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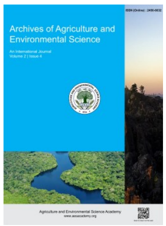

ORIGINAL RESEARCH ARTICLE

CrossMark

Effects of different traditional ripening methods on quality and shelf life of bananas in Chitwan, Nepal

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ABSTRACT

This study evaluates the effects of traditional ripening methods on the shelf life and quality of bananas, focusing on traits like weight loss, pulp-to-peel ratio, firmness, TSS, TA, pH, and TSS/TA ratio over 10 days. The experiment is conducted in a Completely Randomized Design (CRD) with five treatments and four replications (control, gunny bag, rice straw, tomato, and ethephon 500 ppm). All data were collected at the horticulture lab, AFU where ripening was maintained at 23-27°C with 50-70% relative humidity. ripening was maintained at 23-27°C and 50-70% relative humidity. Significant variations in physiological weight loss (PWL %) were observed, with the highest loss in tomato (9.91%) and ethephon (11.5%), indicating faster ripening, while gunny bag (5.42%) and control (6.43%) showed the lowest. The pulp-to-peel ratio was highest for tomato (2.52) and ethephon (2.62) by Day 10. Firmness decreased across all treatments, with the lowest values in ethephon (0.82) and tomato (0.66). TSS was highest in ethephon (22.95%) and tomato (22.95%). TA was lowest in straw-wrapped bananas (0.25). TSS/TA ratios were highest for ethephon and tomato (49.05). PH decreased in most treatments, with ethephon-treated bananas having the highest pH (4.95) by Day 10. Shelf life varied, with control, gunny bag, and straw lasting over 12 days, while ethephon had the shortest shelf life of 8 days. Despite a shorter shelf life, ethephon and tomato treatments offered better sensory qualities, including softness, sweetness, and visual appeal. Future studies should explore.

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INTRODUCTION

Banana is a monocotyledonous plant in the genus *Musa* spp. (Musaceae, Zingiberales) which is a tropical crop grown widely in warm areas of the tropical and subtropical regions (Heslop-Harrison & Schwarzacher, 2007). It ranks fifth and third regarding productive area and productivity respectively among cultivated fruits in Nepal (Rani *et al*., 2019). In Nepal, it is widely grown in Chitwan, Jhapa, Morang, and Saptari where Chitwan is the largest district regarding the productive area (2,205 ha) and production (47,187 Mt), and 2[nd] largest in terms of yield (22.4 Mt/ha) after Nawalparasi East which has 23.92 Mt/ha productivity according to (MoALD, 2023). Previously, banana farming in Chitwan was concentrated only in 680 ha during 2015 (MoALD, 2015). In contrast, it is now spread into a larger area of 2,205 ha (MoALD, 2023), which is the result of an increase of 224.3% of total cultivable land from the previous 8 years. Major cultivars of banana grown by the farmers of Chitwan is Grand Naine (G9), William Hybrid, and Malbhog (Joshi *et al*., 2020). The Fusarium wilt also known as Panama disease had significantly impacted the Malbhog banana variety, affecting approximately 30% of banana fields in the region (Dhungana, 2022). Due to this reason, farmer started to replace Malbhog with G9 which is more resistant to the panama wilt and also produce higher productivity i.e. around 50 t/ha as compared to 25-30 t/ha productivity of Malbhog variety (Ghimire, 2022). Although, G9 have lots of advantage over Malbhog for cultivation, consumer prefer sweeter and nutritious Malbhog which results in higher prices due to high demand and low supply (Dhungana, 2022). Nepal has 15.85 Mt/ha (MoALD, 2023) average productivity of banana which is very low (almost 30%) as compared to world productivity i.e. 22.64 Mt/ha (Ghimire *et al.*, 2023). However, productivity of Chitwan is at accelerating rate i.e. 22.4 Mt/ha (MoALD, 2023) almost equal to the world productivity. Even though of these factors, a large amount of banana is imported every year primarily from India. According to (Trend Economy, 2023), Nepal has imported banana with the total value of $8.01 million while only few amount of banana ($4.43 thousand) was exported to other countries. Main reason behind this is lagging in minimizing post-harvest loss of the banana as illustrated by (Poudel, 2020) that imported bananas are more appealing for consumer than indigenous because of its large size and bright yellow color. The major issue in indigenous banana marketing is price fluctuation which is driven by two main factors i.e. seasonal oversupply and inconsistent fruit quality (Shrestha *et al.*, 2018). The seasonal oversupply, or "glut," is due to natural seasonality of banana production, limited processing and storage facilities, inefficient post-harvest technology, and inefficient marketing system (Gotame *et al.*, 2018). In banana production and distribution, ripening is the crucial factor which determine fruit quality, shelf life, and marketability (FAO, 2018). Banana is a climacteric fruit that means it continue to ripen even after harvest due to increased ethylene production and respiration rates (John & Marchal, 1995).

Post-harvest losses in bananas can range from 20% to 80% (FAO, 2018) which were mainly caused by poor packaging, poor ripening methods, and transportation-related damage (FAO, 2018). In developing countries like Nepal, producer and distributor primarily use traditional methods of ripening because it is the simple methods with traditional knowledge as well as cost effective, however it lack controlled management of quality and shelf life (Maduwanthi & Marapana, 2017) which is the major reason behind less preferable indigenous production over larger and bright yellow G9 imported from India (Poudel, 2020). Despite the fact that indigenous G9 banana are flavorful than imported one, consumer do not prefer it because of lower pulp content and shelf life that leads to quick spoilage (Trend Economy, 2023). Common traditional techniques used in Nepal for ripening and storage are straw, smoke treatment, heat treatment, gunny bags, and natural ripening agents like ripe tomato, apple that emit ethylene naturally. These are the affordable and great alternatives for hazardous and costly chemical ripening agents but often result in inconsistent quality, shelf life and marketability (Ruwali *et al.*, 2022). There are some cost effective chemical ripening agents such as ethephon, ethylene which are used commercially and valued for their effective ripening process that help to achieve consistent color, texture, sweetness, and shelf life (Timilsina & Shrestha, 2022). However, there is not much research regarding the effectiveness of different ripening methods (Adhikari & GC, 2021) and public health priority over chemical residue have encouraged to research in more sustainable and natural ripening approaches (Pathak & Sanwal, 1999). It is essential to investigate on different traditional ripening methods to address these issue which provide scientific insights into effectiveness of these methods that help to maintain fruit quality and extend shelf life. Therefore, this research is trying to assess the local and commercial ripening techniques on quality parameters including physiological weight loss, pulp to peel ratio, firmness, TSS, TA, TSS/TA, pH, and shelf life. This study aims to improve post-harvest handling practices of banana that address both safety and quality of fruits during ripening process. Therefore, this study was conducted to investigate the effectiveness of traditional ripening methods on the quality and shelf life of bananas in Chitwan, Nepal.

MATERIALS AND METHODS

Research site and time of experiment

Two bunches of bananas for the experiment was brought from Mangalpur, which is located 10 km from Narayangadh in Chitwan, Nepal. The post-harvest analysis was carried out in the post-harvest horticulture laboratory of the Agriculture and Forestry University Rampur, Chitwan, Nepal. Rampur is situated at 27.5°N latitude and 84.4°E longitude, at an elevation of 228 masl, in the Terai belt. This location has hot summers and cool winters due to its humid sub-tropical climate, with an estimated 1582.6 mm of yearly rainfall. Monsoon rains occur from July to September. The experiment was conducted from 5th April to 22nd April 2024. The cultivar G9 was selected because it is one of the most widely grown cultivars in Chitwan.

Design of experiment and treatment details

The experiment was carried out in a Completely Randomized Design (CRD) with five treatments and each treatment was replicated four times. The bunch was dehanded with the help of a sharp knife and divided into fingers and 15 bananas was used for each treatment. The fruits were chosen based on their uniformity in size and free of defects. Fruits was washed with tap water to remove latex and dust. Treatment details for traditional methods of ripening included as: Control (T_1), Packed in gunny bags (T_2), Packed with ethylene-releasing fruit like tomato (T_3), Wrapped in straw (T_4), and Dipping in ethephon solution 500 ppm (T_5). No ripening agent was used for T1 and it was kept open in the air in plastic plates. For T_2, bananas were packed in a gunny bag. Two medium-sized tomatoes 75 g each (150 g) was kept with the banana inside the plastic bag for T_3. Similarly, bananas were wrapped inside the straw weighing 100 grams for T_4. For T_5 bananas was treated by dipping them in the ethephon solution of 500 ppm concentration for 5 min and letting them dry in the shade. Kripone was selected having 39% SL of ethephon to prepare a 500 ppm concentration of ethephon by mixing 1.28 ml of solution per liter of water. All the treatments are held in the ambient conditions.

Details of operation

Measurement of both experiments was done after 3rd day of the experiment i.e. Day 4 and in alternate days up to 50% of rotting i.e. 4, 6, 8, 10, 12 days, and so on. 15 fingers were numbered individually by the tag of number from 1 to 15. Due to the great variation in observation, 15 fingers were divided into 5 nondestructive and 10 destructive. 5 nondestructive samples were used for the observation such as shelf life, color, physiological loss in weight (PLW), and decay loss. 10 destructive samples were used for the observation such as peel-to-pulp ratio, TSS, TA, TSS/TA, and Ascorbic acid.

Shelf life: Shelf life was measured in days from the initiation of the experiment up to 50% of decaying.

Physiological loss in weight (PLW): It was calculated in % by the following formula:

$$\text{PLW\%} = \frac{\text{Initial weight} - \text{Next measurement weight}}{\text{Initial weight}} \times 100$$

Pulp-to-peel ratio

Pulp and peel was separated with the help of a sharp knife and was weighed individually with the weighing balance at the time of TSS and TA determination and expressed as pulp peel ratio as

$$\text{Pulp} - \text{to} - \text{peel ratio} = \frac{\text{Pulp weight}}{\text{Peel weight}}$$

Total Soluble Solids (TSS)

It is measured in ˚Brix and was determined with the help of a hand-held refractometer. For this measurement, a single fruit was selected at random from each replication of all the treatments. The peel was removed, and juice was extracted by grinding, sieving, and squeezing the pulp through muslin cloth. One to two drops of homogenized juice were put on the prism of the refractometer and a reading was obtained. Before recording the observation, calibration must be done. These readings were averaged as per treatment and replications.

Titratable acidity (TA)

It requires 0.1 N NaOH, Phenolphthalein, Pipette, Beaker, Burette, and burette stand for titration. 4 g of NaOH was dissolved in 1 liter of distilled water to prepare the solution of 0.1 N NaOH. It was calculated by using a formula:

$$\text{Titratable acidity (\%)} = \frac{\text{ml of NaOH used} \times 0.1\text{N NaOH} \times \text{equivalent wt.} \times \text{dilution factor} \times 100}{\text{ml of juice take} \times 1000}$$

Equivalent wt. of predominant acid i.e. malic acid = 67.05

TSS/TA

TSS/TA was calculated by using the formula;

$$\text{TSS/TA} = \frac{\text{Total soluble solids}}{\text{Titrable acid}}$$

pH of the juice: pH of the juice was measured with the help of digital pH meter.

Temperature and Relative Humidity (RH): Temperature and RH was recorded each day during experimental period.

Data analysis and data collection techniques

The collected data was compiled by using the MS Excel 2016 and subjected to analysis of variance with the help of R Studio.

RESULTS AND DISCUSSION

Physiological weight loss and pulp to peel ratio

Physiological weight loss in percentage (PWL %) and Pulp to Peel Ratio due to the effect of different traditional ripening methods are presented in the table below. The result show significant variation with increase in physiological weight loss (PWL%) over time across all treatment, which is similar to the findings of (Ruwali *et al.*, 2022). Banana wrapped with rice straw and control maintain moderate physiological weight loss while banana packed with tomato and treated with ethephone show highest physiological loss in weight indicating faster ripening and degradation due to increase in respiration rate, reported by (Mohamed & Abu-Goukh, 2003). Banana packed in gunny bag shows lowest PLW% which aligns with the result of (Tamang, 2024) making it suitable to minimize weight loss during longer storage. Tomato and Ethephon (500ppm) treated fruits show highest pulp to peel ratio by Day 10 which matches with the result of (Timilsina & Shrestha, 2022). Control and straw maintain lowest ratio, suggesting a slower ripening process. Banana stored in gunny bag shows less variation in pulp/peel weight with slight decrease by Day 8.

Firmness and Total Soluble Solids (TSS)

The data related to firmness and total soluble solids of banana treated with different ripening methods are shown in table. Banana's firmness decreased across all treatments throughout the ripening process (Timilsina & Shrestha, 2022). Control and Gunny bag maintain intermediate level of firmness while banana wrapped with straw exhibits the highest firmness. Both tomato and ethephon (500ppm) treated banana lead to the most significant loss of firmness, suggesting more advanced ripening which aligns with the findings of (Tamang, 2024). There is the steady increase in total soluble solids in all treatment due to the conversion of starch into soluble sugars as 85-95% of starch convert into simple sugars such as glucose, fructose which in turn increase sweetness and reduce astringency (Marriott, 1980). Banana treated with ethephon (500ppm) and tomato show highest total soluble solids while control and gunny bag packed banana exhibit moderate level of TSS. Banana wrapped with straw show lowest level of total soluble solids.

Titratable acidity (TA) and TSS/TA

The data related to titratable acidity (TA) and TSS/TA of banana treated with different traditional ripening methods are given in table below. The result shows non-significant variation at day6, and day8 while significant result observed at 10^{th} day after harvest. Control and banana kept in a gunny bag show highest TA (0.145) whereas banana treated with tomato and ethephon (500ppm) maintain moderate and stable TA (0.105). Banana wrapped with rice straw show lowest level of titratable acidity

Table 1. Physiological weight loss in percentage and pulp to peel ratio due to effect of different traditional ripening methods at ambient room temperature (25 ± 2 °C).

Treatments	Physiological weight loss				Pulp to peel ratio			
	Day4	Day6	Day8	Day10	Day4	Day6	Day8	Day10
Control	3.48^{d}	5.26^{d}	5.62^{d}	6.43^{d}	1.83^{ab}	2.36^{a}	1.96^{ab}	1.65^{c}
Gunny bag	2.86^{e}	3.18^{e}	4.43^{e}	5.42^{e}	2.07^{a}	2.32^{a}	1.92^{ab}	2.03^{b}
Tomato	7.48^{b}	8.57^{b}	9.68^{b}	9.91^{b}	1.34^{c}	1.24^{c}	1.78^{b}	2.52^{a}
Straw	5.44^{c}	6.33^{c}	7.06^{c}	7.77^{c}	2.05^{a}	2.08^{ab}	2.02^{ab}	1.64^{c}
Ethephon (500ppm)	7.84^{a}	9.24^{a}	10.06^{a}	11.5^{a}	1.42^{bc}	1.78^{b}	2.24^{a}	2.62^{a}
LSD(0.5)	0.06	0.114	0.155	0.095	0.52	0.46	0.33	0.146
SEm(+-)	0.009	0.017	0.023	0.014	0.08	0.07	0.05	0.021
F-probability	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NS	<0.001
CV%	0.737	1.167	1.402	0.77	20.01	15.63	11.01	4.61
Grand mean	5.42	6.52	7.37	8.21	1.72	1.95	1.98	2.09

Table 2. Firmness and total soluble solids due to effect of different traditional ripening methods at ambient room temperature (25 ± 2°C).

Treatments	Firmness				Total Soluble Solids (TSS)			
	Day4	Day6	Day8	Day10	Day4	Day6	Day8	Day10
Control	7.00^{a}	6.70^{b}	6.73^{a}	2.25^{a}	5.62^{c}	6.375^{c}	6.00^{b}	13.95^{c}
Gunny bag	6.60^{a}	7.08^{b}	6.75^{a}	1.46^{b}	5.25^{c}	5.25^{c}	4.87^{b}	15.45^{b}
Tomato	4.85^{b}	1.70^{c}	2.73^{c}	0.66^{e}	13.13^{b}	19.87^{b}	22.5^{a}	22.95^{a}
Straw	8.03^{a}	8.73^{a}	4.60^{b}	1.32^{c}	6.37^{c}	5.25^{c}	5.62^{b}	10.95^{d}
Ethephon (500ppm)	1.01^{c}	0.81^{c}	0.60^{d}	0.82^{d}	22.1^{a}	22.87^{a}	22.87^{a}	22.95^{a}
LSD(0.5)	1.64	1.33	1.6	0.088	3.4	2.2	1.2	0.58
SEm(+-)	0.24	0.2	0.24	0.013	0.5	0.326	0.178	0.086
F-probability	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CV%	19.83	17.6	24.84	4.51	21.5	12.26	6.46	2.24
Grand mean	5.5	5.01	4.28	1.3	10.5	11.95	12.37	17.25

Table 3. Titratable Acidity and TSS/TA due to effect of different traditional ripening methods at ambient room temperature (25 ± 2 °C).

Treatments	Titratable Acidity (TA)				TSS/TA			
	Day4	Day6	Day8	Day10	Day4	Day6	Day8	Day10
Control	1.6^{a}	0.8^{a}	0.6^{a}	0.65^{a}	4.78^{c}	9.16^{b}	11.43^{b}	21.46^{b}
Gunny bag	0.7^{b}	0.65^{a}	0.5^{a}	0.65^{a}	7.58b^{c}	8.08^{b}	10.25^{b}	23.86^{b}
Tomato	1.0^{ab}	0.7^{a}	0.5^{a}	0.47^{b}	13.65^{b}	42.88^{a}	48.94^{a}	49.05^{a}
Straw	0.7^{b}	0.5^{a}	0.4^{a}	0.25^{c}	9.16b^{c}	14.92^{b}	16.47^{b}	45.9^{a}
Ethephon (500ppm)	0.7^{b}	0.6^{a}	0.4^{a}	0.47^{b}	32.16^{a}	44.74^{a}	56.86^{a}	49.05^{a}
LSD(0.5)	50.63	0.375	0.271	0.086	6.24	13.86	12.24	8.44
SEm(+-)	0.014	0.05	0.04	0.012	0.925	2.06	1.79	1.252
F-probability	<0.05	NS	NS	<0.001	<0.001	<0.001	<0.001	<0.001
CV%	2.13	38.21	37.54	11.43	30.74	44.71	27.93	14.78
Grand mean	0.95	0.65	0.48	0.5	13.46	20.57	28.79	37.87

(TA) i.e. 0.055 at day10. There is significant increase in TSS/TA under all the ripening methods applied. Ethephon (500ppm) and tomato treatment show highest value of TSS/TA while straw treatment outperform control and gunny bag but still behind ethephon and tomato treatment.

pH

The data concern with pH of banana treated with different traditional ripening methods are given in table below. Control, gunny bag, and straw wrapped banana show steady decrease in pH and becoming more acidic over time. Banana treated with tomato show slight decrease in pH at day4 while it increases at day8 and day 10. Ethephon (500ppm) treated banana shows increase in pH and becoming less acidic as compared to other treatments.

Shelf life

The shelf life of bananas varied across different treatments, with the control, gunny bag, and straw treatments maintaining the longest shelf life of more than 12 days each. However, despite their longer storage duration, these treatments resulted in bananas with poor sensory qualities; they exhibited a brownish color, hard firmness, and were less appealing in taste. In contrast, the tomato treatment reduced the shelf life to 10 days, and the ethephon-treated bananas had the shortest shelf life of 8 days. While these latter treatments had shorter durations, they were more effective in preserving desirable eating qualities, offering a better balance between ripeness, taste, and texture.

DISCUSSION

The results of the study demonstrate that different ripening treatments significantly impact both the shelf life and quality of bananas. Tomato and ethephon (500 ppm) treatments acceler-

Table 4. pH due to effect of different traditional ripening methods at ambient room temperature (25 ± 2 °C).

Treatments	pH			
	Day4	Day6	Day8	Day10
Control	5.30 [a]	5.11 [a]	4.93 [a]	4.75 [b]
Gunny bag	5.19 [a]	4.97 [a]	4.64 [c]	4.23 [d]
Tomato	4.36 [b]	4.24 [c]	4.44 [d]	4.58 [c]
Straw	5.18 [a]	5.04 [a]	4.75 [b]	4.25 [d]
Ethephon (500ppm)	4.18 [b]	4.40 [b]	4.64 [c]	4.95 [a]
LSD(0.5)	0.216	0.155	0.026	0.125
SEm(+-)	0.032	0.023	0.023	0.018
F-probability	<0.001	<0.001	<0.001	<0.001
CV%	2.96	2.17	0.377	1.833

Table 5. Shelf life of banana due to effect of different traditional ripening methods at ambient room temperature (25 ± 2 °C).

Treatment	Shelf life	Ripening speed	Quality
Control	>12	Slow ripening	Brownish, hard, less appealing
Gunny bag	>12	Slow ripening	Brownish, hard, less appealing
Tomato	10	Fast ripening	Excellent taste, soft texture, visually appealing
Straw	>12	Slow ripening	Brownish, hard, less appealing
Ethephon (500ppm)	8	Fast ripening	Sweet, soft, desirable taste & texture

ated ripening, reducing the shelf life to 10 and 8 days, respectively. These treatments promoted faster softening and sweetness (higher TSS), producing fruits with superior taste and texture, making them suitable for quick consumption and rapid market turnover. In contrast, treatments with gunny bags, straw, and the control method extended the shelf life to more than 12 days by slowing the ripening process and retaining firmness for longer periods. However, these methods resulted in bananas with reduced sensory appeal, exhibiting a brownish appearance, harder texture, and less desirable taste over time. These results align with findings of (Tamang, 2024) and (Timilsina & Shrestha, 2022) who also reported enhanced ripening with ethylene-based treatments. The faster ripening observed in the tomato and ethephon treatments could be attributed to the production of ethylene gas, which stimulates fruit ripening as stated by (Mohamed & Abu-Goukh, 2003). (Mahajan *et al.*, 2010) stated that the use of ethylene caused a decrease in firmness during ripening, whereas tomatoes release ethylene, which speeds up its own biosynthesis and encourage fruit ripening according to (Zhao *et al.*, 2021). However, the slight decline in quality observed in bananas subjected to straw and gunny bag treatments suggests that while these methods delay ripening, they may not adequately preserve desirable eating qualities during extended storage. These results have practical implications for farmers and traders in selecting appropriate ripening methods. Quick-ripening treatments such as tomato and ethephon are ideal when market demand is high, allowing for faster fruit turnover with optimal taste. On the other hand, straw and gunny bag treatments can help extend shelf life for markets with delayed access, although they may not yield fruits of the highest quality. The trade-off between storage duration and fruit quality emphasizes the importance of aligning ripening techniques with market conditions to optimize profitability and reduce post-harvest losses.

Conclusion

The results of the study showed that ripening techniques significantly influence banana quality, with tomato and ethephon (500 ppm) treatments promoting the quickest ripening, highest sweetness (TSS), and rapid loss of firmness. These treatments reduced the shelf life to 10 and 8 days, respectively, but ensured better taste and quality, making them ideal for immediate consumption and quick market turnover. In contrast, treatments such as straw wrapping and gunny sacks extended the ripening process, resulting in a longer shelf life of more than 12 days. These methods helped maintain the fruit's firmness, preventing it from becoming too soft during storage, but slightly compromised the taste and visual appeal over time. Although the control, gunny bag, and straw treatments provided the longest shelf life, the bananas became brown, hard, and less palatable with extended storage. Therefore, tomato and ethephon treatments are recommended for farmers who prioritize quick ripening and high-quality fruit for immediate sale. However, the study also highlights the need to consider both shelf life and marketable days when choosing a ripening method, enabling farmers to align their storage strategy with market demand and ensure optimal profitability. Based on the findings of this study, further recommendation such as assessment of additional natural ripening agents like apple, citrus peel, eco-friendly, low-energy methods and repeated trials are proposed for further research to develop more comprehensive understanding of banana shelf life and quality over time.

DECLARATIONS

Authors contribution statement

Conceptualization and design: B.P. and S.R.; Laboratory work: B.P. and S.R.; Statistical analysis and synthesis: B.P. and S.R.;

Writing and drafting: B.P. and S.R.; Literature review: B.P. and S.R.; Editing and revising: B.P. All authors have read and agreed to the published version of the manuscript.

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REFERENCES

Adhikari, B., & G.C., A. (2021). Post-harvest practices of horticultural crops in Nepal: Issues and management. *Archives of Agriculture and Environmental Science*, 6(2), 227-233. https://doi.org/10.26832/24566632.2021.0602015

Bhatta, S., Pant, P., Kapri, R., & Mishra, B. P. (2023). Production efficiency of banana cultivation in Chitwan District, Nepal. *Cogent Food and Agriculture*, *9*(1). https://doi.org/10.1080/23311932.2023.2212461

Dhungana, I. S. (2022). "Panama" disease in Malbhog bananas causes problems. *Nepalnews*. https://nepalnews.com/s/business/panama-disease-in-malbhog-bananas-causes-problems

FAO. (2018). *Low cost, high impact solutions for improving the quality and shelf-life of bananas in local markets*. 2.

Ghimire, B., Dhakal, S. C., Marahatta, S., Kafle, N., Bastakoti, R. C., & Sharma, S. (2023b). Production Potential of Banana in Nepal: Growth Trend and A Comparative Analysis. *Food and Agribusiness Management*, *4*(1), 19–24. https://doi.org/10.26480/fabm.01.2023.19.24

Gotame, T., Adhikari, J., & Chhetri, M. B. (2008). Production and marketing constraints of banana enterprise in Nawalparasi district: strategies for research and development. *Nepalese Horticulture*. 6, 8-16.

Heslop-Harrison, J. S., & Schwarzacher, T. (2007). Domestication, genomics and the future for banana. *Annals of Botany*, *100*(5), 1073–1084. https://doi.org/10.1093/aob/mcm191

John, P., & Marchal, J. (1995). Ripening and biochemistry of the fruit. *Bananas and Plantains*. (pp. 434–467). https://doi.org/10.1007/978-94-011-0737-2_15

Joshi, A., Kalauni, D., & Tiwari, U. (2020). Application of Good Agricultural Practices (GAP) by the banana farmers of Chitwan, Nepal. https://doi.org/10.1101/2020.06.12.148551

Maduwanthi, S., & Marapana, R. (2017). Biochemical changes during ripening of banana: A review. *International Journal of Food Science and Nutrition*, *2*, 166-170.

Mahajan, B. V. C., Kaur, T., Gill, M. I. S., Dhaliwal, H. S., Ghuman, B. S., & Chahil, B. S. (2010). Studies on optimization of ripening techniques for banana. *Journal of Food Science and Technology*, *47*(3), 315–319. https://doi.org/10.1007/s13197-010-0050-0

Marriott, J., & Palmer, J. K. (1980). Bananas — physiology and biochemistry of storage and ripening for optimum quality. *C R C Critical Reviews in Food Science and Nutrition*, *13*(1), 41–88. https://doi.org/10.1080/10408398009527284

Ministry of Agriculture and Livestock Development (MoALD). (2015). Statistical information on Nepalese agriculture 2070/71 (2013/14). *MoALD*, 222. https://nepalindata.com/media/resources/bulkuploaded/Statistical_information_on_Nepalese_Agriculture_2013-2014_eng_may_17.pdf

Ministry of Agriculture and Livestock Development (MoALD). (2023). Statistical Information on Nepalese Agriculture 2078/79 (2021/22). *MoALD*, 269. https://giwmscdnone.gov.np/media/app/public/285/posts/1715754883_66.pdf

Mohamed, H. E., & Abu-Goukh, A. A. (2003). Effect of ethrel in aqueous solution and ethylene released from ethrel on mango fruit ripening. *The Journal of Horticultural Science and Biotechnology*, 78(4), 568–573. https://doi.org/10.1080/14620316.2003.11511665

Pathak, N., & Sanwal, G. G. (2013). Regulation of the ripening of banana (Musa acuminata) fruits by chemicals. *The Indian Journal of Agricultural Sciences*, 69 (1). https://epubs.icar.org.in/index.php/IJAgS/article/view/26192

Poudel, R. (2020). G9 banana more disease-resistant but less marketable, farmers say. *The Kathmandu Post*. https://www.itfnet.org/v1/2020/07/nepal-g9-banana-more-disease-resistant-but-less-marketable-farmers-say/

Rani, R., Mahato, J. L., & Raj, H. (2019). Genetic analysis and inter-relationship of yield attributing traits in Amaranthus germplasm. *Journal of Pharmacognosy and Phytochemistry*, *8*, 162-165.

Ruwali, A., Thakuri, M. S., Pandey, S., Mahat, J., & Shrestha, S. (2022). Effect of different ripening agents in storage life of banana (*Musa paradisiaca*) at Deukhuri, Dang, Nepal. *Journal of Agriculture and Food Research*, *10*, 100416. https://doi.org/10.1016/j.jafr.2022.100416

Shrestha, A., Sapkota, B., Regmi, R., & Dhungana, S. M. (2018). Economics of production and marketing of banana in Chitwan district, Nepal. *Azarian Journal of Agriculture*, *5*(1), 12–19.

Tamang, M., Bhujel, P., Yadav, P. K., & Marahattha, S. (2024). Effect of different post-harvest practices on the quality of bananas (G9). *Research Square*. https://doi.org/10.21203/rs.3.rs-4639495/v1

Timilsina, U., & Shrestha, A. K. (2022). Effect of different concentration of ethephon on banana (cv. Malbhog) ripening and post- harvest life at laboratory condition. *Archives of Agriculture and Environmental Science*, 7(1), 20-25. https://doi.org/10.26832/24566632.2022.070104

Trend Economy (2022). Nepal Imports and Exports World | Bananas Value (US$) and Value Growth, YOY (%) 2011 - 2022. (n.d.-c). *Trendeconomy*. https://trendeconomy.com/data/h2/Nepal/0803

Zhao, T., Nakano, A., & Iwasaki, Y. (2021). Differences between ethylene emission characteristics of tomato cultivars in tomato production at plant factory. *Journal of Agriculture and Food Research*, *5*, 100181. https://doi.org/10.1016/j.jafr.2021.100181