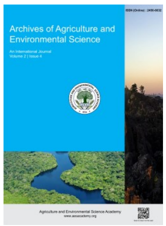
Archives of Agriculture and Environmental Science 9(3): 436-441 (2024)
https://doi.org/10.26832/24566632.2024.090305

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE

CrossMark

Effect of different packaging materials on banana ripening and shelf-life in Dang, Nepal

Dipak Giri[1], Jitesh Jung Lamichhane[1*], Gayatri Bhandari[2] and Manoj Basnet[3]

[1]Institute of Agriculture and Animal Sciences Campus of Live Sciences, Tulsipur, Dang, Nepal
[2]Institute of Agriculture and Animal Science, Lamjung Campus, Nepal
[3]Institute of Agriculture and Animal Science, Paklihawa Campus, Nepal
[*]Corresponding author's E-mail: jungjitesh8@gmail.com

ARTICLE HISTORY

Received: 29 June 2024
Revised received: 07 September 2024
Accepted: 10 September 2024

Keywords

Fiber and plastic bags
Modified atmosphere packaging (MAP)
Physical quality
Ripening agent

ABSTRACT

This research was conducted to evaluate the effect of different packaging materials on the shelf life and banana quality (cv G9) at the laboratory, Campus of Live Sciences, Tulsipur, Dang, Nepal. The different packaging materials were used as high-density non-perforated polyethylene bags, low-density non-perforated polyethylene bags, low-density perforated polyethylene bags, fiber bags, jute bags, paddy straw with cardboard, and a control treatment (in open trays). The research was conducted in a completely randomized design (CRD) with three replications. The bananas were packed in different packaging materials after being treated with a 250 ppm ethephon solution. Parameters such as peel color, physiological weight loss, pulp-to-peel ratio, total soluble solids (TSS), titratable acidity (TA), and Benedict test were assessed at two-day interval. Analysis of variance (ANOVA) showed highly significant differences for all the recorded parameters except TA. Unpackaged fruits lost 22.92% of their weight, while fruits packed in high-density non-perforated polythene (HDNP) and low-density non-perforated polythene (LDNP) bags lost 13.27% and 6.15%, respectively. Peel colour development from green mature to yellow was observed first in bananas packed in low-density perforated polyethylene (LDPP) bags followed by open trays, jute bags, and paddy straws. The lowest pulp-to-peel ratio was observed in HDNP and LDNP bags. It can be concluded that packaging bananas in high-density and low-density non-perforated polyethylene bags resulted in longer shelf life. The sweetness, aroma, and mouthfeel of bananas in jute bags, fiber bags, and paddy straws were highly accepted. Thus, LDPP bags were found effective in early ripening and uniform yellow colour development on bananas.

Citation of this article: Giri, D., Lamichhane, J. J., Bhandari, G., & Basnet, M. (2024). Effect of different packaging materials on banana ripening and shelf-life in Dang, Nepal. *Archives of Agriculture and Environmental Science*, 9(3), 436-441, https://dx.doi.org/10.26832/24566632.2024.090305

INTRODUCTION

The name 'banana' is derived from the Arabic word 'banana' which means 'finger' (Boning, 2006). The term "banana" generally includes several species and hybrids that are in the genus *Musa* in the Musaceae family. Based on the basic chromosome, *Musa* is divided into four sections: *Australimusa* and *Callimusa*, which have n=10, and *Eumusa* and *Rhodochlamys*, which have n=11 (Cheeseman, 1947). Banana has both wild and cultivated genotypes with considerable genetic diversity and a wide range of morphological characteristics. Most commercially cultivated bananas are triploids (2n=3x=33) with the genome of AAA, AAB, and ABB originating from polyploidization and interspecific hybridization of the two diploid species *M. acuminate* and *M. balbisiana* (Pua, 2015). Bananas are among the largest herbaceous plants, with pseudo-stems reaching heights of 2-8 m in cultivated varieties and up to 10-15 m in some wild species (Eldad & Deborah, 2016). These plants are primarily found on the margins of tropical rainforests (Wong *et al.*, 2002; Heslop-Harrison & Schwarzacher, 2007). Based on the geographical situation of Nepal, bananas can be cultivated from the Terai region to the mid hills, at altitudes up to 1500 masl, where frost does not occur usually (Gautam & Dhakal, 1991).

Banana is an ideal fruit for athletes and manual workers (Stein *et al.*, 1972; Dunford, 2006). According to 2016 export figures, the banana industry generates around 8 billion USD per year (FAOSTAT, 2017). Banana production in Nepal was 278,890 tons in 2019, up from 44,800 tons in 2000, growing at an average annual rate of 10.82% (Knoema, 2020). Bananas are categorized as climacteric fruits. They do not ripen early and uniformly on the plant, so they are harvested when green and fully mature (Bal, 2014). Bananas are usually harvested at the pre-climacteric stage, and for commercial purposes, they are artificially ripened. (Maduwanthi & Marapana, 2019). Ripening is the final stage of the development of fruit, involving a series of physiological and biochemical events that lead to changes in colour, flavour, aroma, and texture making the fruit both attractive and tasty (Singal *et al.*, 2012). It is a natural process that makes the fruit edible. The climatic fruits become sweeter, less green, and softer as it ripens after harvested from plants. During ripening process both acidity and sweetness rise, although the fruits still taste sweeter (Rahman & Chowdhury, 2008).

Ethylene is a crucial plant hormone that regulates and coordinates the different aspects of the ripening process, including colour development, aroma production, and texture changes (Klee & Giovannoni, 2011). Ethylene plays a major role in the ripening of the fruits by coordinating the expression of the genes responsible for the conversion of starch to sugar, aroma production, and increasing the activity of cell wall degrading enzymes (Abeles & Morgan, 1992; Gray *et al.*, 1994). Physiological changes during ripening include pigment and sugar accumulation, aromatic compound production, and flesh softening (Gapper *et al.*, 2013). The physiological change during ripening differs from variety to variety (Moreno *et al.*, 2021). Colour is an important indicator of ripening and influences consumer acceptability, as consumers usually judge the banana's quality based on visual assessment (Hou *et al.*, 2015). Change in the colour of a banana is the first visual indicator of ripening and is used for determining fruit quality (Thompson, 2003).

Post-harvest treatments and varieties cause significant variation in total soluble solids (TSS) content during storage (Akter *et al.*, 2013). Various packaging materials have been tested over the years which have produced inconsistent results. Appropriate packaging is necessary for efficient handling (Abdul-Rahaman *et al.*, 2017). Packaging is an important postharvest handling practice for bananas. From harvesting to final consumption, banana quality decreases, leading to considerable waste. This loss can be kept at a minimum by improving packaging materials or by improving traditional packaging practices (Hailu *et al.*, 2012). Packaging isolates the product from its external environment and reduces exposure to pathogens and contaminants, thereby extending shelf life (Mir & Beadey, 2004). Bananas packaged in polyethylene bags showed longer shelf life and maintained the chemical qualities better than those packaged in dried banana leaves or teff straw (Hailu *et al.*, 2012). Proper storage, handling, and marketing techniques can be devised by studying the fruit's shelf (Dadzie & Orchard, 1997). Many investigations have been conducted on the post-harvest handling of bananas, however, very few studies have been published on the effect of packaging materials on ripening and shelf-life behavior in bananas. This research aims to provide insights into effective packaging methods for small-scale farmers and evaluate the efficacy of different packaging materials on banana ripening and shelf life.

MATERIALS AND METHODS

An experiment was conducted in the horticulture laboratory at the Campus of Live Sciences, Tulsipur, Dang. Materials used included non-perforated low-density polyethylene bags, non-perforated high-density polyethylene bags, fiber bags, jute bags, paddy straw, refractometer, weighing balance, grinding machine, cardboard, and other lab equipment. Chemicals used included NaOH, Benedict reagent, Phenolphthalein, and Ethephon. Bunch of unripe bananas (G9 variety) was brought to the campus laboratory from the market. The bunch of was divided into three sections: the top portion, the middle portion, and the bottom portion. Hands were detached from each portion, and each portion was assigned to a replication to reduce the bias. Bananas of uniform size with green peel color were selected for our study. Individual fingers were detached and damaged fruits were eliminated. The fingers were left for 1 hour to dry the latex. Then, the fingers were dipped in 250 ppm ethephon solution for a minute which was prepared by adding 2.5 ml of ethephon in 10 litters of water. Then, the dipped fingers were left in the shade to dry for 15 minutes. 7 unripe treated fingers were kept in packaging materials according to their treatment. The maximum temperature recorded in the lab was 30.2°C and the minimum temperature was 15°C. The experiment was conducted using a Completely Randomized Design (CRD). CRD is the simplest experimental design in which treatments are replicated but not blocked, meaning they are assigned in a completely random manner. The design included 7 treatments with 3 replications each. After data collection, the data were tabulated in Microsoft Excel 2013. The mean values of the data for different parameters recorded in the study were analysed using R-Stat software. Data were subjected to analysis of variance (ANOVA) to evaluate the significance of treatment effect. Mean of each other within the parameter will be compared by Duncan's Multiple Test (DMRT) 5% level of significance.

Parameters evaluated

Color analysis: Peel color changed from green to yellow and from yellow to brown. This was measured by visually matching the peel color against a color chart. Observations were made at two-days interval.

Physiological weight loss: Banana fingers were weighed using a digital balance. Every two days, weight measurements were taken before and after separating the sample. Weight loss percentage was calculated as follows:

$$\text{Weight loss} = \frac{\text{Wi} - \text{Wf}}{\text{Wi}} * 100$$

Where, W_i = Initial weight; W_f = Final weight

Titratable Acidity (TA): The acidity of a banana was measured through titratable acidity. The banana sample was crushed and filtered through muslin cloth to obtain the banana juice. 10 ml of banana juice was taken on a conical flask and then 3-5 drops of phenolphthalein was added as an indicator. The juice was titrated with 0.1N NaOH solution until the indicator changed to a pink color, and the titration volume was recorded from the burette. The TA is expressed as citric acid using the following formula:

$$\%\ \text{Acid} = \frac{(\text{ml NaOH}) * (\text{N of the base in mol per litre}) * (\text{Eq. wt. of acid})}{(\text{Sample volume in ml}) * 10}$$

Benedict's test: Reducing sugar was estimated by using Benedict's reagent. A sample from each treatment was selected and crushed. 2.5 ml of crushed fruit pulp were taken on the test tube and 5 ml of benedict reagent was added on each test tube and test tubes were placed on a boiling water bath for 5 minutes to develop a color. Color development ranged from green, yellow, orange, to red (brick red) based on the sugar content.

Softening starting days and shelf life: Softening was simply observed by pressing the bananas with fingers. It was done gently to avoid external injury to the fruit. The shelf life of the commodity was determined by assessing its condition, including color, softness, and aroma.

Total Soluble Solid (TSS): Total Soluble Solid content was recorded using a hand refractometer. Crushed fruit pulp (1-2 drops) was placed on the prism of the refractometer and the readings were observed through the eyepiece. The prism was washed with distilled water and dried with tissue paper between samples. The refractometer was standardized against distilled water (0% TSS).

Table 1. Different treatments used to find their effectiveness in the ripening and shelf life of bananas at Dang.

Treatments	
T1	HDNP bags
T2	LDNP bags
T3	LDPP bags
T4	Fiber bags
T5	Paddy straw with cardboard
T6	Jute bags
T7	Control

Pulp peel ratio: Banana pulp was separated from the peel manually. Separate weights of the peel and pulp were taken at different stages of ripening from their respective samples. The pulp-peel ratio was calculated as follows:

$$\text{Pulp peel ratio} = \frac{\text{Weight of pulp}}{\text{Weight of peel}}$$

Marketability: The relationship between different packaging materials and the marketability of bananas was analysed in 1,3,5,7,9,11 days.

RESULTS AND DISCUSSION

Color analysis and Physiological loss in weight (%)

The interrelationship between different packaging materials and the peel color change of bananas was found to be highly significant. Colour analysis of the fruits, a basic criterion for evaluating fruit ripening, was done by visually matching the peel color against a colour chart. The faster color change was observed in bananas packed in low-density perforated polyethylene bags i.e. 7 at the 7th day of ripening followed by those in open tray, paddy straw, and jute bag. The lowest color development was observed in bananas packed in non-perforated polyethylene bags i.e., 3.67 on the 11th day on both T1 and T2. On the other hand, the highest weight loss was observed in bananas placed in an open tray i.e., control treatment. This result agrees with previous research indicating that the rate of ethylene production and respiration is very high in such conditions (Burg & Burg, 1967). The weight loss in bananas packed in high-density and low-density non-perforated bags was found to be lower compared to those kept in open trays and perforated polyethylene poly bags. This finding is consistent with reports by Thompson (2001) and Kifle & Birhanu (2020), which noted lower physiological weight loss in bananas packed in polyethylene bags compared to other packaging materials.

Table 2. Effect of packaging on peel color and physiological weight loss of banana.

Treatment	Peel color of the banana					Physiological loss in weight (%)				
	Day 3	Day 5	Day 7	Day 9	Day 11	Day 3	Day 5	Day 7	Day 9	Day 11
T1	2.00^{b}	2.00^{b}	3.00^{b}	3.50^{b}	3.67^{a}	0.18^{d}	0.74^{d}	1.55^{e}	3.25^{c}	13.27^{a}
T2	2.00^{b}	2.00^{b}	3.00^{b}	3.50^{b}	3.67^{a}	0.12^{d}	0.23^{d}	0.43^{e}	2.43^{c}	6.15^{a}
T3	3.00^{a}	4.00^{a}	7.00^{a}	-	-	2.06^{c}	3.93^{c}	5.83^{d}	-	-
T4	2.67^{a}	3.83^{a}	5.67^{a}	6.67^{a}	-	4.68^{b}	8.37^{b}	12.15^{c}	19.31^{b}	-
T5	3.00^{a}	3.67^{a}	6.00^{a}	7.00^{a}	-	4.77^{b}	8.44^{b}	12.28^{bc}	19.59^{b}	-
T6	3.00^{a}	4.17^{a}	6.67^{a}	7.00^{a}	-	5.13^{ab}	9.23^{ab}	13.48^{ab}	20.92^{ab}	-
T7	3.00^{a}	4.00^{a}	6.00^{a}	7.00^{a}	-	5.66^{a}	10.13^{a}	14.77^{a}	22.92^{a}	-
Mean	2.67	3.38	5.33	5.77	3.67	3.23	5.87	8.64	14.74	9.71
CV (%)	12.13	18.25	22.54	12.55	7.87	10.31	9.64	8.67	7.90	82.9
LSD (0.05)	0.55 ***	1.05 ***	2.05 ***	1.26 ***	0.65 ***	0.58 ***	0.99 ***	1.31 ***	2.07 ***	18.3

Means with same letter in column are not significantly different at p = 0.05 by DMRT. * indicates 5% level of significance, ** indicates 1% level of significance, *** indicates 0.1% level of significance, LSD = Least significant difference, CV = Coefficient of variance.

Table 3. Effect of packaging on titratable acidity and reducing sugar of banana.

Treatment	Titratable acidity (%)					Benedict test				
	Day 1	Day 5	Day 7	Day 9	Day 11	Day 1	Day 5	Day 7	Day 9	Day 11
T1	0.288	0.179^{a}	0.206^{a}	0.17^{a}	0.196^{a}	1.2	2.00^{bc}	2.33^{bc}	2.33^{c}	2.67^{a}
T2	0.288	0.128^{b}	0.171^{ab}	0.164^{a}	0.115^{b}	1.2	1.67^{c}	2.00^{c}	2.67^{bc}	3.00^{a}
T3	0.288	0.128^{b}	0.140^{b}	-	-	1.2	3.67^{a}	3.67^{a}	-	-
T4	0.288	0.113^{b}	0.157^{b}	0.118^{a}	0.129^{b}	1.2	3.00^{ab}	4.00^{a}	4.00^{a}	-
T5	0.288	0.119^{b}	0.149^{b}	0.138^{a}	0.143^{ab}	1.2	3.00^{ab}	3.33^{ab}	3.67^{a}	-
T6	0.288	0.121^{b}	0.154^{b}	0.134^{a}	0.112^{b}	1.2	3.33^{a}	3.67^{a}	3.33^{ab}	-
T7	0.288	0.153^{ab}	0.149^{b}	0.166^{a}	0.108^{b}	1.2	4.00^{a}	4.00^{a}	4.00^{a}	-
Mean	0.288	0.135	0.161	0.148	0.135	1.2	2.95	3.28	3.33	2.83
CV (%)		22.17	17.61	22.44	26.48	-	20.41	19.03	16.82	14.40
LSD		0.051	0.048	0.057	-	-	1.03***	1.07***	0.97**	0.92

Means with same letter in column are not significantly different at p = 0.05 by DMRT. * indicates 5% level of significance, ** indicates 1% level of significance, *** indicates 0.1% level of significance, LSD = Least significant difference, CV = Coefficient of variance.

Table 4. The effect of packaging on softening started days and shelf life.

Treatment	Softening started Days	Shelf life (Days)
T1	6.00^{a}	11.00^{ab}
T2	6.33^{a}	11.33^{a}
T3	3.00^{b}	7.00^{c}
T4	3.67^{b}	9.00^{bc}
T5	3.33^{b}	9.00^{bc}
T6	4.00^{b}	8.00^{c}
T7	3.33^{b}	8.00^{c}
Mean	4.24	9.05
CV (%)	23.91	13.64
LSD (0.05)	1.73***	2.11**

Means with same letter in column are not significantly different at p = 0.05 by DMRT. * indicates 5% level of significance, ** indicates 1% level of significance, *** indicates 0.1% level of significance, LSD = Least significant difference, CV = Coefficient of variance.

Titratable Acidity (TA) and Benedict test

The interrelationship between different packaging materials and TA was found to be non-significant. The TA was higher in bananas packed in low-density and high-density non-perforated polyethylene bags. Generally, TA values were highest at an early stage of storage, indicating that unripe fruits are more acidic than ripened ones; thus, ripening results in decrease of acidity. Packaging on non-perforated polyethylene bags limits the supply of oxygen to bananas for respiration, slowing the ripening process and leading to higher acidity compared to other treatments. For the Benedict's test, which evaluates reducing sugar content, the effect of packaging materials was highly significant. Reducing sugar accumulation was higher in bananas stored in open trays and fiber bags. This is likely due to the rapid onset of the pre-climacteric and climacteric phases and the subsequent peaks in starch hydrolysis (Marriot, 1980).

Softening starting days and shelf life

Softening of fruits indicates the initiation of ripening. The effect of different packaging materials on the starting day of softening was found to be highly significant. The fastest softening was observed in bananas packed in a low-density perforated polyethylene bag (3 days). Softening was observed between 3 to 7 days across different treatments (Table 4). Shelf life, measured by appearance, firmness, shrinkage, weight loss, and other keeping qualities, has been found to be extended by seal packaging for many fruits (Ben-Yehoshua *et al.*, 1995) and bananas (Krishnamurthy *et al.*, 1985). The effect of different packaging materials on the shelf life of bananas was highly significant. The shelf life was longest (11 days) for bananas packed in high-density and low-density non-perforated polyethylene bags, while the shortest shelf-life (7 days) was observed in bananas packed in low-density perforated polyethylene bags and open. Similar results were reported by Abiso *et al.* (2018).

Total Soluble Solids (TSS) and Pulp peel ratio

The data revealed an increase in the TSS content of the fruit during the ripening period under all treatments. The maximum TSS (17.00° Brix) was observed in bananas packed in Low-Density perforated polyethylene bags. The minimum TSS was observed in bananas packed in low-intensity non-perforated polyethylene bags. Similar increases in TSS have been reported by Abdullah *et al.* (2016) and Abiso *et al.* (2018). The interaction between the treatment and pulp peel ratio was highly significant. During the ripening, the pulp peel ratio increased gradually. The maximum pulp-peel ratio was found in bananas kept in open trays and fiber bags.

Table 5. Effect of packaging on total soluble solids and shelf life of banana.

Treatment	Total soluble solids					Pulp-peel ratio				
	Day 1	Day 5	Day 7	Day 9	Day 11	Day 1	Day 5	Day 7	Day 9	Day 11
T1	2.66	8.83^{b}	10.33^{c}	11.50^{b}	12.17^{a}	1.48	1.67^{cd}	1.90^{a}	1.99^{c}	2.22^{b}
T2	2.66	6.33^{c}	8.00^{d}	10.67^{b}	11.90^{a}	1.48	1.51^{d}	1.84^{a}	2.27^{bc}	2.18^{b}
T3	2.66	15.00^{a}	17.00^{a}	-	-	1.48	2.11^{bc}	2.89^{a}	-s	-
T4	2.66	13.67^{a}	15.16^{b}	16.50^{a}	-	1.48	2.15^{bc}	2.70^{a}	3.83^{a}	3.24^{ab}
T5	2.66	14.83^{a}	15.57^{b}	16.43^{a}	-	1.48	2.73^{a}	2.05^{a}	3.32^{ab}	2.77^{ab}
T6	2.66	14.27^{a}	15.33^{b}	16.20^{a}	-	1.48	2.57^{ab}	2.67^{a}	3.73^{a}	3.77^{a}
T7	2.66	14.00^{a}	15.10^{b}	16.20^{a}	-	1.48	2.43^{ab}	2.72^{a}	3.04^{abc}	3.25^{ab}
Mean	2.66	12.41	13.79	14.48	12.03	1.48	2.17	2.39	3.03	2.88
CV (%)		6.81	3.99	3.98	6.14	-	15.04	30.25	22.20	21.68
LSD (0.05)		1.48***	0.96***	***	1.67***	-	0.56***	1.24	1.16**	**

Means with same letter in column are not significantly different at p = 0.05 by DMRT. * indicates 5% level of significance, ** indicates 1% level of significance, *** indicates 0.1% level of significance, LSD = Least significant difference, CV = Coefficient of variance.

Table 6. Effect of packaging on the marketability of banana.

Treatment	Marketability of banana					
	Day 1	Day 3	Day 5	Day 7	Day 9	Day 11
T1	100^{a}	100^{a}	100^{a}	100^{a}	63.8^{a}	46.67^{a}
T2	100^{a}	100^{a}	100^{a}	100^{a}	67.6^{a}	43.33^{a}
T3	100^{a}	100^{a}	100^{a}	66.0^{b}	-	-
T4	100^{a}	100^{a}	100^{a}	71.4^{b}	50^{ab}	-
T5	100^{a}	100^{a}	100^{a}	71.4^{b}	40^{abc}	-
T6	100^{a}	100^{a}	90.47^{b}	69.6^{b}	46.67^{ab}	-
T7	100^{a}	100^{a}	100^{a}	67.8^{b}	20^{bc}	-
Mean	100	100	98.63	78.03	41.15	12.86
CV (%)	2.74	2.74	4.23	12.07	57.19	102.87
LSD (0.05)	4.69	4.69	7.13	16.09***	40.23	22.60***

Means with same letter in column are not significantly different at p = 0.05 by DMRT. * indicates 5% level of significance, ** indicates 1% level of significance, *** indicates 0.1% level of significance, LSD = Least significant difference, CV = Coefficient of variance.

Marketability

The interrelationship between different packaging materials and the marketability of bananas was highly non-significant. Marketability decreased with the development of black spots on the peel and the onset of rot at the tip of the bananas. The most marketable bananas were found in high-density and low-density non-perforated polyethylene bags i.e., 46.67 and 43.33 on the 11th day of ripening. The least marketable banana was those packed in perforated polyethylene bags and open trays.

Conclusion

From the above studies, it is evident that among all the treatment options, postharvest packaging of bananas in low-density perforated polyethylene bags is excellent for accelerating ripening. Conversely, packaging in low-density non-perforated polyethylene bags extends the shelf life and post-harvest-longevity. Packaging bananas in jute bags, fiber bags, and paddy straws maintains the normal shelf life while improving the flavour, texture, taste, and overall quality of G9 variety of bananas. Based on intended use of bananas, different types of modified atmospheric packaging and traditional packaging materials can be used. For quick consumption or local market, bananas do not necessarily need packaging. However, to prevent external injury, bananas can be stored in perforated polyethylene bags. For long-term storage, bananas can be packed in the non-perforated polyethylene bags. To ensure best quality, bananas can be packed in fiber and jute bags.

DECLARATIONS

Author contribution: Conceptualization: D.G., J.J.L., G.B. and M.B.; Methodology: D.G. and M.B.; Software and validation: D.G. and J.J.L.; Data curation: D.G.; Writing-original draft preparation: D.G., J.J.L., and G.B.; Writing-review and editing: D.G., J.J.L. and G.B., Supervision: M.B. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

Ethics approval: This study did not involve any animal or human participant and thus ethical approval was not applicable.

Consent for publication: All co-authors gave their consent to publish this paper in AAES.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Supplementary data: Not available.

REFERENCES

Abdul-Rahaman, A., Abdul-Wahab, S., Leori, I., & Pasenaa. P. (2017). Modified insulated punnete and conventional packaging films for retail storage of robusta banana fruits. *Journal of Scientific Agriculture*, *1*, 46-53.

Abdullah, H., M. A. Rohaya, & H. Z. Zaipun. (2016). Physico- chemical changes during maturation and after ripening of bananas (Musa sapientum cv Embum). *MARDI Research Bulletin*, *13*(3), 341-347.

Abeles, F., & Morgan. P. (1992). Ethylene in plant biology. Salveit San Diego: Academic Press.

Abiso, E., Alemnew, A., Eshetu, S. & Awoke, M. (2018). Effect of packaging materials and post-harvest treatment on post-harvest quality and shelf life of banana fruits. *Animal*, *Food Science and Technology*, *19*(2), 292-299.

Akter, H., Hassan, M., Rabbani, M., & Mahmad., A. (2013). Effect of variety and postharvest treatments on shelf-life and quality of Banana. *Journal Environment Science and Natural Resources*, *6*(2), 163-175.

Ben-Yehoshua, S. Rodov, S., Fang, D., & Kim, J. (1995). Performed antifungal compounds of citrus fruits: effect of postharvest treatments with heat and growth regulators. *Journal of Agriculture and Food Chemistry*, *43*(4), 1062-1066.

Boning, C. (2006). Florida's best fruiting plants. *Florida: Pineapple Press Inc.*

Burg, S. & Burg, E. (1967). Molecular requirements for the biological activity of ethylene. *Plant Physiology*, *40*(1), 144-152.

Cheeseman, E. (1947). Classification of the bananas II . *Kew Bulletin*, *2*, 106-117.

Dadzie, B. & Orchard, J. (1997). Routine post-harvest screening of banana/plantain hybrids: criteria and methods. INIBAP Technical Guidelines 2. *International Plant Genetic Resources Institute, Rome, Italy*, 18-62.

Bal, J. (2014). Fruit growing. New Delhi: *Kalyani Publishers.*

Dunford (2006). Sports Nutrition: A practice manual for professionals. *American Dietetic Association.*

Eldad, B. & Deborah, A. (2016). Banana Morphology- part II: The aerial shoot. *Banana and Plantains*, 189-192. https://doi.org/10.1007/978-94-011-0737-2_8

FAOSTAT. 2017. FAOSTAT-Statistical Database, (2017).

Gapper, N., McQuinn, R., & Giovannoni, J. (2013). Molecular and genetic regulation of fruits ripening. *Plant Molecular Biology*, *82*(6), 575-591.

Gautam, D.M. & Dhakal, D.D. (1991). Falfultatha audyogik bali. Bharatpur, Chitwan: Pavitra and Rupa Publication, Nepal.

Gray, J., Picton, S., Giovannoni, J., & Grierson, D. (1994). The use of transgenic and naturally occurring mutants to understand and manipulate tomato fruit ripening. *Plant, Cell and Environment*, *17*(5), 557-571.

Hailu, M., Worknesh, T., & Belew, D. (2012). Effect of packaging materials on the quality of banana cultivars. *African Journal of Agriculture Research*, *7*(7), 1226-1237.

Heslop-Harrison, J. & Schwarzacher, T. (2007). Domestication, genomics and the future for bananas. *Annal of Botany*, *100*, 1073-1084.

Hou, J., Hu, Y., Hou, L., Guo, K., Takaaki, S. & Hou, J. (2015). Classification of ripening stages of bananas based on a support vector machine. *International Journal of Agriculture and Biological Engineering*, 99-103.

Kifle, Z. & Birhanu, T. (2020). Effect of different packaging materials on self life and quality of banana. *International Journal of African and Asian Studies.* 61, 1-6.

Klee, H., & Giovannoni, J. (2011). Genetics and control of tomato fruit ripening and quality attributes. *Annual Review of Genetics*, *45*, 41-59.

Knoema. (2020). Banana production quantity. *Retrieved from banana production quantity:* http://knoema.com/atlas/Nepal/topics/Agriculture/Crops-Production-Quantity-tonnes/Bananas-production?mode=am

Krishnamurthy, S., Kushalappa, C., & Prakash, M. (1985). Studies on the shelf life and quality of Robusta bananas as affected by post-harvest treatments. *Journal of Horticulture Science*, *60*(4), 549-556.

Maduwanthi, S. & Marapana, R. (2019). Induced Ripening Agents and their Effect on Fruit Quality of Banana. *International Journal of Food Science*, 4.

Marriot, J. (1980). Banana- Physiology and biochemistry of storage and ripening for optimum quality. *Critical Review in Food Science and Nutrition*, 13, 41-88.

Mir, N., & Beadey, R. (2004). Modified atmosphere packaging, postharvest physiology, and storage of tropical and subtropical fruits. *CAB International London, UK.*

Moreno, J. L., Tran, T., Cantero-Tubilla, B., Lopez-Lopez, K., Lavalle, L. A., & Dufour, D. (2021). Physiochemical and physiological changes during the ripening of Banana (Musaceae) fruit grown in Colombia. *International Journal of Food Science and Technology*, *56*, 1171-1183.

Pua, E.-C. (2015). Banana. *Biotechnology in Agriculture and Forestry*, 60, 2-4.

Rahman, A. U., Chowdhury, F. R., & Alam, M. D. B. (2008). Artificial ripening: what we are eating. *Journal of Medicine*, *9*(1), 42-44. Retrieved from https://doi.org/10.3329/jom.v9il.1425

Singal, Kumud & Thakral. (2012). Application of apple as a ripening agent for bananas. *Indian Journal of Natural Products and Resources*, *3*(1), 61-64

Stein, Z.M., Susser, G., Saenger, F., & Marolla. (1972). Nutrition and mental performance. *Science*, 708-713.

Thompson, F. (2001). Post-harvest loss of fruits and vegetables in horticulture state farms. *Acta Horticulturae*, *270*, 261-270.

Thompson, A. (2003). Fruits and vegetables harvesting, handling and storage (2nd Edi. ed.). *UK: Blackwell Publishing*.

Wong, C., Argent, G., Set, O., Lee, S. K., & Y. Y, G. (2002). Assessment of the validity of the sections in Musa (Musaceae) using AFLP. *Annuals of Botany*, *90*, 231-238.