{e}	12.42^{e}	17.14^{c}	0.00	0.00	4.27
T_4	Dried Palash Leaves	4.62^{e}	8.54^{h}	14.23^{h}	19.00^{d}	0.00^{*}	0.00^{*}	8.87
T_5	High Density Poly Bags	3.30^{ab}	6.81^{b}	10.40^{b}	14.73^{ab}	18.54^{a}	23.65^{b}	9.35
T_6	Jute Bags	6.85^{g}	10.24^{k}	16.14^{k}	0.00^{*}	0.00^{*}	0.00^{*}	3.17
T_7	Low Density Poly Bags	3.20^{a}	6.43^{a}	10.23^{a}	14.32^{a}	18.42^{a}	23.05^{a}	7.94
T_8	Newspaper	6.95^{g}	10.11^{j}	16.02^{j}	0.00^{*}	0.00^{*}	0.00^{*}	6.51
T_9	Nylon Bags	4.52^{e}	8.12^{g}	$14.2.10^{g}$	17.47^{c}	0.00^{*}	0.00^{*}	6.03
T_{10}	Paddy Straw	7.02^{g}	11.00^{l}	16.62^{l}	0.00^{*}	0.00^{*}	0.00^{*}	8.86
T_{11}	Paper Bags	4.30^{d}	7.98^{f}	12.68^{f}	17.29^{c}	0.00^{*}	0.00^{*}	9.70
T_{12}	Shrink Film	3.68^{c}	7.08^{d}	12.02^{d}	15.22^{b}	19.31^{b}	0.00^{*}	3.38
	SE (m)±	0.07	0.02	0.03	0.20	0.14	0.09	
	C.D. at 5%	0.20	0.05	0.09	0.60	0.42	0.26	

(1) DAS:-Days after storage.
(2) Value marked as * indicates fruit gets spoiled.
(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means

Table 2.4: Effect of different packaging materials on fruit firmness (kg/cm2) of banana *cv*. Grand Naine during storage under the ambient condition

Notations	Treatments	Fruit Firmness (kg/cm2)						
		3 DAS	6 DAS	9 DAS	12 DAS	15 DAS	18 DAS	Mean
T_0	Control (No packaging)	8.62^{a}	8.10^{a}	7.02^{a}	0.00^{*}	0.00^{*}	0.00^{*}	3.87
T_1	Banana Leaves	9.15^{b}	8.26^{abc}	7.20^{ab}	5.43^{a}	0.00^{*}	0.00^{*}	5.00
T_2	Cling Film	9.25^{bc}	8.55^{cd}	7.53^{de}	6.43^{d}	$4.2.19^{b}$	2.10^{a}	6.34
T_3	Corrugated Fiber Board (CFB)	9.20^{bc}	8.35^{abcd}	7.34^{bcd}	5.97^{c}	0.00	0.00	5.14
T_4	Dried Palash Leaves	9.16^{bc}	8.28^{abcd}	7.26^{abc}	5.52^{a}	0.00^{*}	0.00^{*}	5.03
T_5	High Density Poly Bags	9.30^{c}	8.60^{cd}	7.62^{abc}	$6.59d^{e}$	4.21^{b}	2.11^{a}	9.57
T_6	Jute Bags	8.89^{ab}	8.22^{abc}	7.17^{ab}	0.00^{*}	0.00^{*}	0.00^{*}	4.04
T_7	Low Density Poly Bags	9.34^{c}	8.66^{d}	7.69^{e}	6.70^{e}	4.42^{c}	2.87^{b}	6.61
T_8	Newspaper	8.92^{ab}	8.26^{abc}	7.21^{ab}	0.00^{*}	0.00^{*}	0.00^{*}	4.06
T_9	Nylon Bags	9.18^{bc}	8.25^{abc}	7.20^{ab}	5.75^{b}	0.00^{*}	0.00^{*}	5.06
T_{10}	Paddy Straw	8.68^{a}	8.13^{ab}	7.15^{ab}	0.00^{*}	0.00^{*}	0.00^{*}	3.99
T_{11}	Paper Bags	9.20^{bc}	8.35^{abcd}	7.34^{bcd}	5.85^{b}	0.00^{*}	0.00^{*}	5.12
T_{12}	Shrink Film	9.22^{bc}	8.50^{bcd}	7.49^{cde}	6.39^{d}	4.02^{a}	0.00^{*}	5.93
	SE (m)±	0.12	0.13	0.09	0.08	0.05	0.02	
	C.D. at 5%	0.37	0.39	0.26	0.22	0.14	0.06	

(1) DAS:-Days after storage.
(2) Value marked as * indicates fruit gets spoiled.
(3) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Table 2.5: Effect of different packaging materials on Shelf life (days) of Banana *cv*. Grand Naine during storage

Notations	Treatments		Shelf life (Days)
T_0	Control (No packaging)		9.33^{a}
T_1	Banana Leaves		12.67^{b}
T_2		Cling Film	18.00^{d}
T_3	Corrugated Fibre Board (CFB)		12.67^{b}
T_4	Dried Palash Leaves		12.00^{b}
T_5	High Density Poly Bags		18.33^{d}
T_6		Jute Bags	9.33^{a}
T_7	Low Density Poly Bags		18.67^{d}
T_8		Newspaper	9.67^{a}
T_9		Nylon Bags	12.67^{b}
T_{10}	Paddy Straw		9.33^{a}
T_{11}		Paper Bags	12.00^{b}
T_{12}		Shrink Film	15.67^{c}
	SE (m)±		0.40
	C.D. at 5%		1.17

(1) DAS:-Days after storage.
(2) The superscript letters signifies that the treatment means with similar letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Conclusion

From the present investigation findings, it can be concluded that various treatments had a significant effect on physical parameters of banana fruits during storage period. The treatment T_7 (Low density poly bags) was found most effective for enhancing the physical parameters of banana fruit throughout storage under ambient condition.

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