EFFECT OF DIFFERENT HARVESTING STAGES AND WRAPPING MATERIALS ON POST-HARVEST QUALITY, SHELF LIFE AND VALUE ADDITION OF DRAGON FRUIT (*Hylocereus polyrhizus*)

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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Nagaland University
October 2024

I, Alemla Imchen, hereby declare that the subject matter of this Thesis is the record of work done by me, that the contents of this Thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute. This is being submitted to the Nagaland University for the degree of Doctor of Philosophy in Horticulture (Fruit Science).

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CERTIFICATE – I

This is to certify that the thesis entitled **"Effect of different harvesting stages and wrapping materials on post-harvest quality, shelf life and value addition of dragon fruit (*Hylocereus polyrhizus*)"** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Horticulture in (Fruit Science), is the record of research work carried out by Alemla Imchen, Registration No. Ph.D./HOR/00344, under my personal supervision and guidance.

The result of the investigation reported in the thesis has not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN HORTICULTURE (FRUIT SCIENCE)

This is to certify that the thesis entitles "**Effect of different harvesting stages and wrapping materials on post-harvest quality, shelf life and value addition of Dragon fruit (*Hylocereus polyrhizus*)**", Admission No. Ph-281/19 & Registration No. Ph.D./HOR/00344 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Fruit Science) has been examined by the Advisory Board and External examiner on …………

The performance of the student has been found **Satisfactory/ Unsatisfactory**.

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Date:
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CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
I	INTRODUCTION	1-7
II	REVIEW OF LITERATURE	
	2.1 Effect of harvesting stages on post-harvest quality and shelf life of dragon fruit	8-16
	2.2 Effect of wrapping materials on post-harvest quality and shelf life	16-20
	2.3 Value addition in dragon fruit	20-24
III	MATERIALS AND METHODS	
	3.1Experimental site	25
	3.2 Climatic conditions	25
	3.3 Cultural practices	25
	3.4 Experimental details	27-35
IV	RESULTS AND DISCUSSION	
	4.1 To study the effect of different harvesting stages and wrapping materials on post-harvest quality and shelf life of Dragon fruit	36-96
	4.2 To study the best harvest stage of dragon fruit to prepare Ready-to-Serve (RTS) beverage	97-110
V	SUMMARY AND CONCLUSIONS	111-115
VI	REFERENCES	i-xv

LIST OF TABLES

TABLE NO.	TITLE	PAGES
3.1	Meteorological data recorded during the period of crop investigation (July 2020 to March 2022)	26
4.1	Effect of different harvesting stages and wrapping materials on firmness of dragon fruit	39
4.2	Interaction effect of different harvesting stages and wrapping materials on firmness of dragon fruit	40
4.3	Effect of different harvesting stages and wrapping materials on physiological loss in weight of dragon fruit	41
4.4	Interaction effect of different harvesting stages and wrapping materials on Physiological Loss in Weight of dragon fruit	42
4.5	Effect of different harvesting stages and wrapping materials on shelf life of dragon fruit	45
4.6	Interaction effect of different harvesting stages and wrapping materials on shelf life of dragon fruit	45
4.7	Effect of different harvesting stages and wrapping materials on post-harvest spoilage of dragon fruit	46
4.8	Interaction effect of different harvesting stages and wrapping materials on post-harvest spoilage of dragon fruit	47
4.9	Effect of different harvesting stages and wrapping materials on fruit weight of dragon fruit	49
4.10	Interaction effect of different harvesting stages and wrapping materials on fruit weight of dragon fruit	50

4.11	Effect of different harvesting stages and wrapping materials on pulp weight of dragon fruit	51
4.12	Interaction effect of different harvesting stages and wrapping materials on pulp weight of dragon fruit	52
4.13	Effect of different harvesting stages and wrapping materials on peel weight of dragon fruit	53
4.14	Interaction effect of different harvesting stages and wrapping materials on peel weight of dragon fruit	54
4.15	Effect of different harvesting stages and wrapping materials on Total Soluble Solids of dragon fruit	57
4.16	Interaction effect of different harvesting stages and wrapping materials on Total Soluble Solids of dragon fruit	58
4.17	Effect of different harvesting stages and wrapping materials on titratable acidity of dragon fruit	59
4.18	Interaction effect of different harvesting stages and wrapping materials on titratable acidity of dragon fruit	60
4.19	Effect of different harvesting stages and wrapping materials on TSS-Acid ratio of dragon fruit	64
4.20	Interaction effect of different harvesting stages and wrapping materials on TSS-Acid ratio of dragon fruit	65
4.21	Effect of different harvesting stages and wrapping materials on total sugar of dragon fruit	66
4.22	Interaction effect of different harvesting stages and wrapping materials on total sugar of dragon fruit	67
4.23	Effect of different harvesting stages and wrapping materials on reducing sugar of dragon fruit	69
4.24	Interaction effect of different harvesting stages and wrapping materials on reducing sugar of dragon fruit	70

4.25	Effect of different harvesting stages and wrapping materials on non- reducing sugar of dragon fruit	71
4.26	Interaction effect of different harvesting stages and wrapping materials on non- reducing sugar of dragon fruit	72
4.27	Effect of different harvesting stages and wrapping materials on ascorbic acid of dragon fruit	76
4.28	Interaction effect of different harvesting stages and wrapping materials on ascorbic acid of dragon fruit	77
4.29	Effect of different harvesting stages and wrapping materials on total phenolic content in pulp of dragon fruit	78
4.30	Interaction effect of different harvesting stages and wrapping materials on total phenolic content in pulp of dragon fruit	79
4.31	Effect of different harvesting stages and wrapping materials on total phenolic content in peel of dragon fruit.	82
4.32	Interaction effect of different harvesting stages and wrapping materials on total phenolic content in peel of dragon fruit.	83
4.33	Effect of different harvesting stages and wrapping materials on betacyanin content in pulp of dragon fruit.	86
4.34	Interaction effect of different harvesting stages and wrapping materials on betacyanin content in pulp of dragon fruit.	86
4.35	Effect of different harvesting stages and wrapping materials on betacyanin content in peel of dragon fruit.	87
4.36	Interaction effect of different harvesting stages and wrapping materials on betacyanin content in peel of dragon fruit.	88

4.37	Effect of different harvesting stages and wrapping materials on pectin content of dragon fruit.	89
4.38	Interaction effect of different harvesting stages and wrapping materials on pectin content of dragon fruit.	90
4.39	Effect of different harvesting stages and wrapping materials on flavor of dragon fruit.	93
4.40	Effect of different harvesting stages and wrapping materials on color of dragon fruit.	94
4.41	Effect of different harvesting stages and wrapping materials on taste of dragon fruit.	95
4.42	Effect of different harvesting stages and wrapping materials on overall acceptability of dragon fruit.	96
4.43	Effect of different harvest stage of dragon fruit on TSS content of RTS beverage	101
4.44	Effect of different harvest stage of dragon fruit on pH of RTS beverage	101
4.45	Effect of different harvest stage of dragon fruit on titratable acidity of RTS beverage	102
4.46	Effect of different harvest stage of dragon fruit on ascorbic acid of RTS beverage	102
4.47	Effect of different harvest stage of dragon fruit on total sugar of RTS beverage	104
4.48	Effect of different harvest stage of dragon fruit on reducing sugar of RTS beverage	104
4.49	Effect of different harvest stage of dragon fruit on non-reducing sugar of RTS beverage	105
4.50	Effect of different harvest stage of dragon fruit on appearance of RTS beverage	107
4.51	Effect of different harvest stage of dragon fruit on taste of RTS beverage	107

4.52	Effect of different harvest stage of dragon fruit on odor of RTS beverage	108
4.53	Effect of different harvest stage of dragon fruit on overall acceptability of RTS beverage	108
4.54	Effect of different harvest stage of dragon fruit on microbial count of RTS beverage	110

LIST OF FIGURES

FIGURE NO	CAPTION	IN BETWEEN PAGES
4.1	Individual and interaction effect of harvesting stages and wrapping materials on firmness	42-43
4.2	Individual and interaction effect of harvesting stages and wrapping materials on PLW	42-43
4.3	Individual and interaction effect of harvesting stages and wrapping materials on Post harvest spoilage	47-48
4.4	Individual and interaction effect of harvesting stages and wrapping materials on Total Soluble Solids	60-61
4.5	Individual and interaction effect of harvesting stages and wrapping materials on Titratable acidity	60-61
4.6	Individual and interaction effect of harvesting stages and wrapping materials on TSS-Acid ratio	67-68
4.7	Individual and interaction effect of harvesting stages and wrapping materials on Total sugar content	67-68
4.8	Individual and interaction effect of harvesting stages and wrapping materials on Reducing sugar content	72-73
4.9	Individual and interaction effect of harvesting stages and wrapping materials on Non-reducing sugar content	72-73
4.10	Individual and interaction effect of harvesting stages and wrapping materials on Ascorbic acid content	79-80

4.11	Individual and interaction effect of harvesting stages and wrapping materials on Total phenolic acid content in pulp	79-80
4.12	Individual and interaction effect of harvesting stages and wrapping materials on Total phenolic acid content in peel	83-84
4.13	Individual and interaction effect of harvesting stages and wrapping materials on Betacyanin content in pulp	83-84
4.14	Individual and interaction effect of harvesting stages and wrapping materials on Betacyanin content in peel	90-91
4.15	Individual and interaction effect of harvesting stages and wrapping materials on Pectin content in peel	90-91
4.16	Effect of harvesting stages on TSS and pH of Dragon fruit RTS	102-103
4.17	Effect of harvesting stages on Titratable acidity and Ascorbic acid of Dragon fruit RTS	102-103
4.18	Effect of harvesting stages on Total Sugar and Reducing sugar in Dragon fruit RTS	110-111
4.19	Effect of harvesting stages on Appearance and Taste in Dragon fruit RTS	110-111
4.20	Effect of harvesting stages on Odour and overall acceptability in Dragon fruit RTS	110-111
4.21	Effect of harvesting stages on Microbial count in Dragon fruit RTS	110-111

LIST OF PLATES

PLATE NO	CAPTION	IN BETWEEN PAGES
1	Aerial view of the farm located at Seithekema- C village	25-26
2	Overview of the research farm	25-26
3	Intercultural operations: Pollination & weeding	28-29
4	Tagged fruits	28-29
5	Harvesting of fruits	28-29
6	Different harvesting stages of dragon fruit	28-29
7	Different wrapping materials used (i. Control ii. Half dried banana leaves iii. Brown paper iv. EPE foam net v. Shrink wrapping)	28-29
8	Shrink wrapping of dragon fruits	28-29
9	Isolation and identification of disease found in dragon fruit plant	32-33
10	Steps on preparation of dragon fruit RTS beverage	35-36
11	RTS beverage prepared during the two trials	35-36
12	Effect of harvesting stages and wrapping on dragon fruit at Day 0	37-38
13	Effect of harvesting stages and wrapping on dragon fruit at Day 2	37-38
14	Effect of harvesting stages and wrapping on dragon fruit at Day 4	37-38

15	Effect of harvesting stages and wrapping on dragon fruit at Day 6	37-38
16	Effect of harvesting stages and wrapping on dragon fruit at Day 8	37-38
17	Sensory evaluation of RTS beverage	109-110
18	Format used for organoleptic evaluation	109-110
19	Effect of harvesting stages on Microbial count ($x10^5$ cfu/ml) in Dragon fruit RTS	110-111

LIST OF ABBREVIATIONS/SYMBOLS

ANOVA	: Analysis of variance
@	: At the rate
ºC	: Degree Celsius
%	: Per cent
cv	: Cultivar
CD	: Critical difference
cm	: Centimeter
DAA	: Days after Anthesis
Df	: Degree of freedom
DAH	: Days after Harvesting
DAS	: Days after Storage
et. al.	: Et. alibi and others
viz.	: namely
etc.	: Et. cetera
kg	: Kilogram
g	: Gram
µg	: Micro gram
ha	: Hectare
i.e.	: That is
No.	: Number
PLW	: Physiological Loss in Weight
SAS	: School of Agricultural Sciences
SS	: Sum of Square

ABSTRACT

A study on "**Effect of different harvesting stages and wrapping materials on post-harvest quality, shelf life and value addition of Dragon fruit (*Hylocereus polyrhizus*)**" was conducted for two consecutive years during 2020-2022 in a private dragon fruit farm at Seithekema-C, Chümoukedima district, Nagaland and post-harvest quality and laboratory analysis were done in the Department of Horticulture, School of Agricultural Sciences, Nagaland University, Medziphema campus.

The first experiment was laid out in Factorial Completely Randomized Design replicated thrice, consisting of two factors *viz*., Harvesting stages (H) and Wrapping materials (W). The first factor consisted of 3 harvesting stages *viz.,* H_1- 25 Days after anthesis (DAA), H_2- 30 DAA and H_3- 35 DAA and the second factor consisted of 4 wrapping materials and one absolute control *viz*., W_1- Control, W_2- banana leaves, W_3- brown paper, W_4- EPE foam mesh, W_5- Shrink wrap. Fruits were tagged in the morning followed after anthesis and matured fruits were harvested according to the treatments requirement and stored in CFB boxes for further observations. Physiochemical analysis were conducted at 48 hours interval. Analysis of variance (ANOVA) revealed significant differences among the treatments for all the characters studied. Titratable acidity and firmness gradually decreased with increase in storage duration. Increase in TSS, total sugar, reducing sugar and ascorbic acid were analyzed in all the harvesting stages during the initial storage days, whereby, it reduced thereafter. Fruits harvested at 30 DAA showed a more steady decline in the quality parameters. Shelf life in days was more in 25 DAA and PLW was found to be lesser. On the 8th day after storage, betacyanin content was found to have retained more in 30 DAA and total phenolic content in 25 DAA in both peel and pulp. Among the wrapping materials, there was significant difference during the time of storage. It was noticed that the quality parameters remained fairly constant in shrink wrapping as compared to the other treatments. In case of interaction effect, on the 8th day of storage, the highest values for TSS (12.27ºB), total sugar (8.02%), reducing sugar (5.25%), non-reducing sugar (2.63%), firmness (6.34 kg/cm^2) and betacyanin in peel (35.42 mg/100g) was recorded in H_2W_5 (30 DAA in shrink wrapping), while higher Total phenolic content in peel (13.60 mg GAE/g) and pulp (5.28 mg GAE/g), ascorbic acid (9.12 mg/100 ml), pectin (5.11%), acidity (0.33%) and shelf life (11.27 days) were recorded in H_1W_5 (25 DAA in shrink wrapping), also lower PLW (1.78%) and post-harvest spoilage (7%). In case of sensory evaluation, values recorded maximum in terms of flavor (8.4) and overall acceptability (8.51) on storage fruits at 4th day under treatment H_2W_3 (30 DAA in brown paper).

Thus, it may be concluded that *H. polyrhizus* grown in Chümoukedima area of Nagaland reach physiological maturity between 30 to 35 DAA and optimum stage for harvest is 30 DAA, where post-harvest quality can be maintained for a longer period

of time. Based on the results, 30 DAA in shrink wrapping was found to be the best treatment for enhancing the post-harvest life of dragon fruit.

The second experiment was laid out in Completely Randomized Design (CRD) with five replications where four different harvesting stages of dragon fruit was used to prepare Ready to Serve (RTS) beverage to find out the best maturity stage for value addition. The treatments consisted of T_1- 25 DAA, T_2- 30 DAA, T_3- 35 DAA, T_4- 40 DAA and observations were taken every 30 days for a period of 3 months. In this experiment, potassium sorbate was used as preservative. After trial and error, the RTS for all the treatments was prepared with the composition of 12% juice, 10% sugar, 0.2% citric acid and 0.02% preservative and remaining water made up volume of 100mL. During the initial stage of observation, data recorded on TSS, total sugar, reducing sugar depicted higher values in fruit juice of T_4 (40 DAA) and an increasing trend was observed. On all days of study, titratable acidity was recorded highest in T_1(25 DAA). At the end of observation period, the maximum TSS and total sugar were reported in H_3 (35 DAA) with 13.84 ºB and 12.00% respectively, whereby, maximum titratable acidity (0.47%) and ascorbic acid (0.51 mg/100mL) in H_1 (25 DAA) and reducing sugar (3.0%) and pH (4.11) in T_4 (40 DAA) were recorded. The highest mean scores was computed in T_3 (35 DAA) in terms of appearance (8.04), taste (7.14), odour (6.36), and overall acceptability (7.20). On almost all the days of analysis, microbial count (4.40 x 10^5 cfu/mL) was recorded lowest in T_1 (25 DAA).

Thus, it may be concluded that T_3 (35 DAA) is the optimum harvest stage for value addition of dragon fruit with optimum values of TSS, total sugar, reducing sugar with better organoleptic acceptability and less microbial population during storage.

Keywords: *Hylocereus polyrhizus*, maturity indices, day of anthesis, wrapping materials, RTS.

CHAPTER I

INTRODUCTION

INTRODUCTION

Dragon fruit (*Hylocereus* spp.) is a herbaceous, perennial, epiphytic cactus, widely known as Kamalam, strawberry pear or pitaya, of the cactus family Cactaceae. The fruit features vibrant red, leathery skin adorned with green scale-like structure enclosing a juicy pulp constituting 70 to 80% of ripe fruit. The pulp, which may be white or red in color depending on the species contains numerous small black seeds. It is native to the tropical and subtropical regions of Mexico, Central America, and parts of South America. The most common species are *H. undatus, H. polyrhizus*, *H.* (S*elenicerus*) *megalanthus* and *H. costaricencis* (Pavithra and Mini, 2023). The cultivation of dragon fruit is widespread across various countries, particularly in areas characterized by tropical and subtropical climates. Largest producer and exporter of dragon fruit globally is Vietnam, particularly the white-fleshed variety (*H. undatus*), sharing 51.1% of world's production consisting an area of 55,419 hectares with productivity of 22 to 23 metric tonnes per hectare yearly (Ali *et. al*., 2024). Other major dragon fruit cultivating countries are Thailand, Indonesia, Taiwan, Sri Lanka, Japan, Bangladesh, Malaysia, Philippines, Australia, United States and China (Jalgaonkar *et. al*., 2020). In recent times, dragon fruit has emerged as a widely-loved fruit owing to its unique inherent qualities such as its big showy flowers that blooms at night time, its vibrant, aesthetically attractive and peculiar shaped fruits, which are low in calories, with high fiber and rich antioxidant properties. As such, dragon fruit has earned the sobriquets such as- Queen of the Night, Wondrous fruit of the 21st century (Ali *et. al*., 2024), Belle of the night, Noble woman (Mondal and Alam, 2023), Cinderella plant (Perween *et. al*., 2018) and Health fruit (Wakchaure *et. al*., 2023). It is regarded as a promising and profitable fruit crop with immense potential for the future (Gunasena *et. al*., 2006).

Dragon fruit was brought into India in the early 1990s (Arivalagan *et al*., 2019). Gradually overtime, its cultivation has increased significantly with the intervention of governmental schemes as Mission for Integrated Development of Horticulture (MIDH) (Anon., 2023). Currently, over 6,000 hectares are under dragon fruit cultivation, with

MIDH aiming to expand this area to 50,000 hectares by 2025 (Wakchaure *et. al*., 2023). This exotic fruit has established niche growing areas in the states of Gujarat, Maharashtra, West Bengal, Karnataka, Chhattisgarh, Andhra Pradesh, Telangana, Tamil Nadu, Mizoram, Nagaland, Odisha and Andaman and Nicobar islands (Anon., 2023). Among the states, Gujarat leads with approximately 34% of the country's total production (Anon., 2020). However, the current domestic production is insufficient to meet national demand, leading to substantial imports from neighbouring countries namely, Thailand, Vietnam, Malaysia, and Sri Lanka.

Dragon fruit is highly adaptable to diverse agroclimatic conditions and also very easy to propagate. It has high drought tolerance and easy adaptability to harsh climatic conditions owing to its modified stem structure for water storage, reduced or absence of leaves, waxy surfaces and night-time opening of tissues for absorption of carbon dioxide (CAM pathway) (Luders and McMahon, 2006). According to Wakchaure *et. al.* (2021, 2023), dragon fruit is an ideal stress-tolerant plant suitable for cultivation in "moderate to low rainfall regions, drought-prone areas, and arid/semi-arid regions with degraded lands" and holds huge potential of crop diversification, particularly in neglected barren lands of India. Dragon fruit can be sexually propagated through its seeds which has a viability of 83% and seeds germinates after 6 days (Elobeidy, 2006). Though sexual propagation is important for breeding programs and genetic studies, the fruits comes to bearing after 4 to 5 years (Patel *et. al*., 2023) and the plants are not true to type due to cross pollination (Andrade *et. al*., 2005) and a lot of variability exist among the plants, thus, propagation by seed is not used for commercial multiplication of dragon fruit. Apparently, asexual propagation through stem cutting is considered the most useful and popular method of plant multiplication in dragon fruit (Singh and Rani, 2023). The usage of stem cuttings is most popular to produce true to type as well as large number of plantlets (Malsawmkimi *et. al*., 2019) and fruiting stage is reached more rapidly with cuttings within one and half years of planting. For propagation, mature stem segments of 15 to 30 cm are taken from two years old mother plants during the months of November to March as this period corresponds with elevated endogenous auxin concentrations, thereby enhancing the survival rate of cuttings (Nandi *et. al*., 2019).

Dragon fruit exhibits a crop cycle lasting approximately six months, typically from May to November, though it may occasionally extend from late April to December.

During this period, the plant undergoes four to seven flowering and fruiting flushes annually. As a long day plant, photoperiod strongly influences its flowering and fruit set, along with other environmental factors such as temperature, humidity, and rainfall. The flowers open at night and are hermaphroditic in nature which are mostly pollinated by nocturnal pollinators like bats and moths, while some flowers remain open till morning, bees act as pollinators in such cases. Dragon fruit has mixed breeding system in which fruit setting occurs through selfing and out-crossing (Nangare *et. al*., 2020). Hand pollination is usually done to ensure proper fruit set and good commercial fruit size. Poor genetic diversity, self-incompatible varieties and absence of pollinators are some of the reasons that makes hand pollination a prerequisite in dragon fruit cultivation. According to a study conducted by Li *et. al*. (2020), the optimal window for manual pollination is from 8:00 pm to 2:00 am in the morning whereas, Pérez *et. al.* (2023) has opined that the dragon fruit pollens remain viable and successful manual pollination can be done during the timeframe of 10:00 pm at night till 5:00 am of the next morning. The latter also records best consistency of collected pollens and highest percentage of viability was found from 2:00 am to 4:00 am with maximum average viability of 96% which can affect the size of the fruit. Manual pollination is carried out by collecting the pollen from one flower and using a small brush to pollinate many flowers.

Dragon fruit is not only a lucrative, robust and resilient plant but also as a tropical superfood owing to its rich nutritional profile. Minerals such as potassium, phosphorus, magnesium and sodium present are reportedly higher than those in mango, mangosteen and pineapple (Gunasena *et. al*., 2007; Stintzing *et. al*., 2003). Fruits are high in fibre content, lesser content of fats and carbohydrates, seeds contain 50 per cent of essential fatty acids- linoleic acid and linolenic acid (Sowane, 2017; Perween *et. al*., 2018). Dragon fruit is also regarded as a medicinal plant and has been traditionally utilized in various Asian countries as a component of herbal remedies and folk medicine (Sofowora *et. al*., 2013). However, the reported nutritional values are highly variable, such as ascorbic acid which in some studies are reported to be lower than the expected range of antioxidant properties that dragon fruit is known for, this is because ascorbic acid is sensitive to light and air and the concentration in fruit varies according to the type of cultivation, the stage of maturity and the conditions of cultivation (Luu *et. al.,* 2021). Dragon fruit is also rich in phytochemical compounds such as betalain, polyphenols, flavonoids, carotenoids, terpenoids, steroids, saponins, alkaloids and tannins (Kanchana *et. al*., 2018; Mahdi *et. al*., 2018) which are present in both the pulp and peel portions of the fruit. There is potential to use dragon fruit extract as an alternative to chemical colourants in the food and cosmetic industry as it contains betalain. Betalain are water-soluble pigments that comprise red-purple betacyanin and yellow betaxanthins. Red-purple colored dragon fruit is a pure source of betacyanin, as betaxanthins are totally absent, which explains the deep glowing red-purple color of the flesh (Le Bellec *et. al*., 2006). Betacyanin pigment has antioxidant properties that exhibit health benefits hence making it a potential source as natural pigment and functional ingredient in edible and cosmetic products (Yee and Wah., 2016).

Dragon fruit is increasingly gaining recognition for its nutritional and medicinal properties, with promising potential in India both for fresh consumption and value-added processing. However, the absence of adequate post-harvest infrastructure and technological interventions has adversely affected its marketability and availability of quality fruits to consumers (Rodeo *et. al*., 2018). Furthermore, dragon fruit is categorized as a non- climacteric fruit. Data shows that it has a low respiration rate during the maturation period and should be harvested when ripe for good quality (Van To *et. al*., 2000). The stage of maturation of fruit at harvest affects post-harvest development and influences the final quality. Fruit harvested prematurely is prone to physiological disorders due to cellular disorganization and susceptible to chilling injury, while, overripe fruits are likely to show rapid senescence, resulting in quantitative and qualitative losses. Consequently, an understanding of measurement of maturity is pivotal to postharvest handling. The right harvesting period may differ depending on the agroclimatic conditions where the crop is grown because different growing environments can have different effects on the physical development and nutritional quality of the product by influencing the inducement of the biosynthesis of secondary metabolic products and health-promoting phytochemicals (Singh *et. al*., 2022). The association between harvest timing and specific ripeness stages is critical for the long-term storage of fruits (Ozgen *et al*., 2002). So also in dragon fruit, harvesting at optimum maturity stage is essential to maintain consistency and ensure the quality of value-added products. Fruits harvested at different maturity possess different biochemical constituents and physiological properties that make the fruits react somewhat differently to the post-harvest treatments (Awang *et. al.,* 2013) and in as much react differently while processing into different value-added products.

Dragon fruit is inherently highly perishable in nature and prone to peel shrivelling and rapid water loss after few days of harvesting. It is prerequisite to harvest at the correct stage and employ efficient post-harvest management practices. Packaging is the connecting link between production and consumption and is of dire importance in the post-harvest value chain. According to Matche (2005), "for most part, packaging cannot delay or prevent fresh fruit and vegetables from spoilage, however, packaging serve to protect against contamination, damage and most importantly, against excess moisture loss and incorrect packaging can accelerate spoilage". Thus, packaging in most horticultural produces is better than no packaging. In rural areas, horticultural produces like fruits and vegetables are sent to various mandis and markets without any packaging or mainly in wooden boxes, bamboo baskets, Corrugated Fibre Board (CFB) boxes, jute bags, plastic crates etc., as such these methods typically lack adequate cushioning and protection, leading to mechanical damage and deterioration in produce quality during transit. Wrapping the produce individually before placing inside the carrier may provide protection from the change in external conditions and wear and tear exerted during the transportation. After harvest, rapid shriveling of dragon fruit and mechanical injury are important problems that decreases marketability, storage life, and aesthetic appeal (Rodeo *et al*., 2018). Mechanical injury leads to the development of sunken areas from increased water loss. This injury can be avoided by harvesting fruit at the appropriate ripeness stages and by careful handling after harvest (Van To *et. al*., 2002). According to Mizrahi and Nerd (1999), dragon fruits may be stored for 10 days at room temperature if the proper maturation stage has been reached before harvest. Since consumers typically choose fruits and vegetables based only on appearance, there is a greater chance that these goods will be colored or chemically treated to increase their appeal and deceive the buyer about their true quality. These post-harvest practices have the potential to negatively impact the nutritional value of the product in addition to having detrimental effects on human health (Panghal *et. al*., 2018). Thereby, wrapping of individual dragon fruits before placing inside the carrier for transport or marketing can reduce the probable damages and moisture loss to some extent and retain quality and shelf life for a longer time.

According to Rana *et al*., 2015, individually wrapped fruit have a more passively modified atmosphere which remains different from ambient surrounding, unlike controlled atmospheric storage where fruits are constantly exposed to a conventional atmosphere. Different packaging and cushioning materials, such as bamboo and teak leaves, typing paper, newspaper, rice paper, and polyethylene bags, have different effects on the physical and chemical quality of fruits when they are kept at room temperature. These effects include TSS, acidity, vitamin C, pectin content, and organoleptic rating including physical weight loss and skin color (Kumar *et. al*., 2012). A feasible technology of wrapping dragon fruit, with consideration of the long term needs of the ecosystem, without involvement of huge capital for dragon fruit farmers is needed. Use of locally available materials can be used for reducing moisture loss, retain shelf life and provide efficient handling.

Ready-to-serve (RTS) beverages have gained popularity due to the convenience they offer. With the growing awareness of health and nutrition among consumers, there is an increasing preference and demand for healthier beverage options in the market scene. Dragon fruit in itself is a nutritive plant with less sugar and high water and dietary fibre content which makes it an ideal option for making ready-to-serve beverage product. Maturity stage is an important aspect in value addition of dragon fruit as it determines the desired composition of the processed end product. The fruit physiochemical composition affects the quality and content of health benefit compounds of the beverage (Sew *et. al.,* 2013). The fruits which have not attained harvest maturity are bland to taste and does not hold the requisite nutritional capacity. There is immense scope in ready-to-serve beverage prepared from dragon fruit as it is ticks the boxes for consumer preference in terms of nutrition, taste and versatility. Use of preservative is essential to enhance the shelf life and maintain quality of processed product. Beverages are proved to be good nutrient media for microbial growth and thus proper care during processing and storage, along with use of preservative is vital to control growth of microorganisms. Sorbic acid or potassium sorbate are used as preservative in the food and beverage industry due to their antimicrobial properties. They are novel, natural organic compound, highly efficient, safe and nonpoisonous, as they are unsaturated fatty acids and their salts, they integrate into the normal fat metabolism in human body and ultimately oxidized into carbon dioxide and finally water. This preservative do not accumulate in the human body and are approved worldwide and used as standard products in the food industry (Jorge, 2003).

Dragon fruit output is predicted to increase as the area under cultivation continues to grow. India's dragon fruit production increased dramatically from 400 hectares in 2017 to 3000-4,000 hectares in 2020, according to estimates obtained by ICAR-NIASM from farmers, entrepreneurs and state agricultural departments nationwide. As of right now, the country's total area under dragon fruit cultivation is over 6000 hectares, with a target area expansion under MIDH of 50,000 hectares by 2025 (Wakchaure *et al*., 2023). Exploring opportunities for value addition through processing is crucial given the constant growth and production in order to maintain production levels and make the excess products easily processed (Karunakaran and Arivalagan, 2019). A variety of commercial products including juice, nectar, jam, jelly, syrup, ice cream, flour, yoghurt, preserves, candies and baked products can be made from dragon fruit. Because of its unique flavor and large market, the processed product can be more appealing to customers who might dislike raw dragon fruit. Since dragon fruit is a seasonal fruit that is primarily accessible from May to October, high-quality goods made from it may appeal to consumers who like the fruit throughout the year, particularly for its nutritional and therapeutic qualities.

Taking into account the need for an in depth study on the maturity stages and its influence on the post-harvest attributes of dragon fruit and the need for proper packaging in relation to its harvesting stage, this study was conceived to articulate the right harvesting stage for fresh consumption as well as in the processed form of an RTS beverage. Thus, the study was undertaken on the topic "Effect of different harvesting stages and wrapping materials on post-harvest quality, shelf life and value addition of Dragon fruit (*Hylocereus polyrhizus*)" with the following objectives:-

1. To study the effect of different harvesting stages and wrapping materials on post-harvest quality and shelf life of dragon fruit.
2. To study the best harvest stage of Dragon fruit to prepare Ready- to- serve (RTS) beverage.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

An attempt has been made to collect and review the relevant literature available on various aspects of work done till date on effect of harvesting stages and wrapping materials on post-harvest quality, shelf life and processing of dragon fruit. Literature on the mentioned aspects was reviewed and presented in respect to dragon fruit and other fruits under the following subheads:

2.1 Effect of harvesting stages on post-harvest quality and shelf life of dragon fruit

Van To *et. al.* (2000) conducted a study to generate and disseminate the appropriate pre- and post- harvest technologies for dragon fruit to end users. The optimal harvesting time vary between the 25^{th} and 28^{th} days after flowering for export and the 29- 30^{th} days after flowering for local markets. The physico- chemical changes occurring during the fruit maturity period, such as respiration rate, total soluble solids, total acidity, firmness, skin colour etc., were determined and used for evaluation of shelf life. The chilling sensitivity of fruit depends on the harvesting time and they were more sensitive 25 days after flowering as compared to the rest of the experimental period. The optimal storage condition is 5ºC and 90% relative humidity to prolong postharvest life.

Van To *et. al*. (2002) carried out an experiment to study the effect of harvesting time, use of plant growth regulators and modified atmosphere packaging on dragon fruit. The study indicated harvesting was optimal at 28- 30 days after flowering, on the basis of the indices of color, total soluble solids (TSS), titratable acidity and color. Best practice also included spraying the fruit with a mixture of gibberellic acid, α-naphthalene acetic acid (NAA) and β-NAA at a formulation of 8, 150 and 400 ppm, respectively, on the 11^{th} day after flowering. This treatment increased fruit weight, TSS and flesh and bract firmness.

Phebe *et. al.* (2009) conducted a study to determine colour, total betacyanin content and its separation in the peel and flesh of red-fleshed pitaya fruit harvested at 25, 30 and 35 days after flower anthesis (DAA) and to examine the usefulness of tristimulus colour measurement as predictors of pigment content in red-fleshed pitaya fruits. There were significant relationships between DAA and colour (L*, C* and h° values), and total betacyanin contents of peel and flesh of red-fleshed pitaya fruit. A total of three types betacyanin were separated from peel and flesh of pitaya fruit at 30 and 35 DAA while for 25 DAA, only one type of betacyanin was separated. The total concentration of betacyanin in the fruit peel of 25, 30 and 35 DAA was 0.24, 3.99 and 8.72 mg/mL, respectively. The fruit flesh contains 2.40, 7.93 and 11.70 mg/mL betacyanin at 25, 30 and 35 DAA, respectively, which was higher than peel.

Jamaludin *et. al*. (2010) studied on the determination of physico- chemical (weight, length, diameter, stomatal density, respiration rate, colour, soluble solids concentration, titratable acidity, chlorophyll and betacyanin content) and structural changes of red- fleshed dragon fruit from 5 to 35 days after pollination (DAP) in order to explain their growth, development, maturations and ripening stages. Results showed that fruit growth of red- fleshed dragon fruit followed a sigmoid pattern. Significant changes in colour were obtained in both peel and pulp as DAP progressed as both changed from green to red- violet colour at ripening. There was significant increase in soluble solids concentration and titratable acidity with continuous increase in betacyanin content as DAP progressed.

Punitha *et. al.* (2010) evaluated three different temperatures- low (6°C), intermediate (16°C) and high (ambient) (23°C±2) for 14 days to study the physiochemical properties of *Hylocereus polyrhizus*. Attributes showing greatest tendency to be affected in storage temperature include reduction in fruit firmness and increase in peel colour. Total soluble solids values were maintained at 6°C as opposed to high temperature in which the values decreased especially at 16°C. Furthermore, the percentage of reduction of total sugar, total reducing sugar was less in fruit kept at low temperature while pH value increased gradually regardless of storage temperature. Based on the visual appearance and organoleptic properties, fruit kept at 6°C resulted in better storage condition compared to intermediate and ambient.

Dhall *et. al.* (2012) studied the effect of individually shrink wrapped immature green cucumber cv. ‘Padmini’ fruits with Cryovac D955 (60 guage) film and stored at 12±1 °C, 90–95% RH as well as ambient conditions (29–33 °C, 65–70% RH). It was concluded that individual shrink wrapped cucumber can be stored well up to 15 days at 12±1 °C and 90–95% RH and for 5 days at ambient conditions (29–33 °C, 65–70% RH) with maximum retention of green colour, no spoilage, minimum weight and firmness loss and very good sensory quality attributes whereas, unwrapped fruits can be stored well up to 9 days at 12 ± 1 °C and 90–95% RH and for 2 days at ambient conditions with maximum retention of physiochemical quality attributes.

Enciso *et. al*. (2011) conducted a study to evaluate postharvest quality of pithaya fruits (*Hylocereus undatus* Haw.) in three maturity stages: initial, medium and complete, which corresponds to 25-50, 50-75 and 75-100% of red peel color respectively. Fruits were stored under marketing conditions (20 ± 2ºC). physical and chemical characteristics were evaluated during 12 d and physiological characteristics during 8 d. By the end of the storage period, weight loss was higher (P≤ 0.05) in fruits harvested at initial maturity (7.8 %), than in fruits of medium (6.1%) and complete (5.6%) maturities. Shelf life for fruits with medium and complete maturity was between 6 and 8 d, whereas for initial maturity was 10 d, but in the last ones the less intense red color affected fruit quality.

Awang *et. al*. (2013) conducted a study to examine the activity of Polygalacturonase (PG) and Pectin Methylesterase (PME) enzymes during storage in dragon fruit harvested at 28 (Index 3) and 34 (Index 5) days after anthesis and postharvest treated with 0, 2.5, 5.0 and 7.5gL^{-1} $CaCl_2$. PG activity of Index 5 fruits increased almost linearly during storage while its activity in Index 3 fruits was low at the early days of storage and later continued to increase until day seven. At both maturity indices, the PME activity was low at the early days of storage and later continued to increase until day seven. Overall results obtained indicated that CaCl post-harvest treatment reduced both PME and PG activities thus slowing down the softening process giving an evidence that calcium possess a distinguishable role in the reducing softening of fruit, regardless of maturity index.

Ortiz and Takahashi (2015) conducted an experiment to analyze the physical and chemical characteristics of the maturation process of pitaya fruit (*Hylocereus undatus*) to identify indicators that can be used to determine the point of physiological maturity and establish the optimal timing of physiological maturity and establish the optimal timing of physiological maturity for harvesting the fruit. Harvesting of fruit began 21 days after anthesis and lasted 12 days, with 4 fruits harvested per day. The experimental design used was Completely randomized design and four replicate experiments were performed. Results showed that physiological maturity occurred between 30^{th} and 32^{nd} days after anthesis and this proved to be the optimal period for harvest with high soluble solid content and recommended values of total acidity, pH and soluble solid to acidity ratio.

Sobral *et. al*. (2018) studied the harvest point of red pitaya produced in the north of Minas Gerais, Brazil, according to physical and chemical changes during refrigerated storage. The experiment was conducted through a Completely Randomized design in a 3 x 5 factorial scheme composed of three treatments (ripening stages) and five post- harvest assessment days (0, 5, 10, 15 and 20), with four repeats of four fruits per experimental unit. Results indicated harvest should happen at stage 2 or 3, when fruits have a brighter red hue and also these stages have higher soluble solid contents and reduced pulp acidity during storage in relation to fruits harvested at S1.

Magalhaes *et. al.* (2019) conducted a study to evaluate the quality evolution of red-fleshed dragon fruit at different development stages and to ascertain the ideal season for fruit harvest. Quality measurements were taken every two days, from 28 to 42 days after anthesis. Significant physical and physico-chemical changes occurred in red-fleshed dragon fruit during its development, including increase in soluble solids, pH, diameter and mass, as well as decrease in acidity, firmness, and skin thickness. Skin color and external appearance were found to be good indicators of the degree of maturity and can be thus be used to determine the fruit harvest point. From 34 to 42 days, the fruits showed characteristics appropriate for consumption and commercialization. The findings demonstrated that fruit should be harvested at 34 days of anthesis or when the fruit skin is predominantly reddish, when destined to more distant markets. For marketing in nearby markets and immediate consumption, fruits should be harvested after 36 days or with intense red coloration.

Magalhaes *et. al*. (2019) conducted a study to evaluate the evolution of physical and physiochemical characteristics of white-fleshed dragon fruit during its development. The visual changes in different developmental stages showed their potential use as morphological markers in the determination of fruit ripening, especially the appearance of fruit scales. Based on the analyzed variables, the ideal time indicated for commercialization in the short or medium term is 34- 38 days after anthesis.

Chowdhury *et. al.* (2020) conducted a study to determine the effect of preharvest fruit bagging materials as well as variety on the yield, postharvest qualities and shelf life of dragon fruit. The two-factor experiment was comprised of two varieties viz., V1: BAU dragon fruit-1 (White flesh) and V2: BAU dragon fruit-2 (Red flesh) and five bagging materials viz., T0: non-bag (Control), TCB: cloth bag, TBB: brown paper bag, TBP: black polythene bag and TWP: white polythene bag. Results showed that fruit bagging with black polythene bag significantly improved fruit fresh weight (287.47 g), fruit diameter (7.91 cm), peel-flesh ratio (5.97), total dry weight (61.33 g/fruit), reduced days to maturity (22 days) and peel weight (48.11 g) of BAU dragon fruit-1 while black polythene bag extended shelf life (12.05 days), increased total soluble solids (TSS) (14.40%) and reduced peel thickness (0.21 cm) of BAU dragon fruit-2. From the findings of this study, it can be stated that preharvest fruit bagging with black polythene bag would be the best option as bagging material to improve the yield, postharvest quality and shelf life of dragon fruit.

Martineli *et. al.* (2021) studied to examine the respiratory activity and post-harvest alterations of pitaya picked in the commercially immature stage of ripeness, by comparing them with fruits picked fully ripe. Physical and chemical aspects of the fruits were evaluated in two harvests, in 2019 and 2020. Six days after harvest, there was an increase in respiratory activity and a change in color in both ripe and commercially immature fruits. Therefore, pitayas picked commercially immature in both harvests had an increase in respiratory activity post-harvest, with a change in skin color during storage; and six days after harvest, in the 2019 harvest, the fruits resembled those that ripened on the plant, without having their quality compromised. However, in the 2020 harvest, six days after harvest, the fruits picked fully ripe showed soluble solids/titratable acidity ratio, betacyanin and ascorbic acid contents similar to those measured in the commercially immature fruits.

Chang (2021) investigated the effect of preharvest application of forchlorfenuron (CPPU) and perforated polyethylene bag packaging (PPE) on maintaining the postharvest quality of red-fleshed cv. 'Da-Hong' pitaya (*Hylocereus polyrhizus* sp.) fruit. On the flowering day, 100 mg·L−1 CPPU was sprayed on the bracts and water was used as the control. After harvest, all fruits were divided into three package treatments, which were packed without bags, packed with and without PPE bags, and stored at 5 ± 0.5 ºC and 90 ± 5% relative humidity for 21 days, followed by 7 days at 20 ºC and 75 ± 5% relative humidity without bags for quality evaluation. Significantly higher bract thickness (2.26 vs. 1.44 mm), longer fruit length (120.5 vs. 109.04 mm), and greater firmness (1.56 vs. 1.04 kg·cm−2) were recorded for the CPPU treated fruit at harvest. Preharvest application of CPPU with perforated packaging resulted in significantly greener bracts, a lower yellow index, fewer chilling incidences, and a lower decay ratio, but there was a slight decrease in respiration rate during cold storage at 5 ºC for 21 days. However, all criteria reached the threshold when fruits were transferred to 20 ºC for 7 days. In conclusion, preharvest CPPU application plus perforated packaging is the best combination for the long-term storage of red-fleshed pitaya fruit at 5 ºC.

Junior *et. al.* (2021) conducted a study to analyze the changes that occur during the growth and ripening of white-fleshed dragon fruit. Physical and physicochemical and chemical fruit characterization analyses were conducted at several development stages (7, 14, 21, 28, 35 and 42 days after anthesis). Increases in length, fruit mass and pulp, yield and soluble solids were observed, as well as reductions in skin thickness, strength and pulp pH. Significant and important levels in mineral for the human diet. were found, especially nitrogen, potassium, calcium, manganese, iron and zinc. Intense changes in seed maturation and biomass accumulation occurred during the fruit growth phase, while in the maturation stage the main changes are related to the improvement of the organoleptic characteristics such as acidity reduction and content of soluble solids, besides the reduction of the mass and thickness of the skin. The ideal harvest point, whereas organoleptic characteristics and visual aspects, is around 35 days, when fruit reached physiological maturity; however, at 42 days, the fruit pulp still had sufficient quality for consumption.

Deep *et. al.* (2022) investigated the right harvest time and maturity indices for red and white pulp dragon fruit. Growth and developmental studies were undertaken using destructive (total soluble solids (TSS), titratable acidity and TSS: acid ratio) and non-destructive methods (fruit weight, specific gravity, peel colour and heat units). Fruits were collected at seven intervals (7, 14, 21, 26, 31, 36 and 41 days after flowering) to assess the right maturity. All these methods were used to standardize the optimum maturity and right time for the harvest of red and white pulp dragon fruit. Harvesting dragon fruits between 31-36 days after flowering (DAF) was found ideal for optimum maturity and quality. Both red and white pulp fruits harvested at 31 DAF showed better quality in terms of physic-chemical and sensory attributes.

Franco *et. al.* (2022) conducted a study to determine the physiochemical changes at harvest and during low-temperature storage of white- fleshed dragon fruit harvested at 31, 33, and 35 days after anthesis (DAA). The fruit was then stored at 5 ºC for 5 weeks or at 13 ºC for 3 weeks followed by post-storage at 20 ºC. At harvest, fruit harvested at 35 DAA had the highest value of TSS/TA ratio, while 31 DAA fruit had the highest total phenolic content. Dragon fruit harvested at 33-35 DAA can be stored at 5°C for three weeks with post-storage life of 9 days at 20 ºC. Fruit harvested at 31 DAA exhibited flesh translucency after three weeks at 5 ºC, an indication of chilling injury. Physiochemical changes did not vary significantly during storage at 5 ºC and 13 ºC except for the marked decrease in acidity in all maturity stages. When presented to sensory panellists, preference was higher in fruit harvested at 35 DAA than at 33 and 31 DAA. All things considered, the best harvest maturity stage for prolonged storage at 5 ºC is 35 DAA, while 31-33 DAA for 13 ºC storage.

Singh *et. al.* (2022) studied the changes in physical attributes, and bioactive and mineral content in red-fleshed dragon fruit grown in semi-arid conditions in India at six developmental stages. The fruit physical characteristics, along with eating quality parameters were observed at optimum at 35 days after anthesis (DAA). The decrease in total phenolics (29.96%), total flavonoids (41.06%), and vitamin C (75.3%) occurred throughout the fruit development stages, whereas the content of betalains, which was detected initially at 25 DAA, increased (48.6%) with the progression of the fruit development stages. However, the antioxidant capacity and free radical scavenging activity demonstrated variable trends throughout the fruit maturation period. There was an increasing trend in all the minerals up to 35 days, followed by a slight decrease, except for phosphorus content, which increased until the last stage of evaluation. The colour characteristics, in conjunction with the bioactive and antioxidant potential determined in the present study, suggest that red-fleshed dragon fruit can be harvested at 35 DAA for long-distance transportation, and from 35 to 40 DAA for local marketing.

Zitha *et. al.* (2022) investigated the changes in the bioactive compounds and antioxidant activity of the red-fleshed dragon fruit at eight development stages. In general, the levels of total phenolic compounds tested using Folin-Ciocalteu, and Fast Blue BB reagents, betacyanin, betaxanthin, anthocyanins, and antioxidant activity by TEAC, FRAP, and ß-carotene bleaching increased over the fruit development stages, whereas vitamin C content significantly decreased. Six phenolic compounds were identified, including catechin, vanillin, gallic acid, caffeic acid, chlorogenic acid, and ferulic acid. Catechin was the majority compound, followed by vanillin. All these compounds decreased during fruit development; chlorogenic and ferulic acids were only detected 30 days after anthesis. Based on the results, the suitable harvest period of red-fleshed dragon fruit is between 36 and 38 days after anthesis.

Trong *et. al.* (2022) investigated the physiological and biochemical changes during the development and maturation of red-fleshed dragon fruit grown in Vietnam. The fruits reached a maximum size at 32 DAA. Chlorophyll content increased gradually from fruit formation to 18 DAA, then rapidly decreased until fruit ripening, whereas carotenoid content increased gradually from fruit formation to ripening. Starch and total organic acids contents gradually increased and reached maximum values at 18 and 22 DAA, respectively, and then declined. The contents of reducing sugars, lipids and vitamin C increased as the fruit proceeded towards ripening, reached maximum values at 32 DAA and then declined once the fruit was overripe. Proteins content gradually increased from 6 to 14 DAA and then decreased as the fruit proceeded towards ripening. These results suggest that red-fleshed dragon fruit should be harvested at 32 DAA to maximize the nutritional value and quality of the fruit.

2.2 Effect of wrapping materials on post- harvest quality and shelf life.

Hayat *et. al*. (2005) carried out a study on the effect of different concentrations of calcium chloride (1%, 1.5%, 2%), paraffin wax coating and different wrapping materials (polyethylene, carton paper) in order to increase the shelf life and to avoid postharvest loses of Banky cultivars of apple. Physical and chemical characteristics were analyzed after 15, 30, 45 and 60 days of storage. All the treatments had significant effect on shelf life of fruits. However, Calcium chloride (2%) was reported superior to all other treatments and retained consumer acceptability even after 60 days of storage followed by polyethylene packaging.

Freitas and Mitcham (2013) investigated the quality of pitaya fruit (*Hylocereus undatus*) as influenced by storage temperature and packaging to determine the best combination of storage temperature and use of perforated plastic bags to maintain the postharvest quality of the fruit. Fruits were stored at 5, 7 or 10ºC with and without a perforated plastic bag for 20 days, followed by five days at 20ºC without bag for shelf-life determination. Storage at 5ºC, followed by 7ºC maintained better visual appearance of the pitaya fruit after 20 days, by reducing decay incidence and severity, maintaining greener bracts compared with fruit stored at 10ºC.

Ali *et. al.* (2014) conducted a study to evaluate a double layer coating for maintenance of quality of dragon fruit during storage at 10±2 °C and 80±5 % RH for 28 days. Significant differences ($p<0.05$) were observed between control and the treated fruit. However, a double layer coating with 600 nm droplet. size + 1.0 % conventional chitosan showed promising results in all the tested parameters, while the fruit treated with 1,000 nm droplet. size + 1.0 % conventional chitosan showed some negative effects on fruit surface. Increase in weight loss was 12.0 % in fruit treated with 600 nm droplet. size and 1.0 % conventional chitosan as compared to the control. Antioxidants and gaseous analysis also proved the efficacy of double layer coatings with 600 nm droplet. size + 1.0 % conventional chito- san. Thus it was concluded that double layer coating could be used for maintaining quality in dragon fruit for up to 28 days without any off-flavours.

Kumar *et. al*. (2014) carried out an investigation to know the optimum concentration of calcium salts and the best wrapping material for increasing shelf life of guava. Fruits treated with calcium chloride 1% and wrapped in newspaper recorded minimum reduction in fruit size (length and breadth), weight and best in organoleptic evaluation during storage period.

Mahajan *et. al.* (2014) conducted a study on the effect of packaging films on shelf life and quality of peach under super and ordinary market. conditions. Fruits of cultivar 'Shan-i-Punjab' harvested at colour break stage and packed in paper moulded trays followed by wrapping with different packaging films viz. cryovac heat shrinkable RD- 106, cling and low density polyethylene (LDPE) film. After packaging, the fruits were stored under two different conditions i.e. super-market. conditions (18–20 °C; 90–95 % RH) and ordinary market. conditions (28–30 °C; 60–65 % RH). The shrink film helped in reducing the loss in weight, firmness, decay incidence and maintained the various qualities attributes like total soluble solids, sugars, acidity and ascorbic acid content of the fruits during shelf-life better than unwrapped control fruits. The data revealed that RD-106 film proved quite effective in prolonging the shelf-life and maintaining the quality of peach fruits for 9 and 4 days under super market. conditions (SMC) and ordinary market. conditions (OMC), respectively as against 6 and 2 days only in case of unpacked control fruits under both the marketing conditions. The results suggest that shrink film could be used in packaging of peach without negative effects on quality.

Cabrera *et. al.* (2017) conducted a research aimed to study banana (*Musa paradisiaca*) leaf as primary packaging to minimize the loss of quality of lulo stored at different temperatures. Use of banana leaf as primary package decreased weight loss and the color changes as a result of ripening process. The Young's modulus and firmness values was higher. The proposal packaging configuration (lulos packed with banana leaf in plastic crates of 80×60×20 cm) is an easy alternative to get. and preserve the quality of lulo fruits for a longer storage time.

Bhuvaneswari *et. al*. (2017) conducted a study on the shelf-life extension of papaya (*Carica papaya* L.) packaged in customized Corrugated Fibre Box (CFB) box after subjecting to vibration and drop tests. Papaya cv. Red Lady harvested at two streak stage, packaged in customized CFB box of size 450x300x300mm, 5 ply rate, 20 kg/cm^2 bursting strength with inbuilt cushioning papaya withstood vibration and drop test as compared to those packaged in CFB boxes of 18 kg/cm^2 bursting strength. The fruits packaged in these boxes and stored at 18ºC had less weight loss, more firmness, less spoilage, higher TSS and carotenoids content in subsequent storage compared to those other packages. The papaya fruits had a shelf life and marketability of 12 days at low temperature storage (18ºC, 80% RH) and 6 days at ambient storage condition (28-30ºC, 55% RH).

Rana and Siddique (2018) carried out a study to assess the effect of different individual packaging on the shelf life guava. The individual wrapping of fruits were carried out in LDPE films by cling, shrink, vacuum and modified atmosphere packaging (MAP) and stored at room temperature (37 °C). In control fruits significant compositional changes along with the total phenol content and ascorbic acid were observed with higher decay loss. However, wrapping of fruits maintained the natural freshness and helped in retaining the marketability of the fruits. Vacuum packing and MAP showed minimum PLW (3.5%), decay loss and ripening during storage. Cling wrapping and shrink wrapping were the best treatments that enhanced the shelf life of fruits by 4 days at room temperature.

Suwanti *et. al.* (2018) conducted a study to investigate the effect of the packaging methods (paper. Active paper and edible coating) on the characteristics of papaya MJ9 (weight loss, firmness, TSS, titratable acidity, pH, vitamin C and total mold and yeast). The packaging methods were control (F1), wrapping paper (F2), wrapping active paper (F3), combination of edible coating and wrapping paper (F4) and combination of edible coating and wrapping active paper (F5). The results showed that paper packaging, edible coating and active paper packaging significantly affected weight loss, firmness, TSS, titratable acidity, pH, vitamin C and total mold and yeast of papaya.

Castro *et. al*. (2020) conducted an experiment to extend the storage and shelf life of dragon fruit through modified atmosphere packaging (MAP) in combination with storage at low temperature. Excellent quality fruit harvested at 25- 30 days after flowering were sleeved in polystyrene fruit cup and individually packed in 50.8 μm thick polyethylene (PE) and polypropylene (PP) non perforated plastic bags. Sample fruits were withdrawn every 2 weeks from storage at 5ºC and transferred to 20 ºC for shelf life evaluation. MAP- stored fruit remained in excellent condition for up to 6 weeks at 5ºC without any shriveling thus fruits were firm, and bracts remained green.

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Prashanth *et. al.* (2022) conducted a study to identify the synergistic effect of chitosan coating with different concentrations on the postharvest quality and shelf life of dragon fruits stored at ambient conditions. Dragon fruits were coated with 2 %, 3 % and 4 % chitosan solution and stored at ambient temperature for 14 days. The results indicated that chitosan coating with 4% significantly reduced the decrease of PLW, firmness, TSS, TA, ascorbic acid content and partially inhibited decay. These results also showed that chitosan coating @ 4% is the most effective treatment for improving the postharvest quality and prolong the shelf life of dragon fruits when stored at ambient condition.

Lata *et. al.* (2023) conducted a study to analyse the postharvest quality and shelf life of white and red pulp dragon fruit stored in ambient conditions (25±3°C and 60±5% RH) for 1 week. Physiological loss in weight, acidity, total soluble solids, ascorbic acid, antioxidant activity, total phenols, and flavonoids were measured on day 0, 2, 5 and 7. A significant decrease in biochemical composition and weight was observed during storage. Among pulp colour types, red pulp fruits had significantly higher total soluble solids, total sugars, ascorbic acid, flavonoids, antioxidant activity (0.33 times more), and total phenols (2 times more) whereas titratable acidity was approx. 2 times higher in white pulp fruit on day 7. However, physiological loss in weight and postharvest spoilage were higher in red pulp fruits (3 times more than white pulp) on the last day of storage (day 7). The white pulp fruit showed a better fruit quality and shelf life in ambient conditions. The results indicated that red and white pulp fruit had a 5- and 7-day shelf life, respectively, in ambient conditions as spoilage and weight loss were much higher than the acceptable range in red pulp fruit on day 7.

2.3 Value addition in Dragon fruit

Chansamrankul *et. al*. (2008) studied the quality and shelf life of fresh cut dragon fruit product prepared on day 0, 2, 4 and 6 days after harvesting stored at ambient temperature (around 30ºC). Fresh cut dragon fruit were packed in foam tray and over wrapping with polyvinyl chloride (PVC) film and then stored at 4ºC. Results on qualities and physical changes determined daily showed that weight loss at 0 and 4 days after harvesting was higher than that at 2 and 6 days after harvesting, respectively. Results indicated that the suitable duration for preparing fresh cut product from dragon fruit was 2- 4 days after harvesting judged by eating and external appearance.

Woo *et. al*. (2011) studied the stability of Betalain pigment from red dragon fruit (*Hylocereus polyrhizus*). The fruit extract obtained demonstrated absorbance peaks at 230 and 537 nm under UV/Vis spectrophotometric analysis. Absorbance peak at 537 indicated the presence of betacyanin. Refrigeration storage (4ºC) condition without light exposure managed to preserve the color of fruit juice up to 3 weeks.

Dam (2013) conducted a series of studies to optimize the processing of wine from fruit pulp, betacyanin and jam from fruit peel, soft drink from plant stems and tea from flowers. Based on these studies, optimized protocols were developed. For extracting betacyanin, pre drying to 32% moisture content was done at 55% for 45-60 min before extraction using 1:5 (g:ml) raw material and water ratio, pH 5.0, and temperature of 25ºC for 10 min; this protocol yielded 14.82% betacyanin. For producing jam from fruit skin, 0.3% pectinase and 0.2% pectin to produce a product of good structure, color and taste. For making soft drink from plant stems, moderately accepted product was produces after 2 hours of incubation with 0.25% Pectinex Ultra SP at 45-55ºC and pH 4.5. effective extraction volume was observed at the ratio of 1:4 (raw material and water), blending ratio of 10.4% sugar, 0.1% citric acid, 0.03% Kiwi flavor and pasteurization temperature 95ºC for 10 min. For producing tea from the flower remnants, the product mix included 10% dried dragon fruit flower, 0.2% licorice, 0.08% citric acid, 0.03% aroma, 9% sugar and 80.69% water; the product had brownish yellow color, taste and aroma better than other tea products in the Vietnamese market.

Sew *et. al.* (2013) conducted a study to determine the optimum maturity stage at harvest of red flesh pitaya (RFP) fruits for juice and puree production. RFP fruits from five different maturity stages, namely 25, 27, 20, 33 and 35 days after anthesis (DAA) were analyzed for the changes in their physio-chemical characteristics. It was found that there was no extractable juice from RFP fruits harvested at 25 and 27 DAA. It is recommended that the optimum maturity stage for juice and puree production is 30 DAA.

Trimedona *et. al*. (2020) studied the antioxidant properties of herbal tea prepared from red dragon fruit peel with the addition of ginger. The herbal tea prepared with hot oven drying methods, where the fresh peel of dragon fruit and ginger were cut into small pieces and dried at 60ºC and ground into tea powder then mixed as treatments. Results showed that the addition of ginger has no significant effect on phenolic content, and betacyanin content decreased by the addition of ginger.

Sambasevam *et. al*. (2020) conducted a study on the evaluation of natural pigment extracted from dragon fruit (*Hylocereus polyrhizus*) peels using water as a solvent in the extraction method. The colour pigment content was determined based on the absorbance and characterized using Ultraviolet- visible (UV-Vis) at 535nm and Fourier Transform Infrared (FTIR) spectrometer, respectively. Results analysis from the pigment extract showed that the optimum conditions were achieved at 4 hours, 25ºC and pH 5 for extraction time, temperature and pH, respectively. In conclusion, the natural pigment extracted from dragon fruit peels using water as a solvent in the extraction method has a high potential to be used as a natural colourant.

Hendra *et. al.* (2020) studied the antioxidant activity from pigment and non- pigment extracts from the peel of dragon fruit. The pigment was extracted by using maceration with ethanol HCl while non- pigment extraction was carried out by using methanol followed by partition with hexane, dichloromethane and ethyl acetate, respectively. The antioxidant activity was analyzed by using DPPH method. The results showed that the pigment extract exhibited high antioxidant activity with IC_{50}: 159.6 ppm while ethyl acetate extract showed weak activity and the hexane and DCM showed no antioxidant activity. Therefore, the pigment from the peel possess antioxidant activity and further investigation of antioxidant activities are needed by using different methods and to determine the chemical structure responsible in this activity.

Minh *et. al.* (2019) conducted a study on production and preservation of Dragon fruit nectar. Results showed that dragon fruit nectar had the best quality by adjusting at pH 4.2, sugar supplementation 8%, 95ºC in 10 minutes, storage at 4 ± 2ºC in glass bottle.

Foke *et. al* (2018) conducted a study to develop RTS beverage using dragon fruit. Preliminary investigations were carried out based on the standards specified for RTS fruit drinks to develop a suitable recipe. RTS beverages were prepared containing four levels of dragon fruit juice (8%, 10%, 12% and 14%), citric acid (0.2%, 0.3%, 0.4% and 0.5%) with 12 per cent sugar and 0.01 per cent potassium Meta bisulphite. Sensory evaluation was conducted using 25 untrained panelists to determine the best juice concentration to develop the RTS. Proportion with 12 per cent dragon fruit juice and 0.4 per cent citric acid was selected as the best level for the development of dragon fruit ready to serve beverage. Storage study for analysis of acidity, TSS, ascorbic acid and pH from 0 to 50 days was investigated for the prepared beverage at a regular interval of ten days. A slight increase in acidity and TSS and decrease in pH and ascorbic acid in samples stored at room temperature was observed.

Jalgaonkar *et. al*. (2018) conducted a study on the response surface optimization for development of Dragon fruit based ready to serve drink. Dragon fruit based RTS was formulated using dragon fruit (60-80% v/v), grapefruit juice (0-10% v/v) and sugar syrup (2-6% v/v). Results showed that there was significant (P,0.01) effect of incorporating grape juice and sugar syrup which further improved the organoleptic properties of the blended RTS. Optimum juice percentages obtained for the best blend formulation were: Dragon fruit (70%), grapefruit juice (5%) and sugar syrup (3%) respectively.

Priatni and Pradita (2015) conducted a study to evaluate the stability of betacyanin extract from red dragon fruit peels. In this study, the betacyanin extract from the peels of red dragon fruit was extracted by methanol and water. The stability of this pigment was evaluated by monitored the effects of storage time and pH by spectrophotometer at wavelength 538 nm. Results analysis of red dragon fruit peels extract shown that for five hours in room temperature, betacyanin content in methanol extract was decreased about 10.44%, meanwhile betacyanin content in water extract was decreased about 22.58%. Betacyanin content was obtained from peels which extracted by methanol pH 5 (515.20 μg/100 g) higher than betacyanin content in water pH 5 (491.16 μg/100 g). Arrhenius data showed that betacyanin extract in water follow the first-order kinetic model with its half life time (t ½) at 25°C was 23 hours and 90%-shelf life was 76 hours.

Jayasinghe *et. al*. (2015) conducted a study to investigate the possibility of developing a novel fruit- yoghurt incorporated with white dragon fruit and evaluated its eating quality parameters. An initial survey was conducted to find out consumer preference for value added dragon fruit products in Sri Lanka. Pasteurized dragon fruit enriched yoghurt (5%, 7.5%, 10% and 12.5% w/w) were prepared with the suitable concentrations of sugar and gelatin and sensory properties, pH, titratable acidity, total solid, fat, solid-non-fat (SNF) and microbiological properties of the product were examined.

Wong and Siow (2015) studied to determine the effects of heat pasteurization, pH adjustment, ascorbic acid addition as well as storage under agitation and light or dark condition on betacyanin content in red-fleshed dragon fruit (*Hylocereus polyrhizus*) juice and concentrate. The concentrate was produced by concentrating clarified red-fleshed dragon fruit juice in a rotary evaporator at 40 °C. UV-Visible spectrophotometer was used for analysing betacyanin content. Addition of 0.25 % ascorbic acid, pH 4.0, and pasteurization at 65 °C for 30 min were selected as the best processing conditions to retain betacyanin content in red-fleshed dragon fruit juice. Light degraded betacyanin in both juice and concentrate models.

Thirugnanasambandham and Sivakumar (2015) conducted a study to optimize the operating parameters in Microwave assisted extraction process (MIE) such as temperature, mass of the sample, extraction time on betalain content from dragon fruit peel using three factors three levels Box- Behnkem response surface design (BBD). Temperature 35ºC, mass of sample of 20g and treatment time of 8 mins was found to be the optimum conditions with 9mg/L of Betalain content obtained.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation entitled “**Effect of different harvesting stages and wrapping materials on post-harvest quality, shelf life and value addition of dragon fruit (*Hylocereus polyrhizus*)**” was conducted for two consecutive years during 2020-2022 in a private dragon fruit farm located at Seithekema-C village, Chümoukedima district, Nagaland, India and post-harvest quality analysis were done at the Department of Horticulture, School of Agricultural Sciences, Nagaland University. The details of the methodology used during the experimental trials for recording various observations and analysis are presented as follows:

3.1 Experimental site:

The present experiment was carried out on a dragon fruit farm located at Chümoukedima, Dimapur, Nagaland situated at 25.78º N latitude and 93.79º E longitudes at an elevation of 171 m above mean sea level, having a sub-tropical climate.

3.2 Climatic conditions

The area of the farm experiences humid subtropical conditions with predominantly high humidity of 70-90%. The mean temperature ranges between 21ºC to 33ºC during the summer and 10ºC to 15ºC during the winter. The average rainfall varies between 2000 to 2500 mm starting from April until September’s end; however, from November to March, it remains more or less dry. The meteorological data during the period of study (Table 3.1) were obtained from the ICAR Regional Centre, Jharnapani, Nagaland.

3.3 Cultural practices

The surrounding circumference of each pillar of plants were kept weed free through regular manual weeding and areas between the row of pillars were maintained through trimming of weeds with the help of brush cutter. Regular irrigation was provided during the dry period, while it was avoided during the rainy season due to availability of adequate moisture in soil and to avoid rotting of stems and roots. Pruning was done by

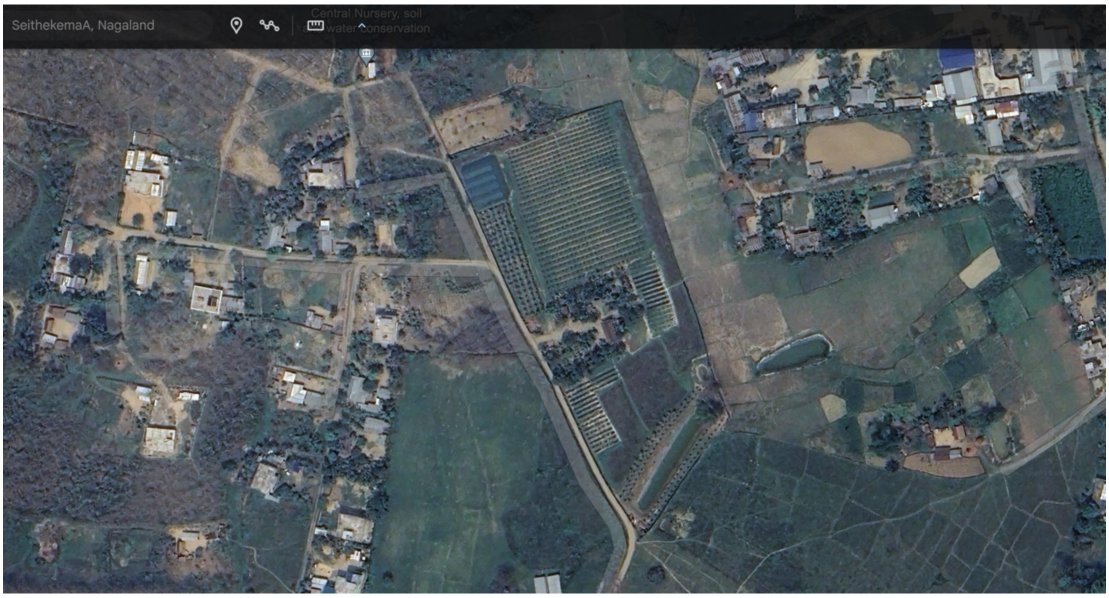


Plate 1: Aerial view of the farm located at Seithekema- C village

Plate 2: Overview of the research farm

Table 3.1: Meteorological data recorded during the period of crop investigation (July 2021 to December 2022)

Year	Month	Average min. temp. (ºC)	Average max. temp. (ºC)	Average min. RH (%)	Average max. RH (%)	Average sunshine (hrs.)	Total rainfall (mm)
2021	May	21.90	32.80	58.00	90.00	4.70	90.80
	June	24.30	33.10	69.00	93.00	3.40	125.50
	July	24.50	32.40	74.00	94.00	2.60	199.90
	August	23.00	31.20	74.00	95.00	5.20	175.70
	September	25.00	33.70	70.00	93.00	4.40	80.30
	October	24.50	32.40	74.00	94.00	2.60	199.90
	November	10.04	23.70	62.00	97.00	6.10	0.90
	December	17.00	27.30	60.00	97.40	7.00	0.00
2022	January	10.10	22.70	56.00	96.00	6.00	34.60
	February	9.60	23.20	48.00	95.00	7.10	56.30
	March	15.50	32.20	40.00	90.00	6.20	2.30
	April	19.90	30.90	68.00	90.00	6.80	175.07
	May	21.90	30.50	71.00	92.00	4.60	224.70
	June	23.90	32.00	72.00	95.00	3.70	160.80
	July	24.31	33.61	69.00	92.00	5.00	375.82
	August	24.13	33.30	70.00	94.00	4.80	261.81
	September	23.80	33.10	68.00	94.00	4.20	116.20
	October	22.10	32.10	68.00	95.00	5.30	130.00
	November	14.80	28.50	51.00	96.00	8.00	0.00
	December	11.30	25.10	51.00	95.00	6.30	16.40

Source: ICAR, Jharnapani, Nagaland

removing unwanted shoots growing on the downside of main stem, diseased, tangled or overlapping and unproductive shoots were removed to maintain a healthy canopy. Hand pollination of flowers were performed during nighttime to ensure fruit set and good fruit size.

3.4 Experimental details

3.4.1 Experiment 1: To study the effect of different harvesting stages and wrapping materials on post- harvest quality and shelf life of dragon fruit

Layout and Experimental design:

The experiment was laid out in Factorial Randomized Block Design with different harvesting stages and wrapping materials. Dragon fruit flowers were tagged the next morning following the night of anthesis and harvested accordingly.

Name of crop	:	Dragon fruit (*Hylocereus polyrhizus*)
Experimental design	:	Factorial Randomized Block Design
Age of plants	:	4 years
Number of factors	:	2
Number of replications	:	3
Total number of treatment combinations	:	15

Factor 1: Harvesting stages (H)

H_1: 25 DAA

H_2: 30 DAA

H_3: 35 DAA

*DAA: Days after Anthesis

Factor 2: Wrapping materials (W)

W_1: Control (No wrapping)

W_2: Banana leaves wrapping (half dried)

W_3: Brown paper wrapping (80 gsm)

W_4: EPE foam net wrapping (4-8 mm thick)

W_5: Shrink wrapping (perforated LDPE film)

Treatment combinations

H_1W_1	H_2W_1	H_3W_1
H_1W_2	H_2W_2	H_3W_2
H_1W_3	H_2W_3	H_3W_3
H_1W_4	H_2W_4	H_3W_4
H_1W_5	H_2W_5	H_3W_5

Fruits were wrapped and packed in 5- ply CFB boxes and stored at ambient temperature. The following observations were recorded at 48 hours interval.

Observations recorded

3.4.1.1 Fruit morphological changes during storage

a) Textural changes of fruit skin (firmness)

Firmness of fruit was determined with the help of a penetrometer fitted with 11 mm probe.

b) Physiological loss in weight (%)

The percentage of weight loss was estimated by subtracting the weight in terms of the fruits on different dates of observation from the initial weight of the fruits and then calculated using the equation below:

$$PLW\ (\%) = \frac{Initial\ wt.of\ fruit - Wt.of\ fruit\ on\ day\ of\ observation}{Initial\ wt.of\ fruits}\ x\ 100$$

c) Shelf life (days)

Shelf life was determined by counting the number of days from the first day of harvest/ storage till the fruits becomes unmarketable (in appearance, damage, rotting etc.) at ambient temperature.

Plate 3: Intercultural operations: pollination & weeding

Plate 4: Tagged fruits

Plate 5: Harvesting of fruits

Plate 6: Different harvesting stages of dragon fruit

i.

ii.

iii.

Plate 7: Different wrapping materials used (i. Control ii. Half dried banana leaves iii. Brown paper iv. EPE foam net v. Shrink wrapping)

Plate 8: Shrink wrapping of dragon fruits

d) Post-harvest spoilage (%)

The percentage of post-harvest spoilage was estimated by subtracting the number of infected fruits on different dates of observation from the initial number of fresh fruits and use the following equation to calculate:

$$Post\ harvest\ spoilage\ (\%) = \frac{Initial\ No.of\ fresh\ fruits - No\ of\ infected\ fruits\ on\ day\ of\ observation}{Initial\ No.of\ fresh\ fruits}\ x\ 100$$

3.3.1.1 Physico chemical composition of fruits

a) Fruit weight (g)

Fruit weight was recorded using a weighing balance and mean data represented in gram.

b) Pulp weight (g)

Pulp weight was measured using a weighing balance and mean data represented in gram.

c) Peel weight (g)

Pulp weight was measured using a weighing balance and mean data was represented in gram.

d) TSS (ºB)

TSS content was determined using a hand refractometer and expressed as ºBrix (A.O.A.C. 1994).

e) Titratable acidity (%)

Titratable acidity was estimated by titrating diluted supernatant against 0.1N NaOH solution using phenolphthalein as an indicator and the results expressed in percentage (A.O.A.C. 1994).

f) **TSS: Acid ratio**

TSS: acid ratio was calculated by dividing the values of the TSS with acidity.

g) **Total sugar (%)**

Total sugar content of the fruit was estimated by titrating the fruit juice against Fehling ‘A’ and Fehling ‘B’ reagents using methylene blue as indicator, (A.O.A.C. 1994). Data thus obtained was presented in percent (%).

h) **Reducing sugar (%)**

Reducing sugar was estimated by titrating Fehling A and Fehling B reagent using methylene blue as indicator. Precipitation of deep brick red color indicate the end point and the titrate value was used for calculation of reducing sugar and expressed in percentage.

i) **Non- reducing sugar (%)**

Non- reducing sugar was calculated by using the following formula: (A.O.A.C. 1994)

Non- reducing sugar (%) = (Total sugar – Reducing sugar) x 0.95

j) **Ascorbic acid (mg/100g pulp)**

Ascorbic acid was estimated using 2, 6- dichlorophenol indophenol dye by titrating as given by A.O.A.C (1994). The following formula was used for determining the ascorbic acid content in mg/100g pulp:

$$Vitamin\ C = \frac{Titrate\ value\ x\ dye\ factor\ x\ vol.made\ up\ (25\ ml)}{Aliquot\ of\ sample\ taken\ for\ determination\ (5\ ml) x\ Vol.of\ sample\ taken\ for\ estimation (2.5\ ml)}\ x\ 100$$

k) **Total phenolic content (mg GAE/g fresh wt.)**

Folin-Ciocalteau’s reagent was used for total phenolic content determination (Singleton *et. al.,* 1999). Homogenize 5g of sample with

20 ml of methanol (80%) in a pestle and mortar. Pool the extracts and make up the volume to 50 ml. Take 0.5 ml of the extract in test tubes, add 0.2 ml of Folin-Ciocalteau's Phenol Reagent followed by 3.3 ml of distilled water and mix well. After 2 minutes, add 1 ml of sodium carbonate solution and mix. Allow to stand at room temperature for 30 minutes and read the blue color in a spectrophotometer at 700nm. The samples were prepared in triplicate for each analysis, and the average value of absorbance was used to plot the calibration curve to determine the level of phenolics in the extracts. Total phenolic content of the extracts was expressed as mg gallic acid equivalents (GAE) per gram of sample in fresh weight (mg/g). Standard curve was prepared using Gallic acid as standard. The total phenolic contents in all the samples were calculated by the using the formula:

$$C = c\,x\,\frac{V}{m}$$

Where,

C= Total phenolic content in mg GAE/g fresh weight
c= Concentration of gallic acid obtained from calibration curve in mg/ml
V= Volume of extract in ml
m= Mass of extract in gram

l) Betacyanin pigment in peel (mg/100 g of fresh weight)

The betacyanin content in both peel and pulp were estimated by measuring the absorbance of the aqueous extract by following the method laid out by Abdul Razak *et. al.* (2017). Five grams of sample were mixed with methanol to make up volume to 50 ml by using mortar and pestle. The treated samples were subjected to centrifuge at 3000 rpm for 10 minutes. Supernatant was collected and filtrated using filter no. 41. Absorbance was measured at 538 nm using a spectrophotometer UV-Vis against methanol as blank. The readings obtained was used to calculate the total betacyanin concentration (mg/100 g of fresh weight) using the equation:

$$\frac{A\ (MW)\ x\ V\ x\ (DF)\ x\ 1000}{ELW}\ 100$$

Where, A= absorbance at 538 nm (λ max), L (path length) = 1.0 cm, DF= dilution factor, V= volume extract (mL), W= fresh weight of extracting material (g). For betanin, E (mean molar absorptivity) = 6.5 x 10^4 L/mol cm and MW (molecular weight) = 550 g/mol.

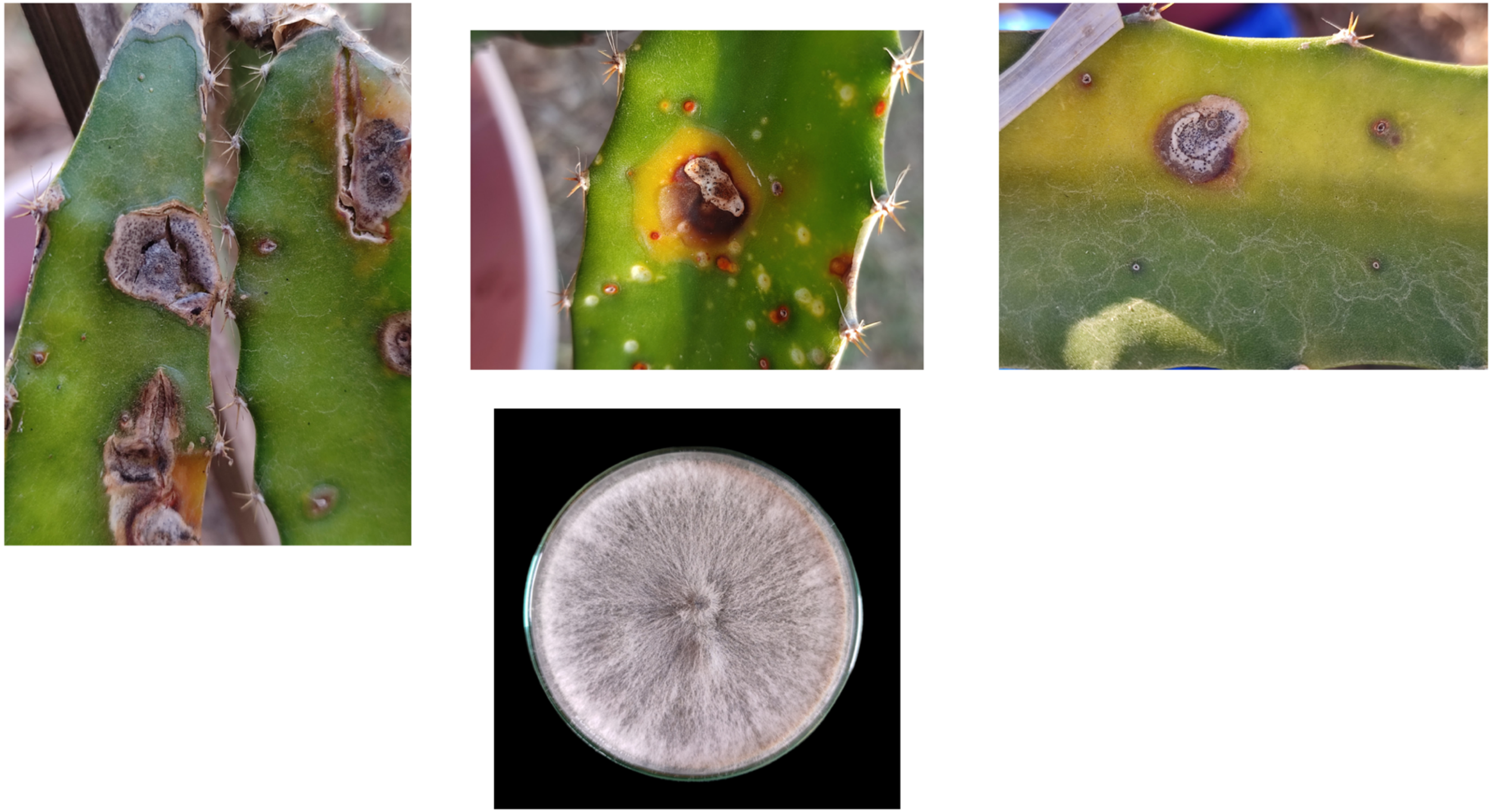
m) Pectin content (%)

Pectin content in peel was determined as calcium pectate using the gravimetric method described by Rangana (1986). Taking 25g of the sample in one litre beaker. Add 400 ml water. Boil for one hour. Replace the evaporated water by addition of distilled water. Cool it. Transfer to 500 ml volumetric flask. Filter through Whatman No.4 filter. Take 100 ml of the filtrate in two beakers. Add 300 ml distilled water to each. Then, add 10 ml IN NaOH solution and keep overnight. Add 50 ml IN acetic acid. Wait for 5 minutes. Now add $CaCl_2$ solution and keep it for one hour. Boil it for one minute. Then, take two Whatman No.4 filters. Wash with distilled water, dry in an oven at 100 °C for two hours and then weigh. Filter the solution through Whatman No. 4 filters. Wash with distilled water to make free from chloride ions. Add a few drops of silver nitrate solution. Put the white precipitates (on filter paper in a petri dish) in an oven, dry and weigh again. The pectin content was calculated and expressed as per cent using the equation below:

$$\text{Pectin (\%)}= \frac{\text{Wt. of calcium pectate x 500 x 100}}{\text{Wt. of sample x ml of aliquot taken for estimation}}$$

3.4.1.2 Sensory evaluation

The fruits were evaluated for sensory attributes viz., flavour, colour, taste and overall acceptability by 5 trained panels using nine- point hedonic scale as described by Rangana (2003), where 1 represents extremely disliked and 9 represent extremely liked.



Disease identified in farm- Stem canker: caused by ***Neoscytalidium dimidiatum.***

Plate 9: Isolation and identification of disease found in dragon fruit plant

3.4.2 Experiment 2: To study the best harvest stage of Dragon fruit to prepare Ready-to-Serve (RTS) beverage.

Name of crop : Dragon fruit (*Hylocereus polyrhizus*) Red fleshed

Experimental design : Completely Randomized Design

Number of treatments : 4

Number of replications : 5

Treatments:

T_1: 25 days after anthesis

T_2: 30 days after anthesis

T_3: 35 days after anthesis

T_4: 40 days after anthesis

Flow chart for preparation of Ready to Serve (RTS) beverage (Srivastava and Kumar, 2017)

After trial and error, RTS for all treatments were prepared maintaining composition of 12% juice, 10% sugar, 0.2% citric acid and 0.02% preservative (potassium sorbate) and remaining water made up volume of 100mL.

Selection of dragon fruit

↓

Sorting, washing, peeling and cutting

↓

Extraction of juice

↓

Mixing with strained sugar solution

↓

Addition of citric acid

↓

Addition of potassium sorbate

↓

Addition of remaining water

↓

Homogenization

↓

Removal of scum

↓

Filling hot into sterilized bottles

↓

Pasteurization (80°C for 10 mins)

↓

Cooling and storage

The product was stored at ambient temperature and the following observations was recorded at 30 days interval for a period of three months.

Observations recorded

1. **TSS (°B)**

   The TSS of RTS beverage was determined using EMRA hand refractometer (0-32 °B) calibrated at 20^{0}C (A. O. A. C. 1994), and the result was expressed in Brix (^{0}B).

2. **pH**

   The pH of RTS was determined using a digital pH. During testing, probe of calibrated pH meter was inserted into the sample and stable values were noted.

3. **Titratable acidity (%)**

   Titratable acidity was estimated by titrating the RTS beverage against 0.1N NaOH solution using phenolphthalein as an indicator and expressed in term of percentage (Ranganna, 2003).

4. **Ascorbic acid (%)**

   Ascorbic acid content was estimated by visual titration method of 2, 6 Dichlorophenol Indophenols dye as suggested by (A. O. A. C.,1994). The result obtained was expressed in mg/100 g of RTS beverage.

5. **Total sugar (%)**

   Total sugar content of the RTS beverage was estimated by titrating the fruit juice against Fehling 'A' and Fehling 'B' reagents using methylene blue as indicator, (A.O.A.C. 1994). Data thus obtained was presented in percent (%).

6. **Reducing sugar (%)**

   Reducing sugar of the RTS beverage was estimated by titrating Fehling A and Fehling B reagents using methylene blue as an indicator. Precipitation of deep brick red colour of the solution indicated the end point and the titratable value was used for calculation of reducing sugar content and expressed in percentage (%) (A.O.A.C. 1994).

7. **Non- reducing sugar (%)**

Non reducing sugar was calculated by subtracting Reducing sugar from Total sugar and expressed in percentage (%).

Non reducing sugar = (Total sugar –Reducing sugar) x 0.95

8. **Organoleptic test (Hedonic scale rating)**

i) Appearance
ii) Taste
iii) Odour
iv) Overall acceptability

9. **Microbial count (x10^3 cfu/ml)**

Microbial analysis was done to determine total plate count of the samples using potato dextrose agar media for yeast and mould by the method recommended by Harrigan and McCance (1966). Potato dextrose agar media was prepared and the samples were serially diluted up to 10^{-5} dilution factor. 0.25 ml of the samples, suspended in saline solution, was transferred to the respective petri dishes of potato dextrose agar media. Three replicates were taken for each dilution. The inoculated petri dishes were incubated in an incubator for 48 hours at 37+1°C for counting of yeast and mould.

Statistical analysis

The data of the experiment recorded was statistical evaluated by the analysis of variance method (Gomez and Gomez, 2010). The mean values of different treatments were analysed with the statistical software along with corresponding standard error of mean (S.E.m.±). The critical difference at 5 per cent level of significance was computed.

Step 1: Sterilization of bottles

Step 2: Washing, peeling and cutting of dragon fruit

Step 3: Extraction of juice

Step 4: Mixing with strained sugar solution

Step 5: Addition of citric acid and potassium sorbate

Step 6: Homogenization

Step 7: Removal of scum

Step 8: Filling hot into sterilized bottles and corking

Step 9: Pasteurization (80ºc for 10 mins)

Step 10: Cooling, labelling and storage

Plate 10: Steps on preparation of dragon fruit RTS beverage

Plate 11: RTS beverage prepared during the two trials

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The present study entitled "**Effect of different harvesting stages and wrapping materials on post-harvest quality, shelf life and value addition of Dragon fruit (*Hylocereus polyrhizus*)**" was conducted for two consecutive years during 2020-2022 in a private farm located at Seithekema-A village, Chümoukedima district, Nagaland and post-harvest quality and laboratory analysis were conducted at the Department of Horticulture, School of Agricultural Sciences, Nagaland University. the detailed data collected during the period of study and the results have been presented in this chapter, supported by respective tables and figures.

4.1 To study the effect of different harvesting stages and wrapping materials on post-harvest quality and shelf life of Dragon fruit.

Data obtained during the 2020-21 and 2021-22 experimental seasons are presented and the pooled data are discussed below under the following subheadings:

4.1.1 Textural changes of fruit skin/ firmness (kg/cm^2)

The data presented in Table 4.1 and Figure 4.1 showed significant differences among the treatments due to the effect of harvesting stages and wrapping materials. It was observed that fruit firmness significantly reduced as fruits were kept for prolonged storage. Among the harvesting stages, highest values on firmness was recorded in H_1 (25 DAA) on all the days of analysis, while a maximum of mean 11.07 kg/cm^2 was recorded on 0 DAH which reduced to a minimum of 7.10 on 8 DAH. The lowest value of 3.63 kg/cm^2 was recorded in H_3 (35 DAA) on 8 DAH. Similar trend has been reported by Singh *et. al.* (2022) where firmness was maximum at harvest stage of 25 DAA and firmness reduced as the maturity stage increased. Data pertaining to wrapping materials on firmness showed a decreasing trend where, maximum retention of firmness was observed in W_5 (shrink wrapping). Highest value (6.37 kg/cm^2) was observed in W_5 (shrink wrapping) while minimum value (4.42 kg/cm^2) was observed in W_1 (Control).

In case of interaction effect, the data presented in Table 4.2 and Figure 4.1 signified significant variation among the treatments. With the progression in storage period, a decreasing trend was observed and on the last day of observation, maximum firmness was recorded in H_1W_5 (25 DAA, shrink wrapping) with pooled value of 8.23 kg/cm^2 followed by H_1W_2 (25 DAA, brown paper) and minimum firmness (2.62 kg/cm^2) was recorded in H_3W_1 (35 DAA, no wrapping).

In dragon fruit, as maturation progresses, peel thickness decreases along with reduction in fruit firmness. Change in cell wall texture is an important criterion of fruit ripening which leads to reduction in firmness. This reduction may be due to degradation of cell wall components (pectin, cellulose, hemicellulose) and metabolism of cell contents (Wang *et. al*., 2024) caused by the action of hydrolytic enzymes (Singh *et. al.,* 2022) as a part of fruit maturation and ripening. During post-harvest storage, there is increased respiration, evaporation and transpiration which causes loss of moisture and reduction in firmness. Individual wrapping of fruits enhance post-harvest life and retain firmness for a longer period compared to devoid of wrapping. Shrink wrapping reduces loss of moisture by minimizing the rate of transpiration, forming a barrier that increases resistance to water vapor thus, maintaining firmness of fruit.

4.1.2 Physiological loss in weight (%)

Analytical data on the Physiological loss in weight (PLW) is presented in Table 4.3 and Figure 4.2. Data on the harvesting stages of dragon fruit shows that during the period of storage, highest weight loss was recorded in H_3 (35 DAA) with values ranging from 1.65 to 8.05%, while minimum weight loss was observed in H_2 (25 DAA) ranging from 0.86 to 4.02%. Loss in moisture content and dry matter content results in weight loss whereby, during the initial stage of maturity, fruits are more firm, higher peel thickness and lower metabolic activity, thus, weight loss is lesser and slower. Peel thickness plays an important role in post-harvest quality and shelf life as they protect against water loss and biological damages (Singh *et. al.,* 2022). Among the wrapping materials, the minimum PLW was observed in W_5 (Shrink wrapping) with values ranging from 0.45 to 2.31% while maximum was recorded in control (W_1).

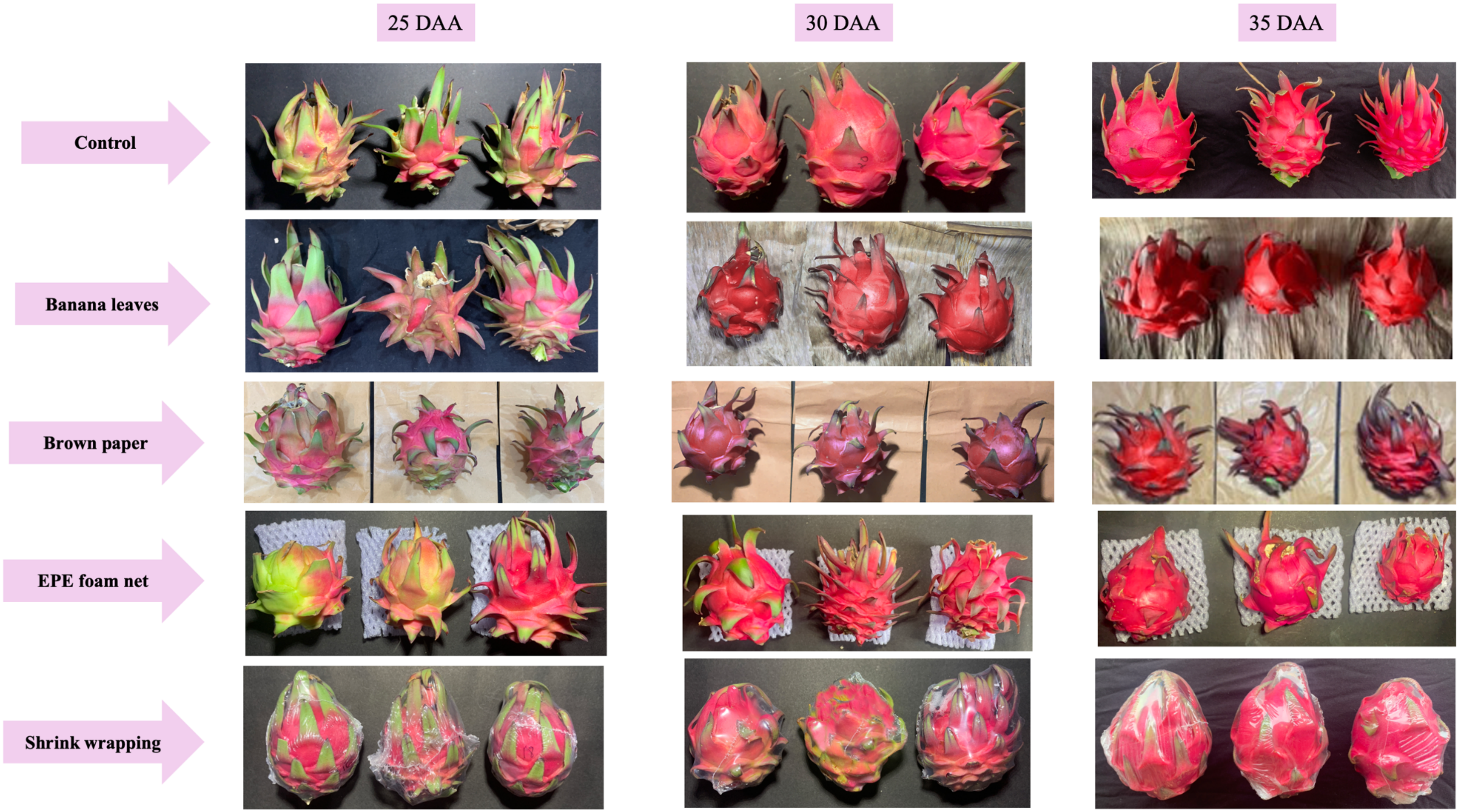


Plate 12: Effect of different harvesting stages and wrapping materials on dragon fruit at Day 0

Plate 13: Effect of different harvesting stages and wrapping materials on dragon fruit at Day 2

Plate 14: Effect of different harvesting stages and wrapping materials on dragon fruit at Day 4

Plate 15: Effect of different harvesting stages and wrapping materials on dragon fruit at Day 6

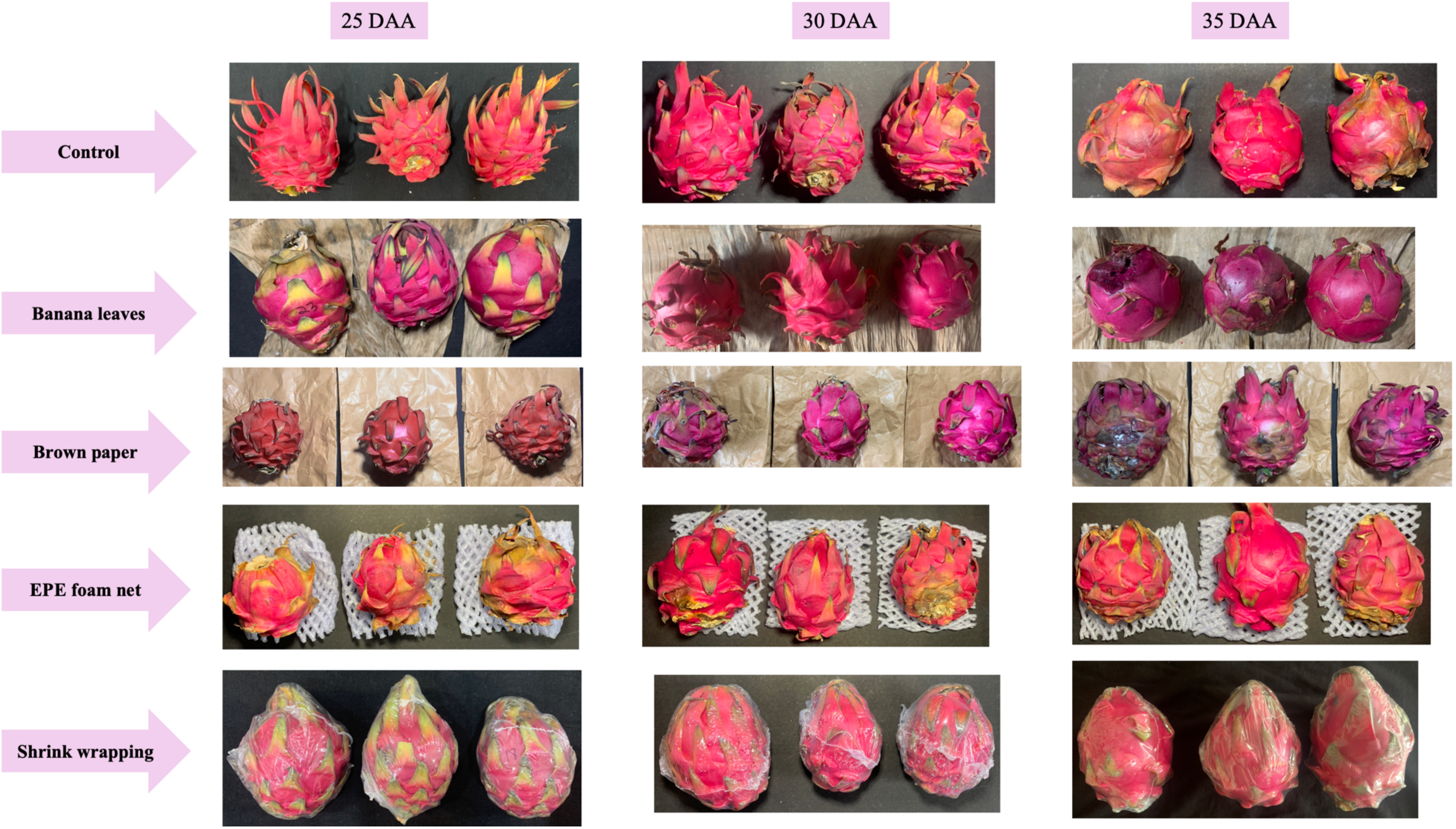


Plate 16: Effect of different harvesting stages and wrapping materials on dragon fruit at Day 8

Shrink wrapping inevitably performed better as it retained the firmness of the fruit by reducing rate of respiration and transpiration, thus retarding physiological changes and consequently decrease the rate of PLW during storage.

Interaction effect of harvesting stages and wrapping materials on dragon fruit is presented in Table 4.4 and Figure 4.2 which indicated high significant variation among the treatments. Maximum weight loss was observed in the control treatment of later stage of harvest (H_3W_0) and the least loss in weight was recorded in H_1W_4 (25 DAA, shrink wrapping).

4.1.3 Shelf life (days)

The data on shelf life of dragon fruit as influenced by harvesting time and wrapping materials is presented in Table 4.5 which depicts a significant variation among the treatments. Pooled data indicates highest shelf life in H_1 (25 DAA) with 10.04 days in ambient temperature followed by 8.13 days in H_2 (30 DAA) and lowest in H_3 (35 DAA) with 5.83 days. In regard to wrapping materials, the highest shelf life was observed in W_5 (Shrink wrapping) with 9.34 days followed by W_3 (Brown paper) with retention of fruits up to 8.33 days in storage. The data on interaction effect of harvesting stages and wrapping materials is laid out in table 4.6 which depicts to have significant variation among the treatments. The maximum shelf life is observed in H_1W_5 (25 DAA, shrink wrapping) with 11.27 days of storage while the minimum storage life is seen in H_3W_0 (35 DAA, no wrapping) with 4.30 days.

Packaging extend shelf life by slowing down respiration rate and transpiration that reduces weight loss and desiccation. According to Choudhury *et. al*. (2018), dragon fruit peels consist of active stomata which are majorly concentrated in the scales compared to other parts of the peel. Wrapping of fruits acts as physical barrier to moisture loss and affect the atmospheric conditions within the fruit to a certain extent and thus extends the shelf life and reduce rapid shriveling in comparison to control fruits. Partly similar finding has been reported by Lata *et. al*. (2023) where *H. polyrhizus* had a 5- day shelf life when harvested at 31-33 days after fruit set. Also, To *et. al.* (2000), reported dragon fruit harvested after 28-30 DAA when kept under modified atmosphere (MA) in PE bag at 10ºC could be stored for 35 days, while control

Table 4.1: Effect of different harvesting stages and wrapping materials on firmness of dragon fruit

Treatments	*Firmness*														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
Harvesting stages (H)															
H_1	10.91^{a}	11.23^{a}	11.07^{a}	10.38^{a}	10.85^{a}	10.62^{a}	9.75^{a}	10.06^{a}	9.91^{a}	8.34^{a}	8.68^{a}	8.51^{a}	7.25^{a}	6.95^{a}	7.10^{a}
H_2	8.98^{b}	9.27^{b}	9.12^{b}	8.50^{b}	8.87^{b}	8.68^{b}	7.61^{b}	8.28^{b}	7.95^{b}	5.99^{b}	6.84^{b}	6.42^{b}	5.00^{b}	5.28^{b}	5.14^{b}
H_3	7.87^{c}	7.36^{c}	7.62^{c}	7.05^{c}	6.99^{c}	7.02^{c}	6.41^{c}	6.43^{c}	6.42^{c}	4.78^{c}	5.17^{c}	4.97^{c}	3.84^{c}	3.43^{c}	3.63^{c}
SEm±	*0.14*	*0.13*	*0.10*	*0.07*	*0.07*	*0.05*	*0.09*	*0.06*	*0.05*	*0.10*	*0.08*	*0.06*	*0.06*	*0.07*	*0.05*
CD (P=0.05)	*0.40*	*0.38*	*0.27*	*0.20*	*0.19*	*0.14*	*0.25*	*0.18*	*0.15*	*0.28*	*0.22*	*0.17*	*0.19*	*0.19*	*0.13*
Wrapping materials (W)															
W_1	9.33^{a}	9.44^{a}	9.38^{a}	8.40^{c}	8.90^{bc}	8.65^{b}	7.25^{c}	8.19^{bc}	7.72^{c}	5.53^{d}	6.10^{e}	5.81^{d}	4.42^{e}	4.42^{d}	4.42^{e}
W_2	9.27^{a}	8.97^{a}	9.12^{a}	8.37^{c}	8.51^{d}	8.44^{c}	7.78^{d}	8.08^{c}	7.93^{b}	6.11^{c}	6.48^{d}	6.29^{c}	4.91^{d}	4.67^{d}	4.79^{d}
W_3	9.45^{a}	9.27^{a}	9.36^{a}	9.09^{a}	9.00^{b}	9.04^{a}	8.29^{a}	8.41^{ab}	8.35^{a}	6.73^{d}	7.31^{b}	7.02^{b}	5.79^{b}	5.63^{b}	5.71^{b}
W_4	9.17^{a}	9.36^{a}	9.26^{a}	8.46^{c}	8.85^{c}	8.65^{b}	7.90^{b}	8.13^{c}	8.01^{b}	6.14^{c}	6.88^{c}	6.51^{c}	5.32^{c}	5.00^{c}	5.16^{c}
W_5	9.03^{a}	9.41^{a}	9.22^{a}	8.90^{b}	9.25^{a}	9.08^{a}	8.40^{a}	8.48^{a}	8.44^{a}	7.33^{a}	7.73^{a}	7.53^{a}	6.36^{a}	6.38^{a}	6.37^{a}
SEm±	*0.18*	*0.17*	*0.12*	*0.09*	*0.08*	*0.06*	*0.11*	*0.08*	*0.07*	*0.12*	*0.10*	*0.08*	*0.08*	*0.08*	*0.06*
CD (P=0.05)	*NS*	*NS*	*NS*	*0.26*	*0.24*	*0.17*	*0.32*	*0.24*	*0.20*	*0.36*	*0.28*	*0.22*	*0.24*	*0.25*	*0.17*

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA

W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.2: Interaction effect of different harvesting stages and wrapping materials on firmness of dragon fruit

Treatments (H x W interaction)	***Firmness***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	10.70^{a}	11.31^{a}	11.01^{a}	9.89^{b}	10.64^{b}	10.27^{c}	8.40^{c}	9.87^{b}	9.14^{c}	7.10^{c}	7.68^{c}	7.39^{d}	6.53^{c}	6.11^{c}	6.32^{d}
H_1W_2	11.01^{a}	10.77^{a}	10.89^{a}	10.12^{b}	10.25^{b}	10.19^{c}	9.55^{b}	10.35^{a}	9.95^{b}	7.80^{b}	8.32^{e}	8.06^{c}	6.72^{c}	6.26^{c}	6.49^{cd}
H_1W_3	11.25^{a}	11.29^{a}	11.27^{a}	11.01^{a}	11.00^{a}	11.00^{a}	10.49^{a}	10.13^{ab}	10.31^{a}	9.15^{a}	9.19^{a}	9.17^{b}	7.77^{a}	7.67^{b}	7.72^{b}
H_1W_4	10.76^{a}	11.42^{a}	11.09^{a}	10.13^{b}	11.14^{a}	10.63^{b}	9.81^{b}	9.86^{b}	9.84^{b}	8.16^{b}	8.55^{b}	8.36^{c}	7.19^{b}	6.29^{c}	6.74^{c}
H_1W_5	10.81^{a}	11.37^{a}	11.09^{a}	10.77^{a}	11.21^{a}	10.99^{a}	10.50^{a}	10.12^{ab}	10.31^{a}	9.48^{a}	9.67^{a}	9.58^{a}	8.03^{a}	8.43^{a}	8.23^{a}
H_2W_1	9.40^{b}	9.29^{b}	9.35^{bc}	8.56^{d}	8.93^{c}	8.74^{f}	7.47^{d}	8.26^{cd}	7.87^{e}	5.50^{d}	5.73^{f}	5.61^{g}	4.16^{f}	4.48^{e}	4.32^{gh}
H_2W_2	8.73^{bc}	8.94^{b}	8.84^{c}	8.10^{d}	8.37^{d}	8.24^{g}	7.44^{d}	8.03^{d}	7.74^{e}	5.86^{d}	6.34^{e}	6.10^{f}	4.53^{ef}	4.77^{e}	4.65^{f}
H_2W_3	9.20^{b}	9.63^{b}	9.42^{b}	9.04^{c}	9.28^{c}	9.16^{e}	7.69^{d}	8.43^{cd}	8.06^{d}	6.03^{d}	7.41^{cd}	6.72^{e}	5.12^{d}	5.54^{d}	5.33^{e}
H_2W_4	8.90^{bc}	8.93^{b}	8.91^{b}	8.23^{d}	8.41^{d}	8.32^{g}	7.46^{d}	8.11^{d}	7.78^{e}	5.49^{de}	6.98^{d}	6.24^{ef}	4.85^{de}	5.26^{d}	5.06^{e}
H_2W_5	8.67^{bc}	9.56^{b}	9.11^{b}	8.56^{d}	9.34^{c}	8.95^{ef}	8.00^{c}	8.57^{c}	8.28^{d}	7.08^{c}	7.76^{c}	7.42^{d}	6.33^{c}	6.34^{c}	6.34^{d}
H_3W_1	7.89^{bc}	7.70^{c}	7.80^{d}	6.74^{g}	7.13^{e}	6.94^{d}	5.89^{f}	6.44^{e}	6.16^{g}	3.98^{g}	4.88^{gh}	4.43^{i}	2.57^{h}	2.67^{g}	2.62^{j}
H_3W_2	8.07^{cd}	7.21^{cd}	7.64^{d}	6.90^{ef}	6.92^{ef}	6.91^{i}	6.36^{ef}	5.86^{f}	6.11^{g}	4.66^{f}	4.78^{h}	4.72^{i}	3.49^{g}	2.98^{g}	3.24^{i}
H_3W_3	7.90^{d}	6.88^{d}	7.39^{d}	7.21^{ef}	6.70^{f}	6.96^{i}	6.70^{e}	6.67^{e}	6.68^{f}	5.00^{ef}	5.33^{fg}	5.17^{h}	4.47^{ef}	3.67^{f}	4.07^{h}
H_3W_4	7.85^{bc}	7.72^{c}	7.78^{d}	7.03^{ef}	6.99^{ef}	7.01^{hi}	6.42^{ef}	6.42^{e}	6.42^{fg}	4.79^{f}	5.12^{gh}	4.95^{h}	3.92	3.45^{f}	3.68^{g}
H_3W_5	7.62^{bc}	7.31^{cd}	7.46^{d}	7.38^{e}	7.20^{g}	7.29^{h}	6.70^{e}	6.75^{e}	6.73^{f}	5.44^{de}	5.76^{f}	5.60^{g}	4.74^{de}	4.38^{e}	4.56^{fg}
SEm±	**0.31**	**0.30**	**0.21**	**0.16**	**0.15**	**0.11**	**0.19**	**0.14**	**0.12**	**0.21**	**0.17**	**0.14**	**0.14**	**0.15**	**0.10**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**0.42**	**0.30**	**0.56**	**0.41**	**0.34**	**0.62**	**0.49**	**0.39**	**0.42**	**0.42**	**0.29**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA

W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.3: Effect of different harvesting stages and wrapping materials on Physiological Loss in Weight of dragon fruit

Treatments	***Physiological Loss in Weight (PLW)***											
	Day 2			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
Harvesting stages (H)												
H_1 (25 DAA)	0.86^{c}	0.86^{c}	0.86^{c}	1.06^{c}	1.22^{c}	1.14^{c}	2.37^{c}	2.55^{c}	2.46^{c}	4.01^{c}	4.03^{c}	4.02^{c}
H_2 (30 DAA)	1.08^{b}	1.20^{b}	1.14^{b}	1.67^{b}	1.78^{b}	1.72^{b}	3.53^{b}	3.75^{b}	3.64^{b}	5.23^{b}	5.10^{b}	5.17^{b}
H_3 (35 DAA)	1.51^{a}	1.78^{a}	1.65^{a}	3.11^{a}	2.90^{a}	3.01^{a}	5.26^{a}	4.99^{a}	5.12^{a}	8.16^{a}	7.93^{a}	8.05^{a}
SEm±	**0.07**	**0.07**	**0.05**	**0.05**	**0.04**	**0.03**	**0.07**	**0.06**	**0.04**	**0.09**	**0.07**	**0.06**
CD (P=0.05)	**0.21**	**0.21**	**0.14**	**0.15**	**0.13**	**0.10**	**0.19**	**0.16**	**0.12**	**0.27**	**0.21**	**0.17**
Wrapping materials (W)												
W_1 (No wrapping)	1.93^{a}	1.87^{a}	1.90^{a}	2.95^{a}	2.82^{a}	2.89^{a}	5.37^{a}	5.54^{a}	5.46^{a}	8.41^{a}	8.42^{a}	8.42^{a}
W_2 (Banana leaves)	1.29^{b}	1.45^{b}	1.37^{b}	2.23^{b}	2.21^{b}	2.22^{b}	4.31^{b}	4.40^{b}	4.36^{b}	6.71^{b}	6.79^{b}	6.75^{b}
W_3 (Brown paper)	1.14^{b}	1.19^{b}	1.16^{c}	1.73^{d}	1.89^{c}	1.81^{c}	3.41^{d}	3.37^{d}	3.39^{d}	5.49^{c}	5.34^{c}	5.41^{d}
W_4 (EPE foam net)	1.19^{b}	1.22^{b}	1.20^{bc}	1.96^{c}	1.80^{c}	1.88^{c}	4.02^{c}	3.97^{c}	4.00^{c}	5.81^{c}	5.51^{c}	5.66^{c}
W_5 (Shrink wrap)	0.21^{c}	0.68^{c}	0.45^{d}	0.85^{e}	1.12^{d}	0.99^{d}	1.48^{e}	1.55^{e}	1.51^{e}	2.59^{d}	2.38^{d}	2.48^{e}
SEm±	**0.09**	**0.09**	**0.06**	**0.07**	**0.06**	**0.04**	**0.09**	**0.07**	**0.06**	**0.13**	**0.09**	**0.08**
CD (P=0.05)	**0.27**	**0.27**	**0.18**	**0.19**	**0.17**	**0.12**	**0.25**	**0.21**	**0.16**	**0.37**	**0.27**	**0.22**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA

W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.4: Interaction effect of different harvesting stages and wrapping materials on Physiological Loss in Weight of dragon fruit

Treatments (H x W interaction)	*Physiological Loss in Weight (PLW)*											
	Day 2			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
H_1W_1	1.67^{bc}	1.35^{cd}	1.51^{bc}	1.86^{d}	1.82^{ef}	1.84^{e}	3.20^{f}	3.53^{e}	3.37^{g}	5.94^{e}	5.79^{d}	5.86^{d}
H_1W_2	1.15^{d}	1.09^{de}	1.12^{de}	1.29^{ef}	1.46^{h}	1.37^{g}	2.81^{g}	3.03^{f}	2.92^{h}	4.80^{g}	5.03^{e}	4.92^{e}
H_1W_3	0.56^{e}	0.70^{ef}	0.63^{f}	0.72^{g}	0.97^{ij}	0.84^{h}	2.12^{h}	2.38^{g}	2.25^{j}	3.78^{h}	3.45^{g}	3.61^{f}
H_1W_4	0.88^{de}	0.83^{ef}	0.86^{e}	1.10^{f}	1.14^{i}	1.12^{h}	2.67^{g}	2.59^{g}	2.63^{i}	3.83^{h}	4.04^{f}	3.94^{f}
H_1W_5	0.04^{f}	0.33^{g}	0.19^{g}	0.35^{h}	0.72^{j}	0.53^{i}	1.04	1.23^{i}	1.13^{k}	1.70^{j}	1.84^{j}	1.77^{i}
H_2W_1	1.83^{b}	1.78^{b}	1.80^{b}	2.77^{c}	2.56^{d}	2.67^{d}	4.83^{c}	5.38^{b}	5.10^{d}	7.48^{d}	7.71^{c}	7.60^{c}
H_2W_2	1.19^{d}	1.29^{cd}	1.24^{cd}	1.85^{d}	2.01^{e}	1.93^{i}	4.25^{d}	4.54^{c}	4.40^{e}	5.73^{ef}	5.94^{d}	5.83^{d}
H_2W_3	1.03^{d}	1.08^{de}	1.05^{de}	1.49^{e}	1.77^{ef}	1.63^{f}	3.43^{ef}	3.38^{f}	3.41^{g}	4.92^{g}	4.60^{e}	4.76^{e}
H_2W_4	1.25^{cd}	1.25^{cd}	1.25^{cd}	1.52^{e}	1.51^{gh}	1.52^{fg}	3.86^{e}	4.06^{d}	3.96^{f}	5.25^{fg}	4.92^{e}	5.09^{e}
H_2W_5	0.10^{f}	0.62^{fg}	0.36^{f}	0.70^{g}	1.03^{i}	0.86^{h}	1.28^{i}	1.41^{i}	1.34^{k}	2.77^{i}	2.36^{i}	2.57^{h}
H_3W_1	2.29^{a}	2.47^{a}	2.38^{a}	4.22^{a}	4.09^{a}	4.15^{a}	8.09^{a}	7.70^{a}	7.90^{a}	11.82^{a}	11.78^{a}	11.80^{a}
H_3W_2	1.54^{bc}	1.96^{b}	1.75^{b}	3.56^{b}	3.16^{b}	3.36^{b}	5.87^{b}	5.62^{b}	5.75^{b}	9.60^{b}	9.40^{b}	9.50^{b}
H_3W_3	1.82^{b}	1.79^{b}	1.80^{b}	2.98^{c}	2.92^{bc}	2.95^{c}	4.68^{c}	4.34^{c}	4.51^{e}	7.78^{d}	7.96^{c}	7.87^{c}
H_3W_4	1.43^{bc}	1.57^{bc}	1.50^{bc}	3.27^{b}	2.74^{cd}	3.00^{c}	5.53^{b}	5.28^{b}	5.40^{c}	8.33^{c}	7.56^{c}	7.95^{c}
H_3W_5	0.49^{e}	1.09^{de}	0.79^{b}	1.52^{e}	1.62^{fg}	1.57^{fg}	2.11^{h}	2.01^{h}	2.06^{j}	3.29^{h}	2.95^{h}	3.12^{g}
SEm±	**0.16**	**0.16**	**0.11**	**0.11**	**0.10**	**0.08**	**0.15**	**0.13**	**0.10**	**0.22**	**0.16**	**0.14**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.33**	**0.29**	**0.21**	**0.43**	**0.36**	**0.28**	**0.65**	**0.46**	**0.39**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

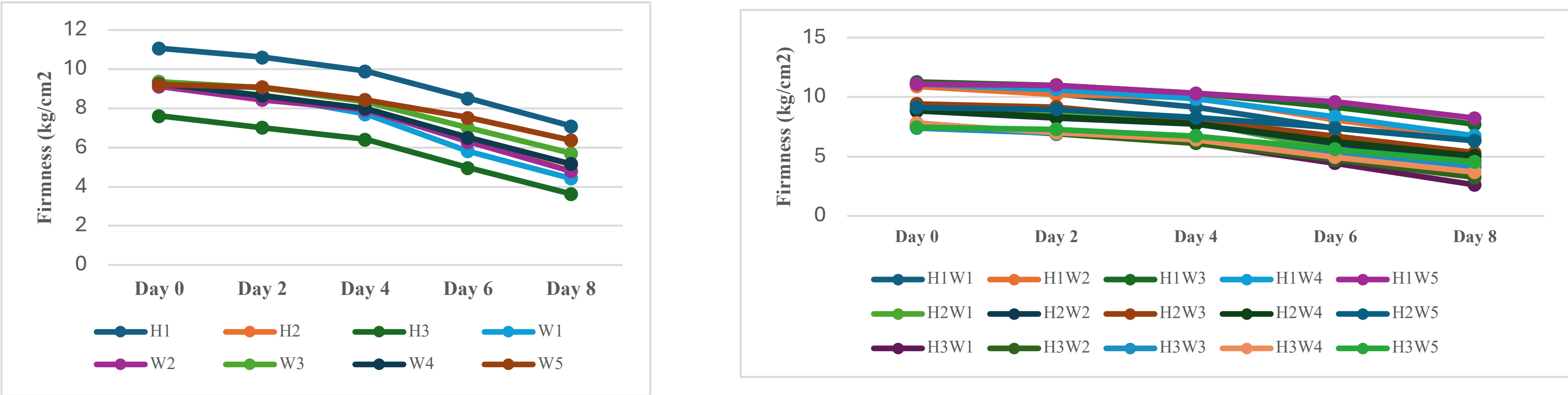


Figure 4.1: Individual and interaction effect of harvesting stages and wrapping materials on firmness

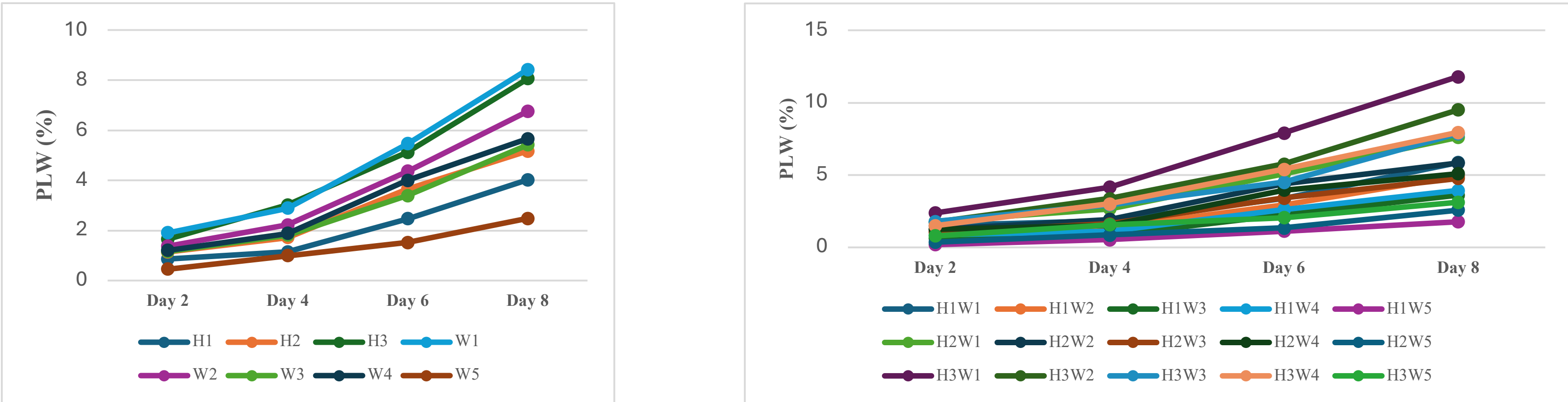


Figure 4.2: Individual and interaction effect of harvesting stages and wrapping materials on PLW

fruits retained for 14 days and more matured fruits (40 DAA) in the same MA bag showed 50% lower shelf life.

4.1.4 Post-harvest spoilage (%)

Data pertaining to effect of harvesting stages and wrapping materials on post-harvest spoilage is presented in Table 4.7 and Figure 4.3. The pooled date of two seasons depicts significant differences among the treatments. On the last day of storage, the minimum spoilage was recorded in the immature stage (25 DAA) with 16.76% and the maximum spoilage in 35 DAA (43.53%). Among the wrapping materials, minimum spoilage was observed in shrink wrapping and maximum spoilage was recorded in control fruits. Fruit quality deteriorate after harvest leading to incidence of spoilage due to microorganisms as well as rapid physiological processes like weight loss, respiration and accelerated ripening in dragon fruit (Ali *et. al.,* 2014). Dhall *et. al*. (2012) reported that lower decay incidence and better retention of green color was observed in shrink wrapped cucumber, which is concurrent to the result seen in this study.

Interaction effect of harvesting stages and wrapping materials on dragon fruit presented in Table 4.8 and Figure 4.3 highlighted maximum post-harvest spoilage in H_3W_1 (35 DAA, no wrapping) with 9.78% on the day 4 of storage which increased to 53.49% on the last day of storage. Minimum values ranging from 0% on 4^{th} day to 7.24% on the last day of storage was recorded in H_1W_5 (25 DAA, shrink wrapping).

4.1.5 Fruit weight (g)

The data on individual effects of harvesting stages and wrapping materials is presented in Table 4.9. The data depicted an increasing trend in fruit weight with the advancement in maturity stages of dragon fruit. On the day of harvest, highest fruit weight was observed in H_3 (35 DAA) with average weight of 240.42 g and the least fruit weight was recorded in H_1 (25 DAA) with an average weight of 183.49 g. Jamaludin *et. al*. (2010) and Malgalhaes *et. al.* (2019) have reported similar findings of an increasing trend in fruit size, up to 35 DAA followed by a meager decline as the fruit continue to develop, whereby Chang and Yen (1997) reported that dragon fruits harvested at 50 DAF are 50% heavier in comparison to initial stages (30 DAA). Also, Prasad *et. al.* (2000) and Babu *et. al*. (2017) have reported a linear increase in fruit weight of pomegranate from fruit set to harvest. This increase in weight is mainly due to the physiochemical changes during fruit development and maturation, where there is accumulation of water, sugars, other solutes and seed maturation (Jamaludin *et. al*., 2010; Chitarra and Chitarra, 2005).

Data pertaining to the effect of wrapping materials on fruit weight presents a significant difference, where the fruits decreased in weight in all the treatments during the storage period. However, the least decline in weight during the time of storage is recorded in shrink wrapping (W_5) followed by W_3 (brown paper) and maximum reduction is recorded in control (W_1). The analytical data on the interaction effect of harvesting stages and wrapping materials presented in Table 4.10 elucidates a significant difference where the highest weight on the last day of storage was recorded in H_2W_5 (30 DAA, shrink wrapping) with an average weight of 211.47g and the minimum weight (147.39 g) is recorded in H_1W_1 (25 DAA, no wrapping).

4.1.6 Pulp weight (g)

The data on pulp weight of dragon fruit as influenced by harvesting time and wrapping materials is presented in Table 4.11. At harvest, pooled data indicates highest pulp weight in H_3 (30 DAA) with 174.38 g followed by 158.89 g in H_2 (30 DAA) and lowest in H_1 (25 DAA) with 103 g, which indicates that pulp weight increased with advancement in maturity stages. Ortiz and Takahashi (2015) also reported that as dragon fruit matures, pulp mass increased linearly. Additionally, Singh *et. al*. (2022) corroborated with these findings that dry matter content of dragon fruit pulp increased up to 35 DAA, as a result of rapid cell differentiation, after which there was a decrease, up to 45 DAA of the evaluation. During the time of storage, a declining trend was observed in all the maturity stages. In regard to wrapping materials, significant effect was not found on pulp weight during the initial days of storage. On the last day of observation, maximum pulp weight was recorded in W_5 (shrink wrapping) with 136.97 g and the minimum value (119.58 g) was found in W_1 (control). Hailu *et. al.* (2012) reported in banana that fruit packaged in LDPE and HDPE bags exhibited slower enzymatic activity when compared to banana fruits packaged in dried

Table 4.5: Effect of different harvesting stages and wrapping materials on shelf life of dragon fruit

Treatments	*Shelf life (Days)*		
	2021	***2022***	***Pooled***
Harvesting stages (H)			
H_1 (25 DAA)	10.09^{a}	9.99^{a}	10.04^{a}
H_2 (30 DAA)	8.04^{b}	8.22^{b}	8.13^{b}
H_3 (35 DAA)	5.83^{c}	5.84^{c}	5.83^{c}
SEm±	*0.11*	*0.07*	*0.06*
CD (P=0.05)	*0.31*	*0.20*	*0.18*
Wrapping materials (W)			
W_1 (No wrapping)	]	7.03^{d}	6.93^{d}
W_2 (Banana leaves)	7.82^{c}	7.71^{c}	7.77^{c}
W_3 (Brown paper)	8.37^{b}	8.29^{b}	8.33^{b}
W_4 (EPE foam net)	7.69^{c}	7.57^{c}	7.63^{c}
W_5 (Shrink wrap)	9.20^{a}	9.49^{a}	9.34^{a}
SEm±	*0.14*	*0.09*	*0.08*
CD (P=0.05)	*0.41*	*0.26*	*0.24*

Table 4.6: Interaction effect of different harvesting stages and wrapping materials on shelf life of dragon fruit

Treatments (H x W interaction)	*Shelf life (Days)*		
	2021	***2022***	***Pooled***
H_1W_1 (25 DAA, no wrapping)	9.34^{b}	9.33^{d}	9.34^{d}
H_1W_2 (25 DAA, Banana leaves)	9.50^{b}	9.10^{d}	9.30^{d}
H_1W_3 (25 DAA, Brown paper)	10.67^{a}	10.32^{b}	10.49^{b}
H_1W_4 (25 DAA, EPE foam net)	9.83^{b}	9.79^{c}	9.81^{c}
H_1W_5 (25 DAA, Shrink wrap)	11.10^{a}	11.43^{a}	11.27^{a}
H_2W_1 (30 DAA, no wrapping)	7.18^{d}	7.15^{f}	7.16^{f}
H_2W_2 (30 DAA, Banana leaves)	8.11^{c}	8.33^{e}	8.22^{e}
H_2W_3 (30 DAA, Brown paper)	8.00^{c}	8.40^{e}	8.20^{e}
H_2W_4 (30 DAA, EPE foam net)	7.22^{d}	7.26^{e}	7.24^{f}
H_2W_5 (30 DAA, Shrink wrap)	9.67^{b}	9.96^{bc}	9.82^{c}
H_3W_1 (35 DAA, no wrapping)	4.00^{g}	4.60^{i}	4.30^{j}
H_3W_2 (35 DAA, Banana leaves)	5.87^{f}	5.70^{h}	5.78^{i}
H_3W_3 (35 DAA, Brown paper)	6.44^{ef}	6.17^{g}	6.30^{h}
H_3W_4 (35 DAA, EPE foam net)	6.00^{f}	5.67^{h}	5.83^{i}
H_3W_5 (35 DAA, Shrink wrap)	6.83^{e}	7.07^{f}	6.95^{g}
SEm±	*0.24*	*0.15*	*0.14*
CD (P=0.05)	*0.70*	*0.44*	*0.41*

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

Table 4.7: Effect of different harvesting stages and wrapping materials on Post-harvest spoilage of dragon fruit

Treatments	*Post-harvest spoilage (%)*								
	Day 4			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
Harvesting stages (H)									
H_1	0.00^{c}	0.00^{b}	0.00^{c}	4.43^{c}	4.65^{c}	4.54^{c}	17.00^{c}	16.52^{c}	16.76^{c}
H_2	4.07^{b}	5.03^{a}	4.55^{b}	11.92^{b}	12.91^{b}	12.41^{b}	33.24^{b}	26.48^{b}	29.86^{b}
H_3	7.59^{a}	5.68^{a}	6.64^{c}	21.82^{a}	24.58^{a}	23.20^{a}	41.19^{a}	45.87^{a}	43.53^{a}
SEm±	**1.18**	**0.47**	**0.64**	**0.35**	**0.04**	**0.17**	**0.10**	**0.14**	**0.09**
CD (P=0.05)	**3.41**	**1.37**	**1.80**	**1.00**	**0.11**	**0.49**	**0.30**	**0.40**	**0.25**
Wrapping materials (W)									
W_1	6.48^{a}	5.04^{a}	5.76^{a}	16.89^{a}	21.03^{a}	18.96^{a}	40.80^{a}	39.43^{a}	40.11^{a}
W_2	5.85^{a}	3.64^{b}	4.75^{ab}	15.09^{b}	16.73^{b}	15.91^{b}	34.67^{b}	32.90^{b}	33.78^{b}
W_3	2.83^{ab}	3.80^{b}	3.32^{b}	11.04^{c}	12.07^{d}	11.55^{d}	29.71^{c}	27.92^{d}	28.81^{d}
W_4	3.33^{ab}	3.67^{b}	3.50^{b}	11.93^{c}	12.92^{c}	12.43^{c}	29.94^{c}	29.09^{c}	29.52^{c}
W_5	0.93^{b}	1.70^{c}	1.31^{b}	8.66^{d}	7.48^{e}	8.07^{e}	17.26^{d}	18.77^{e}	18.02^{e}
SEm±	**1.52**	**0.61**	**0.82**	**0.45**	**0.05**	**0.22**	**0.13**	**0.18**	**0.11**
CD (P=0.05)	**NS**	**1.76**	**2.32**	**1.29**	**0.14**	**0.63**	**0.39**	**0.52**	**0.32**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

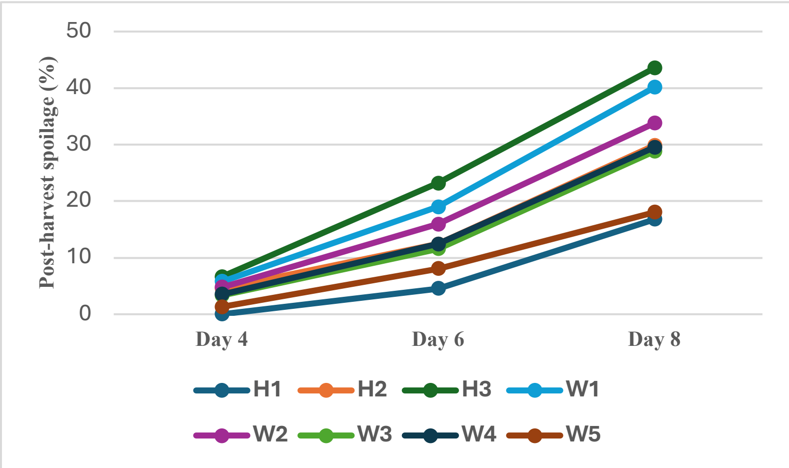
Table 4.8: Interaction effect of different harvesting stages and wrapping materials on Post-harvest spoilage of dragon fruit

Treatments (H x W interaction)	*Post-harvest spoilage (%)*								
	Day 4			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	0.00^{c}	0.00^{e}	0.00^{e}	8.33^{f}	9.63^{j}	8.98^{i}	29.17^{h}	25.33^{h}	27.25^{h}
H_1W_2	0.00^{c}	0.00^{e}	0.00^{e}	5.17^{g}	5.66^{k}	5.42^{j}	18.33^{j}	19.21^{k}	18.77^{i}
H_1W_3	0.00^{c}	0.00^{e}	0.00^{e}	3.45^{g}	3.33^{m}	3.39^{k}	15.45^{k}	14.59^{m}	15.02^{j}
H_1W_4	0.00^{c}	0.00^{e}	0.00^{e}	3.47^{g}	2.92^{n}	3.20^{k}	15.90^{k}	15.12^{m}	15.51^{j}
H_1W_5	0.00^{c}	0.00^{e}	0.00^{e}	1.72^{h}	1.73^{o}	1.73^{l}	6.14^{k}	8.33^{n}	7.24^{k}
H_2W_1	8.33^{ab}	6.67^{ab}	7.50^{ab}	15.66^{d}	18.33^{f}	17.00^{e}	41.76^{d}	37.44^{e}	39.60^{e}
H_2W_2	5.33^{ab}	4.76^{bc}	5.05^{ab}	16.67^{d}	16.07^{g}	16.37^{f}	39.33^{e}	29.26^{g}	34.30^{f}
H_2W_3	3.33^{b}	5.17^{bc}	4.25^{cd}	10.33^{ef}	12.33^{i}	11.33^{h}	34.51^{f}	23.48^{j}	29.00^{g}
H_2W_4	3.33^{b}	5.21^{bc}	4.27^{cd}	11.67^{e}	12.66^{h}	12.17^{g}	31.60^{g}	24.35^{i}	27.98^{h}
H_2W_5	0.00^{c}	3.33^{cd}	1.67^{d}	5.28^{g}	5.14^{l}	5.21^{j}	18.97^{j}	17.87^{l}	18.42^{i}
H_3W_1	11.11^{a}	8.45^{a}	9.78^{a}	26.68^{a}	35.11^{a}	30.90^{a}	51.45^{a}	55.52^{a}	53.49^{a}
H_3W_2	12.22^{a}	6.17^{ab}	9.20^{ab}	23.44^{b}	28.45^{b}	25.95^{b}	46.33^{b}	50.23^{b}	48.28^{b}
H_3W_3	5.17^{ab}	6.22^{ab}	5.70^{bc}	19.33^{c}	20.56^{d}	19.94^{d}	39.17^{e}	45.68^{d}	42.43^{d}
H_3W_4	6.67^{ab}	5.80^{ab}	6.23^{ab}	20.66^{c}	23.19^{c}	21.92^{c}	42.33^{c}	47.80^{c}	45.07^{c}
H_3W_5	2.78^{b}	1.77^{d}	2.27^{d}	18.97^{c}	15.57^{e}	17.27^{e}	26.68^{i}	30.11^{f}	28.39^{g}
SEm±	**2.64**	**1.06**	**1.42**	**0.77**	**0.08**	**0.39**	**0.23**	**0.31**	**0.19**
CD (P=0.05)	***NS***	***NS***	***NS***	**2.23**	**0.24**	**1.10**	**0.67**	**0.90**	**0.55**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping



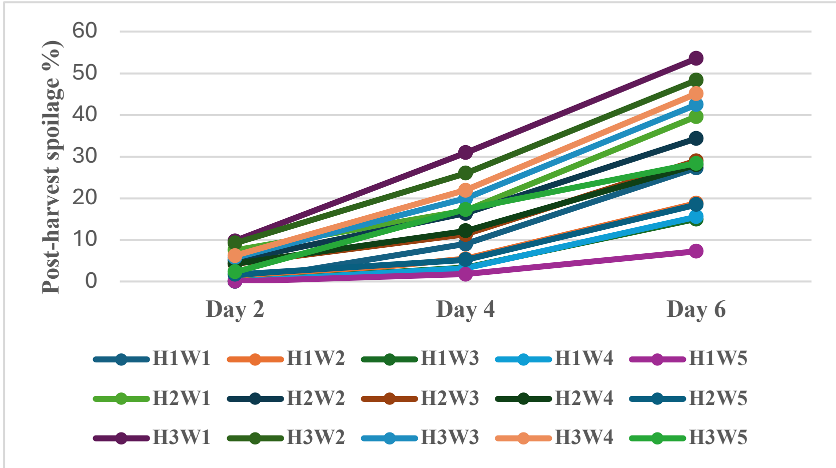


Figure 4.3: Individual and interaction effect of harvesting stages and wrapping materials on Post-harvest spoilage

banana leaf and teff straw or non-packaged fruits, as a result starch degradation was slower.

The data on interaction effect of harvesting stages and wrapping materials on pulp weight of dragon fruit is laid out in Table 4.12. With the progress in storage, a decreasing trend was observed despite the harvesting stages and wrapping materials used and on the final day of observation, the maximum pulp weight was recorded in H_2W_5 (30 DAA, shrink wrapping) with 152.08 g while the minimum pulp weight was found in H_1W_2 (25 DAA, banana leaves) with 85.09 g.

4.1.7 Peel weight (g)

The data on effect of harvesting stages on peel weight is presented in Table 4.13 which shows significant differences among the treatments. Maximum peel weight was recorded in fruits harvested at H_1 (25 DAA) with 80.49 g followed by H_2 (30 DAA) at harvest with 66.05 g. The lowest value was recorded in H_3 (35 DAA) with 55.70 g. This finding is in conformity with Franco *et. al.* (2022) and Singh *et. al.* (2022) who reported peel content and thickness decreased with fruit maturity and development which the latter explains degradation and decomposition of cell wall components, mainly cellulose, hemicellulose and pectin are responsible for the decreased size and weight of fruit skin.

The effect of wrapping materials on peel weight is presented in Table 4.13, where significant variation is observed in the later days of storage. Among the wrapping materials, shrink wrapping retained the peel mass better compared to the other treatments. On the last day of storage, the highest peel weight was recorded in W_5 (shrink wrapping) with 59.21 g and the minimum weight (49.53 g) is found in control (W_1).

Table 4.14 showcases the interaction effect of harvesting stages and wrapping materials on peel weight of dragon fruit where on most days the statistical difference was found to be non-significant. On the last day of evaluation, the highest peel weight was recorded in H_1W_5 (25 DAA, shrink wrapping) and the minimum value was recorded in H_3W_4 (35 DAA, EPE foam net).

Table 4.9: Effect of different harvesting stages and wrapping materials on fruit weight of dragon fruit

Treatments	***Fruit weight (g)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
Harvesting stages (H)															
H_1	179.27^{a}	187.71^{c}	183.49^{c}	176.87^{c}	184.13^{c}	180.50^{c}	174.47^{c}	182.01^{c}	178.24^{c}	162.07^{b}	175.59^{c}	168.83^{b}	149.27^{c}	168.65^{b}	158.96^{c}
H_2	216.47^{b}	213.07^{b}	214.77^{b}	213.00^{b}	208.78^{b}	210.89^{b}	208.93^{b}	205.33^{b}	207.13^{b}	202.47^{a}	199.31^{b}	200.89^{a}	197.27^{a}	194.09^{a}	195.68^{a}
H_3	232.20^{a}	248.65^{a}	240.42^{a}	228.93^{a}	244.07^{a}	236.50^{a}	220.27^{a}	231.17^{a}	225.72^{a}	197.67^{a}	208.20^{a}	202.93^{a}	186.93^{b}	192.07^{a}	189.50^{b}
SEm±	**3.66**	**2.13**	**2.12**	**3.74**	**1.34**	**1.99**	**1.79**	**1.59**	**1.20**	**2.87**	**0.95**	**1.51**	**1.91**	**1.30**	**1.15**
CD (P=0.05)	**10.56**	**6.16**	**5.98**	**10.79**	**3.88**	**5.62**	**5.16**	**4.60**	**3.39**	**8.29**	**2.75**	**4.28**	**5.52**	**3.74**	**3.27**
Wrapping materials(W)															
W_1	206.67^{a}	213.58^{b}	210.12	202.89^{a}	209.15^{b}	206.02^{a}	194.44^{c}	199.62^{c}	197.03^{c}	175.00^{c}	188.51^{c}	181.75^{e}	161.67^{d}	176.55^{c}	169.11^{d}
W_2	210.11^{a}	222.25^{a}	216.18	206.78^{a}	218.51^{a}	212.65^{a}	200.89^{b}	207.89^{b}	204.39^{b}	183.44^{bc}	196.27^{b}	189.86^{cd}	173.00^{c}	180.83^{bc}	176.92^{c}
W_3	206.22^{a}	215.20^{ab}	210.71	203.00^{a}	210.74^{b}	206.87^{a}	198.56^{bc}	205.80^{b}	202.18^{b}	190.89^{b}	195.87^{b}	193.38^{bc}	181.89^{b}	188.63^{b}	185.26^{b}
W_4	209.56^{a}	214.19^{b}	211.87	205.67^{a}	208.05^{b}	206.86^{a}	201.22^{b}	200.84^{bc}	201.03^{bc}	184.67^{bc}	187.23^{c}	185.95^{de}	176.78^{bc}	182.09^{b}	179.44^{c}
W_5	214.00^{a}	217.16^{ab}	215.58	213.00^{a}	215.19^{a}	214.10^{a}	211.00^{a}	216.71^{a}	213.86^{a}	203.00^{a}	203.94^{a}	203.47^{a}	195.78^{a}	196.58^{a}	196.18^{a}
SEm±	**4.72**	**2.75**	**2.73**	**4.82**	**1.73**	**2.56**	**2.31**	**2.06**	**1.55**	**3.71**	**1.23**	**1.95**	**2.47**	**1.67**	**1.49**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**5.01**	**NS**	**6.67**	**5.94**	**4.37**	**10.71**	**3.55**	**5.52**	**7.12**	**4.83**	**4.22**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA

W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.10: Interaction effect of different harvesting stages and wrapping materials on fruit weight of dragon fruit

Treatments (H x W interaction)	*Fruit weight (g)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
H_1W_1	185.00^{de}	189.33^{cd}	187.17^{d}	181.67^{cd}	185.46^{ef}	183.56^{f}	178.67^{d}	180.97^{gh}	179.82^{fg}	154.67^{f}	176.29^{g}	165.48^{f}	136.00^{g}	158.78^{e}	147.39^{g}
H_1W_2	175.67^{e}	194.72^{cd}	185.19^{d}	172.67^{d}	190.54^{e}	181.60^{f}	169.00^{d}	185.73^{g}	177.37^{g}	158.33^{ef}	181.70^{g}	170.02^{ef}	140.00^{g}	156.45^{e}	148.22^{g}
H_1W_3	175.00^{e}	185.67^{d}	180.33^{d}	173.00^{d}	181.00^{f}	177.00^{f}	173.00^{d}	175.40^{h}	174.20^{g}	162.67^{ef}	170.90^{h}	166.78^{f}	155.00^{f}	174.37^{d}	164.69^{f}
H_1W_4	179.67^{e}	183.83^{d}	181.75^{d}	176.67^{d}	179.52^{f}	178.09^{f}	172.67^{d}	175.63^{g}	174.15^{g}	159.33^{e}	169.00^{i}	164.17^{f}	146.33^{fg}	171.17^{d}	158.75^{f}
H_1W_5	181.00^{de}	185.00^{d}	183.00^{d}	180.33^{cd}	184.15^{ef}	182.24^{f}	179.00^{d}	192.33^{f}	185.67^{f}	175.33^{de}	180.05^{g}	177.69^{e}	169.00^{e}	182.48^{c}	175.74^{e}
H_2W_1	202.33^{cd}	208.68^{bc}	205.51^{c}	197.33^{bc}	204.25^{d}	200.79^{e}	190.67^{c}	199.40^{f}	195.03^{e}	182.67^{cd}	194.23^{ef}	188.45^{d}	177.67^{de}	189.53^{bc}	183.60^{cd}
H_2W_2	214.00^{bc}	219.00^{b}	216.50^{bc}	210.33^{b}	214.30^{c}	212.32^{de}	207.00^{b}	209.26^{ef}	208.13^{d}	201.67^{bc}	201.12^{cd}	201.39^{b}	196.00^{bc}	196.04^{a}	196.02^{b}
H_2W_3	220.00^{ab}	213.67^{b}	216.83^{bc}	216.67^{ab}	210.11^{cd}	213.39^{d}	211.67^{b}	205.78^{ef}	208.72^{d}	203.67^{ab}	198.71^{de}	201.19^{b}	198.00^{bc}	193.19^{ab}	195.59^{b}
H_2W_4	218.67^{ab}	209.00^{bc}	213.83^{bc}	215.00^{ab}	202.02^{d}	208.51^{d}	211.33^{b}	197.18^{f}	204.26^{d}	203.00^{ab}	192.70^{f}	197.85^{bc}	196.33^{bc}	187.12^{bc}	191.73^{b}
H_2W_5	227.33^{ab}	215.00^{b}	221.17^{b}	225.67^{ab}	213.22^{c}	219.45^{cd}	224.00^{a}	215.02^{de}	219.51^{c}	221.33^{a}	209.78^{b}	215.56^{a}	218.33^{a}	204.60^{ab}	211.47^{a}
H_3W_1	232.67^{ab}	242.71^{a}	237.69^{a}	229.67^{ab}	237.75^{b}	233.71^{ab}	214.00^{b}	218.50^{cd}	216.25^{c}	187.67^{cd}	195.00^{c}	191.33^{cd}	171.33^{de}	181.33^{c}	176.33^{de}
H_3W_2	240.67^{a}	253.04^{a}	246.85^{a}	237.33^{a}	250.70^{a}	244.02^{a}	226.67^{a}	228.67^{bc}	227.67^{b}	190.33^{bc}	206.00^{bc}	198.17^{bc}	183.00^{cd}	190.00^{ab}	186.50^{c}
H_3W_3	223.67^{ab}	246.26^{a}	234.96^{a}	219.33^{ab}	241.11^{ab}	230.22^{bc}	211.00^{b}	236.20^{ab}	223.60^{b}	206.33^{ab}	218.00^{a}	212.17^{s}	192.67^{bc}	198.33^{a}	195.50^{b}
H_3W_4	230.33^{ab}	249.74^{a}	240.04^{a}	225.33^{ab}	242.60^{ab}	233.97^{ab}	219.67^{a}	229.70^{b}	224.68^{b}	191.67^{bc}	200.00^{cd}	195.83^{bc}	187.67^{bc}	188.0^{bc}	187.83^{c}
H_3W_5	233.67^{ab}	251.48^{a}	242.58^{a}	233.00^{a}	248.20^{a}	240.60^{ab}	230.00^{a}	242.78^{a}	236.39^{a}	212.33^{a}	222.00^{a}	217.17^{a}	200.00^{b}	202.67^{a}	201.33^{b}
SEm±	**8.17**	**4.77**	**4.73**	**8.35**	**3.00**	**4.44**	**4.00**	**3.56**	**2.68**	**6.42**	**2.13**	**3.38**	**4.27**	**2.90**	**2.58**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**11.55**	**NS**	**7.57**	**NS**	**6.14**	**NS**	**NS**	**8.37**	**NS**

Note: NS = Non-significant at 5% level of significance

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.11: Effect of different harvesting stages and wrapping materials on pulp weight of dragon fruit

Treatments	Pulp weight (g)														
	Day 0			Day 2			Day 4			Day 6			Day 8		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
Harvesting stages (H)															
H_1	107.47^{c}	98.53^{c}	103.00^{c}	106.53^{b}	98.88^{c}	102.70^{c}	105.67^{b}	98.88^{c}	102.28^{c}	101.07^{b}	99.87^{c}	100.47^{c}	93.67^{b}	98.66^{c}	96.16^{b}
H_2	153.40^{b}	144.05^{b}	148.72^{b}	160.60^{a}	154.19^{b}	157.40^{b}	159.07^{a}	153.50^{b}	156.28^{b}	149.07^{a}	141.04^{b}	145.06^{b}	148.53^{a}	139.66^{b}	144.10^{a}
H_3	177.33^{a}	191.42^{a}	184.38^{a}	168.07^{a}	177.94^{a}	173.00^{a}	162.60^{a}	169.24^{a}	165.92^{a}	151.67^{a}	159.88^{a}	155.77^{a}	144.80^{a}	147.15^{a}	145.97^{a}
SEm±	**4.47**	**2.05**	**2.46**	**4.06**	**1.69**	**2.20**	**2.83**	**1.92**	**1.71**	**3.37**	**1.24**	**1.79**	**2.82**	**1.43**	**1.58**
CD (P=0.05)	**12.92**	**5.92**	**6.96**	**11.72**	**4.87**	**6.22**	**8.19**	**5.54**	**4.84**	**9.72**	**3.59**	**5.07**	**8.14**	**4.13**	**4.47**
Wrapping materials(W)															
W_1	144.67^{a}	142.64^{a}	143.65^{a}	142.89^{a}	142.65^{ab}	142.77^{a}	137.11^{a}	137.13^{a}	137.12^{b}	124.67^{b}	130.25^{b}	127.46^{b}	116.78^{b}	122.38^{c}	119.58^{c}
W_2	145.11^{a}	147.95^{a}	146.53^{a}	144.33^{a}	147.23^{a}	145.78^{a}	141.33^{a}	140.53^{a}	140.93^{ab}	128.78^{b}	132.56^{b}	130.67^{b}	122.78^{b}	121.81^{c}	122.29^{c}
W_3	143.11^{a}	146.92^{a}	145.02^{a}	141.89^{a}	145.15^{ab}	143.52^{a}	139.56^{a}	144.02^{a}	141.79^{ab}	137.44^{ab}	138.70^{a}	138.07^{a}	133.00^{a}	135.98^{a}	134.49^{ab}
W_4	148.33^{a}	141.55^{a}	144.94^{a}	147.11^{a}	139.91^{b}	143.51^{a}	145.44^{a}	137.11^{a}	141.28^{ab}	135.00^{ab}	128.09^{b}	131.55^{b}	132.89^{b}	127.90^{b}	130.39^{b}
W_5	149.11^{a}	144.27^{a}	146.69^{a}	149.11^{a}	143.38^{ab}	146.25^{a}	148.78^{a}	143.92^{a}	146.35^{a}	143.78^{a}	138.40^{a}	141.09^{a}	139.56^{a}	134.38^{a}	136.97^{a}
SEm±	**5.78**	**2.65**	**3.18**	**5.24**	**2.18**	**2.84**	**3.66**	**2.47**	**2.21**	**4.34**	**1.60**	**2.32**	**3.64**	**1.85**	**2.04**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**12.55**	**4.63**	**6.55**	**10.50**	**5.33**	**5.77**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.12: Interaction effect of different harvesting stages and wrapping materials on pulp weight of dragon fruit

Treatments (H x W interaction)	*Pulp weight (g)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
H_1W_1	114.67^{d}	101.32^{cd}	107.99^{c}	111.33^{c}	102.14^{cd}	106.74^{e}	108.67^{c}	101.54^{e}	105.10^{e}	96.00^{c}	101.92^{d}	98.96^{e}	83.67^{f}	90.08^{f}	86.88^{ef}
H_1W_2	102.33^{d}	105.49^{c}	103.91^{c}	101.67^{c}	104.32^{c}	102.99^{e}	101.00^{c}	104.77^{e}	102.89^{e}	97.00^{c}	104.95^{d}	100.98^{e}	84.67^{ef}	85.51^{f}	85.09^{f}
H_1W_3	106.33^{d}	100.53^{cd}	103.43^{c}	106.33^{c}	99.79^{cd}	103.06^{e}	107.00^{c}	98.17^{e}	102.59^{e}	105.00^{c}	98.95^{de}	101.98^{e}	102.00^{de}	107.29^{e}	104.65^{d}
H_1W_4	105.00^{d}	93.09^{cd}	99.05^{c}	104.33^{c}	94.87^{cd}	99.60^{e}	102.00^{c}	95.69^{e}	98.85^{e}	97.33^{c}	94.15^{e}	95.74^{e}	90.33^{de}	102.25^{e}	96.29^{e}
H_1W_5	109.00^{d}	92.22^{d}	100.61^{c}	109.00^{c}	93.26^{d}	101.13^{e}	109.67^{c}	94.25^{e}	101.96^{e}	110.00^{c}	99.39^{de}	104.69^{e}	107.67^{d}	108.15^{e}	107.91^{d}
H_2W_1	144.00^{c}	142.93^{b}	143.46^{b}	142.67^{b}	149.06^{b}	145.86^{d}	140.00^{b}	147.51^{d}	143.76^{d}	136.33^{b}	142.93^{c}	139.63^{d}	136.00^{bc}	141.48^{b}	138.74^{c}
H_2W_2	149.67^{c}	146.42^{b}	148.05^{b}	157.00^{ab}	155.77^{b}	156.39^{cd}	155.33^{ab}	153.77^{cd}	154.55^{c}	147.33^{ab}	139.32^{c}	143.33^{cd}	145.67^{a}	138.15^{cd}	141.91^{c}
H_2W_3	152.67^{bc}	148.58^{b}	150.63^{b}	165.67^{ab}	157.38^{b}	161.52^{bc}	163.33^{a}	155.84^{bc}	159.59^{bc}	145.33^{ab}	144.44^{c}	144.89^{cd}	144.67^{a}	143.23^{bc}	143.95^{bc}
H_2W_4	159.33^{ab}	137.30^{b}	148.32^{b}	168.00^{ab}	150.66^{b}	159.33^{cd}	167.67^{a}	149.33^{cd}	158.50^{bc}	154.67^{ab}	133.06	143.86^{cd}	155.00^{a}	132.61^{d}	143.80^{bc}
H_2W_5	161.33^{ab}	145.00^{b}	153.17^{b}	169.67^{a}	158.09^{b}	163.88^{bc}	169.00^{a}	161.05^{bc}	165.03^{ab}	161.67^{a}	145.47^{c}	153.57^{c}	161.33^{a}	142.83^{bc}	152.08^{ab}
H_3W_1	175.33^{ab}	183.67^{a}	179.50^{a}	174.67^{a}	176.76^{a}	175.72^{ab}	162.67^{a}	162.33^{bc}	162.50^{ab}	141.67^{ab}	145.92^{c}	143.79^{cd}	130.67^{c}	135.57^{cd}	133.12^{c}
H_3W_2	183.33^{a}	191.94^{a}	187.64^{a}	174.33^{a}	181.61^{a}	177.97^{a}	167.67^{a}	163.04^{bc}	165.35^{a}	142.00^{ab}	153.40^{b}	147.70^{cd}	138.00^{bc}	141.76^{bc}	139.88^{c}
H_3W_3	170.33^{ab}	191.66^{a}	181.00^{a}	153.67^{ab}	178.29^{a}	165.98^{ab}	148.33^{b}	178.06^{a}	163.20^{ab}	162.00^{a}	172.69^{a}	167.35^{a}	152.33^{ab}	157.41^{a}	154.87^{a}
H_3W_4	180.67^{ab}	194.26^{a}	187.47^{a}	169.00^{a}	174.21^{a}	171.61^{ab}	166.67^{a}	166.32^{ab}	166.49^{a}	153.00^{ab}	157.07^{b}	155.04^{b}	153.33^{ab}	148.83^{ab}	151.08^{ab}
H_3W_5	177.00^{ab}	195.59^{a}	186.29^{a}	168.67^{ab}	178.80^{a}	173.73^{ab}	167.67^{a}	176.45^{a}	172.06^{a}	159.67^{a}	170.33^{a}	165.00^{ab}	149.67^{a}	152.16^{a}	150.92^{ab}
SEm±	**10.00**	**4.59**	**5.50**	**9.08**	**3.77**	**4.92**	**6.34**	**4.29**	**3.83**	**7.53**	**2.78**	**4.01**	**6.30**	**3.20**	**3.53**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**10.82**	**NS**	**8.02**	**NS**	**NS**	**9.23**	**NS**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.13: Effect of different harvesting stages and wrapping materials on peel weight of dragon fruit

Treatments	***Peel weight (g)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
Harvesting stages (H)															
H_1	71.80^{a}	89.18^{a}	80.49^{a}	70.33^{a}	85.26^{a}	77.80^{a}	68.80^{a}	79.59^{a}	74.20^{a}	61.00^{a}	75.72^{a}	68.36^{a}	55.60^{a}	69.99^{a}	62.80^{a}
H_2	63.07^{b}	69.02^{b}	66.05^{b}	52.40^{c}	54.59^{c}	53.50^{c}	49.87^{c}	51.83^{c}	50.85^{c}	53.40^{b}	58.26^{b}	55.83^{b}	48.73^{b}	54.44^{b}	51.58^{b}
H_3	54.87^{c}	56.52^{c}	55.70^{c}	60.87^{b}	66.14^{b}	63.50^{b}	57.67^{b}	61.93^{b}	59.80^{b}	46.00^{c}	48.32^{c}	47.16^{c}	42.13^{c}	44.92^{c}	43.53^{c}
SEm±	**2.30**	**1.12**	**1.28**	**2.28**	**0.73**	**1.20**	**2.14**	**0.86**	**b1.15**	**2.14**	**0.76**	**1.14**	**2.10**	**0.68**	**1.10**
CD (P=0.05)	**6.64**	**3.25**	**3.62**	**6.60**	**2.10**	**3.39**	**6.17**	**2.48**	**3.26**	**6.19**	**2.21**	**3.22**	**6.06**	**1.95**	**3.12**
Wrapping materials (W)															
W_1	62.00^{a}	70.94^{ab}	66.47^{a}	60.00^{a}	66.50^{b}	63.25^{b}	57.33^{a}	62.49^{b}	59.91^{b}	50.33^{b}	58.25^{b}	54.29^{b}	44.89^{b}	54.17^{c}	49.53^{c}
W_2	65.00^{a}	74.30^{a}	69.65^{a}	62.44^{a}	71.28^{a}	66.86^{ab}	59.56^{a}	67.36^{a}	63.46^{ab}	54.67^{ab}	63.72^{a}	59.19^{a}	50.22^{a}	59.02^{b}	54.62^{b}
W_3	63.11^{a}	68.27^{b}	65.69^{a}	61.11^{a}	65.59^{b}	63.35^{b}	59.00^{a}	61.77^{b}	60.39^{ab}	53.44^{ab}	57.17^{b}	55.31^{b}	48.89^{b}	52.65^{c}	50.77^{bc}
W_4	61.22^{a}	71.48^{ab}	66.35^{a}	58.56^{a}	68.14^{b}	63.35^{b}	55.78^{a}	62.21^{b}	58.99^{b}	49.67^{b}	59.14^{b}	54.40^{b}	43.89^{b}	54.20^{c}	49.04^{c}
W_5	64.89^{a}	72.89^{a}	68.89^{a}	63.89^{a}	71.81^{a}	67.85^{a}	62.22^{a}	68.42^{a}	65.32^{a}	59.22^{a}	65.55^{a}	62.39^{a}	56.22^{a}	62.20^{a}	59.21^{a}
SEm±	**2.97**	**1.45**	**1.65**	**2.95**	**0.94**	**1.55**	**2.76**	**1.11**	**1.49**	**2.77**	**0.99**	**1.47**	**2.71**	**0.87**	**1.42**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**2.71**	**NS**	**NS**	**3.20**	**NS**	**NS**	**2.85**	**4.15**	**7.82**	**2.52**	**4.02**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.14: Interaction effect of different harvesting stages and wrapping materials on peel weight of dragon fruit

Treatments (H x W interaction)	*Peel weight (g)*														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	70.33^{ab}	88.01^{a}	79.17^{a}	70.33^{a}	83.32^{bc}	76.83^{a}	70.00^{ab}	79.43^{b}	74.71^{a}	58.67^{ab}	74.38^{bc}	66.52^{ab}	52.33^{ab}	68.69^{b}	60.51^{bc}
H_1W_2	73.33^{ab}	89.22^{a}	81.28^{a}	71.00^{a}	86.22^{ab}	78.61^{a}	68.00^{ab}	80.96^{ab}	74.48^{a}	61.33^{ab}	76.75^{ab}	69.04^{ab}	55.33^{ab}	70.94^{ab}	63.14^{ab}
H_1W_3	68.67^{ab}	85.14^{a}	76.90^{a}	66.67^{ab}	81.21^{c}	73.94^{a}	66.00^{ab}	77.23^{b}	71.62^{a}	57.67^{ab}	71.94^{c}	64.81^{bc}	53.00^{ab}	67.08^{b}	60.04^{bc}
H_1W_4	74.67^{a}	90.74^{a}	82.71^{a}	72.33^{a}	84.65^{bc}	78.49^{a}	70.67^{a}	75.38^{b}	73.02^{a}	62.00^{a}	74.85^{bc}	68.43^{ab}	56.00^{ab}	68.92^{b}	62.46^{ab}
H_1W_5	72.00^{ab}	92.78^{a}	82.39^{a}	71.33^{a}	90.89^{a}	81.11^{a}	69.33^{ab}	84.95^{a}	77.14^{a}	65.33^{a}	80.67^{a}	73.00^{a}	61.33^{a}	74.33^{a}	67.83^{a}
H_2W_1	58.33^{c}	65.76^{b}	62.05^{b}	54.67^{bc}	55.19^{fg}	54.93^{cd}	50.67^{cd}	51.89^{fg}	51.28^{de}	46.33^{c}	51.30^{fg}	48.82^{fg}	41.67^{c}	48.05^{fg}	44.86^{ef}
H_2W_2	64.33^{ab}	72.58^{b}	68.46^{b}	53.33^{bc}	58.53^{ef}	55.93^{cd}	51.67^{cd}	55.49^{ef}	53.58^{cd}	54.33^{ab}	61.80^{de}	58.07^{cd}	50.33^{ab}	57.90^{cd}	54.12^{cd}
H_2W_3	67.33^{ab}	65.08^{cd}	66.21^{b}	51.00^{c}	52.74^{g}	51.87^{d}	48.33^{d}	49.94^{g}	49.14^{de}	58.33^{ab}	54.27^{f}	56.30^{de}	53.33^{ab}	49.96^{f}	51.65^{de}
H_2W_4	59.33^{bc}	71.70^{bc}	65.52^{bc}	47.00^{c}	51.36^{g}	49.18^{d}	43.67^{d}	47.86^{g}	45.76^{e}	48.33^{bc}	59.64^{e}	53.99^{de}	41.33^{c}	54.51^{de}	47.92^{de}
H_2W_5	66.00^{ab}	70.00^{bc}	68.00^{b}	56.00^{bc}	55.13^{fg}	55.57^{cd}	55.00^{cd}	53.96^{ef}	54.48^{cd}	59.67^{ab}	64.31^{d}	61.99^{cd}	57.00^{ab}	61.77^{c}	59.38^{c}
H_3W_1	57.33^{c}	59.04^{de}	58.19^{cd}	55.00^{bc}	60.99^{e}	57.99^{cd}	51.33^{cd}	56.17^{ef}	53.75^{cd}	46.00^{c}	49.08^{g}	47.54^{f}	40.67^{c}	45.77^{g}	43.22^{fg}
H_3W_2	57.33^{c}	61.10^{de}	59.22^{cd}	63.00^{ab}	69.09^{d}	66.05^{b}	59.00^{bc}	65.63^{c}	62.32^{b}	48.33^{c}	52.60^{f}	50.47^{ef}	45.00^{bc}	48.24^{fg}	46.62^{ef}
H_3W_3	53.33^{c}	54.60^{e}	53.97^{de}	65.67^{ab}	62.82^{e}	64.24^{b}	62.67^{ab}	58.15^{de}	60.41^{bc}	44.33^{c}	45.31^{h}	44.82^{g}	40.33^{c}	40.92^{h}	40.63^{fg}
H_3W_4	49.67^{c}	51.99^{e}	50.83^{e}	56.33^{bc}	68.39^{d}	62.36^{bc}	53.00^{cd}	63.38^{cd}	58.19^{b}	38.67^{c}	42.93^{h}	40.80^{g}	34.33^{c}	39.17^{h}	36.75^{g}
H_3W_5	56.67^{c}	55.90^{de}	56.28^{de}	64.33^{ab}	69.40^{d}	66.87^{b}	62.33^{ab}	66.33^{c}	64.33^{b}	52.67^{ab}	51.67^{fg}	52.17^{ef}	50.33^{ab}	50.50^{ef}	50.42^{d}
SEm±	**5.14**	**2.51**	**2.86**	**5.11**	**1.63**	**2.68**	**4.78**	**1.92**	**2.57**	**4.79**	**1.71**	**2.54**	**4.69**	**1.51**	**2.46**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**4.70**	**NS**	**NS**	**NS**	**NS**	**NS**	**4.94**	**NS**	**NS**	**4.37**	**NS**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

4.1.8 Total Soluble Solids (ºB)

The experimental results pertaining to TSS content is presented in Table 4.15 and Figure 4.4 which outline that there was a significant influence of harvesting stages and wrapping materials. At 0 DAH, highest TSS content was recorded in H_3 (35 DAA) with 13.48 ºB and minimum in the initial stage of harvest H_1 (25 DAA) with 8.44 ºB. Singh *et. al.* (2022) elucidated that TSS increased steadily with progression of maturity until 40 DAA. During storage, an increasing trend in TSS content was observed until day 4 in all the harvesting stages, which was preceded by a reduction in TSS content. On the last day of storage, minimum TSS content (7.77 ºB) was recorded in H_1 (25 DAA) and the maximum value (11.06 ºB) was recorded in H_2 (30 DAA). Similar results were reported by Lata *et. al.* (2023) and Mustafa *et. al.* (2018) where a significant decline in TSS content was observed in dragon fruit during the storage period.

Regarding the influence of wrapping materials on TSS content, maximum retention of TSS was recorded in shrink wrapped fruits (W_5) which decreased from 11.46 º B on day 1 to 10.62 ºB on day 8 of storage. Minimum TSS content on the last day of storage was recorded in control (9.02 ºB). Fruits continue to respire after harvest and undergo biochemical changes, thus, utilization of sugars during respiration, hydrolysis of insoluble polysaccharides into sugars and other metabolic activities (Lata *et. al.,* 2023), enzymatic activities and microbial growth (Awang *et. al.,* 2011) may lead to reduction in TSS.

The interaction effect (Table 4.16 and Figure 4.4) of harvesting stages and wrapping materials on TSS content of dragon fruit was found to be statistically significant on most days during the time of observation. Maximum retention of TSS content was observed in H_2W_5 (30 DAA, shrink wrapping) with highest TSS content (12.27 ºB) on the last day of storage, followed by H_2W_3 (30 DAA, brown paper) with 11.38 ºB which was on par with H_2W_4 (30 DAA, EPE foam net) with TSS (11.30 ºB). The minimum value (7.32 ºB) was recorded in H_1W_1 (25 DAA, control). TSS content projects an approximate measurement of the concentration of soluble substances in the fruit juice, which correlates to the fruit's overall flavor profile and also indicate the available energy in the fruit to continue respiration process and other metabolic activities.

4.1.9 Titratable acidity (%)

A perusal of data presented in Table 4.17 and Figure 4.5 on the effect of harvesting stages and wrapping materials on acidity in dragon fruit revealed significant differences among the treatments. At day 0, the maximum acidity (0.47) was recorded in H_1 (25 DAA) which followed a decreasing trend with maturity, and at 35 DAA (H_3) minimum acidity content was recorded with 0.24%. On all the days of observation, maximum acidity was recorded in 25 DAA with values ranging from 0.49% to 0.25% and minimum acidity ranging from 0.25 to 0.14% was observed in H_3. A steady decrease in acidity was observed in H_2 (30 DAA) during the period of storage with values ranging from 0.33 to 0.20%. There was continuous and progressive decrease in acidity as maturity stage and fruit development progressed in dragon fruit which was also reported by Singh *et. al.* (2022) and Magalhaes *et. al.* (2019). This reduction may be due to the usage of organic acids as substrate in physiochemical processes such as respiration or their conversion into sugars (Chitarra and Chitarra, 2005).

During storage, the acidity abated irrespective of maturity stages and wrapping materials used. On the last day of observation, the highest acidity content was recorded in W_5 (Shrink wrapping) with a mean value of 0.25% and the minimum acidity was recorded in W_1 (no wrapping) with 0.16%. Wrapping fruits can slow down the respiration process by limiting their exposure to oxygen and thus reduce the hydrolysis of organic acids leading to higher acidity in treated fruits as compared to unwrapped fruits. Also, fruits with higher acidity tend to have higher shelf life as stated by Deepthi *et. al.* (2016) in guava and Padmavathi (1999) in banana.

The interaction effect of various harvesting stages and wrapping materials on titratable acidity of dragon fruit (Table 4.18 and Figure 4.5) elucidated significant variation among the treatments. At day 8 of storage, maximum acidity (0.33%) was found under the treatment H_1W_5 (25 DAA, Shrink wrapping) and minimum acidity (0.10%) was recorded in H_3W_1 (35 DAA, no wrapping) which was at par with H_3W_2 (35 DAA, banana leaves) and H_3W_4 (35 DAA, EPE foam net). The decreasing trend may be due to ambient temperature that causes depletion of substrates due to increased rate of respiration and other metabolic processes (Punitha *et. al.,* 2010).

Table 4.15: Effect of different harvesting stages and wrapping materials on Total Soluble Solids (TSS) of dragon fruit

Treatments	*Total Soluble Solids (˚Brix)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
Harvesting stages (H)															
H_1	8.44^{c}	8.44^{c}	8.44^{c}	8.99^{c}	8.84^{c}	8.91^{c}	9.13^{c}	9.19^{c}	9.16^{c}	7.83^{c}	7.92^{c}	7.87^{c}	7.72^{c}	7.82^{c}	7.77^{c}
H_2	12.19^{b}	11.75^{b}	11.97^{b}	12.33^{b}	12.57^{b}	12.45^{b}	12.98^{b}	13.15^{b}	13.07^{b}	11.51^{b}	11.87^{a}	11.69^{a}	11.07^{a}	11.05^{a}	11.06^{a}
H_3 (35 DAA)	13.45^{a}	13.51^{a}	13.48^{a}	14.19^{a}	13.93^{a}	14.06^{a}	14.34^{a}	14.03^{a}	14.18^{a}	12.00^{a}	11.40^{b}	11.70^{b}	10.82^{b}	10.26^{b}	10.54^{b}
SEm±	**0.23**	**0.25**	**0.17**	**0.10**	**0.15**	**0.09**	**0.08**	**0.16**	**0.09**	**0.05**	**0.07**	**0.04**	**0.06**	**0.05**	**0.04**
CD (P=0.05)	**0.65**	**0.72**	**0.47**	**0.28**	**0.42**	**0.25**	**0.24**	**0.48**	**0.26**	**0.14**	**0.20**	**0.12**	**0.18**	**0.13**	**0.11**
Wrapping materials (W)															
W_1	11.02^{a}	11.63^{a}	11.33^{a}	11.75^{b}	11.40^{bc}	11.57^{b}	12.46^{a}	11.99^{a}	12.23^{a}	9.58^{e}	9.92^{c}	9.75^{d}	9.06^{c}	8.98^{d}	9.02^{e}
W_2	11.72^{a}	10.87^{a}	11.29^{a}	12.17^{a}	12.06^{a}	12.11^{a}	12.28^{a}	12.41^{a}	12.35^{a}	10.46^{c}	10.05^{c}	10.25^{c}	9.59^{d}	9.36^{c}	9.47^{d}
W_3	11.25^{a}	10.87^{a}	11.06^{a}	11.77^{b}	11.32^{c}	11.55^{b}	11.29^{b}	11.94^{a}	11.62^{b}	10.87^{b}	10.47^{b}	10.67^{b}	10.12^{b}	10.14^{b}	10.13^{b}
W_4	11.41^{a}	11.28^{a}	11.35^{a}	11.78^{b}	11.93^{ab}	11.86^{b}	12.46^{a}	11.93^{a}	12.20^{a}	10.16^{d}	10.56^{b}	10.36^{c}	9.89^{c}	9.52^{c}	9.71^{c}
W_5	11.40^{a}	11.52^{a}	11.46^{a}	11.73^{b}	12.18^{a}	11.95^{a}	12.26^{a}	12.35^{a}	12.30^{a}	11.14^{a}	10.99^{a}	11.07^{a}	10.70^{a}	10.55^{a}	10.62^{a}
SEm±	**0.29**	**0.32**	**0.22**	**0.13**	**0.19**	**0.11**	**0.11**	**0.21**	**0.12**	**0.06**	**0.09**	**0.05**	**0.08**	**0.06**	**0.05**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**0.54**	**0.32**	**0.31**	**NS**	**0.34**	**0.18**	**NS**	**0.16**	**0.23**	**0.17**	**0.14**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.16: Interaction effect of different harvesting stages and wrapping materials on Total Soluble Solids (TSS) of dragon fruit

Treatments (H x W interaction)	***Total Soluble Solids (˚Brix)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	8.64^{d}	8.12^{d}	8.38^{d}	9.27^{d}	8.68^{d}	8.98^{e}	9.34^{ef}	9.45^{d}	9.40^{d}	7.77^{gh}	7.59^{h}	7.68^{hi}	7.20^{h}	7.43^{k}	7.32^{j}
H_1W_2	9.04^{d}	8.99^{d}	9.01^{d}	9.32^{d}	8.72^{d}	9.02^{e}	9.50^{ef}	10.07^{d}	9.78^{d}	7.45^{i}	7.73^{gh}	7.59^{i}	7.21^{h}	7.75^{j}	7.48^{ij}
H_1W_3	8.12^{d}	8.24^{d}	8.18^{d}	8.64^{d}	8.80^{d}	8.72^{e}	8.92^{f}	8.83^{e}	8.88^{ef}	8.01^{fg}	7.86^{gh}	7.94^{g}	8.03^{fg}	8.13^{i}	8.08^{h}
H_1W_4	7.96^{d}	8.14^{d}	8.05^{d}	8.83^{d}	8.87^{d}	8.85^{e}	8.85^{f}	8.00^{e}	8.43^{f}	7.63^{hi}	8.03^{fg}	7.83^{gh}	7.80^{g}	7.49^{jk}	7.64^{i}
H_1W_5	8.45^{d}	8.74^{d}	8.60^{d}	8.87^{d}	9.11^{d}	8.99^{e}	9.05^{f}	9.61^{d}	9.33^{de}	8.26^{f}	8.40^{f}	8.33^{f}	8.37^{f}	8.30^{i}	8.34^{g}
H_2W_1	12.00^{c}	12.45^{bc}	12.23^{bc}	11.86^{c}	11.63^{c}	11.75^{d}	13.38^{b}	12.66^{c}	13.02^{bc}	10.53^{e}	11.30^{d}	10.92^{e}	10.11^{de}	9.85^{g}	9.98^{f}
H_2W_2	12.23^{c}	11.26^{c}	11.75^{c}	12.74^{b}	13.11^{b}	12.92^{c}	12.63^{cd}	12.85^{c}	12.74^{c}	11.76^{c}	11.53^{d}	11.65^{d}	10.43^{d}	10.35^{ef}	10.39^{de}
H_2W_3	12.56^{bc}	10.93^{c}	11.74^{c}	12.75^{b}	11.94^{c}	12.34^{cd}	12.30^{d}	13.37^{ab}	12.84^{c}	11.82^{c}	12.21^{d}	12.01^{c}	11.01^{c}	11.74^{b}	11.38^{b}
H_2W_4	12.20^{c}	11.21^{c}	11.71^{c}	12.25^{bc}	13.04^{b}	12.64^{c}	13.63^{b}	13.65^{ab}	13.64^{b}	11.29^{d}	11.87^{c}	11.58^{d}	11.65^{b}	10.96^{d}	11.30^{b}
H_2W_5	11.97^{c}	12.90^{ab}	12.43^{bc}	12.07^{c}	13.12^{b}	12.59^{c}	12.98^{c}	13.22^{b}	13.10^{bc}	12.14^{b}	12.45^{a}	12.29^{b}	12.17^{a}	12.36^{a}	12.27^{a}
H_3W_1	12.43^{c}	14.33^{a}	13.38^{ab}	14.11^{a}	13.89^{ab}	14.00^{ab}	14.67^{a}	13.85^{ab}	14.26^{a}	10.44^{e}	10.89^{e}	10.66^{e}	9.87^{e}	9.65^{h}	9.76^{f}
H_3W_2	13.90^{ab}	12.35^{bc}	13.13^{b}	14.45^{a}	14.34^{a}	14.40^{a}	14.72^{a}	14.32^{a}	14.52^{a}	12.18^{b}	10.87^{e}	11.53^{d}	11.12^{c}	9.98^{f}	10.55^{d}
H_3W_3	13.08^{ab}	13.45^{ab}	13.27^{ab}	13.91^{a}	13.24^{ab}	13.57^{b}	12.67^{cd}	13.62^{ab}	13.14^{b}	12.78^{a}	11.34^{d}	12.06^{bc}	11.32^{bc}	10.55^{e}	10.94^{c}
H_3W_4	14.07^{a}	14.50^{a}	14.29^{a}	14.26^{a}	13.89^{ab}	14.07^{ab}	14.89^{a}	14.14^{ab}	14.52^{a}	11.54^{cd}	11.78^{bc}	11.66^{d}	10.21^{d}	10.13^{f}	10.17^{e}
H_3W_5	13.78^{ab}	12.93^{ab}	13.36^{ab}	14.24^{a}	14.30^{a}	14.27^{a}	14.73^{a}	14.22^{ab}	14.48^{a}	13.04^{a}	12.13^{ab}	12.58^{a}	11.55^{b}	10.98^{c}	11.27^{bc}
SEm±	**0.50**	**0.56**	**0.38**	**0.22**	**0.33**	**0.20**	**0.19**	**0.37**	**0.21**	**0.11**	**0.16**	**0.10**	**0.14**	**0.10**	**0.09**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.54**	**1.07**	**0.58**	**0.31**	**0.45**	**0.27**	**0.40**	**0.30**	**0.25**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.17: Effect of different harvesting stages and wrapping materials on Titratable acidity of dragon fruit

Treatments	*Titratable acidity (%)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
Harvesting stages (H)															
H_1	0.49^{a}	0.48^{a}	0.49^{a}	0.44^{a}	0.41^{a}	0.43^{a}	0.40^{a}	0.36^{a}	0.38^{a}	0.31^{a}	0.29^{a}	0.30^{a}	0.25^{a}	0.25^{a}	0.25^{a}
H_2	0.35^{b}	0.31^{b}	0.33^{b}	0.32^{b}	0.25^{b}	0.29^{b}	0.30^{b}	0.24^{b}	0.27^{b}	0.23^{b}	0.22^{b}	0.22^{b}	0.20^{b}	0.19^{b}	0.20^{b}
H_3	0.27^{c}	0.23^{c}	0.25^{c}	0.23^{c}	0.20^{c}	0.21^{c}	0.20^{c}	0.19^{c}	0.20^{c}	0.17^{c}	0.17^{c}	0.17^{c}	0.14^{c}	0.14^{c}	0.14^{c}
SEm±	**0.009**	**0.014**	**0.009**	**0.007**	**0.006**	**0.005**	**0.007**	**0.005**	**0.004**	**0.005**	**0.004**	**0.003**	**0.005**	**0.005**	**0.004**
CD (P=0.05)	**0.027**	**0.042**	**0.024**	**0.020**	**0.017**	**0.013**	**0.020**	**0.014**	**0.012**	**0.014**	**0.013**	**0.009**	**0.016**	**0.015**	**0.011**
Wrapping materials (W)															
W_1	0.35^{b}	0.36^{a}	0.35^{a}	0.30^{d}	0.30^{bc}	0.30^{b}	0.26^{c}	0.22^{d}	0.24^{d}	0.19^{e}	0.19^{d}	0.19^{d}	0.16^{c}	0.16^{d}	0.16^{e}
W_2	0.37^{ab}	0.32^{a}	0.35^{a}	0.32^{cd}	0.28^{c}	0.30^{b}	0.28^{c}	0.26^{c}	0.27^{c}	0.21^{d}	0.21^{c}	0.21^{c}	0.17^{c}	0.18^{c}	0.17^{de}
W_3	0.37^{ab}	0.36^{a}	0.36^{a}	0.34^{bc}	0.30^{bc}	0.32^{ab}	0.32^{ab}	0.27^{ab}	0.29^{b}	0.27^{b}	0.24^{b}	0.25^{b}	0.22^{b}	0.21^{b}	0.22^{b}
W_4	0.39^{a}	0.34^{a}	0.36^{a}	0.38^{a}	0.31^{ab}	0.34^{a}	0.31^{b}	0.26^{c}	0.29^{b}	0.23^{c}	0.22^{c}	0.22^{c}	0.18^{c}	0.18^{c}	0.18^{cd}
W_5	0.37^{ab}	0.33^{a}	0.35^{a}	0.35^{ab}	0.33^{a}	0.34^{a}	0.34^{a}	0.30^{a}	0.32^{a}	0.30^{a}	0.28^{a}	0.29^{a}	0.26^{a}	0.25^{a}	0.25^{a}
SEm±	**0.012**	**0.019**	**0.011**	**0.014**	**0.007**	**0.008**	**0.009**	**0.006**	**0.005**	**0.006**	**0.006**	**0.004**	**0.007**	**0.007**	**0.005**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.039**	**0.021**	**0.022**	**0.026**	**0.018**	**0.016**	**0.018**	**0.016**	**0.012**	**0.020**	**0.019**	**0.014**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.18: Interaction effect of different harvesting stages and wrapping materials on Titratable Acidity of dragon fruit

Treatments (H x W interaction)	***Titratable acidity (%)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	0.46^{c}	0.48^{a}	0.47^{b}	0.39^{cd}	0.42^{ab}	0.41^{c}	0.35^{b}	0.31^{c}	0.33^{bc}	0.26^{de}	0.23^{de}	0.25^{d}	0.21^{cd}	0.20^{de}	0.21^{de}
H_1W_2	0.45^{c}	0.47^{a}	0.46^{b}	0.40^{cd}	0.38^{b}	0.39^{c}	0.33^{bc}	0.35^{b}	0.34^{b}	0.23^{e}	0.26^{cd}	0.24^{de}	0.20^{cd}	0.24^{bc}	0.22^{cd}
H_1W_3	0.47^{bc}	0.53^{a}	0.50^{ab}	0.43^{bc}	0.40^{b}	0.41^{c}	0.43^{a}	0.36^{ab}	0.40^{a}	0.35^{b}	0.31^{b}	0.33^{b}	0.26^{b}	0.26^{b}	0.26^{b}
H_1W_4	0.55^{a}	0.50^{a}	0.53^{a}	0.57^{a}	0.45^{a}	0.51^{a}	0.45^{a}	0.37^{ab}	0.41^{a}	0.31^{c}	0.29^{bc}	0.30^{c}	0.23^{bc}	0.23^{b}	0.23^{cd}
H_1W_5	0.53^{ab}	0.45^{a}	0.49^{ab}	0.50^{ab}	0.42^{ab}	0.46^{b}	0.47^{a}	0.39^{a}	0.43^{a}	0.40^{a}	0.37^{a}	0.39^{a}	0.34^{a}	0.32^{a}	0.33^{a}
H_2W_1	0.34^{de}	0.33^{b}	0.34^{c}	0.30^{ef}	0.26^{d}	0.28^{de}	0.27^{c}	0.20^{fg}	0.23^{fg}	0.19^{gh}	0.19^{fg}	0.19^{g}	0.17^{e}	0.16^{fg}	0.16^{g}
H_2W_2	0.38^{d}	0.27^{b}	0.33^{c}	0.35^{de}	0.26^{d}	0.30^{d}	0.33^{bc}	0.23^{ef}	0.28^{de}	0.24^{de}	0.21^{ef}	0.22^{ef}	0.19^{de}	0.17^{ef}	0.18^{fg}
H_2W_3	0.35^{de}	0.34^{b}	0.35^{c}	0.33^{de}	0.26^{d}	0.30^{d}	0.30^{bc}	0.25^{de}	0.27^{de}	0.25^{de}	0.23^{de}	0.24^{de}	0.22^{cd}	0.21^{cd}	0.22^{cd}
H_2W_4	0.36^{d}	0.30^{bc}	0.33^{c}	0.34^{de}	0.27^{cd}	0.31^{d}	0.29^{c}	0.24^{e}	0.26^{ef}	0.22^{ef}	0.20^{ef}	0.21^{fg}	0.20^{cd}	0.19^{de}	0.19^{ef}
H_2W_5	0.32^{de}	0.31^{b}	0.32^{c}	0.30^{ef}	0.31^{c}	0.31^{d}	0.31^{bc}	0.28^{cd}	0.30^{cd}	0.27^{d}	0.25^{d}	0.26^{d}	0.25^{b}	0.24^{bc}	0.24^{bc}
H_3W_1	0.24^{f}	0.26^{b}	0.25^{d}	0.21^{g}	0.21^{e}	0.21^{f}	0.18^{d}	0.17^{g}	0.17^{i}	0.12^{i}	0.14^{h}	0.13^{i}	0.09^{f}	0.11^{h}	0.10^{h}
H_3W_2	0.28^{f}	0.23^{cd}	0.26^{d}	0.21^{g}	0.22^{de}	0.22^{f}	0.19^{d}	0.19^{g}	0.19^{hi}	0.16^{h}	0.16^{gh}	0.16^{h}	0.12^{f}	0.13^{gh}	0.12^{h}
H_3W_3	0.29^{ef}	0.20^{d}	0.25^{d}	0.26^{fg}	0.23^{de}	0.24^{ef}	0.22^{d}	0.20^{fg}	0.21^{gh}	0.20^{fg}	0.19^{fg}	0.19^{fg}	0.18^{e}	0.16^{fg}	0.17^{fg}
H_3W_4	0.25^{f}	0.23^{cd}	0.24^{d}	0.22^{fg}	0.21^{e}	0.22^{f}	0.19^{d}	0.18^{g}	0.19^{hi}	0.15^{h}	0.16^{gh}	0.16^{gh}	0.11^{f}	0.12^{h}	0.12^{h}
H_3W_5	0.27^{f}	0.22^{cd}	0.25^{d}	0.25^{fg}	0.24^{de}	0.25^{ef}	0.23^{d}	0.22^{ef}	0.23^{fg}	0.23^{ef}	0.21^{ef}	0.22^{ef}	0.19^{de}	0.18^{de}	0.19^{ef}
SEm±	**0.021**	**0.032**	**0.019**	**0.024**	**0.013**	**0.013**	**0.016**	**0.011**	**0.009**	**0.011**	**0.010**	**0.007**	**0.012**	**0.011**	**0.008**
CD (P=0.05)	**0.060**	**NS**	**NS**	**0.068**	**NS**	**0.038**	**0.046**	**NS**	**0.027**	**0.030**	**0.028**	**0.020**	**NS**	**NS**	**NS**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

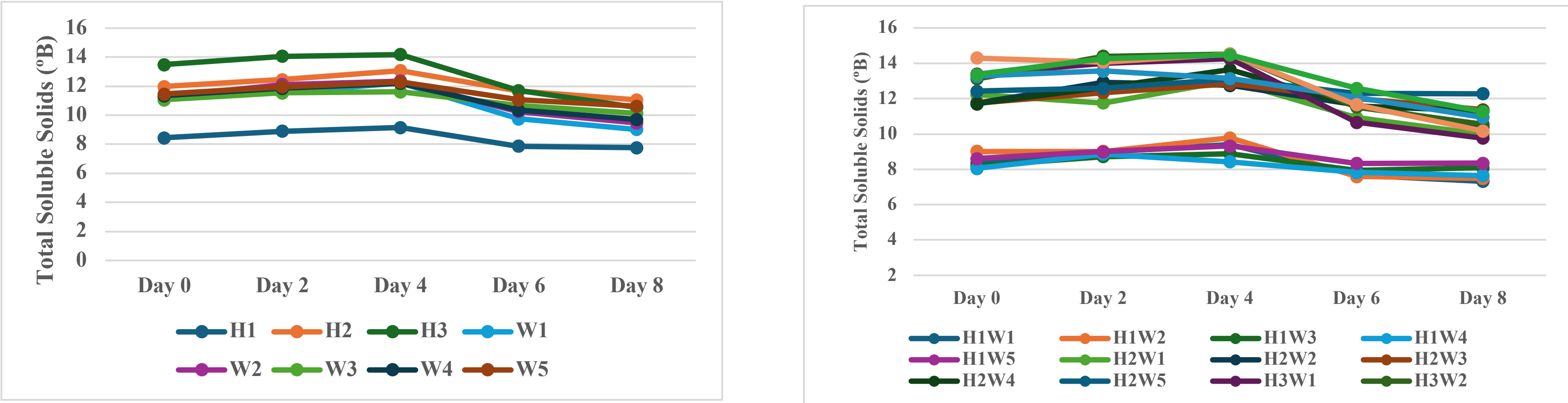


Figure 4.4: Individual and interaction effect of harvesting stages and wrapping materials on Total Soluble Solids

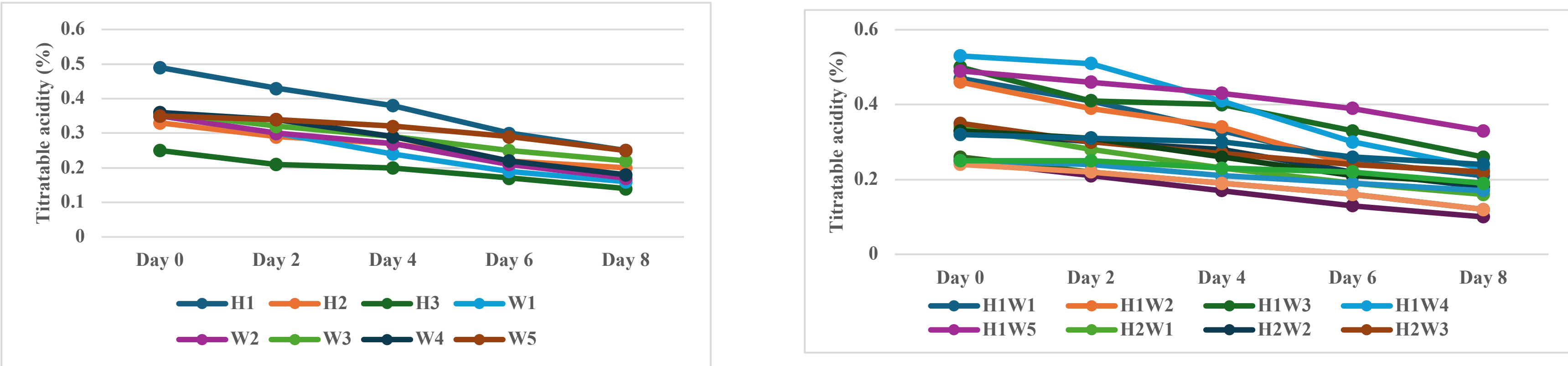


Figure 4.5: Individual and interaction effect of harvesting stages and wrapping materials on Titratable acidity.

4.1.10 TSS-Acid ratio

The results obtained from TSS- Acid ratio presented in Table 4.19 and Figure 4.5 showed a significant difference among the harvesting stages and reflected an increasing trend during the time of storage. At the time of harvest, minimum value was recorded at 25 DAA (H_1) with (17.64) which may be due to increased acidity in immature fruits and the maximum TSS-acid ratio was recorded in H_3 (35 DAA) with 55.74 followed by H_2 (30 DAA) with 37.30. Similar trend of increase in TSS-acid ratio with progression in maturity stage was reported by Ortiz and Takahashi (2015) in dragon fruit and Babu *et. al.* (2017) in pomegranate. It was reported by To *et. al.* (2002) that the optimum TSS- acid ratio for dragon fruit is approximately 40 and fruits achieved this value at 31 DAA.

Wrapping materials also has a significant effect on the TSS-acid ratio of dragon fruit during the storage period. During storage, the TSS-acid ratio in fruits packaged in shrink wrapping (W_5) was found to be more stable as compared to the other treatments. At the end of storage, the maximum value (65.90) was recorded in W_1 (no wrapping) and the minimum ratio was found in W_5 (shrink wrapping) with 45.61. TSS-acid ratio is related to the palatability of the fruit, representing the balance between sweet. and sour taste. Dragon fruit normally has low sugar content and a progressive decrease in acidity also occurs during storage.

Data regarding the interaction effect of harvesting stages and wrapping materials on TSS-acid ratio is presented in Table 4.20 and Figure 4.5 which shows an increasing trend. On the last day of storage, maximum TSS-acid ratio was recorded in H_3W_1 (35 DAA, no wrapping) and minimum value was recorded in H_1W_5 (25 DAA, shrink wrapping). Considering the optimum TSS-acid ratio as 40, the ideal retention of balance between TSS and acidity was observed in harvest at 30 DAA with shrink wrapping until day 4 of storage.

4.1.11 Total sugar (%)

The findings on total sugar content as influenced by harvesting stages and wrapping fruits in dragon fruit is tabulated in Table 4.21 and Figure 4.7 which shows significant difference among the treatments. On the day of harvest (day 0), highest total sugar content (8.43%) was recorded in H_3 (35 DAA) and minimum value (4.90%) was recorded in H_1 (25 DAA), which projects an increase in the amount of total sugar content with the advancement in fruit maturation. During the storage period, slight increase in sugar content was observed until day 4 in H_1, after which there was a progressive decrease. Highest total sugar content during the entire storage days was recorded at day 4 in H_2 (30 DAA) with 9.11%. At the end of observation (day 8), highest total sugar content (7.14%) was observed in H_2 (30 DAA) followed by H_3 (35 DAA) and the least sugar content (4.20%) in initial harvest (H_1- 25 DAA). Similar decreasing trend has been reported by Punitha *et. al.* (2010) and Lata *et. al.* (2022) in dragon fruit.

Likewise, wrapping materials had significant effect on the total sugar content of dragon fruit on all days of observation, except on the day of harvest. A decreasing trend was observed during the days of storage. Total sugar content for control fruits with no wrapping had higher rate of reduction throughout storage compared to the wrapped fruits. On the final day of observation, the maximum total sugar content (6.54%) was recorded in W_5 (shrink wrapping) followed by W_3 (brown paper) with 5.78%, while the minimum content (4.43%) was found in W_1 (no wrapping).

Date concerning the interaction effect on total sugar content in dragon fruit presented in Table 4.22 and Figure 4.7 showed significant variation among the treatments. On the final day of observation (day 8), the maximum value (8.02%) was recorded in H_2W_5 (30 DAA, shrink wrapping) followed by H_2W_3 (30 DAA, brown paper) with 7.56% and the minimum amount of total sugar (3.42%) was recorded in H_3W_1 (25 DAA, no wrapping). Dragon fruit being a non- climacteric fruit (Mizrahi and Nerd, 1999), generally achieve the peak sweetness before harvest and lack accumulation of carbohydrates within the fruits, thus, typically do not undergo significant conversion of starch to sugar after harvest, also there is lack of additional source of assimilates for sugar unlike fruits still attached to tree (Punitha *et. al.,* 2010). After harvest, fruits continue to respire and the sugar that is produced within the fruit are consumed for energy. This ongoing respiration lead to a gradual decrease in sugar content over time during storage.

4.1.12 Reducing sugar (%)

With regard to effect of harvesting stages on reducing sugar content in dragon fruit, from the data presented in Table 4.23 and Figure 4.8, significant variation was observed on all the days of observation. On the day of harvest, maximum value (5.35%) was recorded in H_3 (35 DAA) and minimum reducing sugar content (3.48) in H_1 (25 DAA). A similar trend to total sugar content was observed during the storage period. On the last day of observation, the highest retention of reducing sugar was recorded in H_2 (30 DAA), followed by H_3 (35 DAA) and the minimum value was recorded in H_1 (25 DAA). Fairly similar finding has been reported by Trong *et. al.* (2022) where reducing sugar content increased rapidly as the fruit progressed towards ripening and a maximum was reached at 32 DAA, after which there was a decrease, which he remarked that the fruit undergo ripening stage and a large amount of organic acids and starch are converted into sugar. The primary sugar in dragon fruit are glucose and fructose, while sucrose is present in lesser amount (Wang *et. al.,* 2024; Wu *et. al.,* 1997).

Wrapping materials also had a significant effect on all the days of observation except on the day of harvest as presented in Table 4.23 and Figure 4.8. The maximum reduction in reducing sugar was recorded in W_1 (control) followed by W_2 (Banana leaves) and the minimum decrease was observed in W_5 (Shrink wrapping) with the highest value (4.58%) on the last day of observation. Shrink wrapping projected a more steady decrease in the sugar content during the storage period as compared to the other treatments. This may be due to its ability reduce the rate of respiration and minimize the use of soluble substrates for such metabolic activities.

Data presented in Table 4.24 and Figure 4.8 on the interaction effect of harvesting stages and wrapping materials on reducing sugar show significant variation where H_2W_5 (30 DAA, shrink wrapping) retained the highest amount of reducing sugar with, as compared to other treatments and H_3W_1 (35 DAA, no wrapping) showed the highest deterioration in the reducing sugar content with 5.25% and 2.36% respectively on the last day of storage.

Table 4.19: Effect of different harvesting stages and wrapping materials on Total Soluble Solids (TSS)- Acid of dragon fruit

Treatments	*Total Soluble Solids: Acid*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
Harvesting stages (H)															
H_1	17.44^{c}	17.83^{c}	17.64^{c}	20.49^{c}	21.49^{c}	20.99^{c}	23.26^{c}	25.97^{c}	24.62^{c}	26.21^{c}	27.66^{a}	26.94^{a}	32.36^{a}	32.08^{a}	32.22^{a}
H_2	35.14^{b}	39.46^{b}	37.30^{b}	38.25^{b}	46.39^{b}	42.32^{b}	44.19^{b}	56.04^{b}	50.11^{b}	50.26^{b}	61.35^{b}	55.80^{b}	55.01^{b}	58.17^{b}	56.59^{b}
H_3	51.29^{a}	60.19^{a}	55.74^{a}	62.74^{a}	62.88^{a}	62.81^{a}	72.79^{a}	74.09^{a}	73.44^{a}	72.16^{a}	67.62^{a}	69.89^{c}	83.29^{c}	75.90^{c}	79.60^{c}
Sem±	*1.52*	*1.54*	*1.08*	*1.17*	*1.01*	*0.77*	*1.42*	*1.48*	*1.02*	*1.28*	*1.72*	*1.07*	*1.82*	*1.50*	*1.18*
CD (P=0.05)	*4.39*	*4.45*	*3.06*	*3.38*	*2.91*	*2.18*	*4.09*	*4.26*	*2.89*	*3.70*	*4.96*	*3.03*	*5.27*	*4.32*	*3.34*
Wrapping materials (W)															
W_1	35.92^{a}	37.23^{a}	36.57^{a}	43.43^{a}	43.92^{ab}	43.68^{ab}	53.84^{a}	59.37^{a}	56.60^{a}	57.11^{a}	61.78^{a}	59.45^{a}	67.70^{a}	64.11^{a}	65.90^{a}
W_2	33.94^{a}	39.45^{a}	36.70^{a}	42.93^{ab}	46.60^{a}	44.76^{a}	49.27^{a}	54.75^{ab}	52.01^{b}	53.08^{ab}	53.83^{b}	53.45^{b}	62.56^{a}	57.47^{b}	60.02^{b}
W_3	33.05^{a}	39.72^{a}	36.39^{a}	38.00^{b}	41.89^{b}	39.94^{b}	39.75^{b}	48.51^{cd}	44.13^{c}	45.02^{c}	49.42^{b}	47.22^{c}	48.01^{b}	50.60^{c}	49.31^{c}
W_4	35.02^{a}	39.59^{a}	37.31^{a}	39.43^{ab}	44.56^{ab}	41.99^{ab}	48.68^{a}	52.43^{bc}	50.55^{b}	51.36^{b}	53.11^{b}	52.24^{b}	61.66^{a}	58.04^{b}	59.85^{b}
W_5	35.19^{a}	39.81^{a}	37.50^{a}	38.68^{b}	40.96^{b}	39.82^{b}	42.18^{b}	45.11^{d}	43.65^{c}	41.14^{c}	42.91^{c}	42.03^{d}	44.51^{d}	46.70^{c}	45.61^{c}
SEm±	*1.96*	*1.99*	*1.40*	*1.51*	*1.30*	*1.00*	*1.83*	*1.91*	*1.32*	*1.65*	*2.22*	*1.38*	*2.35*	*1.93*	*1.52*
CD (P=0.05)	*NS*	*NS*	*NS*	*4.36*	*NS*	*2.82*	*5.28*	*NS*	*3.74*	*4.77*	*6.40*	*3.91*	*6.80*	*5.58*	*4.31*

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

Table 4.20: Interaction effect of different harvesting stages and wrapping materials on Total Soluble Solids (TSS)- Acid ratio of dragon fruit

Treatments (H x W interaction)	*Total Soluble Solids : Acid*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	18.90^{d}	17.07^{d}	17.99^{d}	24.59^{d}	20.55^{f}	22.57^{d}	26.94^{gh}	30.84^{f}	28.89^{g}	30.14^{f}	32.88^{e}	31.51^{f}	34.98^{ef}	36.67^{e}	35.82^{f}
H_1W_2	20.14^{d}	20.04^{d}	20.09^{d}	23.72^{de}	23.20^{f}	23.46^{d}	29.42^{g}	28.52^{f}	28.97^{g}	32.95^{f}	29.81^{e}	31.38^{f}	36.26^{e}	33.49^{ef}	34.87^{f}
H_1W_3	17.45^{d}	16.17^{d}	16.81^{d}	20.26^{de}	22.04^{f}	21.15^{de}	20.80^{gh}	24.31^{f}	22.56^{gh}	23.12^{g}	25.37^{e}	24.24^{g}	31.47^{f}	31.06^{ef}	31.27^{fg}
H_1W_4	14.62^{d}	16.22^{d}	15.42^{d}	16.01^{e}	19.91^{f}	17.96^{e}	19.86^{h}	21.53^{f}	20.70^{h}	24.36^{g}	27.75^{e}	26.06^{fg}	34.43^{ef}	33.20^{ef}	33.82^{f}
H_1W_5	16.11^{d}	19.63^{d}	17.87^{d}	17.89^{de}	21.73^{f}	19.81^{de}	19.28^{h}	24.65^{f}	21.96^{h}	20.49^{g}	22.50^{e}	21.50^{g}	24.67^{f}	25.97^{f}	25.32^{g}
H_2W_1	35.46^{c}	37.54^{c}	36.50^{c}	39.33^{c}	44.96^{e}	42.15^{c}	50.38^{cd}	63.43^{bc}	56.90^{cd}	56.44^{d}	74.62^{a}	65.53^{c}	60.50^{cd}	62.95^{c}	61.73^{c}
H_2W_2	32.28^{c}	43.32^{c}	37.80^{c}	36.87^{c}	51.18^{d}	44.02^{c}	38.82^{f}	58.66^{cd}	48.74^{ef}	49.94^{e}	62.22^{bc}	56.08^{d}	55.93^{cd}	60.03^{cd}	57.98^{cd}
H_2W_3	36.45^{c}	36.89^{c}	36.67^{c}	39.17^{c}	45.43^{de}	42.30^{c}	41.45^{ef}	54.23^{de}	47.84^{ef}	47.34^{e}	62.09^{c}	54.72^{d}	50.20^{cd}	56.11^{cd}	53.15^{de}
H_2W_4	33.96^{c}	38.11^{c}	36.03^{c}	36.09^{c}	48.43^{d}	42.26^{c}	47.66^{de}	57.02^{cd}	52.34^{de}	51.84^{de}	58.54^{cd}	55.19^{d}	59.34^{cd}	58.74^{cd}	59.04^{cd}
H_2W_5	37.56^{c}	41.44^{c}	39.50^{c}	39.78^{c}	41.94^{e}	40.86^{c}	42.62^{ef}	46.84^{e}	44.73^{f}	45.73	49.26^{d}	47.49^{e}	49.06^{d}	53.05^{d}	51.06^{e}
H_3W_1	53.41^{ab}	57.06^{ab}	55.24^{ab}	66.38^{a}	66.24^{a}	66.31^{a}	84.19^{a}	83.84^{a}	84.02^{a}	84.75^{a}	77.85^{a}	81.30^{a}	107.62^{a}	92.70^{a}	100.16^{a}
H_3W_2	49.42^{ab}	54.97^{b}	52.20^{b}	68.19^{a}	65.41^{ab}	66.80^{a}	79.58^{a}	77.06^{a}	78.32^{a}	76.34^{b}	69.45^{ab}	72.90^{b}	95.50^{b}	78.90^{b}	87.20^{b}
H_3W_3	45.25^{b}	66.10^{a}	55.68^{ab}	54.56^{b}	58.20^{c}	56.38^{b}	57.00^{bc}	66.98^{b}	61.99^{bc}	64.60^{c}	60.79^{c}	62.69^{c}	62.35^{c}	64.64^{c}	63.50^{c}
H_3W_4	56.48^{a}	64.44^{ab}	60.46^{a}	66.20^{a}	65.33^{ab}	65.77^{a}	78.53^{a}	78.73^{a}	78.63^{a}	77.90^{ab}	73.04^{ab}	75.47^{b}	91.20^{ab}	82.17^{b}	86.69^{b}
H_3W_5	51.89^{ab}	58.36^{ab}	55.12^{ab}	58.38^{b}	59.21^{bc}	58.79^{b}	64.65^{b}	63.86^{bc}	64.25^{b}	57.21^{cd}	56.98^{cd}	57.09^{d}	59.79^{c}	61.09^{c}	60.44^{c}
SEm±	**3.40**	**3.44**	**2.42**	**2.61**	**2.26**	**1.73**	**3.17**	**3.30**	**2.29**	**2.86**	**3.84**	**2.39**	**4.08**	**3.35**	**2.64**
CD (P=0.05)	**NS**	**NS**	**NS**	**7.55**	**6.52**	**4.88**	**9.15**	**9.53**	**6.47**	**8.26**	**NS**	**NS**	**11.77**	**9.66**	**7.46**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

Table 4.21: Effect of different harvesting stages and wrapping materials on Total sugar of dragon fruit

Treatments	*Total sugar (%)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
Harvesting stages (H)															
H_1	4.92^{c}	4.89^{b}	4.90^{c}	5.14^{c}	4.95^{b}	5.04^{c}	5.56^{c}	5.20^{c}	5.38^{c}	4.62^{c}	4.79^{c}	4.71^{c}	4.04^{c}	4.36^{c}	4.20^{c}
H_2	7.13^{b}	8.65^{a}	7.89^{b}	8.61^{a}	8.37^{a}	8.49^{a}	8.99^{a}	9.24^{a}	9.11^{a}	7.18^{a}	8.70^{a}	7.94^{a}	6.68^{a}	7.60^{a}	7.14^{a}
H_3	8.67^{a}	8.18^{a}	8.43^{a}	8.06^{b}	8.05^{a}	8.06^{b}	8.41^{b}	8.01^{b}	8.21^{b}	6.28^{b}	6.60^{b}	6.44^{b}	4.70^{b}	5.17^{b}	4.94^{b}
SEm±	**0.239**	**0.213**	**0.160**	**0.107**	**0.134**	**0.086**	**0.138**	**0.141**	**0.098**	**0.219**	**0.139**	**0.130**	**0.146**	**0.087**	**0.085**
CD (P=0.05)	**0.692**	**0.615**	**0.453**	**0.309**	**0.387**	**0.243**	**0.397**	**0.407**	**0.279**	**0.632**	**0.400**	**0.366**	**0.422**	**0.250**	**0.240**
Wrapping materials (W)															
W_1	6.85^{ab}	7.22^{a}	7.04^{ab}	6.79^{c}	7.32^{ab}	7.06^{b}	6.86^{c}	7.67^{a}	7.27^{b}	5.16^{c}	6.09^{c}	5.62^{c}	4.13^{c}	4.73^{d}	4.43^{e}
W_2	7.25^{a}	7.08^{a}	7.16^{ab}	7.33^{ab}	6.88^{bc}	7.10^{b}	7.94^{ab}	7.09^{b}	7.51^{ab}	5.62^{bc}	6.72^{b}	6.17^{b}	4.61^{c}	5.40^{c}	5.00^{d}
W_3	6.31^{b}	6.97^{a}	6.64^{b}	7.41^{ab}	7.49^{a}	7.45^{a}	7.57^{b}	7.82^{a}	7.70^{a}	6.25^{b}	6.89^{ab}	6.57^{b}	5.43^{b}	6.13^{b}	5.78^{b}
W_4	6.92^{ab}	7.32^{a}	7.12^{ab}	7.73^{a}	6.57^{c}	7.15^{ab}	8.17^{a}	7.15^{b}	7.66^{a}	6.00^{b}	6.45^{bc}	6.22^{b}	5.11^{bc}	5.62^{c}	5.36^{c}
W_5	7.20^{a}	7.61^{a}	7.40^{a}	7.07^{b}	7.37^{a}	7.22^{ab}	7.73^{ab}	7.69^{a}	7.71^{a}	7.11^{a}	7.33^{a}	7.22^{a}	6.41^{a}	6.67^{a}	6.54^{a}
SEm±	**0.309**	**0.275**	**0.207**	**0.138**	**0.173**	**0.111**	**0.178**	**0.182**	**0.127**	**0.283**	**0.179**	**0.167**	**0.189**	**0.112**	**0.110**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.399**	**0.500**	**0.313**	**0.513**	**0.525**	**0.360**	**0.816**	**0.517**	**0.473**	**0.545**	**0.323**	**0.310**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

Table 4.22: Interaction effect of different harvesting stages and wrapping materials on total sugar of dragon fruit

Treatments (H x W interaction)	***Total sugar (%)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	4.76^{e}	5.19^{c}	4.98^{c}	4.80^{f}	4.97^{ef}	4.88^{e}	5.03^{f}	6.15^{e}	5.59^{c}	3.85^{e}	4.84^{e}	4.35^{g}	3.40^{f}	3.43^{g}	3.42^{i}
H_1W_2	5.43^{de}	4.73^{c}	5.08^{c}	5.31^{e}	4.83^{ef}	5.07^{e}	5.33^{f}	4.42^{f}	4.88^{d}	3.72^{e}	5.13^{de}	4.42^{fg}	3.34^{f}	4.39^{f}	3.87^{hi}
H_1W_3	4.19^{e}	4.96^{c}	4.58^{c}	4.77^{f}	5.20^{ef}	4.99^{e}	4.97^{f}	5.76^{e}	5.37^{cd}	5.06^{d}	5.28^{de}	5.17^{ef}	4.66^{de}	4.56^{ef}	4.61^{g}
H_1W_4	5.07^{e}	4.33^{c}	4.70^{c}	5.59^{e}	4.40^{f}	5.00^{e}	6.83^{e}	4.05^{f}	5.44^{cd}	4.87^{de}	3.30^{f}	4.09^{g}	3.39^{f}	4.18^{f}	3.79^{hi}
H_1W_5	5.14^{e}	5.25^{c}	5.20^{c}	5.20^{ef}	5.36^{e}	5.28^{e}	5.65^{f}	5.65^{e}	5.65^{c}	5.62^{d}	5.43^{de}	5.52^{e}	5.43^{cd}	5.26^{d}	5.34^{f}
H_2W_1	7.39^{bc}	8.52^{ab}	7.95^{a}	8.13^{bc}	8.65^{b}	8.39^{bc}	6.80^{e}	9.11^{ab}	7.95^{b}	5.50^{d}	7.64^{b}	6.57^{cd}	5.44^{cd}	6.35^{c}	5.90^{e}
H_2W_2	7.06^{c}	8.18^{ab}	7.62^{b}	8.26^{bc}	7.80^{bc}	8.03^{cd}	10.04^{a}	8.74^{bc}	9.39^{a}	7.20^{bc}	8.50^{a}	7.85^{b}	6.58^{b}	7.26^{b}	6.92^{c}
H_2W_3	6.85^{cd}	8.34^{ab}	7.59^{b}	9.44^{a}	9.54^{a}	9.49^{a}	9.75^{ab}	9.81^{a}	9.78^{a}	7.59^{ab}	8.78^{a}	8.18^{b}	6.82^{ab}	8.29^{a}	7.56^{b}
H_2W_4	6.57^{cd}	9.12^{a}	7.85^{a}	9.02^{a}	6.87^{d}	7.94^{d}	9.09^{bc}	9.38^{ab}	9.23^{a}	6.72^{b}	9.23^{a}	7.98^{b}	6.79^{ab}	7.79^{ab}	7.29^{bc}
H_2W_5	7.78^{ab}	9.09^{a}	8.44^{ab}	8.19^{bc}	9.02^{a}	8.60^{b}	9.27^{ab}	9.15^{ab}	9.21^{a}	8.90^{a}	9.34^{a}	9.12^{a}	7.74^{a}	8.29^{a}	8.02^{a}
H_3W_1	8.40^{ab}	7.96^{ab}	8.18^{ab}	7.45^{d}	8.35^{bc}	7.90^{d}	8.76^{cd}	7.76^{d}	8.26^{b}	6.13^{cd}	5.79^{d}	5.96^{de}	3.56^{f}	4.41^{ef}	3.98^{h}
H_3W_2	9.26^{a}	8.33^{ab}	8.79^{a}	8.42^{bc}	8.01^{bc}	8.21^{bc}	8.44^{cd}	8.12^{cd}	8.28^{b}	5.94^{cd}	6.54^{c}	6.24^{cd}	3.90^{ef}	4.55^{ef}	4.23^{gh}
H_3W_3	7.88^{ab}	7.61^{b}	7.75^{b}	8.03^{bc}	7.72^{c}	7.87^{d}	7.99^{d}	7.90^{d}	7.95^{b}	6.11^{cd}	6.60^{c}	6.36^{cd}	4.82^{cd}	5.53^{d}	5.18^{f}
H_3W_4	9.14^{a}	8.52^{ab}	8.83^{ab}	8.58^{b}	8.45^{bc}	8.51^{bc}	8.60^{cd}	8.01^{cd}	8.31^{b}	6.40^{bc}	6.82^{bc}	6.61^{cd}	5.14^{cd}	4.89^{e}	5.02^{f}
H_3W_5	8.68^{ab}	8.48^{ab}	8.58^{ab}	7.83^{cd}	7.74^{c}	7.78^{d}	8.27^{d}	8.28^{cd}	8.27^{b}	6.82^{bc}	7.23^{b}	7.02^{c}	6.07^{bc}	6.47^{c}	6.27^{d}
SEm±	**0.536**	**0.476**	**0.358**	**0.239**	**0.300**	**0.192**	**0.308**	**0.315**	**0.220**	**0.490**	**0.310**	**0.290**	**0.327**	**0.194**	**0.190**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.692**	**0.866**	**0.543**	**0.888**	**0.910**	**0.623**	**NS**	**0.895**	**0.819**	**NS**	**0.560**	**0.537**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

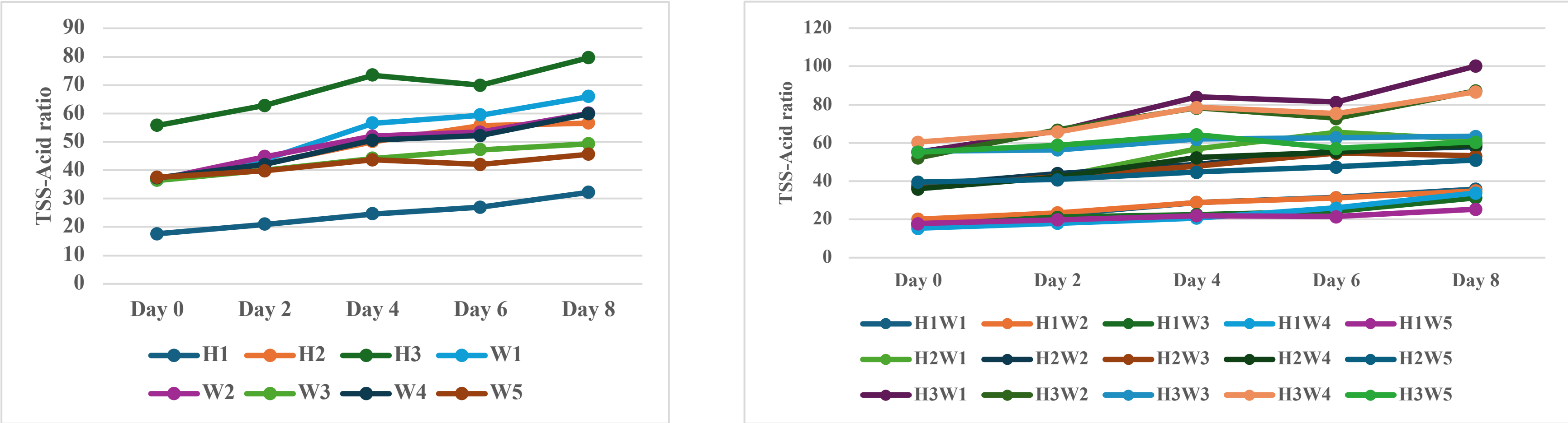


Figure 4.6: Individual and interaction effect of harvesting stages and wrapping materials on TSS-Acid ratio

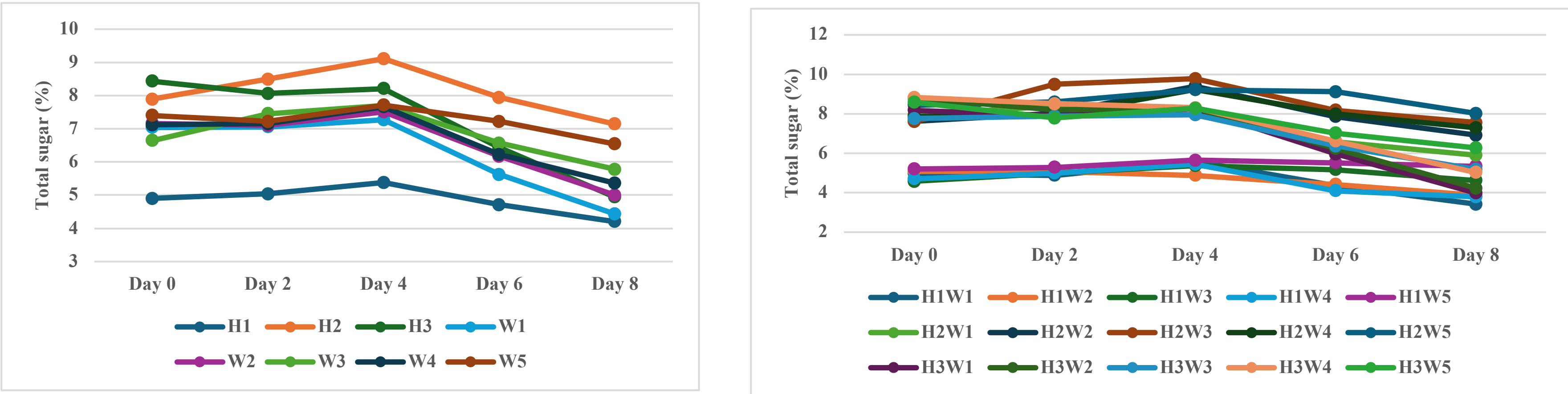


Figure 4.7: Individual and interaction effect of harvesting stages and wrapping materials on Total sugar content

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

4.1.13 Non-reducing sugar (%)

The data on non- reducing sugar content of dragon fruit as influenced by harvesting time and wrapping materials is presented in Table 4.25 and Figure 4.9 which depicts a significant variation among the treatments. At 0 DAH, highest non- reducing sugar content was recorded in H_2 (30 DAA) with 3.05% and minimum in the initial stage of harvest H_1 (25 DAA) with 1.35%. Wrapping materials also had a significant effect on all the days of observation except on the day of harvest as presented in table. On the last day of observation, the maximum non-reducing sugar content was recorded in W_5 (shrink wrapping) followed by W_3 (brown paper) and the minimum content was observed in W_1 (no wrapping) with 1.86%, 1.51% and 1.29% respectively.

Pooled data on interaction effect of harvesting stages and wrapping materials is laid out in Table 4.26 and Figure 4.9 which depicted to have significant variation among the treatments. At the end of storage, maximum retention of non-reducing sugar content was recorded in H_2W_5 (30 DAA, shrink wrapping) with 2.63% while the minimum non-reducing sugar is seen in H_3W_4 (35 DAA, EPE foam net) with 0.83%.

4.1.14 Ascorbic acid (mg/100g pulp)

The data pertaining to effect of harvesting stages and wrapping materials on ascorbic acid content in dragon fruit is presented in Table 4.27 and Figure 4.10 which depicts significant variation among the treatments for all the days of observation except on the day of harvest for wrapping materials. Ascorbic acid was recorded to be more in immature fruits with maximum content (9.82 mg/100ml) in H_1 (25 DAA) and the minimum content (5.04 mg/100ml) in H_3 (35 DAA) on the day of harvest. This finding indicated that ascorbic acid decreased with advancement in fruit maturity so ascorbic acid was higher in fruits harvested at initial maturity, which has also been reported by Franco *et. al.* (2022), Martineli *et. al.* (2020), Enciso *et. al.* (2011) in dragon fruit, Blissett *et. al.* (2019), Baloch and Bibi (2012) in mango, Deepthi *et. al.* (2016) in guava, Kamol *et. al.* (2014), Gomez *et. al.* (2023) in pineapple, Rahman *et. al.* (2014) in strawberry and Rekha *et. al.* (2012) in citrus. On the last day of observation, the maximum ascorbic content was found in H_1 (25 DAA) with 8.22 mg/100ml

Table 4.23: Effect of different harvesting stages and wrapping materials on Reducing sugar of dragon fruit

Treatments	***Reducing sugar (%)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
Harvesting stages (H)															
H_1	3.39^{c}	3.57^{c}	3.48^{c}	3.52^{c}	3.76^{c}	3.64^{c}	3.84^{c}	4.03^{c}	3.94^{c}	3.60^{b}	3.55^{c}	3.58^{c}	2.94^{c}	2.90^{c}	2.92^{c}
H_2	4.71^{b}	4.66^{b}	4.68^{b}	4.80^{b}	4.91^{b}	4.86^{b}	4.93^{b}	5.19^{b}	5.06^{b}	5.02^{a}	5.28^{a}	5.15^{a}	4.75^{a}	4.98^{a}	4.87^{a}
H_3	5.21^{a}	5.48^{a}	5.35^{a}	5.45^{a}	5.67^{a}	5.56$_{a}$	5.48^{a}	5.56^{a}	5.52^{a}	5.10^{a}	4.49^{b}	4.80^{b}	3.79^{b}	3.87^{b}	3.83^{b}
SEm±	**0.054**	**0.071**	**0.045**	**0.008**	**0.021**	**0.011**	**0.073**	**0.040**	**0.042**	**0.066**	**0.066**	**0.046**	**0.092**	**0.075**	**0.059**
CD (P=0.05)	**0.157**	**0.205**	**0.126**	**0.023**	**0.059**	**0.031**	**0.212**	**0.115**	**0.118**	**0.190**	**0.189**	**0.132**	**0.264**	**0.218**	**0.168**
Wrapping materials (W)															
W_1	4.48^{ab}	4.62^{a}	4.55^{a}	4.59^{b}	4.75^{b}	4.67^{b}	4.66^{b}	4.75^{c}	4.70^{b}	3.98^{b}	3.60^{c}	3.79^{c}	3.12^{c}	3.03^{d}	3.08^{d}
W_2	4.50^{a}	4.63^{a}	4.56^{a}	4.64^{a}	4.81^{a}	4.72^{a}	4.43^{b}	4.54^{d}	4.49^{c}	4.79^{a}	4.34^{b}	4.56^{b}	3.67^{b}	3.40^{c}	3.54^{c}
W_3	4.29^{b}	4.40^{a}	4.34^{b}	4.54^{c}	4.75^{b}	4.65^{b}	4.95^{a}	5.08^{b}	5.02^{a}	4.75^{a}	4.82^{a}	4.79^{a}	4.20^{a}	4.19^{b}	4.19^{b}
W_4	4.48^{ab}	4.56^{a}	4.52^{a}	4.60^{b}	4.76^{ab}	4.68^{ab}	4.73^{ab}	4.98^{b}	4.85^{b}	4.58^{a}	4.41^{b}	4.49^{b}	3.81^{b}	4.16^{b}	3.98^{b}
W_5	4.44^{ab}	4.65^{a}	4.55^{a}	4.59^{b}	4.84^{a}	4.71^{a}	4.99^{a}	5.30^{a}	5.14^{a}	4.78^{a}	5.03^{a}	4.90^{a}	4.35^{a}	4.82^{a}	4.58^{a}
SEm±	**0.070**	**0.092**	**0.058**	**0.010**	**0.027**	**0.014**	**0.095**	**0.051**	**0.054**	**0.085**	**0.085**	**0.060**	**0.118**	**0.097**	**0.077**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.030**	**NS**	**0.040**	**0.274**	**0.148**	**0.152**	**0.246**	**0.244**	**0.170**	**0.341**	**0.281**	**0.217**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.24: Interaction effect of different harvesting stages and wrapping materials on Reducing sugar of dragon fruit

Treatments (H x W interaction)	*Reducing sugar (%)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
H_1W_1	3.45^{d}	3.57^{d}	3.51^{d}	3.56^{e}	3.66^{h}	3.61^{f}	3.69^{f}	3.85^{g}	3.77^{h}	2.77^{f}	2.24^{f}	2.51^{g}	2.44^{e}	2.63^{gh}	2.54^{hi}
H_1W_2	3.41^{d}	3.50^{d}	3.45^{d}	3.53^{e}	3.73^{gh}	3.63^{f}	3.82^{f}	4.04^{fg}	3.93^{gh}	3.86^{e}	3.62^{e}	3.74^{f}	2.78^{de}	2.33^{hi}	2.55^{hi}
H_1W_3	3.31^{d}	3.66^{d}	3.48^{d}	3.44^{f}	3.87^{f}	3.65^{f}	4.15^{ef}	4.11^{f}	4.13^{g}	3.76^{e}	4.04^{de}	3.90^{ef}	3.21^{cd}	3.02^{fg}	3.12^{fg}
H_1W_4	3.44^{d}	3.52^{d}	3.48^{d}	3.58^{e}	3.74^{fg}	3.66^{f}	3.71^{f}	3.92^{g}	3.82^{h}	3.82^{e}	3.74^{d}	3.78^{f}	2.54^{e}	3.16^{f}	2.85^{gh}
H_1W_5	3.36^{d}	3.63^{d}	3.50^{d}	3.47^{f}	3.82^{fg}	3.65^{f}	3.85^{f}	4.25^{f}	4.05^{gh}	3.79^{e}	4.11^{d}	3.95^{ef}	3.59^{c}	3.89^{d}	3.74^{e}
H_2W_1	4.76^{c}	4.84^{b}	4.80^{b}	4.85^{c}	4.98^{d}	4.92^{d}	4.80^{de}	5.05^{d}	4.92^{f}	4.87^{cd}	4.62^{c}	4.75^{c}	4.32^{b}	4.35^{cd}	4.34^{d}
H_2W_2	4.75^{c}	4.69^{b}	4.72^{bc}	4.86^{c}	4.82^{e}	4.84^{e}	4.68^{de}	4.70^{e}	4.69^{f}	4.79^{d}	5.27^{ab}	5.03^{bc}	4.81^{ab}	4.68^{bc}	4.75^{bc}
H_2W_3	4.63^{c}	4.19^{c}	4.41^{c}	4.72^{d}	4.87^{de}	4.80^{e}	5.06^{d}	5.38^{c}	5.22^{de}	5.12^{bc}	5.43^{a}	5.27^{ab}	4.90^{ab}	5.19^{a}	5.05^{ab}
H_2W_4	4.74^{c}	4.75^{b}	4.75^{b}	4.82^{c}	4.90^{de}	4.86^{de}	4.93^{cd}	5.30^{c}	5.12^{ef}	5.08^{bc}	5.42^{ab}	5.25^{ab}	4.65^{ab}	5.26^{a}	4.96^{ab}
H_2W_5	4.67^{c}	4.81^{b}	4.74^{b}	4.77^{cd}	4.97^{d}	4.87^{de}	5.19^{bc}	5.54^{bc}	5.37^{d}	5.25^{bc}	5.65^{a}	5.45^{a}	5.07^{a}	5.44^{a}	5.25^{a}
H_3W_1	5.22^{ab}	5.44^{a}	5.33^{a}	5.36^{b}	5.62^{bc}	5.49^{c}	5.48^{ab}	5.36^{c}	5.42^{cd}	4.30^{d}	3.93^{d}	4.12^{e}	2.59^{e}	2.12^{i}	2.36^{i}
H_3W_2	5.33^{a}	5.70^{a}	5.52^{a}	5.52^{a}	5.90^{a}	5.71^{a}	4.79^{cd}	4.89^{d}	4.84^{f}	5.72^{a}	4.12^{d}	4.92^{c}	3.42^{c}	3.20^{f}	3.31^{f}
H_3W_3	4.93^{bc}	5.35^{a}	5.14^{a}	5.47^{a}	5.50^{c}	5.49^{c}	5.65^{ab}	5.75^{b}	5.70^{b}	5.38^{ab}	5.00^{bc}	5.19^{ab}	4.47^{b}	4.37^{cd}	4.42^{cd}
H_3W_4	5.27^{ab}	5.40^{a}	5.33^{a}	5.39^{b}	5.62^{bc}	5.50^{c}	5.54^{ab}	5.70^{b}	5.62^{bc}	4.82^{cd}	4.06^{d}	4.44^{d}	4.22^{b}	4.06^{d}	4.14^{d}
H_3W_5	5.30^{a}	5.51^{a}	5.41^{a}	5.52^{a}	5.73^{b}	5.63^{b}	5.92^{a}	6.11^{a}	6.02^{a}	5.30^{ab}	5.33^{a}	5.31^{ab}	4.37^{b}	5.12^{ab}	4.75^{bc}
SEm±	**0.121**	**0.159**	**0.100**	**0.018**	**0.046**	**0.025**	**0.164**	**0.089**	**0.093**	**0.147**	**0.147**	**0.104**	**0.205**	**0.169**	**0.133**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.052**	**0.133**	**0.070**	**0.474**	**0.257**	**0.264**	**0.426**	**0.423**	**0.294**	**0.591**	**0.487**	**0.375**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.25: Effect of different harvesting stages and wrapping materials on Non- reducing sugar of dragon fruit

Treatments	*Non reducing sugar (%)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
Harvesting stages (H)															
H_1	1.45^{c}	1.25^{c}	1.35^{b}	1.54^{c}	1.13^{c}	1.33^{c}	1.63^{c}	1.11^{c}	1.37^{c}	0.97^{b}	1.18^{c}	1.08^{c}	1.04^{b}	1.39^{b}	1.22^{b}
H_2	2.30^{b}	3.79^{a}	3.05^{a}	3.61^{a}	3.29^{a}	3.45^{a}	3.85^{a}	3.84^{a}	3.85^{a}	2.05^{a}	3.25^{a}	2.65^{a}	1.83^{a}	2.48^{a}	2.16^{a}
H_3	3.29^{a}	2.56^{b}	2.93^{a}	2.48^{b}	2.26^{b}	2.37^{b}	2.79^{b}	2.33^{b}	2.56^{b}	1.12^{b}	2.00^{b}	1.56^{b}	0.87^{b}	1.23^{b}	1.05^{b}
SEm±	**0.236**	**0.211**	**0.158**	**0.103**	**0.124**	**0.081**	**0.156**	**0.144**	**0.106**	**0.213**	**0.152**	**0.131**	**0.150**	**0.108**	**0.092**
CD (P=0.05)	**0.681**	**0.609**	**0.447**	**0.298**	**0.359**	**0.228**	**0.450**	**0.416**	**0.300**	**0.614**	**0.438**	**0.369**	**0.432**	**0.313**	**0.261**
Wrapping materials (W)															
W_1	2.26^{a}	2.47^{a}	2.37^{a}	2.10^{c}	2.44^{a}	2.27^{b}	2.10^{c}	2.77^{a}	2.44^{b}	1.12^{b}	2.37^{a}	1.74^{ab}	0.96^{b}	1.61^{ab}	1.29^{b}
W_2	2.61^{a}	2.32^{a}	2.47^{a}	2.56^{b}	1.96^{b}	2.26^{b}	3.33^{a}	2.42^{ab}	2.88^{a}	0.79^{b}	2.26^{a}	1.53^{b}	0.89^{b}	1.90^{a}	1.40^{b}
W_3	1.92^{a}	2.44^{a}	2.18^{a}	2.72^{ab}	2.60^{a}	2.66^{a}	2.49^{bc}	2.61^{a}	2.55^{ab}	1.42^{b}	1.96^{a}	1.69^{b}	1.18^{b}	1.84^{a}	1.51^{b}
W_4	2.32^{a}	2.63^{a}	2.47^{a}	2.97^{a}	1.73^{b}	2.35^{b}	3.27^{a}	2.06^{b}	2.67^{a}	1.35^{b}	1.94^{a}	1.65^{b}	1.24^{b}	1.39^{b}	1.31^{b}
W_5	2.62^{a}	2.81^{a}	2.71^{a}	2.36^{bc}	2.40^{a}	2.38^{ab}	2.61^{b}	2.27^{ab}	2.44^{b}	2.22^{a}	2.19^{a}	2.20^{a}	1.96^{a}	1.77^{ab}	1.86^{a}
SEm±	**0.304**	**0.272**	**0.204**	**0.133**	**0.160**	**0.104**	**0.201**	**0.186**	**0.137**	**0.274**	**0.196**	**0.169**	**0.193**	**0.140**	**0.119**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.385**	**0.463**	**0.295**	**0.581**	**NS**	**0.388**	**0.793**	**NS**	**0.477**	**0.558**	**NS**	**0.337**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.26: Interaction effect of different harvesting stages and wrapping materials on Non- reducing sugar of dragon fruit

Treatments (H x W interaction)	***Non reducing sugar (%)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	1.25^{cd}	1.54^{cd}	1.39^{d}	1.18^{g}	1.25^{fg}	1.21^{g}	1.27^{g}	2.19^{d}	1.73^{gh}	1.03^{cd}	2.47^{bc}	1.75^{cd}	0.77^{c}	1.25^{de}	1.01^{cd}
H_1W_2	1.92^{bc}	1.17^{cd}	1.54^{cd}	1.69^{fg}	1.05^{g}	1.37^{g}	1.44^{fg}	0.36^{e}	0.90^{i}	0.29^{e}	1.43^{de}	0.86^{e}	0.53^{d}	1.96^{bc}	1.25^{cd}
H_1W_3	0.84^{d}	1.24^{cd}	1.04^{d}	1.26^{g}	1.27^{fg}	1.27^{g}	0.79^{h}	1.57^{d}	1.18^{h}	1.23^{cd}	1.18^{e}	1.20^{de}	1.37^{b}	1.47^{cd}	1.42^{c}
H_1W_4	1.54^{cd}	0.77^{d}	1.15^{d}	1.91^{ef}	0.62^{h}	1.27^{g}	2.96^{de}	0.12^{e}	1.54^{gh}	1.00^{cd}	0.92^{e}	0.96^{e}	0.81^{c}	0.97^{de}	0.89^{d}
H_1W_5	1.69^{bc}	1.54^{c}	1.62^{cd}	1.65^{fg}	1.46^{f}	1.55^{g}	1.72^{fg}	1.33^{d}	1.52^{gh}	1.74^{b}	1.25^{e}	1.49^{de}	1.74^{ab}	1.30^{cd}	1.52^{bc}
H_2W_1	2.50^{a}	3.49^{ab}	3.00^{ab}	3.12^{b}	3.48^{bc}	3.30^{bc}	1.90^{fg}	3.86^{ab}	2.88^{de}	0.60^{d}	2.87^{ab}	1.73^{cd}	1.07^{b}	1.90^{bc}	1.48^{bc}
H_2W_2	2.19^{bc}	3.31^{ab}	2.75^{ab}	3.23^{b}	2.84^{c}	3.04^{cd}	5.09^{a}	3.84^{ab}	4.47^{a}	2.29^{b}	3.07^{ab}	2.68^{b}	1.68^{ab}	2.45^{a}	2.07^{ab}
H_2W_3	2.11^{bc}	3.95^{a}	3.03^{ab}	4.48^{a}	4.43^{a}	4.46^{a}	4.46^{b}	4.21^{a}	4.33^{a}	2.35^{b}	3.18^{ab}	2.76^{b}	1.82^{ab}	2.95^{a}	2.38^{a}
H_2W_4	1.74^{bc}	4.15^{a}	2.94^{ab}	3.99^{a}	1.87^{ef}	2.93^{cd}	3.96^{b}	3.87^{ab}	3.91^{ab}	1.55^{bc}	3.62^{a}	2.59^{b}	2.03^{ab}	2.40^{ab}	2.22^{a}
H_2W_5	2.96^{ab}	4.07^{a}	3.51^{a}	3.24^{b}	3.85^{ab}	3.55^{b}	3.87^{bc}	3.43^{ab}	3.65^{bc}	3.47^{a}	3.51^{a}	3.49^{a}	2.54^{a}	2.71^{a}	2.63^{a}
H_3W_1	3.02^{ab}	2.39^{bc}	2.71^{ab}	1.99^{ef}	2.59^{de}	2.29^{f}	3.12^{cd}	2.28^{c}	2.70^{de}	1.73^{b}	1.77^{de}	1.75^{cd}	1.06^{bc}	1.68^{cd}	1.37^{c}
H_3W_2	3.73^{a}	2.49^{bc}	3.11^{ab}	2.76^{bc}	2.01^{de}	2.38^{ef}	3.46^{bc}	3.06^{bc}	3.26^{cd}	0.21^{e}	2.30^{cd}	1.25^{d}	0.46^{d}	1.28^{de}	0.87^{d}
H_3W_3	2.80^{ab}	2.15^{bc}	2.47^{bc}	2.43^{cd}	2.11^{de}	2.27^{f}	2.23^{ef}	2.04^{c}	2.13^{fg}	0.70^{de}	1.52^{de}	1.11^{d}	0.33^{d}	1.10^{de}	0.72^{d}
H_3W_4	3.68^{a}	2.97^{ab}	3.32^{ab}	3.03^{bc}	2.69^{cd}	2.86^{de}	2.91^{de}	2.19^{c}	2.55^{ef}	1.50^{bc}	2.62^{bc}	2.06^{bc}	0.88^{bc}	0.79^{e}	0.83^{d}
H_3W_5	3.21^{ab}	2.82^{ab}	3.01^{ab}	2.19^{de}	1.91^{ef}	2.05^{f}	2.23^{ef}	2.06^{c}	2.15^{fg}	1.44^{bc}	1.81^{c}	1.62^{cd}	1.61^{a}	1.29^{de}	1.45^{c}
SEm±	**0.527**	**0.471**	**0.354**	**0.231**	**0.278**	**0.180**	**0.349**	**0.322**	**0.237**	**0.469**	**0.304**	**0.280**	**0.335**	**0.242**	**0.206**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.666**	**0.802**	**0.511**	**1.007**	**0.930**	**0.671**	**1.355**	**0.878**	**0.791**	**NS**	**0.699**	**NS**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

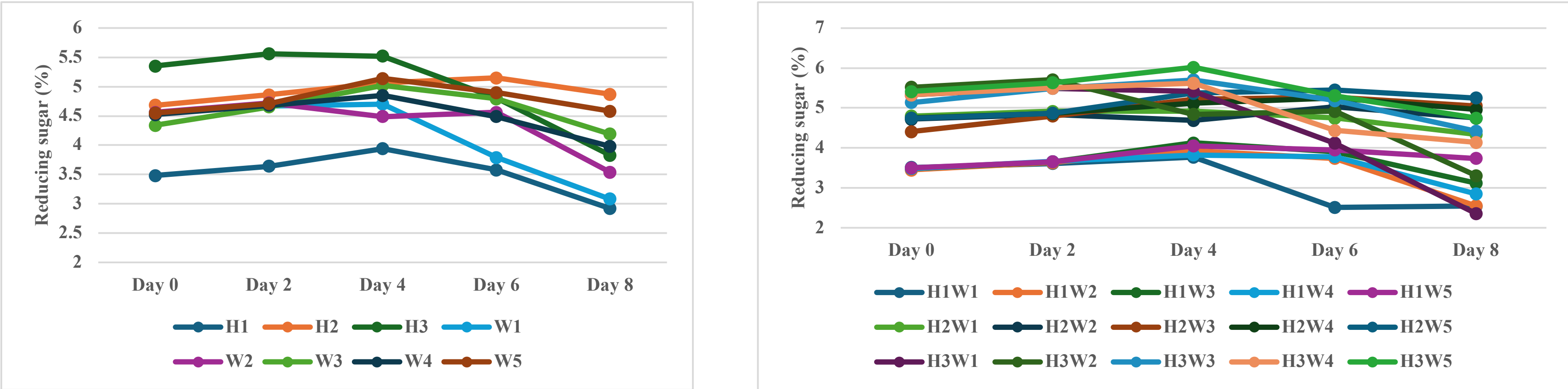


Figure 4.8: Individual and interaction effect of harvesting stages and wrapping materials on Reducing sugar content

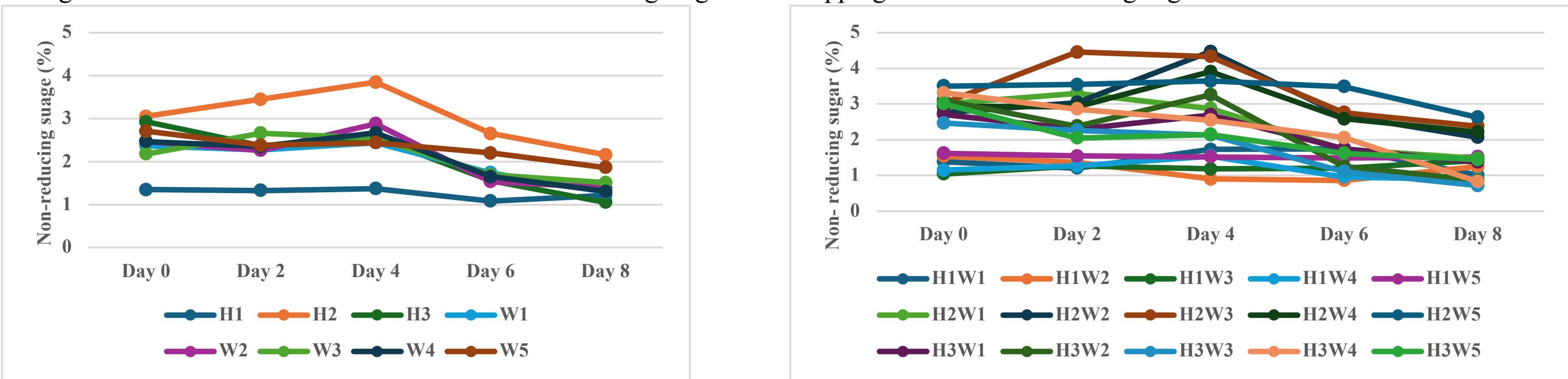


Figure 4.9: Individual and interaction effect of harvesting stages and wrapping materials on Non-reducing sugar content

followed by H_2 (30 DAA) with 5.70 mg/100ml and the minimum in H_3 (35 DAA) with 3.30 mg/100ml. Ripening mechanism involves oxidizing enzymes such as ascorbic acid oxidase, polyphenol oxidase, peroxidase and catalase which are responsible in minimizing the ascorbic acid content in fruits.

According to the data collected on effect of wrapping materials on ascorbic acid of dragon fruit, it was observed that ascorbic acid decreased gradually irrespective of the wrapping materials used. Although at initial days of storage, slight increase was observed. Rahman *et. al.* (2014) reported a similar increase in ascorbic acid content up to 2^{nd} day of storage in strawberry, which points that ascorbic acid synthesis took place during storage period (Cordenunsi *et. al.,* 2005) that may be due to monosaccharides synthesizing ascorbic acid (Nunes *et. al.,* 2006). The highest retention was recorded in W_5 (shrink wrapping) with 6.57 mg/100g pulp on the last day of observation, followed by W_3 (Brown paper leaves), which was at par with W_2 (Banana leaves) and the minimum value was recorded in control (W_1). This might be due to slower rate of respiration in the wrapped fruits as control of respiration becomes a crucial condition for maintaining quality and extending the shelf life (Martineli *et. al.,* 2020).

The interaction effect of harvesting stages and wrapping materials on ascorbic acid resulted in significant difference on almost all the days of analysis (Table 4.28 and Figure 4.10). On the last day of observation, the maximum ascorbic acid content was recorded in H_1W_5 (25 DAA, shrink wrapping) with 9.12 mg/100ml followed by H_1W_3 (25 DAA, brown paper) and the minimum value (2.19 mg/100ml) was recorded in H_3W_1 (35 DAA, no wrapping). Fruits in shrink wrapping irrespective of the harvesting stage retained the highest ascorbic acid content in comparison to other treatments. Similar findings on the influence of shrink wrapping on maintaining higher ascorbic acid content has been reported by Gomez *et. al.* (2023), Rana and Siddiqui (2018) in guava, Mahajan *et. al.* (2015) in peach, Ladaniya (2003) in citrus, Nanda *et. al.* (2001) in pomegranate. After day 4, there was a uniform decrease in ascorbic acid content in all the treatments, irrespective of the harvesting stages and wrapping materials. The reduction in ascorbic acid content during storage may be due to its conversion into dehydroascorbic acid by the action of enzyme ascorbic acid dehydrogenase (Mapson, 1970, Wills *et. al.,* 2007), as ascorbic acid is prone to oxidative degradation. Gomez *et. al.* (2023) reported that maturity stage, storage temperature and packaging in pineapple significantly affected the ascorbic acid content. Rana *et al.,* (2015) noted from their study in guava that 60 to 65% of vitamin C was retained in shrink wrapping as compared to 48% retention in control which may be attributed to modified atmosphere condition (reduced O_2 concentration) around the fruits that leads to slowing down of enzymatic oxidation of vitamin C and conversion of phenols to dehydroascorbic acid.

4.1.15 Total phenolic content in pulp (mg GAE/100g fresh wt.)

Total phenolic content of dragon fruit in pulp was found to be statistically significant among the different harvesting stages for both the years and the pooled data as presented in Table 4.29 and Figure 4.11. At harvest, it was noted that harvesting at initial stage (H_1- 25 DAA) had higher total phenol content (6.87 GAE mg/g) followed by H_2 (30 DAA) with 4.98 GAE mg/g and the minimum content (3.11 GAE mg/g) was recorded in H_3 (35 DAA). This finding indicated a decline in total phenolic content as the fruit underwent development and ripening. Similar trend was reported by Singh *et. al.* (2022), Zitha *et. al.* (2022) in Dragon fruit, Aldhanhani *et. al.* (2022) in Ber, Ahmed *et. al.* (2021) in Date palm, Wojdylo and Oszmianski (2020) in Apple, Vithana *et. al.* (2019) in Mango, where total phenolic content was highest at initial stage of fruit development, thereafter declined with advancement in fruit ripening. The rapid increase in total phenol content during the green stage was due to increase in its biosynthesis or metabolism of phenolic compounds (Aldhanhani *et. al.* 2012) whereby, the continual decrease may be due to increase in the activity of polyphenol oxidase that converts soluble phenolics into insoluble phenolics (Singh *et. al.* 2022) leading to reduction in phenolic synthesis, also phenols are continuously transformed into other substances during development (Zhang *et. al.* 2022).

The use of wrapping materials also had significant effect on the total phenolic content in dragon fruit pulp except during the initial days of storage. On the final day of storage, maximum total phenolic content was found in W_5 (Shrink wrapping) with 3.92 GAE mg/g, followed by W_3 (Brown paper) with 3.16 GAE mg/g and the least amount (1.98 GAE mg/g) was recorded in Control (W_1). Due to higher respiration rate of fruit, more degradation of total phenolic compounds were observed during storage (Lata *et. al.*, 2023; Ali *et. al.,* 2014). It was observed that total phenolic content in Dragon fruit decreased significantly during the storage period, however, wrapping of fruits reduced the rate of decrease as compared to no wrapping. Rana *et. al.* (2015) also reported that reduction in total phenolic content in guava was higher in control fruits as compared to shrink wrapped fruits at the end of trial. The reduction may be due to the activity of enzyme Polyphenol oxidase catalyzing the oxidation of monohydric or dihydric phenols and degradation of phenolics as a result of enzymatic actions (Sheng *et. al.* 2021). Rana and Siddique (2018) noted that during storage, individual wrapping maintained the phenol content by retarding the process of ripening and minimizing the rate of increase in PPO activity.

In regard to the interaction effect of harvesting stages and wrapping materials on total phenolic content in pulp of dragon fruit (Table 4.30 and Figure 4.11), significant differences were observed during the period of storage. Higher values were maintained until the end of storage in fruits of H_1W_5 (25 DAA, shrink wrapping) with 5.28 GAE mg/g, followed by H_2W_5 (30 DAA, shrink wrapping) and the minimum was recorded in H_3W_1 (35 DAA, control) with 0.89 GAE mg/g.

4.1.17 Betacyanin content in pulp (mg/100g of fresh wt.)

The data furnished in Table 4.33 and Figure 4.13 showed significant effects on betacyanin content in pulp of dragon fruit as influenced by different harvesting stages and wrapping materials. Betacyanin is the water-soluble pigment that renders the red-violet color of the pericarp of dragon fruit. On the day of harvest, the highest content was recorded in H_3 (35 DAA) with 38.66 mg/100g while lowest was found in H_1 (25 DAA) with 21.74 mg/100g. Consequently, this depicts an increasing trend in the betacyanin content with the advancement in fruit maturity. This finding is in conformity with Phebe *et. al.* (2009), Jamaludin *et. al.* (2010), Ortiz and Takahashi (2015), Mustafa *et. al.* (2018) and Singh *et. al.* (2022). It was observed that by 25 DAA, the red-violet coloration had already manifested in the pulp which indicated the degradation of chlorophyll and the synthesis of betacyanin. Jamaludin *et. al.* (2010) reported that this red-violet color appears only after seeds have matured. In agreement with Phebe *et. al.* (2009) who reported that synthesis of betacyanin pigment in flesh was earlier than that in peel, it was found that the colour of pulp had turned completed red-violet at the initial harvest stage of 25 DAA while the peel was still green with signs of colour development. Among other factors, the availability of sugar and light activates the

Table 4.27: Effect of different harvesting stages and wrapping materials on Ascorbic acid of dragon fruit

Treatments	*Ascorbic Acid (mg/100 ml)*														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
Harvesting stages (H)															
H_1	9.53^{a}	10.11^{a}	9.82^{a}	9.88^{a}	10.35^{a}	10.12^{a}	9.86^{a}	10.14^{a}	10.00^{a}	9.21^{a}	9.30^{a}	9.25^{a}	7.93^{a}	8.51^{a}	8.22^{a}
H_2	6.40^{b}	7.66^{b}	7.03^{b}	7.19^{b}	7.45^{b}	7.32^{b}	7.55^{b}	7.76^{b}	7.66^{b}	6.74^{b}	6.73^{b}	6.73^{b}	5.76^{b}	5.64^{b}	5.70^{b}
H_3	4.57^{c}	5.50^{c}	5.04^{c}	5.33^{c}	5.25^{c}	5.29^{c}	5.71^{c}	5.02^{c}	5.37^{c}	3.76^{c}	4.09^{c}	3.92^{c}	3.37^{c}	3.24^{c}	3.30^{c}
SEm±	**0.08**	**0.10**	**0.06**	**0.16**	**0.08**	**0.09**	**0.11**	**0.06**	**0.06**	**0.06**	**0.08**	**0.05**	**0.07**	**0.05**	**0.04**
CD (P=0.05)	**0.23**	**0.28**	**0.18**	**0.46**	**0.22**	**0.25**	**0.31**	**0.18**	**0.17**	**0.17**	**0.22**	**0.14**	**0.20**	**0.15**	**0.12**
Wrapping materials(W)															
W_1	6.90^{a}	7.97^{a}	7.43^{a}	6.81^{b}	7.63^{ab}	7.22^{b}	6.91^{b}	7.45^{b}	7.18^{c}	5.67^{b}	5.85^{d}	5.76^{d}	4.62^{d}	4.68^{e}	4.65^{e}
W_2	6.71^{a}	7.74^{ab}	7.23^{b}	7.76^{a}	7.70^{ab}	7.73^{a}	8.14^{a}	7.76^{a}	7.95^{a}	6.48^{c}	6.35^{c}	6.42^{c}	5.49^{c}	5.40^{d}	5.45^{d}
W_3	6.81^{a}	7.70^{ab}	7.25^{b}	7.39^{ab}	7.82^{a}	7.60^{a}	7.86^{a}	7.78^{a}	7.82^{ab}	6.85^{b}	7.15^{a}	7.00^{b}	6.16^{a}	6.29^{b}	6.22^{d}
W_4	6.91^{a}	7.48^{b}	7.20^{b}	7.79^{a}	7.58^{b}	7.69^{a}	7.77^{a}	7.46^{b}	7.61^{b}	6.63^{bc}	6.76^{b}	6.69^{b}	5.78^{b}	5.87^{c}	5.83^{c}
W_5	6.84^{a}	7.89^{a}	7.37^{ab}	7.60^{a}	7.67^{ab}	7.64^{a}	7.86^{a}	7.76^{a}	7.81^{ab}	7.21^{a}	7.41^{a}	7.31^{a}	6.39^{a}	6.74^{a}	6.57^{a}
SEm±	**0.10**	**0.13**	**0.08**	**0.20**	**0.10**	**0.11**	**0.14**	**0.08**	**0.08**	**0.08**	**0.10**	**0.06**	**0.09**	**0.07**	**0.06**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.59**	**NS**	**0.32**	**0.40**	**0.23**	**0.23**	**0.22**	**0.28**	**0.18**	**0.26**	**0.20**	**0.16**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

Table 4.28: Interaction effect of different harvesting stages and wrapping materials on Ascorbic acid of dragon fruit

Treatments (H x W interaction)	*Ascorbic Acid (mg/100 ml)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
H_1W_1	9.50^{a}	10.24^{a}	9.87^{ab}	9.70^{ab}	10.21^{ab}	9.96^{bc}	9.34^{c}	9.86^{b}	9.60^{c}	8.67^{d}	8.43^{c}	8.55^{d}	7.20^{c}	7.53^{d}	7.36^{d}
H_1W_2	9.55^{a}	10.36^{a}	9.96^{ab}	10.54^{a}	10.70^{a}	10.62^{a}	10.55^{a}	9.93^{b}	10.24^{ab}	9.12^{bc}	8.91^{c}	9.02^{c}	7.68^{b}	8.14^{c}	7.91^{c}
H_1W_3	9.43^{a}	9.78^{b}	9.60^{b}	9.22^{b}	9.90^{b}	9.56^{c}	9.30^{c}	10.22^{ab}	9.76^{c}	8.89^{cd}	9.36^{b}	9.13^{c}	8.30^{a}	8.86^{b}	8.58^{b}
H_1W_4	9.66^{a}	9.53^{b}	9.60^{b}	9.58^{b}	10.45^{a}	10.02^{bc}	9.74^{bc}	10.19^{ab}	9.96^{bc}	9.36^{b}	9.70^{ab}	9.53^{b}	7.79^{b}	8.47^{bc}	8.13^{c}
H_1W_5	9.48^{a}	10.65^{a}	10.07^{a}	10.38^{a}	10.47^{a}	10.43^{ab}	10.39^{ab}	10.52^{a}	10.46^{a}	10.00^{a}	10.11^{a}	10.05^{a}	8.68^{a}	9.56^{a}	9.12^{a}
H_2W_1	6.43^{b}	7.97^{c}	7.20^{c}	6.20^{de}	7.45^{d}	6.83^{e}	6.72^{g}	7.38^{d}	7.05^{f}	5.79^{g}	5.64^{f}	5.71^{g}	4.53^{g}	4.26^{g}	4.39^{g}
H_2W_2	6.22^{b}	7.53^{cd}	6.87^{c}	7.68^{c}	7.13^{d}	7.40^{d}	8.34^{d}	8.19^{c}	8.27^{d}	6.63^{f}	6.42^{e}	6.53^{f}	5.42^{f}	5.47^{f}	5.45^{g}
H_2W_3	6.36^{b}	7.84^{c}	7.10^{c}	7.36^{c}	8.07^{c}	7.71^{d}	8.15^{de}	8.23^{c}	8.19^{d}	7.20^{e}	7.48^{d}	7.34^{e}	6.17^{e}	6.34^{e}	6.26^{e}
H_2W_4	6.49^{b}	7.33^{d}	6.91^{c}	7.55^{c}	7.15^{d}	7.35^{de}	7.09^{f}	7.31^{d}	7.20^{ef}	6.70^{f}	6.63^{e}	6.67^{f}	6.05^{e}	5.79^{f}	5.92^{f}
H_2W_5	6.51^{b}	7.61^{cd}	7.06^{c}	7.18^{cd}	7.44^{d}	7.31^{d}	7.43^{ef}	7.70^{d}	7.57^{e}	7.35^{e}	7.49^{d}	7.42^{e}	6.64^{d}	6.33^{e}	6.49^{e}
H_3W_1	4.76^{c}	5.69^{e}	5.23^{d}	4.51^{f}	5.23^{e}	4.87^{g}	4.67^{i}	5.11^{f}	4.89^{h}	2.56^{j}	3.48^{i}	3.02^{j}	2.13^{j}	2.25^{i}	2.19^{k}
H_3W_2	4.35^{c}	5.34^{e}	4.85^{d}	5.07^{f}	5.28^{e}	5.18^{fg}	5.53^{h}	5.16^{f}	5.35^{g}	3.68^{i}	3.74^{hi}	3.71^{i}	3.38^{i}	2.58^{i}	2.98^{j}
H_3W_3	4.64^{c}	5.47^{e}	5.06^{d}	5.59	5.48^{e}	5.54^{f}	6.12^{gh}	4.90^{f}	5.51^{g}	4.45^{h}	4.63^{g}	4.54^{h}	4.00^{h}	3.67^{h}	3.84^{h}
H_3W_4	4.58^{c}	5.59^{e}	5.09^{d}	6.26^{de}	5.13^{e}	5.69^{f}	6.49^{g}	4.88^{f}	5.68^{g}	3.82^{i}	3.94^{h}	3.88^{i}	3.51^{i}	3.34^{h}	3.42^{i}
H_3W_5	4.52^{c}	5.42^{e}	4.97^{d}	5.24^{ef}	5.11^{e}	5.18^{fg}	5.76^{h}	5.06^{f}	5.41^{g}	4.29^{h}	4.65^{g}	4.47^{h}	3.84^{hi}	4.34^{g}	4.09^{h}
SEm±	*0.18*	*0.22*	*0.14*	*0.35*	*0.17*	*0.20*	*0.24*	*0.14*	*0.14*	*0.13*	*0.17*	*0.11*	*0.15*	*0.12*	*0.10*
CD (P=0.05)	*NS*	*0.45*	*NS*	*1.02*	*0.50*	*0.56*	*0.69*	*0.40*	*0.39*	*0.38*	*0.49*	*0.30*	*0.45*	*0.34*	*0.27*

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

Table 4.29: Effect of different harvesting stages and wrapping materials on Total phenol content of dragon fruit pulp

Treatments	*Total phenol content in pulp (mg GAE/g)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
Harvesting stages(H)															
H_1	6.47^{a}	7.28^{a}	6.87^{a}	6.14^{a}	6.59^{a}	6.36^{a}	5.41^{a}	6.09^{a}	5.75^{a}	5.11^{a}	4.44^{a}	4.78^{a}	4.14^{a}	3.87^{a}	4.00^{a}
H_2	4.86^{b}	5.11^{b}	4.98^{b}	4.62^{b}	4.51^{b}	4.56^{b}	4.38^{b}	4.04^{b}	4.21^{b}	3.77^{b}	3.42^{b}	3.60^{b}	3.31^{b}	2.98^{b}	3.15^{b}
H_3	3.10^{c}	3.12^{c}	3.11^{c}	2.70^{c}	2.82^{c}	2.76^{c}	2.37^{c}	2.60^{c}	2.48^{c}	2.13^{c}	2.02^{c}	2.08^{c}	1.70^{c}	1.53^{c}	1.61^{c}
SEm±	**0.14**	**0.22**	**0.13**	**0.09**	**0.14**	**0.08**	**0.09**	**0.05**	**0.05**	**0.02**	**0.10**	**0.05**	**0.04**	**0.07**	**0.04**
CD (P=0.05)	**0.41**	**0.62**	**0.37**	**0.26**	**0.42**	**0.24**	**0.25**	**0.15**	**0.14**	**0.06**	**0.30**	**0.15**	**0.13**	**0.21**	**0.12**
Wrapping materials (W)															
W_1	4.72^{a}	4.98^{a}	4.85^{a}	4.37^{ab}	4.34^{b}	4.36^{b}	3.64^{b}	3.58^{c}	3.61^{d}	3.04^{e}	2.68^{c}	2.86^{c}	2.08^{e}	1.88^{d}	1.98^{d}
W_2	4.62^{a}	5.21^{a}	4.92^{a}	4.30^{b}	4.69^{ab}	4.50^{b}	3.76^{b}	4.20^{b}	3.98^{c}	3.41^{d}	3.33^{b}	3.37^{b}	2.58^{d}	2.48^{c}	2.53^{c}
W_3	4.96^{a}	5.11^{a}	5.04^{a}	4.55^{ab}	4.54^{b}	4.54^{ab}	4.15^{b}	4.19^{b}	4.17^{b}	3.76^{c}	3.28^{b}	3.52^{b}	3.17^{c}	3.14^{b}	3.16^{b}
W_4	5.03^{a}	5.24^{a}	5.14^{a}	4.65^{a}	4.51^{b}	4.58^{ab}	4.27^{a}	4.28^{b}	4.27^{b}	3.88^{b}	2.99^{b}	3.44^{b}	3.43^{b}	2.61^{c}	3.02^{b}
W_5	4.71^{a}	5.30^{a}	5.00^{a}	4.57^{ab}	5.12^{a}	4.84^{a}	4.44^{a}	4.96^{a}	4.70^{a}	4.27^{a}	4.19^{a}	4.23^{a}	3.99^{a}	3.86^{a}	3.92^{a}
SEm±	**0.18**	**0.28**	**0.17**	**0.12**	**0.19**	**0.11**	**0.11**	**0.07**	**0.06**	**0.03**	**0.13**	**0.07**	**0.06**	**0.09**	**0.05**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**0.31**	**0.32**	**0.20**	**0.18**	**0.08**	**0.38**	**0.19**	**0.16**	**0.27**	**0.15**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

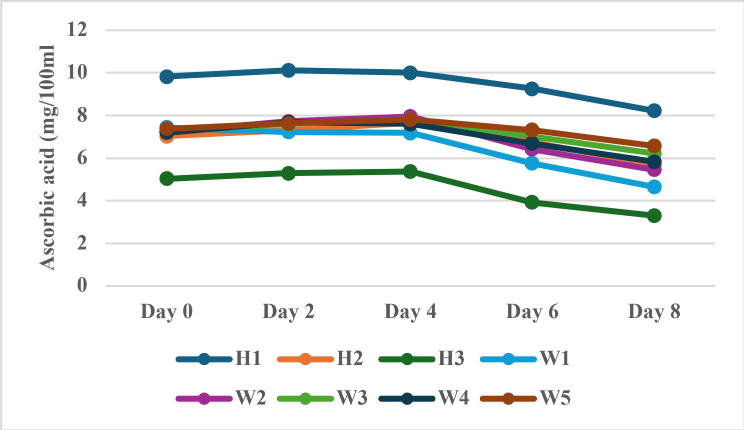
Table 4.30: Interaction effect of different harvesting stages and wrapping materials on Total phenol content of Dragon fruit pulp

Treatments (H x W interaction)	*Total phenol content in pulp (mg GAE/g)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
H_1W_1	6.49^{a}	7.54^{a}	7.01^{a}	5.96^{a}	6.67^{a}	6.31^{ab}	4.48^{de}	5.42^{c}	4.95^{c}	4.01^{f}	3.89^{cd}	3.95^{d}	2.81^{f}	3.28^{d}	3.05^{d}
H_1W_2	6.65^{a}	6.96^{a}	6.81^{a}	6.28^{a}	6.54^{a}	6.41^{ab}	5.27^{c}	5.95^{b}	5.61^{b}	4.94^{d}	4.68^{b}	4.81^{b}	3.59^{de}	3.52^{d}	3.56^{c}
H_1W_3	6.22^{a}	6.82^{a}	6.52^{a}	5.97^{a}	6.25^{a}	6.11^{b}	5.45^{bc}	6.04^{b}	5.75^{b}	5.10^{c}	4.11^{bc}	4.60^{bc}	4.22^{b}	4.03^{bc}	4.13^{b}
H_1W_4	6.45^{a}	7.68^{a}	7.06^{a}	6.10^{a}	6.40^{a}	6.25^{ab}	5.62^{b}	6.19^{b}	5.91^{b}	5.37^{b}	4.14^{bc}	4.76^{b}	4.45^{b}	3.60^{cd}	4.02^{b}
H_1W_5	6.53^{a}	7.39^{a}	6.96^{a}	6.38^{a}	7.11^{a}	6.74^{a}	6.21^{a}	6.83^{a}	6.52^{a}	6.15^{a}	5.39^{a}	5.77^{a}	5.64^{a}	4.91^{a}	5.28^{a}
H_2W_1	4.71^{b}	4.82^{b}	4.77^{b}	4.55^{b}	4.25^{b}	4.40^{c}	4.23^{de}	3.39^{gh}	3.81^{f}	3.23^{g}	2.56^{ef}	2.90^{e}	2.42^{g}	1.58^{f}	2.00^{f}
H_2W_2	4.68^{b}	5.39^{b}	5.03^{b}	4.37^{b}	4.68^{b}	4.52^{c}	3.97^{e}	3.96^{f}	3.97^{f}	3.35^{g}	3.06^{de}	3.21^{ef}	2.81^{f}	2.51^{e}	2.66^{e}
H_2W_3	4.90^{b}	4.96^{b}	4.93^{b}	4.72^{b}	4.25^{b}	4.49^{c}	4.58^{de}	3.68^{fg}	4.13^{ef}	4.02^{f}	3.40^{de}	3.71^{d}	3.42^{e}	3.18^{d}	3.30^{cd}
H_2W_4	5.13^{b}	5.25^{b}	5.19^{b}	4.80^{b}	4.54^{b}	4.67^{c}	4.60^{de}	4.30^{e}	4.45^{de}	3.98^{f}	3.57^{cd}	3.77^{d}	3.78^{d}	3.27^{d}	3.53^{c}
H_2W_5	4.86^{b}	5.11^{b}	4.98^{b}	4.67^{b}	4.82^{b}	4.74^{c}	4.52^{de}	4.84^{d}	4.68^{cd}	4.26^{e}	4.52^{b}	4.39^{c}	4.12^{c}	4.36^{b}	4.24^{b}
H_3W_1	2.97^{cd}	2.58^{c}	2.78^{c}	2.62^{cd}	2.11^{d}	2.37^{e}	2.20^{fg}	1.94^{k}	2.07^{i}	1.87^{j}	1.60^{g}	1.73^{h}	1.01^{k}	0.78^{g}	0.89^{h}
H_3W_2	2.52^{d}	3.29^{c}	2.91^{c}	2.25^{d}	2.86^{cd}	2.56^{de}	2.04^{g}	2.69^{i}	2.36^{hi}	1.92^{j}	2.26^{f}	2.09^{g}	1.34^{j}	1.41^{f}	1.38^{g}
H_3W_3	3.75^{c}	3.55^{c}	3.65^{c}	2.95^{c}	3.12^{c}	3.03^{d}	2.41^{fg}	2.84^{i}	2.62^{gh}	2.16^{i}	2.32^{f}	2.24^{fg}	1.88^{i}	2.19^{e}	2.04^{f}
H_3W_4	3.52^{c}	2.80^{c}	3.16^{c}	3.04^{c}	2.58^{cd}	2.81^{de}	2.59^{f}	2.34^{j}	2.47^{h}	2.30^{h}	1.25^{g}	1.78^{h}	2.07^{hi}	0.96^{g}	1.52^{g}
H_3W_5	2.74^{d}	3.39^{c}	3.06^{c}	2.66^{cd}	3.43^{c}	3.05^{d}	2.60^{f}	3.20^{h}	2.90^{g}	2.41^{h}	2.67^{ef}	2.54^{f}	2.20^{gh}	2.30^{e}	2.25^{f}
SEm±	**0.32**	**0.48**	**0.29**	**0.20**	**0.32**	**0.19**	**0.19**	**0.12**	**0.11**	**0.05**	**0.23**	**0.12**	**0.10**	**0.16**	**0.09**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.55**	**0.34**	**0.32**	**0.13**	**0.66**	**0.33**	**0.28**	**0.47**	**0.27**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping



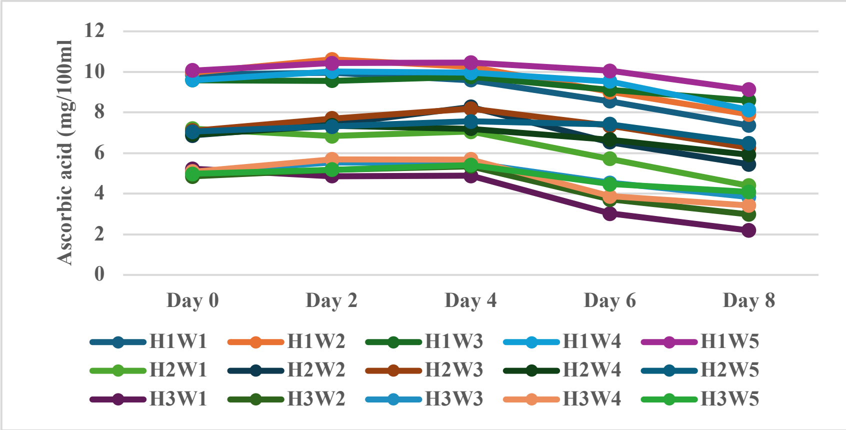
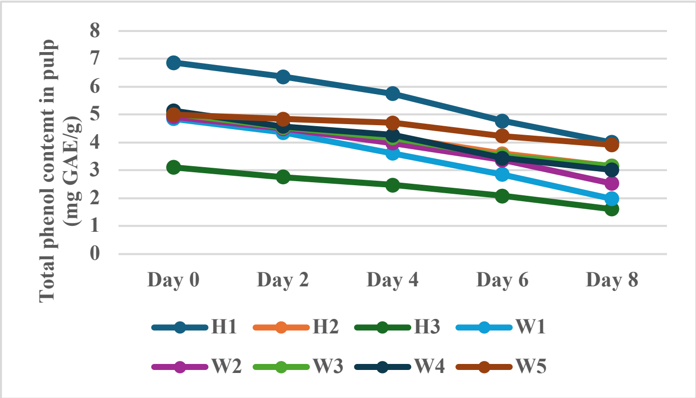


Figure 4.10: Individual and interaction effect of harvesting stages and wrapping materials on Ascorbic acid content



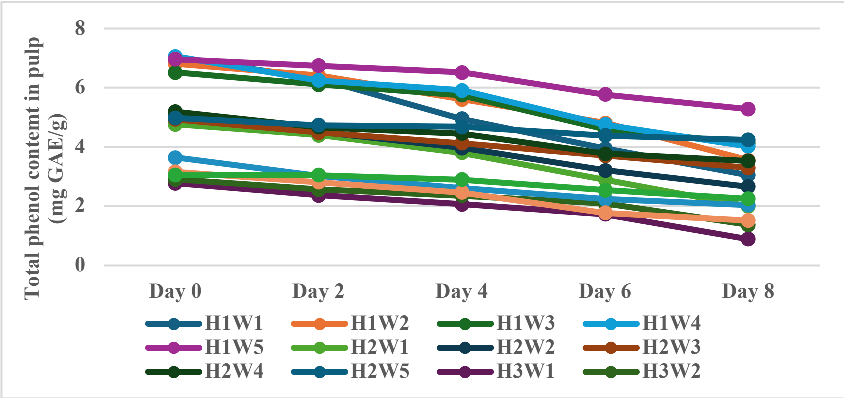


Figure 4.11: Individual and interaction effect of harvesting stages and wrapping materials on Total phenolic content in pulp

synthesis of this pigment, so along with the increase in sugar content, there is increase in betacyanin content as the fruit matures (Castellar *et. al.,* 2003). At the end of observation, the highest betacyanin content was recorded in H_2 (30 DAA) while the lowest was recorded in H_1 (25 DAA) with 30.69 mg/100g and 21.04 mg/100g respectively.

It is evident from table that the use of different wrapping materials had significant effect on the betacyanin content in pulp of dragon fruit during storage. At the end of storage, the minimum degradation of betacyanin was recorded in W_5 (shrink wrap) with 35.31 mg/100g and the maximum reduction was observed in control (W_1) with 25.36 mg/100g content. In all the treatments, slight increase in betacyanin content was observed till day 4, after which there was steady reduction. Lata *et. al.* (2023) reported reduction in betalain content after day 2 of storage at ambient temperature. Chemically, betalains constitute of betacyanin and betaxanthins which are present in dragon fruit, where betacyanin is responsible for the red-violet colour and betaxanthins for yellow colour. These pigments are sensitive to light, temperature and oxygen and exhibits synergistic effect on the degradation of betacyanin (Razak *et. al.,* 2017) which is degradation of betacyanin into batalmic acid and cyclo-Dopa (Chew *et. al.* 2019) that leads to reduction in betacyanin content during storage.

The data on interaction effect of harvesting stages and wrapping materials are presented in Table 4.34 and Figure 4.13 which depicts significant variation among the treatments. In all the treatments, an increasing trend was observed during the initial days, followed by reduction in the betacyanin content. On the last day of observation, the maximum value (35.34 mg/100g) was recorded in H_3W_5 (35 DAA, shrink wrapping) followed by H_2W_5 (30 DAA, shrink wrapping) and the minimum value (21.65 mg/100g) was found in H_3W_1 (35 DAA, control).

4.1.18 Betacyanin content in peel (mg/100g of fresh wt.)

Data presented in Table 4.35 and Figure 4.14 outlines significant variation in the betacyanin content in peel of dragon fruit as influenced by harvesting stages and wrapping materials. Among the harvesting stages, the maximum content (36.53 mg/100g) was recorded in H_3 (35 DAA), followed by H_2 (30 DAA) with 28.70 mg/100g and the minimum value (20.37 mg/100g) was recorded in H_1 (25 DAA). As it was found in pulp, the betacyanin content gradually increased as the fruit undergo maturation and development. Peel loss its green colour due to diminishing chlorophyll content, which is followed by synthesis of betacyanin pigment (Phebe *et. al.*, 2009) giving the red coloration as the fruit advances in maturity. Also, high concentration of pectin in fruit hamper extraction of betacyanin (Chia and Chong, 2015) thus, lower amount is found in immature fruits.

Additionally, table shows significant difference between the wrapping materials where betacyanin is more stable in fruits with shrink wrapping. At the end of observation, the highest betacyanin was recorded in W_5 (shrink wrapping) with 33.71 mg/100g, followed by W_3 (brown paper) with 30.17 mg/100g and the least value (21.10 mg/100g) was recorded in W_1 (no wrapping). In this study, slight increase in betacyanin content after harvest was observed, which has been reported in strawberries that though generally accepted as a non-climacteric fruit, many studies have shown that strawberries continue to develop in both color and anthocyanin content after harvest (Murray *et. al.,* 2024; Goulas & Manganaris, 2011).

Data pertaining to the interaction effect between harvesting stages and wrapping materials is furnished in Table 4.36 and Figure 4.14 which depicts significant effect on the betacyanin content in peel of dragon fruit. It was observed that betacyanin was more stable in the fruit harvested at 30 DAA kept with shrink wrapping. At the end of storage, maximum betacyanin content was recorded in H_2W_5 (30 DAA, shrink wrapping) with 35.42 mg/100g, followed by H_3W_5 (35 DAA, shrink wrapping) with 33.69 mg/100g and the minimum value (19.39 mg/100g) was recorded in H_3W_1 (35 DAA, no wrapping).

4.1.19 Pectin (%)

Table 4.37 and Figure 4.15 represents the data collected on the effect of harvesting stages and wrapping materials on pectin content (calcium pectate), which depicts significant variation among the treatments. At harvest, highest pectin content was recorded in the initial harvest stage i.e., 25 DAA (H_1) with 8.81%, followed by H_2 (30 DAA) and H_3 (35 DAA) with 5.82% and 3.73% respectively. According to a study on estimation of inedible part for pectin content (calcium pectate) in different fruit wastes by Begum *et. al.* (2017), dragon fruit peel is reported as a potential source for pectin production with 24.83% content, which was higher than the result found in this study.

Table 4.31: Effect of different harvesting stages and wrapping materials on Total phenol content of Dragon fruit peel

Treatments	***Total phenol content in peel (mg GAE/g)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
Harvesting stages(H)															
H_1	15.75^{a}	16.25^{a}	16.00^{a}	15.58^{a}	15.93^{a}	15.76^{a}	15.07^{a}	14.83^{a}	14.95^{a}	13.81^{a}	13.33^{a}	13.57^{a}	11.91^{a}	11.92^{a}	11.92^{a}
H_2	11.98^{b}	12.46^{b}	12.22^{b}	11.81^{b}	12.27^{b}	12.04^{b}	10.89^{b}	11.53^{b}	11.21^{b}	10.17^{b}	10.75^{b}	10.46^{b}	9.59^{b}	10.45^{b}	10.02^{b}
H_3	9.90^{c}	9.93^{c}	9.91^{c}	9.70^{c}	9.68^{c}	9.69^{c}	8.97^{c}	8.97^{c}	8.97^{c}	8.18^{c}	8.16^{c}	8.17^{c}	7.27^{c}	7.93^{c}	7.60^{c}
SEm±	*0.27*	*0.25*	*0.18*	*0.27*	*0.24*	*0.18*	*0.15*	*0.06*	*0.08*	*0.07*	*0.07*	*0.05*	*0.08*	*0.13*	*0.08*
CD (P=0.05)	*0.78*	*0.72*	*0.52*	*0.78*	*0.69*	*0.51*	*0.44*	*0.17*	*0.23*	*0.21*	*0.19*	*0.14*	*0.24*	*0.38*	*0.22*
Wrapping materials(W)															
W_1	11.73^{b}	12.93^{a}	12.33^{a}	11.45^{b}	12.45^{ab}	11.95^{b}	10.53^{c}	11.15^{e}	10.84^{c}	9.25^{d}	9.73^{e}	9.49^{d}	8.22^{d}	8.94^{e}	8.58^{e}
W_2	13.17^{a}	12.47^{a}	12.82^{a}	12.95^{a}	12.21^{b}	12.58^{a}	11.92^{ab}	11.46^{d}	11.69^{b}	10.81^{c}	10.36^{d}	10.58^{c}	9.45^{c}	9.43^{d}	9.44^{d}
W_3	12.58^{ab}	13.32^{a}	12.95^{a}	12.37^{ab}	13.15^{a}	12.76^{a}	11.80^{b}	12.46^{a}	12.13^{a}	11.12^{b}	11.23^{b}	11.18^{b}	9.96^{b}	10.77^{b}	10.36^{b}
W_4	12.50^{ab}	13.09^{a}	12.80^{a}	12.36^{ab}	12.87^{ab}	12.61^{a}	11.55^{b}	11.69^{c}	11.62^{b}	10.58^{c}	10.69^{c}	10.64^{c}	9.55^{c}	10.06^{c}	9.80^{c}
W_5	12.73^{a}	12.59^{a}	12.66^{a}	12.71^{a}	12.46^{ab}	12.58^{a}	12.42^{a}	12.12^{b}	12.27^{a}	11.84^{a}	11.73^{a}	11.78^{a}	10.79^{a}	11.30^{a}	11.04^{a}
SEm±	**0.35**	**0.32**	**0.24**	**0.35**	**0.31**	**0.23**	**0.20**	**0.08**	**0.11**	**0.09**	**0.09**	**0.06**	**0.11**	**0.17**	**0.10**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**0.66**	**0.57**	**0.22**	**0.30**	**0.27**	**0.25**	**0.18**	**0.31**	**0.49**	**0.28**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

Table 4.32: Interaction effect of different harvesting stages and wrapping materials on Total phenol content of Dragon fruit peel

Treatments (H x W interaction)	***Total phenol content in peel (mg GAE/g)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	14.70^{cd}	16.54^{ab}	15.62^{c}	14.21^{bc}	15.89^{ab}	15.05^{b}	13.53^{c}	14.15^{c}	13.84^{c}	11.68^{e}	11.74^{d}	11.71^{e}	9.86^{e}	10.23^{cd}	10.04^{d}
H_1W_2	16.78^{a}	16.79^{ab}	16.79^{ab}	16.50^{a}	16.50^{ab}	16.50^{a}	15.67^{a}	15.30^{b}	15.49^{b}	14.10^{c}	13.81^{b}	13.96^{c}	11.63^{c}	11.49^{b}	11.56^{c}
H_1W_3	16.49^{ab}	17.43^{a}	16.96^{a}	16.23^{a}	17.11^{a}	16.67^{a}	15.72^{a}	16.45^{a}	16.08^{a}	14.77^{b}	14.19^{ab}	14.48^{b}	12.54^{b}	13.15^{a}	12.85^{b}
H_1W_4	14.98^{bc}	14.83^{c}	14.91^{c}	15.12^{ab}	14.68^{c}	14.90^{b}	14.56^{b}	13.26^{d}	13.91^{c}	13.45^{d}	12.34^{c}	12.90^{d}	11.87^{c}	11.19^{b}	11.53^{c}
H_1W_5	15.78^{ab}	15.66^{bc}	15.72^{bc}	15.87^{ab}	15.47^{bc}	15.67^{ab}	15.87^{a}	15.00^{b}	15.43^{b}	15.04^{a}	14.56^{a}	14.80^{a}	13.67^{a}	13.52^{a}	13.60^{a}
H_2W_1	10.51^{gh}	12.71^{d}	11.61^{de}	10.46^{e}	12.36^{d}	11.41^{de}	9.30^{f}	11.12^{f}	10.21^{f}	8.87^{h}	10.23^{g}	9.55^{h}	8.44^{g}	9.71^{d}	9.08^{f}
H_2W_2	13.16^{de}	11.04^{ef}	12.10^{d}	12.91^{cd}	10.88^{e}	11.89^{c}	11.44^{de}	10.54^{g}	10.99^{e}	10.36^{f}	9.91^{g}	10.14^{g}	9.59^{ef}	9.58^{de}	9.59^{e}
H_2W_3	11.28^{fg}	12.48^{d}	11.88^{de}	11.12^{ef}	12.50^{d}	11.81^{c}	10.60^{e}	11.75^{e}	11.17^{e}	10.09^{fg}	11.06^{e}	10.58^{f}	9.65^{ef}	10.90^{c}	10.27^{d}
H_2W_4	12.08^{ef}	13.45^{d}	12.76^{d}	11.80^{de}	13.13^{d}	12.47^{cd}	10.78^{e}	12.09^{e}	11.43^{e}	9.82^{g}	10.84^{f}	10.33^{fg}	9.27^{f}	10.58^{c}	9.93^{d}
H_2W_5	12.86^{ef}	12.63^{de}	12.75^{d}	12.77^{cd}	12.50^{d}	12.64^{c}	12.32^{d}	12.14^{e}	12.23^{d}	11.72^{e}	11.70^{d}	11.71^{e}	11.00^{d}	11.47^{b}	11.24^{c}
H_3W_1	9.97^{gh}	9.53^{f}	9.75^{fg}	9.69^{fg}	9.09^{f}	9.39^{fg}	8.75^{f}	8.19^{j}	8.47^{h}	7.21^{j}	7.22^{j}	7.21^{l}	6.34^{j}	6.88^{g}	6.61^{h}
H_3W_2	9.56^{h}	9.59^{f}	9.57^{fg}	9.43^{g}	9.23^{f}	9.33^{g}	8.64^{f}	8.54^{j}	8.59^{h}	7.96^{i}	7.35^{j}	7.66^{k}	7.12^{i}	7.22^{g}	7.17^{g}
H_3W_3	9.97^{gh}	10.05^{f}	10.01^{fg}	9.76^{fg}	9.86^{ef}	9.81^{fg}	9.08^{f}	9.19^{i}	9.13^{g}	8.51^{h}	8.43^{i}	8.47^{j}	7.68^{h}	8.26^{f}	7.97^{f}
H_3W_4	10.45^{gh}	11.00^{f}	10.72^{fg}	10.15^{ef}	10.80^{e}	10.48^{ef}	9.31^{f}	9.73^{h}	9.52^{g}	8.48^{h}	8.88^{h}	8.68^{ij}	7.50^{hi}	8.41^{f}	7.96^{f}
H_3W_5	9.56^{h}	9.47^{f}	9.51^{g}	9.48^{fg}	9.40^{f}	9.44^{fg}	9.08^{f}	9.21^{i}	9.15^{g}	8.76^{h}	8.93^{h}	8.84^{i}	7.71^{h}	8.89^{ef}	8.30^{f}
SEm±	**0.60**	**0.56**	**0.41**	**0.60**	**0.53**	**0.40**	**0.34**	**0.13**	**0.18**	**0.16**	**0.15**	**0.11**	**0.18**	**0.29**	**0.17**
CD (P=0.05)	**NS**	**1.61**	**1.16**	**NS**	**1.54**	**1.14**	**0.98**	**0.38**	**0.52**	**0.47**	**0.44**	**0.31**	**0.53**	**0.85**	**0.49**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

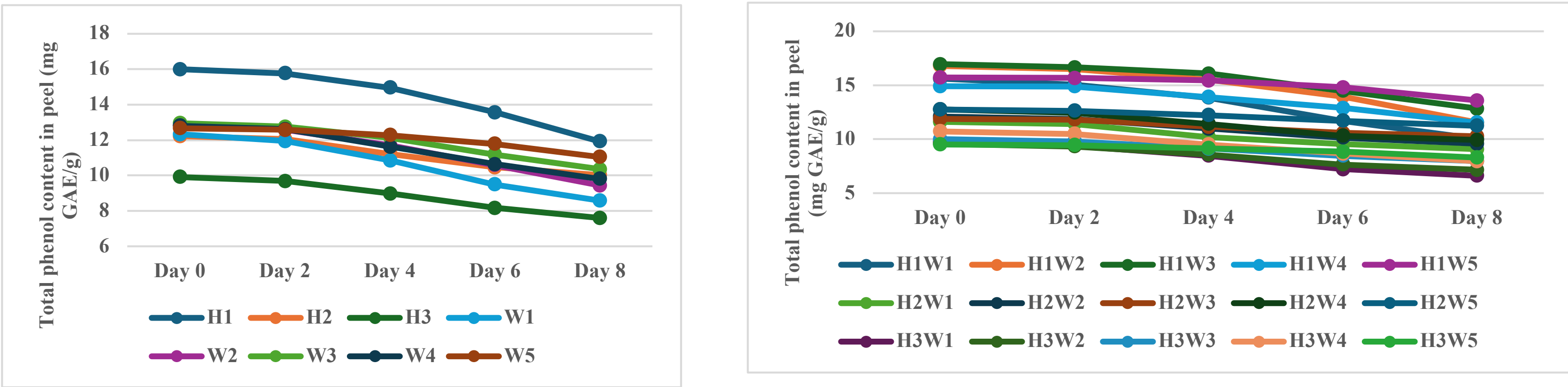


Figure 4.12: Individual and interaction effect of harvesting stages and wrapping materials on Total phenolic content in peel

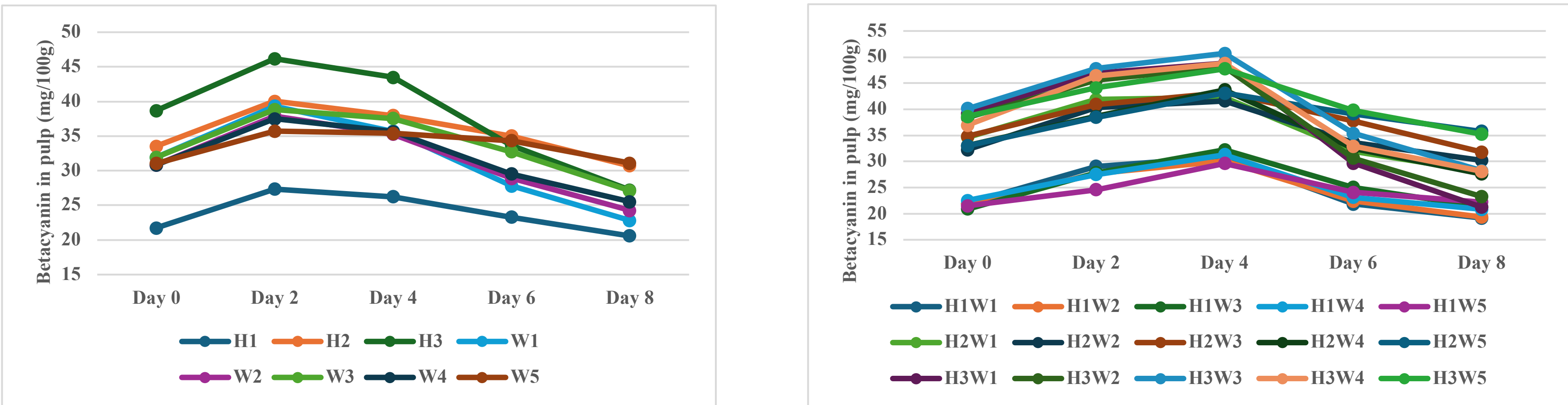


Figure 4.13: Individual and interaction effect of harvesting stages and wrapping materials on Betacyanin content in pulp

H_1W_1- 25 DAA, no wrapping, H_1W_2- 25 DAA, banana leaves , H_1W_3- 25 DAA, brown paper, H_1W_4- 25 DAA, EPE foam net, H_1W_5- 25 DAA, shrink wrapping
H_2W_1- 30 DAA, no wrapping, H_2W_2- 30 DAA, banana leaves , H_2W_3- 30 DAA, brown paper, H_2W_4- 30 DAA, EPE foam net, H_2W_5- 30 DAA, shrink wrapping
H_3W_1- 35 DAA, no wrapping, H_3W_2- 35 DAA, banana leaves , H_3W_3- 35 DAA, brown paper, H_3W_4- 35 DAA, EPE foam net, H_3W_5- 35 DAA, shrink wrapping

Pectin content is directly correlated to the firmness of the fruit (Wang *et. al.*, 2024; Deepthi *et. al.,* 2016) and with the progress in maturation and development, the pectin content decreases due to increase in pectin solubilization (Gonclaves *et. al.*, 2005) since the insoluble form of pectin is prevalent in immature tissues and with maturation, there is a rise in the soluble pectin concentration due to increase in activity of polygalacturonase (PG) and pectin methyl esterase (PME), leading to tissue softening (Chitarra and Chitarra, 2005). A declining trend was recorded during the storage period despite the harvesting stages.

From the statistical data on effect of wrapping materials on pectin content in peel of dragon fruit, it is seen that there was significant variation among the treatments. On both day 4 and day 8, maximum pectin content was recorded in W_5 (shrink wrapping) with 4.89 and 3.91% respectively and the minimum values were recorded in control (W_1) with 3.66 and 2.44% respectively. A declining trend in pectin content was recorded with the advancement in storage which has also been reported by Wang *et. al.* (2024), Warsiki and Rofifah (2018) in dragon fruit, Deepthi *et. al.* (2016), Rana & Siddique (2018) in guava and Wijewardane and Gulreria (2013) in apple. This decline may be due to the action of pectolytic enzymes on natural pectin where insoluble pectin in water turn into water-soluble pectin (Warsiki and Rofifah, 2018; Wijewardane and Gulreria, 2013). The rate of decline during storage was lesser in shrink wrapping due to lower activity of PME enzyme (Mahajan *et. al.*, 2015) which delays the depolymerization of pectin content and maintains the postharvest firmness of the fruit (Wang *et. al.*, 2024).

Data addressing the interaction effect of harvesting stages and wrapping materials on pectin content in dragon fruit is presented in Table 4.38 and Figure 4.15 which reveals significant variation among the treatments. On the last day of observation, the highest content was recorded in H_1W_5 (25 DAA, shrink wrapping) with 5.11%, followed by H_2W_5 (30 DAA, shrink wrapping) with 4.15% and the least value (1.40%) was recorded in H_3W_1 (35 DAA, control). From this study it was perceived that fruits in shrink wrapping retained the pectin content more, despite the harvesting stages.

Table 4.33: Effect of different harvesting stages and wrapping materials on Betacyanin content of Dragon fruit pulp

Treatments	***Betacyanin in pulp (mg/100g)***														
	Day 0			***Day 2***			***Day 4***			***Day 6***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
Harvesting stages (H)															
H_1	20.72^{c}	22.75^{c}	21.74^{c}	27.79^{c}	26.90^{c}	27.34^{c}	26.39^{c}	26.11^{c}	26.25^{c}	23.62^{c}	22.97^{c}	23.29^{c}	20.53^{c}	20.64^{c}	20.58^{c}
H_2	33.11^{b}	33.98^{b}	33.55^{b}	40.74^{b}	39.34^{b}	40.04^{b}	38.32^{b}	37.63^{b}	37.98^{b}	34.58^{a}	35.43^{a}	35.00^{a}	30.99^{a}	30.39^{a}	30.69^{a}
H_3	37.96^{a}	39.35^{a}	38.66^{a}	47.63^{a}	44.70^{a}	46.17^{a}	45.23^{a}	41.76^{a}	43.49^{a}	33.67^{b}	33.67^{b}	33.67^{b}	26.58^{b}	27.87^{b}	27.22^{b}
SEm±	**0.41**	**0.49**	**0.32**	**0.28**	**0.13**	**0.15**	**0.21**	**0.24**	**0.16**	**0.16**	**0.40**	**0.22**	**0.07**	**0.12**	**0.07**
CD (P=0.05)	**1.17**	**1.41**	**0.90**	**0.81**	**0.37**	**0.44**	**0.61**	**0.70**	**0.45**	**0.47**	**1.16**	**0.61**	**0.21**	**0.33**	**0.19**
Wrapping materials (W)															
W_1	30.54^{a}	33.30^{a}	31.92^{a}	40.12^{a}	38.47^{a}	39.30^{a}	36.03^{c}	35.32^{ab}	35.68^{b}	27.54^{e}	28.08^{c}	27.81^{d}	22.90^{e}	22.74^{e}	22.82^{e}
W_2	30.22^{a}	31.41^{b}	30.82^{a}	38.62^{b}	37.14^{b}	37.88^{b}	35.37^{d}	35.19^{bc}	35.28^{b}	28.62^{d}	29.13^{c}	28.88^{c}	24.26^{d}	24.30^{d}	24.28^{d}
W_3	31.08^{a}	32.83^{ab}	31.95^{a}	40.06^{a}	37.61^{b}	38.83^{a}	38.95^{a}	36.15^{a}	37.55^{a}	32.47^{b}	33.00^{b}	32.73^{b}	26.74^{b}	27.49^{b}	27.12^{b}
W_4	30.41^{a}	31.25^{b}	30.83^{a}	38.68^{b}	36.35^{c}	37.51^{b}	37.02^{b}	34.29^{c}	35.66^{b}	30.93^{c}	28.10^{c}	29.51^{c}	25.64^{c}	25.42^{c}	25.53^{c}
W_5	30.74^{a}	31.35^{b}	31.05^{a}	36.13^{c}	35.32^{d}	35.72^{b}	35.85^{d}	34.89^{c}	35.37^{b}	33.55^{a}	35.14^{a}	34.34^{a}	30.62^{a}	31.55^{a}	31.08^{a}
SEm±	**0.53**	**0.63**	**0.41**	**0.36**	**0.16**	**0.20**	**0.27**	**0.31**	**0.21**	**0.21**	**0.52**	**0.28**	**0.27**	**0.37**	**0.23**
CD (P=0.05)	*NS*	*NS*	*NS*	*NS*	**0.47**	**0.56**	**0.78**	**0.90**	**0.58**	**0.60**	**1.50**	**0.79**	**0.78**	**1.06**	**0.65**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.34: Interaction effect of different harvesting stages and wrapping materials on Betacyanin content of Dragon fruit pulp

Treatments (H x W interaction)	*Betacyanin in pulp (mg/100g)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
H_1W_1	21.31^{f}	22.55^{f}	21.93^{e}	29.56^{h}	28.55^{g}	29.05^{h}	31.60^{g}	30.11^{ij}	30.86^{gh}	21.72^{j}	21.92^{g}	21.82^{i}	18.78^{i}	19.56^{h}	19.17^{g}
H_1W_2	20.79^{f}	22.91^{f}	21.85^{e}	28.30^{h}	27.17^{hi}	27.73^{i}	29.70^{h}	30.47^{i}	30.09^{hi}	23.00^{i}	21.78^{g}	22.39^{i}	19.83^{hi}	18.88^{h}	19.35^{g}
H_1W_3	20.02^{f}	21.73^{f}	20.87^{e}	27.89^{h}	27.75^{gh}	27.82^{i}	32.89^{f}	31.57^{h}	32.23^{f}	25.38^{h}	24.71^{f}	25.05^{g}	20.89^{h}	21.70^{g}	21.29^{ef}
H_1W_4	21.15^{f}	23.90^{f}	22.52^{e}	28.13^{h}	26.87^{i}	27.50^{i}	32.95^{f}	29.59^{j}	31.27^{g}	23.45^{i}	22.81^{fg}	23.13^{hi}	20.77^{h}	20.94^{g}	20.85^{f}
H_1W_5	20.32^{f}	22.69^{f}	21.51^{e}	25.08^{i}	24.15^{j}	24.61^{j}	30.66^{gh}	28.55^{k}	29.60^{i}	24.53^{h}	23.63^{f}	24.08^{gh}	22.37^{g}	22.15^{fg}	22.26^{e}
H_2W_1	33.61^{de}	35.67^{cd}	34.64^{c}	42.46^{de}	41.25^{d}	41.86^{e}	44.36^{d}	40.15^{f}	42.25^{e}	31.45^{f}	32.45^{d}	31.95^{e}	29.76^{cd}	26.32^{e}	28.04^{d}
H_2W_2	31.43^{e}	33.00^{de}	32.22^{d}	39.66^{f}	41.09^{d}	40.37^{f}	41.97^{e}	41.20^{e}	41.58^{e}	32.56^{e}	34.68^{c}	33.62^{d}	30.25^{c}	30.17^{c}	30.21^{c}
H_2W_3	34.10^{cd}	35.59^{cd}	34.84^{c}	43.15^{d}	38.64^{e}	40.89^{ef}	46.04^{c}	40.32^{f}	43.18^{d}	36.85^{b}	38.72^{b}	37.79^{b}	32.56^{b}	31.08^{c}	31.82^{b}
H_2W_4	33.85^{de}	32.20^{e}	33.03^{cd}	40.78^{ef}	36.47^{f}	38.62^{g}	48.68^{b}	38.72^{g}	43.70^{d}	35.59^{c}	29.43^{e}	32.51^{de}	28.71^{de}	26.51^{e}	27.61^{d}
H_2W_5	32.56^{d}	33.47^{de}	33.01^{cd}	37.68^{g}	39.24^{e}	38.46^{g}	42.68^{e}	43.56^{d}	43.12^{d}	36.44^{b}	41.86^{a}	39.15^{a}	33.69^{b}	37.87^{a}	35.78^{a}
H_3W_1	36.71^{b}	41.69^{a}	39.20^{a}	48.35^{ab}	45.62^{b}	46.98^{ab}	51.62^{a}	46.04^{c}	48.83^{b}	29.45^{g}	29.85^{e}	29.65^{f}	20.17^{h}	22.35^{fg}	21.26^{ef}
H_3W_2	38.45^{ab}	38.34^{b}	38.39^{ab}	47.91^{ab}	43.18^{c}	45.54^{c}	50.60^{ab}	45.62^{c}	48.11^{b}	30.30^{g}	30.93^{de}	30.62^{ef}	22.70^{g}	23.85^{f}	23.28^{e}
H_3W_3	39.11^{a}	41.17^{a}	40.14^{a}	49.14^{a}	46.45^{a}	47.80^{a}	49.23^{b}	52.20^{a}	50.71^{a}	35.17^{c}	35.55^{c}	35.36^{c}	26.78^{f}	29.71^{cd}	28.24^{d}
H_3W_4	36.22^{bc}	37.65^{bc}	36.93^{b}	47.14^{bc}	45.71^{ab}	46.42^{bc}	50.79^{ab}	46.78^{b}	48.79^{b}	33.74^{d}	32.06^{e}	32.90^{de}	27.45^{ef}	28.81^{d}	28.13^{d}
H_3W_5	39.34^{a}	37.90^{bc}	38.62^{a}	45.62^{c}	42.57^{b}	44.10^{d}	48.35^{b}	47.14^{b}	47.74^{c}	39.67^{a}	39.93^{ab}	39.80^{a}	35.81^{a}	34.62^{b}	35.22^{a}
SEm±	**0.91**	**1.09**	**0.71**	**0.63**	**0.28**	**0.35**	**0.55**	**0.25**	**0.30**	**0.36**	**0.90**	**0.48**	**0.47**	**0.64**	**0.40**
CD (P=0.05)	***NS***	***NS***	***NS***	**1.82**	**0.82**	**0.98**	**1.59**	**0.72**	**0.86**	**1.04**	**2.60**	**1.37**	**1.36**	**1.84**	**1.12**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.35: Effect of different harvesting stages and wrapping materials on Betacyanin content of Dragon fruit peel

Treatments	*Betacyanin in peel (mg/100g)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
Harvesting stages (H)															
H_1	19.56^{c}	21.18^{c}	20.37^{c}	23.55^{c}	23.85^{c}	23.70^{c}	27.95^{c}	27.59^{c}	27.77^{c}	29.33^{c}	31.57^{c}	30.45^{c}	26.68^{c}	26.72^{c}	26.70^{c}
H_2	28.03^{b}	29.37^{b}	28.70^{b}	34.52^{b}	33.52^{b}	34.02^{b}	39.47^{b}	37.90^{b}	38.68^{b}	33.82^{b}	35.79^{b}	34.80^{b}	28.59^{b}	26.73^{b}	27.66^{b}
H_3	37.63^{a}	35.43^{a}	36.53^{a}	43.38^{a}	40.56^{a}	41.97^{a}	43.00^{a}	39.51^{a}	41.26^{a}	33.22^{a}	32.30^{a}	32.76^{a}	25.50^{a}	24.40^{a}	24.95^{a}
SEm±	**0.60**	**0.87**	**0.53**	**0.31**	**0.18**	**0.18**	**0.17**	**0.18**	**0.12**	**0.13**	**0.31**	**0.17**	**0.18**	**0.17**	**0.12**
CD (P=0.05)	**1.73**	**2.51**	**1.49**	**0.88**	**0.53**	**0.50**	**0.48**	**0.53**	**0.35**	**0.36**	**0.90**	**0.48**	**0.51**	**0.50**	**0.35**
Wrapping materials (W)															
W_1	27.45^{b}	29.88^{a}	28.66^{ab}	31.89^{c}	33.94^{a}	32.91^{b}	34.69^{d}	34.09^{c}	34.39^{d}	28.41^{d}	28.56^{d}	28.48^{d}	21.77^{e}	21.10^{e}	21.44^{e}
W_2	27.21^{b}	28.40^{a}	27.80^{b}	32.25^{c}	31.82^{b}	32.03^{c}	35.61^{c}	35.24^{b}	35.42^{c}	30.70^{c}	31.80^{c}	31.25^{c}	24.44^{d}	22.32^{d}	23.38^{d}
W_3	30.27^{a}	29.42^{a}	29.85^{a}	35.33^{a}	33.30^{a}	34.32^{a}	38.63^{a}	37.74^{a}	38.18^{a}	33.63^{b}	34.99^{b}	34.31^{b}	29.19^{b}	28.97^{b}	29.08^{b}
W_4	28.94^{ab}	27.58^{a}	28.26^{ab}	35.88^{a}	31.93^{b}	33.90^{a}	37.24^{b}	32.17^{d}	34.71^{d}	30.94^{c}	31.77^{c}	31.35^{c}	25.82^{c}	23.75^{c}	24.78^{c}
W_5	28.18^{b}	28.02^{a}	28.10^{ab}	33.73^{b}	32.25^{b}	32.99^{b}	37.86^{b}	35.77^{b}	36.81^{b}	36.93^{a}	38.98^{a}	37.96^{a}	33.39^{a}	33.61^{a}	33.50^{a}
SEm±	**0.77**	**1.12**	**0.68**	**0.39**	**0.24**	**0.23**	**0.21**	**0.24**	**0.16**	**0.16**	**0.40**	**0.22**	**0.23**	**0.22**	**0.16**
CD (P=0.05)	***NS***	***NS***	***NS***	**1.14**	**0.68**	**0.65**	**0.62**	**0.69**	**0.45**	**0.47**	**1.17**	**0.62**	**0.66**	**0.64**	**0.45**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.36: Interaction effect of different harvesting stages and wrapping materials on Betacyanin content of Dragon fruit peel

Treatments (H x W interaction)	*Betacyanin in peel (mg/100g)*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
H_1W_1	19.17^{e}	19.30^{ef}	19.24^{f}	22.55^{g}	23.73^{i}	23.14^{i}	25.63^{i}	25.63^{f}	25.63^{i}	26.18^{h}	26.13^{f}	26.15^{h}	21.42^{g}	23.24^{e}	22.33^{i}
H_1W_2	17.71^{e}	23.95^{e}	20.83^{f}	20.43^{h}	26.18^{h}	23.31^{i}	28.52^{h}	29.15^{f}	28.83^{f}	29.23^{f}	30.25^{e}	29.74^{g}	25.55^{ef}	21.74^{fg}	23.65^{h}
H_1W_3	20.46^{e}	18.57^{f}	19.52^{f}	24.15^{h}	21.67^{j}	22.91^{i}	30.11^{g}	30.20^{f}	30.15^{e}	31.08^{e}	33.47^{c}	32.27^{ef}	28.49^{d}	30.78^{c}	29.64^{d}
H_1W_4	21.33^{e}	22.36^{ef}	21.85^{f}	26.73^{g}	25.33^{h}	26.03^{h}	26.46^{i}	26.51^{g}	26.48^{h}	27.25^{g}	32.89^{c}	30.07^{g}	26.51^{e}	25.26^{d}	25.89^{f}
H_1W_5	19.14^{e}	21.73^{e}	20.43^{f}	23.90^{g}	22.36^{j}	23.13^{i}	29.04^{g}	26.46^{g}	27.75^{g}	32.89^{d}	35.12^{b}	34.00^{de}	31.43^{c}	32.59^{b}	32.01^{c}
H_2W_1	27.12^{cd}	29.84^{cd}	28.48^{de}	32.53^{ef}	34.51^{e}	33.52^{f}	36.74^{e}	36.05^{d}	36.40^{d}	30.49^{e}	29.96^{de}	30.22^{d}	24.72^{f}	20.46^{gh}	22.59^{h}
H_2W_2	25.69^{d}	26.18^{d}	25.93^{e}	30.61^{f}	28.08^{g}	29.34^{g}	34.82^{f}	38.23^{c}	36.52^{d}	32.22^{d}	33.37^{c}	32.79^{e}	26.63^{e}	25.33^{d}	25.98^{f}
H_2W_3	29.45^{c}	33.68^{bc}	31.57^{cd}	34.32^{e}	37.57^{d}	35.94^{e}	40.15^{d}	41.47^{a}	40.81^{b}	35.24^{c}	39.60^{a}	37.42^{c}	30.32^{c}	30.42^{c}	30.37^{d}
H_2W_4	30.14^{c}	28.13^{d}	29.13^{d}	41.66^{c}	32.89^{f}	37.28^{d}	46.04^{a}	34.71^{e}	40.37^{b}	33.11^{d}	35.68^{b}	34.40^{d}	25.20^{f}	22.66^{f}	23.93^{h}
H_2W_5	27.75^{cd}	29.04^{cd}	28.39^{de}	33.47^{e}	34.57^{e}	34.02^{f}	39.60^{d}	39.05^{c}	39.33^{c}	38.04^{b}	40.33^{a}	39.19^{b}	36.05^{a}	34.79^{a}	35.42^{a}
H_3W_1	36.05^{b}	40.48^{a}	38.27^{a}	40.59^{cd}	43.56^{a}	42.08^{b}	41.69^{c}	40.59^{b}	41.14^{b}	28.55^{f}	29.59^{e}	29.07^{g}	19.17^{h}	19.61^{h}	19.39^{k}
H_3W_2	38.23^{ab}	35.08^{ab}	36.65^{a}	45.71^{ab}	41.20^{b}	43.45^{a}	43.51^{b}	38.34^{c}	40.92^{b}	30.66^{e}	31.78^{cd}	31.22^{f}	21.15^{g}	19.90^{h}	20.53^{j}
H_3W_3	40.89^{a}	36.02^{ab}	38.45^{a}	47.52^{a}	40.67^{bc}	44.10^{a}	45.62^{a}	41.55^{a}	43.59^{a}	34.58^{c}	31.92^{cd}	33.25^{de}	28.75^{d}	25.71^{d}	27.23^{e}
H_3W_4	35.34^{b}	32.25^{bc}	33.79^{bc}	39.24^{d}	37.57^{d}	38.40^{c}	39.24^{d}	35.28^{de}	37.26^{d}	32.45^{d}	26.73^{f}	29.59^{g}	25.74^{ef}	23.33^{e}	24.54^{g}
H_3W_5	37.65^{ab}	33.30^{bc}	35.48^{ab}	43.84^{b}	39.82^{c}	41.83^{b}	44.94^{b}	41.80^{a}	43.37^{a}	39.88^{a}	41.50^{a}	40.69^{a}	32.68^{b}	33.47^{b}	33.07^{b}
SEm±	**1.34**	**1.94**	**1.18**	**0.68**	**0.41**	**0.40**	**0.37**	**0.41**	**0.28**	**0.28**	**0.70**	**0.38**	**0.39**	**0.39**	**0.28**
CD (P=0.05)	***NS***	**5.61**	**3.33**	**1.97**	**1.18**	**1.13**	**1.07**	**1.19**	**0.78**	**0.81**	**2.02**	**1.07**	**1.14**	**1.12**	**0.78**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.37: Effect of different harvesting stages and wrapping materials on pectin content of Dragon fruit

Treatments	*Pectin content (%)*								
	Day 0			*Day 4*			*Day 8*		
	2021	*2022*	*Pooled*	*2021*	*2022*	*Pooled*	*2021*	*2022*	*Pooled*
Harvesting stages(H)									
H_1	8.75^{a}	8.87^{a}	8.81^{a}	6.06^{a}	5.97^{a}	6.02^{a}	3.98^{a}	4.39^{a}	4.18^{a}
H_2	5.59^{b}	6.05^{b}	5.82^{b}	4.29^{b}	3.79^{b}	4.04^{b}	2.90^{b}	2.99^{b}	2.94^{b}
H_3	3.58^{c}	3.87^{c}	3.73^{c}	2.51^{c}	2.74^{c}	2.63^{c}	1.80^{c}	2.13^{c}	1.96^{c}
SEm±	**0.211**	**0.198**	**0.145**	**0.089**	**0.071**	**0.057**	**0.058**	**0.027**	**0.032**
CD (P=0.05)	**0.610**	**0.573**	**0.410**	**0.256**	**0.205**	**0.161**	**0.168**	**0.077**	**0.090**
Wrapping materials(W)									
W_1	5.93^{a}	6.21^{a}	6.07^{a}	3.72^{c}	3.61^{e}	3.66^{d}	2.32^{d}	2.56^{e}	2.44^{e}
W_2	5.69^{a}	6.16^{a}	5.93^{a}	4.14^{b}	3.88^{d}	4.01^{c}	2.53^{d}	2.82^{d}	2.67^{d}
W_3	6.26^{a}	6.47^{a}	6.37^{a}	4.37^{b}	4.48^{b}	4.42^{b}	3.07^{b}	3.32^{b}	3.19^{b}
W_4	5.84^{a}	6.07^{a}	5.96^{a}	4.19^{b}	4.10^{c}	4.14^{c}	2.70^{c}	3.18^{c}	2.94^{c}
W_5	6.15^{a}	6.41^{a}	6.28^{a}	5.01^{a}	4.76^{a}	4.89^{a}	3.84^{a}	3.97^{a}	3.91^{a}
SEm±	**0.273**	**0.256**	**0.187**	**0.115**	**0.092**	**0.073**	**0.075**	**0.034**	**0.041**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.331**	**0.265**	**0.208**	**0.217**	**0.100**	**0.117**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

Table 4.38: Interaction effect of different harvesting stages and wrapping materials on pectin content of Dragon fruit

Treatments (H x W interaction)	***Pectin content (%)***								
	Day 0			***Day 4***			***Day 8***		
	2021	***2022***	***Pooled***	***2021***	***2022***	***Pooled***	***2021***	***2022***	***Pooled***
H_1W_1	8.15^{a}	9.67^{a}	8.91^{a}	5.56^{cd}	5.74^{b}	5.65^{c}	3.61^{c}	3.96^{d}	3.79^{de}
H_1W_2	8.26^{a}	8.52^{ab}	8.39^{a}	5.78^{bc}	5.53^{b}	5.65^{c}	3.47^{c}	3.88^{d}	3.68^{e}
H_1W_3	9.43^{a}	8.74^{a}	9.09^{a}	6.26^{b}	6.25^{a}	6.26^{b}	4.23^{b}	4.68^{b}	4.45^{b}
H_1W_4	9.11^{a}	8.06^{b}	8.59^{a}	5.80^{bc}	5.78^{b}	5.79^{c}	3.55^{c}	4.25^{c}	3.90^{d}
H_1W_5	8.81^{a}	9.38^{a}	9.10^{a}	6.92^{a}	6.56^{a}	6.74^{a}	5.03^{a}	5.18^{a}	5.11^{a}
H_2W_1	6.16^{b}	5.55^{c}	5.86^{b}	3.65^{f}	2.74^{fg}	3.20^{g}	2.35^{ef}	1.91^{g}	2.13^{i}
H_2W_2	5.20^{b}	6.21^{c}	5.71^{b}	4.26^{e}	3.44^{de}	3.85^{f}	2.56^{de}	2.62^{f}	2.59^{g}
H_2W_3	5.56^{b}	6.37^{c}	5.96^{b}	4.32^{e}	4.31^{c}	4.31^{e}	2.88^{d}	3.23^{e}	3.05^{f}
H_2W_4	4.96^{bc}	5.89^{c}	5.42^{b}	4.03^{ef}	3.84^{d}	3.93^{f}	2.45^{ef}	3.14^{e}	2.79^{g}
H_2W_5	6.06^{b}	6.22^{c}	6.14^{b}	5.17^{d}	4.62^{c}	4.89^{d}	4.26^{b}	4.03^{d}	4.15^{c}
H_3W_1	3.48^{d}	3.42^{d}	3.45^{c}	1.95^{i}	2.35^{g}	2.15^{j}	1.00^{h}	1.81^{i}	1.40^{k}
H_3W_2	3.61^{d}	3.75^{d}	3.68^{c}	2.38^{hi}	2.68^{fg}	2.53^{i}	1.57^{g}	1.94^{hi}	1.75^{j}
H_3W_3	3.80^{cd}	4.31^{d}	4.06^{c}	2.52^{gh}	2.89^{f}	2.70^{hi}	2.11^{f}	2.04^{gh}	2.08^{i}
H_3W_4	3.45^{d}	4.26^{d}	3.86^{c}	2.76^{gh}	2.67^{fg}	2.71^{hi}	2.08^{f}	2.15^{g}	2.12^{i}
H_3W_5	3.57^{d}	3.63^{d}	3.60^{c}	2.95^{g}	3.11^{ef}	3.03^{gh}	2.23^{ef}	2.69^{f}	2.46^{h}
SEm±	**0.472**	**0.444**	**0.324**	**0.199**	**0.159**	**0.127**	**0.130**	**0.060**	**0.072**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**0.459**	**0.360**	**0.375**	**0.172**	**0.202**

Note: NS = Non-significant at 5% level of significance

Figures in the table are mean values and those small letters in superscript are separated by Duncan's Multiple Range Test (DMRT)

H_1- 25 DAA, H_2- 30 DAA, H_3- 35 DAA
W_1- No wrapping, W_2- Banana leaves, W_3- Brown paper, W_4- EPE foam net, W_5- Shrink wrapping

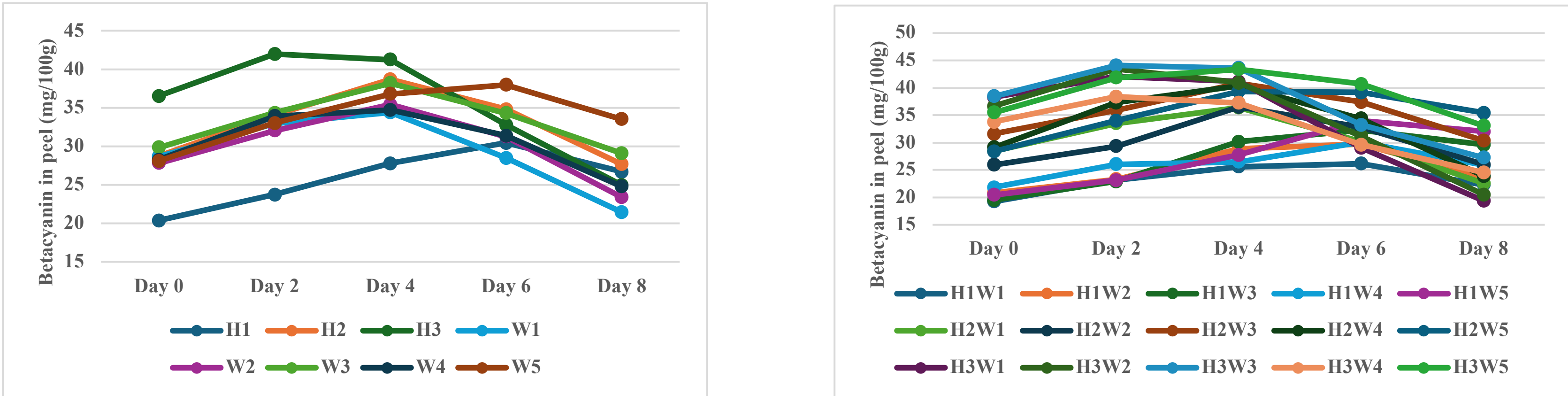


Figure 4.14: Individual and interaction effect of harvesting stages and wrapping materials on Betacyanin content in peel

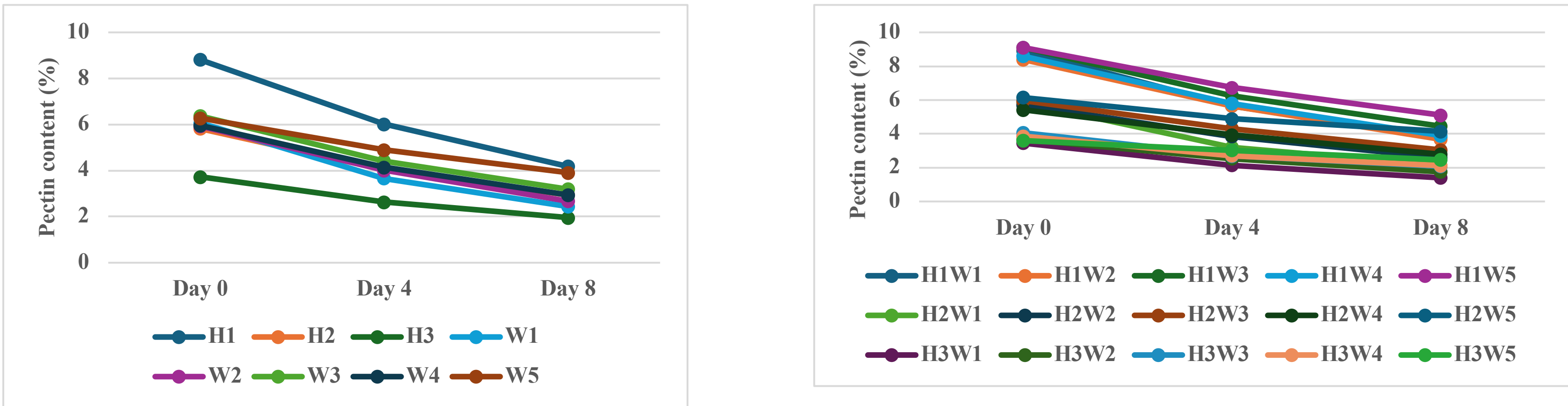


Figure 4.15: Individual and interaction effect of harvesting stages and wrapping materials on Pectin content in peel.

4.1.20 Sensory evaluation

Flavor

The effect of harvesting stages and wrapping materials on flavor of dragon fruit is presented in table 4.39. On the day of harvest, maximum rating was recorded in fruits of late harvest (35 DAA) with a mean rating of 8.2, which may be due to higher TSS content as compared to the other maturity stages and minimum score was recorded in H_1 (25 DAA) harvest with an average score of 5.8. Ho *et. al.* (2020) also recorded positive impact of TSS on overall preference which explain its impact on flavor. At the end storage, maximum score for flavor was recorded in H_2W_5 (30 DAA, shrink wrapping) with a pooled score of 7.5 and the minimum rating was scored in H_1W_2 (25 DAA, banana leaves). Even though degradation of peel was visible, the edible pulp was organoleptically acceptable till the end of storage and the reduction in score during the time of storage may be due to the reduction in physiochemical quality of the fruit such as acidity and firmness (Obenland *et. al*., 2016).

Colour

Table 4.40 showcases the score on colour of dragon fruit as influenced by harvesting stages and wrapping materials. At the time of harvest, higher rankings was attributed to the later harvest i.e., 30 DAA and 35 DAA with an average of 8.4 and 8.6 respectively, while harvest at 25 DAA had an average rating of 7. One of the reasons that dragon fruit is generally sought after is due to its unique, bright aesthetically pleasing colour. During the time of storage, the score for 25 DAA ascended while slight decline was observed for 30 DAA and 35 DAA after day 4 of storage. At the end of storage, maximum rating was recorded in H_2W_5 (30 DAA, shrink wrapping) followed by H_1W_5 (25 DAA, shrink wrapping) with score of 7.7 and 7.4 respectively and the minimum was recorded in H_3W_0 (35 DAA, control).

Taste

The scores pertaining to taste of dragon fruit as influenced by harvesting stages and wrapping materials is presented in table 4.41. On the first day of evaluation, fruits harvested at 35 DAA (H_3) had the highest score followed by 30 DAA (H_2) with average scores of 8.2 and 8.0 respectively, and the lowest score was found in 25 DAA (H_1) with mean rating of 5.8. The panelist remarked the fruits of initial harvest (25 DAA) to be bland. At the end of storage, the highest score was assigned to H_2W_5 (30 DAA, shrink wrapping) followed by H_3W_3 (35 DAA, brown paper) and H_3W_5 (35 DAA, shrink wrapping) with score of 7.6 and 7.4 respectively and the minimum was recorded in H_1W_0 (25 DAA, control). The rate of loss in acidity was higher in the later stage of storage in control fruits thus affect giving insipid taste or lack of flavor as reported by Deepthi (2016) in guava.

Overall acceptability

The effect of harvesting stages and wrapping materials on overall acceptability of dragon fruit is presented in table 4.42. On the first day of evaluation, fruits harvested at 35 DAA (H_3) had the highest score followed by 30 DAA (H_2) with average scores of 8.3 and 8.1 respectively, and the lowest score was found in 25 DAA (H_1) with mean rating of 6.3. At the end of storage, maximum score for flavor was recorded in H_2W_5 (30 DAA, shrink wrapping) with a pooled score of 7.6 and the minimum rating (5.75) was scored in H_1W_2 (25 DAA, banana leaves). This finding is corroborated with Lata *et. al.* (2022) who reported higher sensory scores at 31 DAA compared to other harvesting stages. Ho *et. al.* (2020) also reported same pattern in all sensory attributes with scores decreasing at later storage time.

Table 4.39: Effect of different harvesting stages and wrapping materials on sensory attributes (flavor) of Dragon fruit

Treatments	*Flavor*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*
H_1W_1 (25 DAA, no wrapping)	5.6	5.8	5.7	6.6	7.5	7.0	7.2	8.4	7.8	6.0	6.5	6.2	5.0	5.6	5.3
H_1W_2 (25 DAA, Banana leaves)	5.4	5.7	5.5	6.4	6.5	6.4	7.2	7.2	7.2	6.2	7.0	6.6	5.6	5.8	5.7
H_1W_3 (25 DAA, Brown paper)	6.0	6.0	6.0	7.7	6.0	6.8	7.5	7.7	7.6	6.2	7.4	6.8	6.0	7.0	6.5
H_1W_4 (25 DAA, EPE foam net)	6.4	5.8	6.1	8	7.8	7.9	8.0	7.2	7.6	5.2	5.3	5.2	5.0	5.0	5.0
H_1W_5 (25 DAA, Shrink wrap)	5.6	5.9	5.7	6.6	6.9	6.7	7.8	7.7	7.7	5.4	7.2	6.3	5.2	5.1	5.1
H_2W_1 (30 DAA, no wrapping)	8.4	7.8	8.1	8.2	8.5	8.3	8.1	7.8	7.9	7.8	6.5	7.1	6.8	7.0	6.9
H_2W_2 (30 DAA, Banana leaves)	8.0	8.5	8.2	8.0	8.8	8.4	8.2	7.8	8.0	7.4	7.2	7.3	7.2	6.9	7.0
H_2W_3 (30 DAA, Brown paper)	7.5	8.2	7.8	7.4	8.8	8.1	8.8	8.0	8.4	7.2	7.7	7.4	7.2	7.3	7.2
H_2W_4 (30 DAA, EPE foam net)	7.6	7.8	7.7	8.0	7.8	8.2	8.0	8.5	8.2	8.5	8.2	8.3	7.0	7.0	7.0
H_2W_5 (30 DAA, Shrink wrap)	8.0	8.5	8.2	8.0	8.7	8.3	8.4	8.0	8.2	8.5	8.0	8.2	7.4	7.6	7.5
H_3W_1 (35 DAA, no wrapping)	8.0	8.2	8.1	8.7	8.0	8.3	7.5	7.8	7.6	7.0	7.4	7.2	5.5	6.8	6.1
H_3W_2 (35 DAA, Banana leaves)	8.5	8.0	8.2	8.2	8.0	8.1	7.9	7.8	7.8	7.5	7.6	7.55	6.2	7.3	6.7
H_3W_3 (35 DAA, Brown paper)	8.0	8.4	8.2	8.5	8.2	8.3	7.8	8.0	7.9	7.6	7.8	7.7	7.2	7.4	7.3
H_3W_4 (35 DAA, EPE foam net)	8.5	8.2	8.3	8.5	8.2	8.3	8.2	7.9	8.0	7.8	7.6	7.7	7.3	7.0	7.15
H_3W_5 (35 DAA, Shrink wrap)	8.2	8.0	8.1	8.4	8.0	8.2	8.0	8.0	8.0	7.8	7.8	7.8	7.5	7.2	7.35

Table 4.40: Effect of different harvesting stages and wrapping materials on sensory attributes (color) of Dragon fruit

Treatments	*Colour*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*
H_1W_1 (25 DAA, no wrapping)	6.5	7.3	6.9	7.8	7.3	7.5	7.5	7.2	7.3	7.3	6.5	6.9	7.0	6.8	6.9
H_1W_2 (25 DAA, Banana leaves)	7.5	7.0	7.2	7.5	8.5	8.0	7.5	7.3	7.4	7.4	7.2	7.3	6.5	7.0	6.7
H_1W_3 (25 DAA, Brown paper)	7.7	6.9	7.3	8.0	7.2	7.6	7.6	7.2	7.4	7.5	7.5	7.5	7.3	7.0	7.1
H_1W_4 (25 DAA, EPE foam net)	6.5	7.2	6.8	7.5	7.0	7.2	7.4	7.1	7.2	7.2	6.9	7.0	7.0	6.9	6.9
H_1W_5 (25 DAA, Shrink wrap)	6.8	7.4	7.1	7.8	7.4	7.6	7.8	7.3	7.5	7.8	8.0	7.9	7.6	7.2	7.4
H_2W_1 (30 DAA, no wrapping)	8.5	8.3	8.4	8.5	8.1	8.3	8.3	8.5	8.4	7.5	7.2	7.3	6.5	6.0	6.2
H_2W_2 (30 DAA, Banana leaves)	8.7	9.0	8.8	8.5	8.2	8.3	8.5	8.5	8.5	7.8	7.3	7.5	7.5	6.8	7.1
H_2W_3 (30 DAA, Brown paper)	8.5	7.9	8.2	8.5	8.3	8.4	8.3	7.6	7.9	8.0	7.4	7.7	7.6	6.9	7.2
H_2W_4 (30 DAA, EPE foam net)	8.5	7.8	8.1	8.5	7.5	8.0	8.2	7.1	7.6	7.8	6.8	7.3	7.0	6.5	6.7
H_2W_5 (30 DAA, Shrink wrap)	8.6	8.0	8.3	8.6	7.9	8.2	8.5	8.6	8.5	8.1	7.7	7.9	7.8	7.6	7.7
H_3W_1 (35 DAA, no wrapping)	8.9	8.5	8.7	8.5	8.0	8.2	8.0	7.5	7.7	7.6	6.7	7.1	6.5	5.8	6.1
H_3W_2 (35 DAA, Banana leaves)	8.6	8.2	8.4	8.6	7.9	8.2	8.4	7.6	8.0	7.8	7.1	7.4	7.5	6.9	7.2
H_3W_3 (35 DAA, Brown paper)	8.8	8.2	8.5	8.5	7.8	8.1	8.0	8.4	8.2	7.7	7.3	7.5	7.5	7.0	7.2
H_3W_4 (35 DAA, EPE foam net)	9.0	8.5	8.7	8.8	8.3	8.5	8.4	7.8	8.1	8.0	7.2	7.6	7.2	6.2	6.7
H_3W_5 (35 DAA, Shrink wrap)	8.7	8.3	8.5	8.5	8.0	8.2	8.4	8.5	8.4	8.2	7.5	7.8	7.7	7.0	7.3

Table 4.41: Effect of different harvesting stages and wrapping materials on sensory attributes (taste) of Dragon fruit

Treatments	*Taste*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*
H_1W_1 (25 DAA, no wrapping)	5.2	5.8	5.5	6.6	6.5	6.5	7.6	7.8	7.7	6	7.2	6.6	5.1	5.3	5.2
H_1W_2 (25 DAA, Banana leaves)	6.4	5.7	6.0	6.4	6.5	6.4	7.8	6.0	6.9	6.2	7.5	6.8	5.5	5.4	5.4
H_1W_3 (25 DAA, Brown paper)	5.9	6.0	5.9	7.5	6.3	6.9	7.5	8.0	7.7	7.0	7.4	7.2	6.2	6.0	6.1
H_1W_4 (25 DAA, EPE foam net)	6.4	5.9	6.1	8.0	7.5	7.7	7.6	7.4	7.5	5.2	6.4	5.8	5.0	5.3	5.2
H_1W_5 (25 DAA, Shrink wrap)	5.6	6.2	5.9	6.6	6.9	6.7	7.2	6.8	7.0	7.5	7.2	7.3	6.7	6.7	6.7
H_2W_1 (30 DAA, no wrapping)	8.4	7.8	8.1	8.3	8.3	8.3	7.5	7.4	7.4	6.5	6.3	6.4	5.9	5.8	5.8
H_2W_2 (30 DAA, Banana leaves)	8.0	8.5	8.2	8.2	8.8	8.5	8.2	7.9	8.0	7.5	7.2	7.3	6.4	6.9	6.6
H_2W_3 (30 DAA, Brown paper)	7.5	8.2	7.8	7.4	8.5	7.9	8.3	8.3	8.3	7.2	7.0	7.1	7.1	7.0	7.1
H_2W_4 (30 DAA, EPE foam net)	7.6	7.8	7.7	8.5	7.6	8.0	8.2	8.2	8.2	8.1	8.2	8.15	6.9	7.6	7.2
H_2W_5 (30 DAA, Shrink wrap)	8.0	8.5	8.2	8.3	8.7	8.5	8.0	8.2	8.1	8.4	8.4	8.4	7.4	7.8	7.6
H_3W_1 (35 DAA, no wrapping)	8.0	8.2	8.1	7.8	7.8	7.8	7.5	8.5	8	6.5	7.2	6.8	5.5	5.9	5.7
H_3W_2 (35 DAA, Banana leaves)	8.5	8.0	8.2	8.2	8.0	8.1	8.3	8.4	8.3	7.4	7.2	7.3	6.5	7.3	6.9
H_3W_3 (35 DAA, Brown paper)	8.0	8.4	8.2	8.6	8.3	8.4	7.5	7.5	7.5	7.9	7.4	7.6	7.5	7.4	7.4
H_3W_4 (35 DAA, EPE foam net)	8.5	8.2	8.3	8.5	8.5	8.5	8.2	7.9	8.1	7.5	7.6	7.5	7.3	7.1	7.2
H_3W_5 (35 DAA, Shrink wrap)	8.2	8.0	8.1	8.1	7.9	8.0	7.4	8.0	7.7	8.2	8.1	8.1	7.5	7.3	7.4

Table 4.42: Effect of different harvesting stages and wrapping materials on sensory attributes (overall acceptability) of Dragon fruit

Treatments	*Overall acceptability*														
	Day 0			*Day 2*			*Day 4*			*Day 6*			*Day 8*		
	2021	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*	*2021*	*2022*	*Mean*
H_1W_1 (25 DAA, no wrapping)	5.77	6.30	6.03	7.00	7.10	7.05	7.43	7.80	7.62	6.43	6.73	6.58	5.70	5.90	5.80
H_1W_2 (25 DAA, Banana leaves)	6.43	6.13	6.28	6.77	7.17	6.97	7.50	6.83	7.17	6.60	7.23	6.92	5.87	6.07	5.97
H_1W_3 (25 DAA, Brown paper)	6.53	6.30	6.42	7.73	6.50	7.12	7.53	7.63	7.58	6.90	7.43	7.17	6.50	6.67	6.58
H_1W_4 (25 DAA, EPE foam net)	6.43	6.30	6.37	7.83	7.43	7.63	7.67	7.23	7.45	5.87	6.20	6.03	5.67	5.73	5.70
H_1W_5 (25 DAA, Shrink wrap)	6.00	6.50	6.25	7.00	7.07	7.03	7.60	7.27	7.43	6.90	7.47	7.18	6.50	6.33	6.42
H_2W_1 (30 DAA, no wrapping)	8.43	7.97	8.20	8.33	8.30	8.32	7.97	7.90	7.93	7.27	6.67	6.97	6.40	6.28	6.34
H_2W_2 (30 DAA, Banana leaves)	8.23	8.67	8.45	8.23	8.60	8.42	8.30	8.07	8.18	7.57	7.23	7.40	7.05	6.87	6.96
H_2W_3 (30 DAA, Brown paper)	7.83	8.10	7.97	7.77	8.53	8.15	8.53	8.50	8.51	7.47	7.37	7.42	7.32	7.07	7.19
H_2W_4 (30 DAA, EPE foam net)	7.90	7.80	7.85	8.53	7.63	8.08	8.13	7.95	8.04	8.13	7.73	7.93	6.97	7.03	7.00
H_2W_5 (30 DAA, Shrink wrap)	8.20	8.33	8.27	8.30	8.43	8.37	8.20	8.27	8.23	8.33	8.28	8.31	7.53	7.67	7.60
H_3W_1 (35 DAA, no wrapping)	8.30	8.30	8.30	8.33	7.93	8.13	7.67	7.93	7.80	7.03	7.10	7.07	5.83	6.17	6.00
H_3W_2 (35 DAA, Banana leaves)	8.53	8.07	8.30	8.33	7.97	8.15	8.20	7.93	8.07	7.57	7.30	7.43	6.73	7.17	6.95
H_3W_3 (35 DAA, Brown paper)	8.27	8.33	8.30	8.53	8.10	8.32	7.77	7.97	7.87	7.73	7.50	7.62	7.40	7.27	7.33
H_3W_4 (35 DAA, EPE foam net)	8.67	8.30	8.48	8.60	8.33	8.47	8.27	7.87	8.07	7.77	7.47	7.62	7.27	6.77	7.02
H_3W_5 (35 DAA, Shrink wrap)	8.37	8.10	8.23	8.33	7.97	8.15	7.93	8.17	8.05	8.07	7.80	7.93	7.57	7.17	7.37

4.2 To study the best harvest stage of Dragon fruit to prepare Ready-to-Serve (RTS) beverage.

Data obtained during the 2020-21 and 2021-22 experimental seasons are presented and the pooled data are discussed below under the following subheadings:

4.2.1 Total Soluble Solids (ºB)

The data pertaining to effect of harvesting stages on TSS content of dragon fruit RTS is presented in Table 4.43 and Figure 4.16 which depicts significant variation among the treatments. A critical examination of the pooled data indicated that T_4 (40 DAA) resulted in maximum TSS content during the initial days of storage while, the minimum values were recorded in T_1 (25 DAA). At day 90, the maximum TSS content (13.84ºB) was recorded in T_3 (35 DAA) and the minimum content (11.08ºB) was recorded in T_1 (25 DAA). This finding is corroborated by Sew *et. al.* (2013) who reported that TSS increased with maturity, which may be primarily due to the accumulation of water-soluble monosaccharides such as glucose and fructose, which are the end products of starch and polysaccharide degradation during fruit ripening. This physiological transformation is largely attributed to the increased activity of hydrolytic enzymes such as invertases, amylases, and cellulases, which become more active during the later stages of fruit maturation. These enzymes facilitate the breakdown of starches and structural polysaccharides into simpler, water-soluble sugars such as glucose, fructose, and sucrose, thereby elevating the TSS content (Hossain *et al*., 2014; Shi *et al*., 2023; Yan *et al*., 2024).

In all the treatments, a gradual increase in TSS content was noted during the storage days. Similar finding in RTS has been reported by Pavithra and Mini (2023), Hemalatha *et. al.* (2018), Kumar and Singh (2013), Kausar *et. al.* (2012), Zubia *et. al.* (2017), who attributed the significant increase of TSS in RTS during storage to the co-polymerization of organic acids with sugars and amino acids or due to hydrolysis/conversion of polysaccharides into soluble sugars (oligosaccharides and monosaccharides). The fruits harvested at 40 DAA tend to be cracked or split open with the peel ruptured which may be due to delay in harvest, surplus irrigation or rainfall during ripening period (Wakchaure *et. al.,* 2023) and thus, affects the final quality of the processed product.

4.2.2 pH

Table 4.44 and Figure 4.16 present the data on the effect of harvesting stages of dragon fruit on the pH of the RTS beverage, revealing significant differences among the treatments. Across all storage intervals, the highest pH values were consistently recorded in fruits harvested at T4 (40 DAA), whereas the lowest values were observed in T1 (25 DAA). During storage, a progressive decline in pH was evident in all treatments, with pH values decreasing from 3.40 to 3.14 in T_1 (25 DAA), 3.66 to 3.32 in T_2 (30 DAA), 3.83 to 3.45 in T_3 (35 DAA) and 4.47 to 4.11 in T_4 (40 DAA). This trend is consistent with the findings of Sew et al. (2013), Foke et al. (2018), and Hemalatha et al. (2018), who reported that the pH of dragon fruit juice increases with fruit maturity due to reduced organic acid content. Since pH is inversely related to acidity, the decline in pH during storage is attributed to increased acid concentration or the formation of acidic metabolites. Fatima *et al*. (2024) similarly documented a decreasing pH trend in cucumber and pomegranate-based RTS beverages, correlating with an apparent increase in titratable acidity. The reduction in pH during storage may also result from ongoing biochemical processes such as the breakdown of sugars into organic acids via microbial activity or enzymatic reactions, even under preservation (Prisacaru *et. al.*, 2025)

4.2.3 Titratable acidity (%)

The study revealed that harvesting stages had significant effect on the titratable acidity of dragon fruit RTS as presented in Table 4.45 and Figure 4.17. On all the days of storage, the maximum values were found in T_1 (25 DAA) with a gradual increase from 0.30 to 0.47% in acidity content during the storage period. The minimum values were recorded in T_4 (40 DAA) with values ranging from 0.21 to 0.38%. It was observed that acidity decreased with the advancement in harvesting time which was also reported by Sew *et. al.* (2013) in dragon fruit juice and puree obtained from fruits of different maturity stages.

Acidity is crucial in determining the quality and stability of RTS beverage. Patel and Bhise (2024), Ranjah *et. al.* (2021), Kausar *et. al.* (2020), Zubia *et. al.* (2017) also reported increase in acidity content of RTS beverage during storage. This gradual increase may be attributed to the accelerated biochemical reaction taking place at room temperature during storage, such as degradation of pectin substances, or acid formation due to oxidation of reducing sugars and degradation of polysaccharides or also, by microbial activity leading to production of lactic acid, acetic acid and other organic acids thereby increasing the overall acidity.

4.2.4 Ascorbic acid (mg/100mL)

The data in Table 4.46 and Figure 4.17 representing the effect of maturity stages of dragon fruit on ascorbic acid content in RTS beverage shows significant differences among the treatments. Till Day 60 of observation, the pooled data shows maximum ascorbic acid in T_1 (25 DAA) with a gradual decline from 0.73 to 0.51 mg/100mL during the storage period. The minimum values were recorded in T_4 (40 DAA) with values ranging from 0.38 to 0.23 mg/100mL. At the end of storage period, the maximum ascorbic acid content was recorded in T_1 (25 DAA) with 0.51 mg/100mL.

Ascorbic acid content was found to be low compared to other fruits, also found by Islam *et. al.* (2012) in dragon fruit jelly. This may also be due to the use of potassium sorbate as preservative, also corroborated by the observations of Alli and Kermasha (1989), who noted a significant reduction in ascorbic acid levels in orange juice treated with sorbic acid during storage, as compared to untreated samples.

Ascorbic acid is a crucial antioxidant known for its role in neutralizing free radicals and supporting immune function (Bochare et al., 2020). However, it is highly sensitive to degradation from light, heat, and oxygen exposure. Losses may occur during processing due to thermal degradation and oxidation, especially in more mature fruit, where increased sugar levels (particularly fructose) can accelerate ascorbic acid breakdown (Lee & Kader, 2000). Furthermore, the enzymatic oxidation of ascorbic acid by ascorbic acid oxidase, exacerbated by the presence of residual oxygen in glass containers, may lead to the formation of dehydroascorbic acid, a less stable form (Pavithra & Mini, 2023; Kumar & Singh, 2013).

4.2.5 Total sugar (%)

Data concerning the effect of harvesting stages of dragon fruit on total sugar content in RTS beverage presented in Table 4.47 and Figure 4.18 reflect significant differences among the treatments. Total sugar content was observed to be higher in T_4

(40 DAA) during the initial days of storage while at Day 90, maximum total sugar content was found in T_3 (30 DAA). The total sugar content of all the treatments increased during the storage period and T_3 (35 DAA) had the highest value which increased from 10.80 to 12.00% and T_1 (25 DAA) recorded the minimum amount which increased from 10.30 to 10.77%.

Similar increase in sugar content during storage has been reported by many workers and this gradual rise may be due to a series of reasons such as the hydrolysis of disaccharides and polysaccharides into soluble sugars that increases the total sugar content (Pavithra and Mini, 2023; Udayakumar *et. al.,* 2022) or the inversion of sucrose into glucose and fructose (Hemalatha *et. al.,* 2018). These reactions are further influenced by the fruit's endogenous enzyme activity and residual acidity, which may catalyse the hydrolysis and inversion processes even under preserved conditions.

4.2.6 Reducing sugar (%)

The data pertaining to reducing sugar of dragon fruit RTS as influenced by harvesting stages is laid out in Table 4.48 and Figure 4.18 which depicts significant difference among the treatments. At Day 0, pooled data showed maximum content in T_4 (40 DAA) with 3.15% and minimum value of 1.49% in T_1 (25 DAA). There was gradual increase in reducing sugar content as treatments prolonged in storage. At Day 90 (termination), the maximum reducing sugar content was found in T_4 (40 DAA) which had an increase from 3.15 to 3.20% during the storage period of 90 days, however, and the minimum values was recorded in T_1 (25 DAA) which increased from 1.49 to 1.75%. This increase in reducing sugars during storage can be primarily attributed to the enzymatic inversion of non-reducing sugars such as sucrose into reducing sugars like glucose and fructose. This process, often referred to as sucrose inversion, has been well-documented in various fruit-based beverages (Fatima et al., 2024; Pavithra & Mini, 2023; Hemalatha et al., 2018). Additionally, Rashid et al. (2018) noted that the hydrolysis of organic acids may also contribute to the increase in sugar content by shifting the carbohydrate balance toward simpler sugars. Cywińska-Antonik *et al*. (2023) also emphasized that enzymatic processes significantly contribute to the increase in reducing sugars during storage by converting complex carbohydrates

Table 4.43: Effect of harvesting stages on TSS (ºB) of Dragon fruit RTS

Treatments	TSS (ºB)											
	Day 0			Day 30			Day 60			Day 90		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_1 (25 DAA)	10.11	10.34	10.23	10.23	10.75	10.49	10.23	11.10	10.67	10.57	11.59	11.08
T_2 (30 DAA)	10.69	11.54	11.12	10.77	11.89	11.33	11.16	12.35	11.76	11.56	12.77	12.17
T_3 (35 DAA)	11.33	11.72	11.53	11.64	13.33	12.49	11.94	13.74	12.84	13.34	14.33	13.84
T_4 (40 DAA)	12.57	13.28	12.93	12.80	12.27	12.54	13.12	12.51	12.82	12.67	13.16	12.92
SEm±	**0.10**	**0.02**	**0.05**	**0.07**	**0.24**	**0.13**	**0.10**	**0.05**	**0.05**	**0.03**	**0.03**	**0.02**
CD at 5%	**0.30**	**0.07**	**0.15**	**0.20**	**0.72**	**0.36**	**0.29**	**0.15**	**0.16**	**0.08**	**0.10**	**0.06**

Table 4.44: Effect of harvesting stages on pH (%) of Dragon fruit RTS

Treatments	pH											
	Day 0			Day 30			Day 60			Day 90		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_1 (25 DAA)	3.52	3.27	3.40	3.40	3.18	3.29	3.31	3.12	3.21	3.18	3.10	3.14
T_2 (30 DAA)	3.76	3.56	3.66	3.67	3.55	3.61	3.58	3.46	3.52	3.31	3.33	3.32
T_3 (35 DAA)	3.77	3.89	3.83	3.59	3.70	3.64	3.45	3.63	3.54	3.39	3.52	3.45
T_4 (40 DAA)	4.38	4.55	4.47	4.31	4.54	4.42	4.16	4.33	4.25	4.01	4.20	4.11
SEm±	**0.08**	**0.08**	**0.06**	**0.04**	**0.07**	**0.04**	**0.07**	**0.03**	**0.04**	**0.03**	**0.10**	**0.05**
CD at 5%	**0.25**	**0.24**	**0.17**	**0.11**	**0.22**	**0.12**	**0.22**	**0.09**	**0.11**	**0.08**	**0.30**	**0.15**

Table 4.45: Effect of harvesting stages on Titratable acidity (%) of Dragon fruit RTS

Treatments	Titratable acidity (%)											
	Day 0			Day 30			Day 60			Day 90		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 (25 DAA)	0.31	0.29	0.30	0.36	0.32	0.34	0.42	0.39	0.40	0.48	0.45	0.47
T_2 (30 DAA)	0.25	0.26	0.25	0.29	0.29	0.29	0.35	0.36	0.35	0.41	0.42	0.42
T_3 (35 DAA)	0.25	0.24	0.25	0.28	0.29	0.28	0.36	0.35	0.35	0.40	0.40	0.40
T_4 (40 DAA)	0.21	0.20	0.21	0.26	0.25	0.25	0.32	0.30	0.31	0.38	0.37	0.38
SEm±	**0.01**	**0.00**	**0.00**	**0.01**	**0.01**	**0.00**	**0.01**	**0.01**	**0.00**	**0.01**	**0.01**	**0.00**
CD at 5%	**0.02**	**0.01**	**NS**	**0.02**	**0.02**	**0.01**	**0.02**	**0.02**	**0.01**	**0.02**	**0.02**	**NS**

Table 4.46: Effect of harvesting stages on Ascorbic acid (mg/100 ml) of Dragon fruit RTS

Treatments	Ascorbic acid (mg/100ml)											
	Day 0			Day 30			Day 60			Day 90		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 (25 DAA)	0.76	0.70	0.73	0.73	0.65	0.69	0.66	0.59	0.63	0.54	0.48	0.51
T_2 (30 DAA)	0.59	0.52	0.56	0.57	0.49	0.53	0.53	0.46	0.50	0.47	0.43	0.45
T_3 (35 DAA)	0.56	0.54	0.55	0.55	0.54	0.54	0.49	0.47	0.48	0.48	0.36	0.42
T_4 (40 DAA)	0.36	0.40	0.38	0.29	0.31	0.30	0.26	0.29	0.27	0.22	0.23	0.23
SEm±	**0.03**	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.05**	**0.02**
CD at 5%	**0.09**	**0.05**	**0.05**	**0.04**	**0.04**	**0.03**	**0.04**	**0.04**	**0.03**	**0.04**	**0.14**	**0.07**

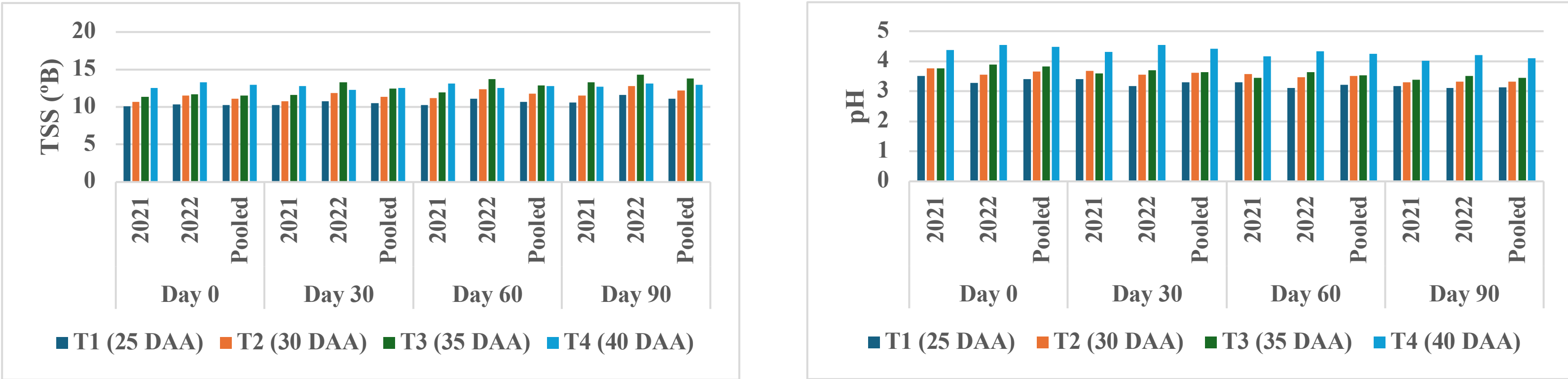


Figure 4.16 : Effect of harvesting stages on TSS and pH of Dragon fruit RTS

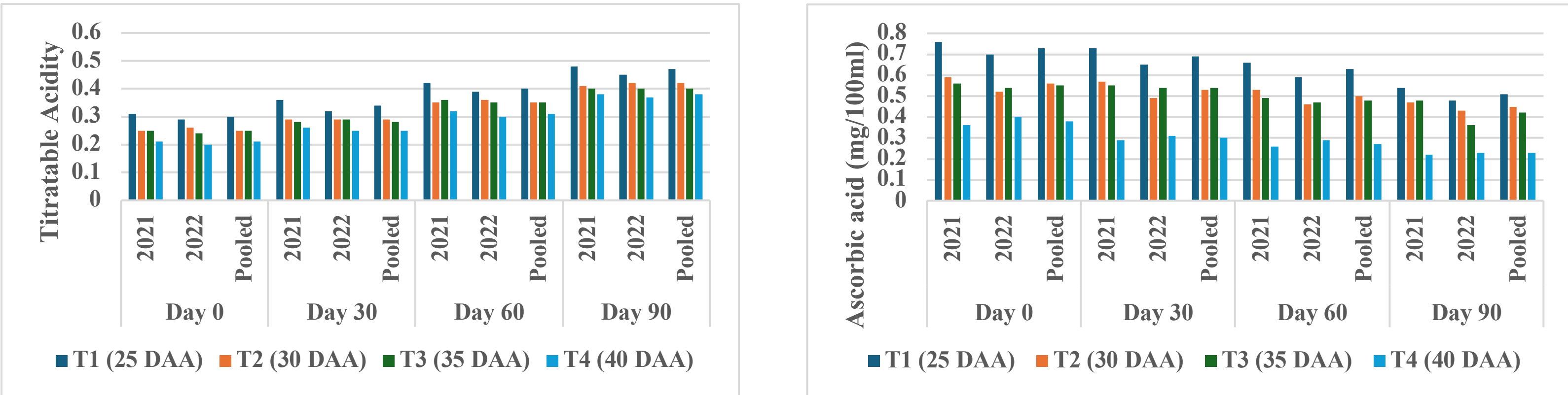


Figure 4.17 : Effect of harvesting stages on Titratable acidity and Ascorbic acid of Dragon fruit RTS

into simpler sugars, thereby enhancing the sweetness and altering the nutritional profile of the beverage.

4.2.7 Non- reducing sugar (%)

Table 4.49 illustrates the data calculated on the non-reducing sugar content for dragon fruit RTS as influenced by different harvesting stages. The statistical data depicts significant variation among the treatments where maximum amount was recorded in T_1 (25 DAA) during the initial days of storage whereby, at the end of storage (Day 90), maximum content was recorded in T_2 (30 DAA) with 8.58%, followed by T_4 (40 DAA) with 8.35%. During the period of observation, a decreasing trend was observed, regardless of the harvesting stages. Verma and Deen (2024) and Hemalatha *et. al.* (2018) have reported similar findings and the gradual decrease in non-reducing content is the consequence of enzymatic conversion of sucrose into reducing sugar.

4.2.8 Organoleptic test (Hedonic scale rating)

Appearance

The scores on appearance of dragon fruit RTS as influenced by different harvesting stages is presented in Table 4.50 and Figure 4.19. Among the treatments, RTS prepared from fruits harvested at 30 DAA (T_2) and 35 DAA (T_3) had higher scores during the 90 days observation. The RTS from initial harvest (T_1- 25 DAA) had lower scores ranging from 5.53 (initiation) to 5.29 (termination) due to the unattractive color as compared to the other treatments. At the end of storage, T_3 (35 DAA) had the highest score which decreased from 8.23 at Day 0 to 8.04 at Day 90. The slight decrease in color score during storage may be due to reduction in the color intensity of the RTS or destruction of the primary pigment which is betacyanin, by hydrolytic reactions or Maillard reaction. However, the reduction in color is not extremely prominent which may be due to higher stability of betacyanin pigment at ambient temperature for the chemical preservative used, which had also been observed by Vinod *et. al.* (2020).

Table 4.47: Effect of harvesting stages on Total sugar (%) of Dragon fruit RTS

Treatments	Total Sugar (%)											
	Day 0			Day 30			Day 60			Day 90		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_1 (25 DAA)	10.02	10.58	10.30	10.32	10.61	10.47	10.58	10.62	10.60	10.71	10.84	10.77
T_2 (30 DAA)	10.24	10.36	10.30	10.38	10.67	10.52	10.81	10.73	10.77	10.93	10.90	10.92
T_3 (35 DAA)	10.48	11.12	10.80	10.52	11.26	10.89	10.72	11.65	11.19	11.56	12.43	12.00
T_4 (40 DAA)	11.18	11.09	11.14	11.20	11.34	11.27	11.41	12.36	11.89	10.92	11.88	11.40
SEm±	**0.11**	**0.13**	**0.09**	**0.12**	**0.07**	**0.07**	**0.08**	**0.01**	**0.04**	**0.06**	**0.06**	**0.05**
CD at 5%	**0.33**	**0.39**	**0.25**	**0.37**	**0.20**	**0.20**	**0.23**	**0.04**	**0.11**	**0.19**	**0.19**	**0.13**

Table 4.48: Effect of harvesting stages on Reducing sugar (%) of Dragon fruit RTS

Treatments	Reducing sugar (%)											
	Day 0			Day 30			Day 60			Day 90		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_1 (25 DAA)	1.01	1.97	1.49	1.08	1.97	1.53	1.27	1.95	1.61	1.52	1.97	1.75
T_2 (30 DAA)	2.19	2.00	2.10	2.25	2.10	2.18	2.50	2.22	2.36	2.68	2.44	2.56
T_3 (35 DAA)	2.33	2.80	2.57	2.53	2.93	2.73	2.69	2.97	2.83	2.74	3.06	2.90
T_4 (40 DAA)	3.42	2.87	3.15	3.36	3.00	3.18	3.44	3.09	3.27	3.42	2.99	3.20
SEm±	**0.19**	**0.18**	**0.13**	**0.13**	**0.06**	**0.07**	**0.08**	**0.08**	**0.06**	**0.05**	**0.05**	**0.03**
CD at 5%	**0.58**	**0.53**	**0.38**	**0.40**	**0.19**	**0.21**	**0.23**	**0.25**	**0.16**	**0.14**	**0.14**	**0.09**

Table 4.49: Effect of harvesting stages on Non- reducing sugar (%) of Dragon fruit RTS

Treatments	Non- reducing sugar (%)											
	Day 0			Day 30			Day 60			Day 90		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 (25 DAA)	8.56	8.18	8.37	7.72	8.14	7.93	7.89	8.08	7.99	7.84	8.04	7.94
T_2 (30 DAA)	7.65	7.94	7.79	8.77	8.21	8.49	8.84	8.24	8.54	8.73	8.42	8.58
T_3 (35 DAA)	7.74	7.90	7.82	7.59	7.92	7.75	7.63	8.25	7.94	7.77	8.39	8.08
T_4 (40 DAA)	7.38	7.81	7.59	7.46	7.92	7.69	7.57	8.80	8.19	7.74	8.97	8.35
SEm±	**0.19**	**0.22**	**0.15**	**0.18**	**0.09**	**0.10**	**0.10**	**0.08**	**0.06**	**0.06**	**0.08**	**0.05**
CD at 5%	**0.58**	**NS**	**0.42**	**0.53**	**NS**	**0.29**	**0.29**	**0.23**	**0.18**	**0.19**	**0.24**	**0.15**

Taste

Table 4.51 and Figure 4.19 depicts the influence of different harvesting stages of dragon fruit on taste of RTS beverage. At Day 0, the maximum score was recorded in T_4 (40 DAA) with 7.14, while the least score (4.81) was recorded in T_1 (25 DAA). During the time of storage, the highest mean score of 7.65 was recorded in T_3 (30 DAA) at Day 30, after which there was a steady decline in the taste scores in all the treatments. The reduction in pH due to increase in titratable acidity affects the organoleptic quality of the RTS. The lower scores allocated for taste of dragon fruit RTS may be due to the mild flavor in itself.

Odor

The scores on the odor aspect of sensory evaluation is presented in Table 4.52 and Figure 4.20, which showed higher scores allocated to the RTS beverage prepared from fruits harvested at T_3 (35 DAA) and T_4 (40 DAA) during the period of storage. There was no varying differences in the scores and on the last day of storage, maximum score was recorded in T_3 (35 DAA) with 6.36, followed by T_4 (40 DAA) with 6.34. The minimum score was recorded in T_1 (25 DAA) with 5.47.

Overall Acceptability

The results of overall acceptability as influenced by different maturity stages of dragon fruit is furnished in Table 4.53 and Figure 4.20. The overall acceptability decreased from 7.34 to 7.26 in T_3 (35 DAA) which was found to be highest on most of the days of observation, followed by T_4 (40 DAA) which decreased from 7.43 at Day 1 to 7.06 at Day 90 (termination). The minimum overall acceptability was observed in T_1 (25 DAA) decreasing from 5.38 to 5.5 which may be due to its juvenile stage of development in sensorial profile. Similar decline in overall sensory quality was reported by Pavithra and Mini (2023) in dragon fruit based blended RTS beverage, Vinod *et. al.* (2020) in dragon fruit pulp preservation and Verma and Deen (2024) in guava, wood apple and ginger blended RTS.

Though sensory score reduced gradually with the storage period, the organoleptic quality of dragon fruit RTS remained acceptable up to the three months

Table 4.50: Effect of harvesting stages on appearance of Dragon fruit RTS

Treatments	Appearance											
	Day 0			Day 30			Day 60			Day 90		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 (25 DAA)	5.33	5.72	5.53	5.25	5.64	5.45	5.14	5.51	5.33	5.2	5.38	5.29
T_2 (30 DAA)	8.53	8.15	8.34	8.47	8.13	8.30	8.16	7.93	8.05	7.98	7.74	7.86
T_3 (35 DAA)	8.22	8.24	8.23	8.19	8.03	8.11	8.33	8.04	8.19	8.16	7.92	8.04
T_4 (40 DAA)	7.89	8.1	7.99	7.73	7.9	7.82	7.75	7.74	7.75	7.52	7.63	7.58

Table 4.51: Effect of harvesting stages on taste of Dragon fruit RTS

Treatments	Taste											
	Day 0			Day 30			Day 60			Day 90		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 (25 DAA)	5.11	4.51	4.81	5.4	4.62	5.01	5.55	4.89	5.22	5.46	4.55	5.01
T_2 (30 DAA)	6.23	6.73	6.48	6.76	7.11	6.94	6.82	7.23	6.48	6.55	6.87	6.71
T_3 (35 DAA)	6.94	6.98	6.96	7.42	7.87	7.61	7.55	7.39	7.14	7.31	7.43	7.37
T_4 (40 DAA)	7.16	7.11	7.14	7.68	7.24	7.45	7.82	8.10	6.96	7.23	7.19	7.21

Table 4.52: Effect of harvesting stages on odour of Dragon fruit RTS

Treatments	Odour											
	Day 0			Day 30			Day 60			Day 90		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 (25 DAA)	5.75	6.12	5.94	5.43	5.89	5.66	5.4	5.74	5.57	5.28	5.65	5.47
T_2 (30 DAA)	6.50	6.89	6.70	6.39	6.74	6.57	6.27	6.53	6.40	6.19	6.43	6.31
T_3 (35 DAA)	6.75	6.75	6.75	6.80	6.88	6.84	6.54	6.65	6.59	6.15	6.56	6.36
T_4 (40 DAA)	6.88	7.13	7.00	6.63	6.69	6.67	6.63	6.61	6.62	6.21	6.48	6.34

Table 4.53: Effect of harvesting stages on overall acceptability of Dragon fruit RTS

Treatments	Overall acceptability											
	Day 0			Day 30			Day 60			Day 90		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 (25 DAA)	5.40	5.35	5.38	5.38	5.33	5.35	5.33	5.24	5.28	5.24	5.05	5.15
T_2 (30 DAA)	6.94	7.18	7.06	7.05	7.28	7.17	6.91	7.11	6.87	6.74	6.90	6.82
T_3 (35 DAA)	7.29	7.39	7.34	7.43	7.61	7.52	7.40	7.46	7.35	7.17	7.35	7.26
T_4 (40 DAA)	7.30	7.58	7.43	7.33	7.50	7.42	7.29	7.49	7.14	6.93	7.18	7.06

storage under ambient storage. The changes may be due to non-enzymatic reactions such as Milliard and caramelization (Rashid *et. al.,* 2018)or due to unfavorable condition such as low pH and fluctuation in temperature at room conditions which causes misplacement of flavor and taste. Sensory evaluation is a necessity for assurance of quality and shelf life of products as sensory characteristics usually depreciate in advance of microbial quality (Sharif *et. al.* 2017).

4.2.9 Microbial count (x10^5 cfu/mL)

The data collected on microbial load in dragon fruit RTS as affected by maturity stages is furnished in Table 4.54 and Figure 4.21 which was found to be significant in the later days of storage. The total plate count (TPC) for fungal growth (yeast and mold) of the different treatments were observed as 0.80 x10^5 cfu/mL, 2.10 x10^5 cfu/mL, 2.30 x10^5 cfu/mL and 3.30 x10^5 cfu/mL of T_1 (25 DAA), T_2 (30 DAA), T_3 (35 DAA) and T_4 (40 DAA) respectively at room temperature after 30 days. The microbial count in all the treatments increased with storage time. After 90 days of storage, the microbial count of fungi was highest in T_4 (40 DAA) with 7.70 x10^5 cfu/mL and the least count was found in T_1 (25 DAA) with 4.40 x 10^5 cfu/mL.

Microbial count was found to be within the safety limit of 50 cfu/mL for consumption up to 3 months of observation. Similar increase in microbial count during storage of RTS beverage was observed by Tarte *et. al.* (2022), Bochare *et. al.* (2020), Kausar *et. al.* (2020), Kumar and Singh (2013), Minh *et. al.* (2019) in dragon fruit nectar and Panchal *et. al.* (2018) in dragon fruit jelly. Microbial count was found to be less due to the use of potassium sorbate as preservative, which is reported to be more effective in inhibiting growth of yeasts and molds than the growth of bacteria (Alli and Kermasha, 1989). The fruits harvested at initial stage have higher total phenolic content and more acidity, which must have translated in the processed product having lower microbial load compared to the other stages of maturity. The possibility of contamination during manufacture process and trapped oxygen in glass bottles could be the cause for the microbial development and multiplication in the RTS beverage. According to Kumar *et. al.* (2015), potassium sorbate act synergistically with citric acid and sucrose (Saranraj and Naidu, 2014) which helps achieve longer shelf life in food products and at optimum concentration, potassium sorbate does not cause major impact on food quality.

Hedonic scale rating test of Dragon fruit RTS

APPEARANCE

Name:	Date:
Designation:	

Instructions:
Taste the given samples, then place a tick (✓) mark on the point in the scale which best describes your feeling and give any remark of your evaluation on the characteristics of the product. Kindly drink water in between evaluations.

SCORE	SAMPLE CODE							
	T_1		T_2		T_3		T_4	
	Rating	Remark	Rating	Remark	Rating	Remark	Rating	Remark
(9) Like extremely								
(8) Like very much								
(7) Like moderately								
(6) Like slightly								
(5) Neither like nor dislike								
(4) Dislike slightly								
(3) Dislike moderately								
(2) Dislike very much								
(1) Dislike extremely								

Hedonic scale rating test of Dragon fruit RTS

ODOUR

Name:	Date:
Designation:	

Instructions:
Taste the given samples, then place a ✓ (tick) mark on the point in the scale which best describes your feeling and give remark of your evaluation on the characteristics of the product. Kindly drink water in between evaluations.

SCORE	SAMPLE CODE							
	T_1		T_2		T_3		T_4	
	Rating	Remark	Rating	Remark	Rating	Remark	Rating	Remark
(9) Like extremely								
(8) Like very much								
(7) Like moderately								
(6) Like slightly								
(5) Neither like nor dislike								
(4) Dislike slightly								
(3) Dislike moderately								
(2) Dislike very much								
(1) Dislike extremely								

Hedonic scale rating test of Dragon fruit RTS

TASTE

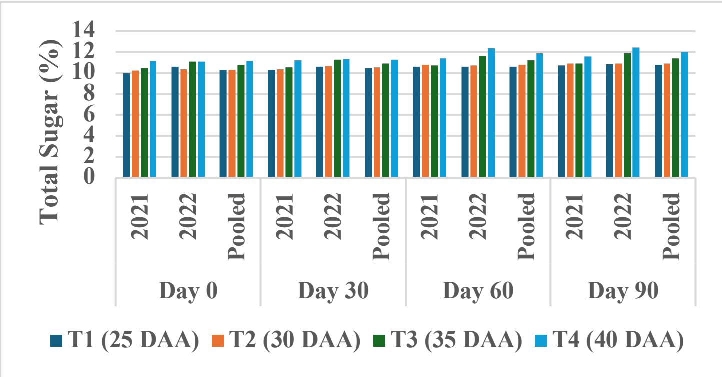
Name:	Date:
Designation:	

Instructions:
Taste the given samples, then place a ✓ (tick) mark on the point in the scale which best describes your feeling and give remark of your evaluation on the characteristics of the product. Kindly drink water in between evaluations.

SCORE	SAMPLE CODE							
	T_1		T_2		T_3		T_4	
	Rating	Remark	Rating	Remark	Rating	Remark	Rating	Remark
(9) Like extremely								
(8) Like very much								
(7) Like moderately								
(6) Like slightly								
(5) Neither like nor dislike								
(4) Dislike slightly								
(3) Dislike moderately								
(2) Dislike very much								
(1) Dislike extremely								

Table 4.54: Effect of harvesting stages on Microbial count (x10^5 cfu/ml) of Dragon fruit RTS

Treatments	Microbial count (x10^5 cfu/ml)											
	Day 0			Day 30			Day 60			Day 90		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 (25 DAA)	0.00	0.00	0.00	1.00	0.60	0.80	2.40	2.00	2.20	4.60	4.20	4.40
T_2 (30 DAA)	0.00	0.00	0.00	3.00	1.20	2.10	4.20	5.00	4.60	5.00	5.80	5.40
T_3 (35 DAA)	0.00	0.00	0.00	2.20	2.40	2.30	4.60	4.80	4.70	5.80	6.00	5.90
T_4 (40 DAA)	0.00	0.00	0.00	3.80	2.80	3.30	7.20	6.60	6.90	7.40	8.00	7.70
SEm±	-	-	-	**0.41**	**0.32**	**0.26**	**0.47**	**0.35**	**0.30**	**0.68**	**0.35**	**0.38**
CD at 5%	-	-	-	**1.24**	**0.95**	**0.75**	**1.42**	**1.06**	**0.85**	**2.04**	**1.04**	**1.10**



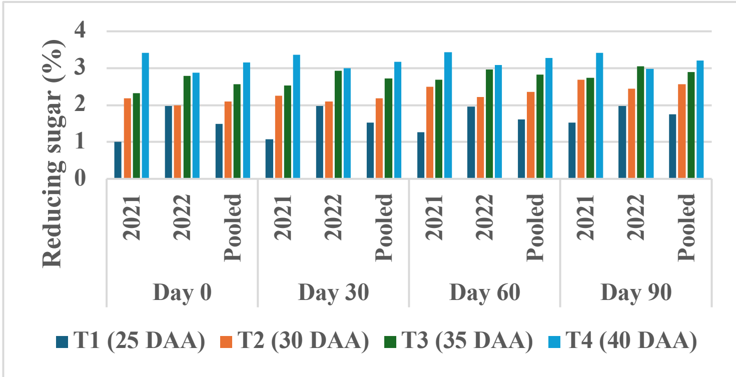
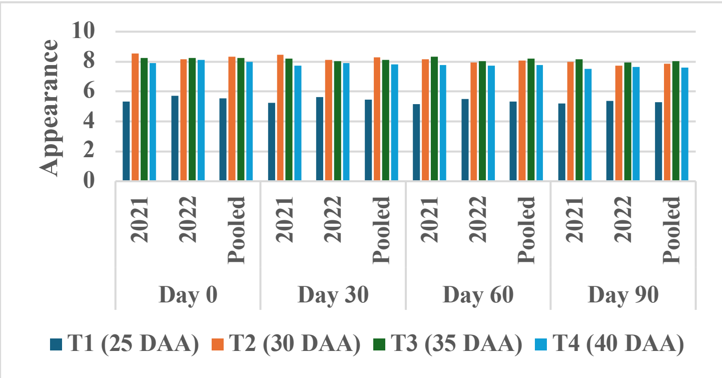


Figure 4.18 **:** Effect of harvesting stages on Total sugar an Reducing sugar of Dragon fruit RTS



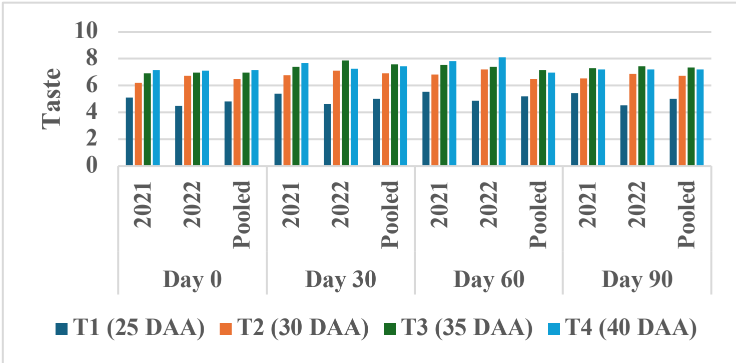
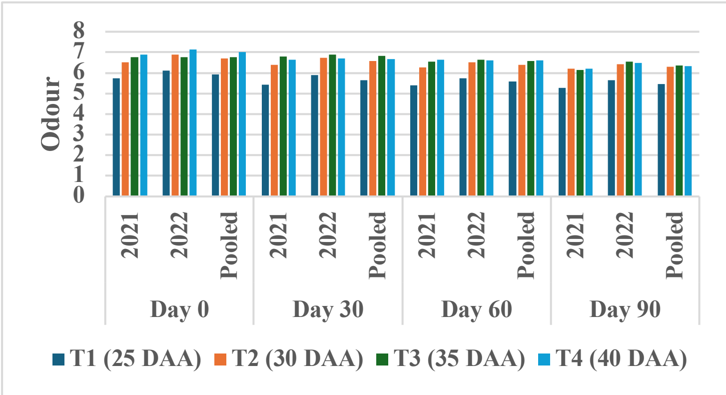


Figure 4.19 **:** Effect of harvesting stages on Appearance and Taste of Dragon fruit RTS



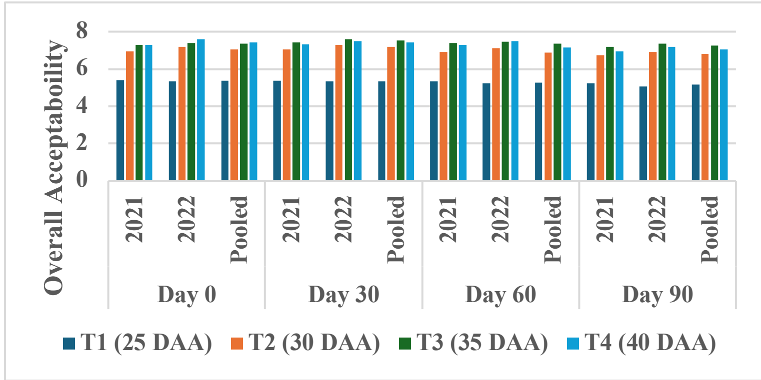


Figure 4.20 **:** Effect of harvesting stages on Odour and Overall Acceptability of Dragon fruit RTS

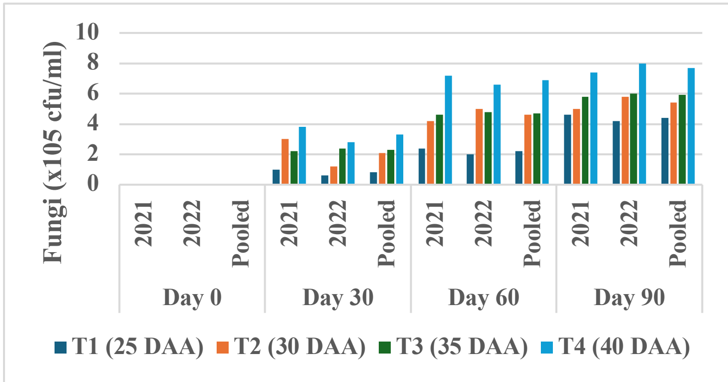


Figure 4.21 **:** Effect of harvesting stages on Microbial count in Dragon fruit RTS

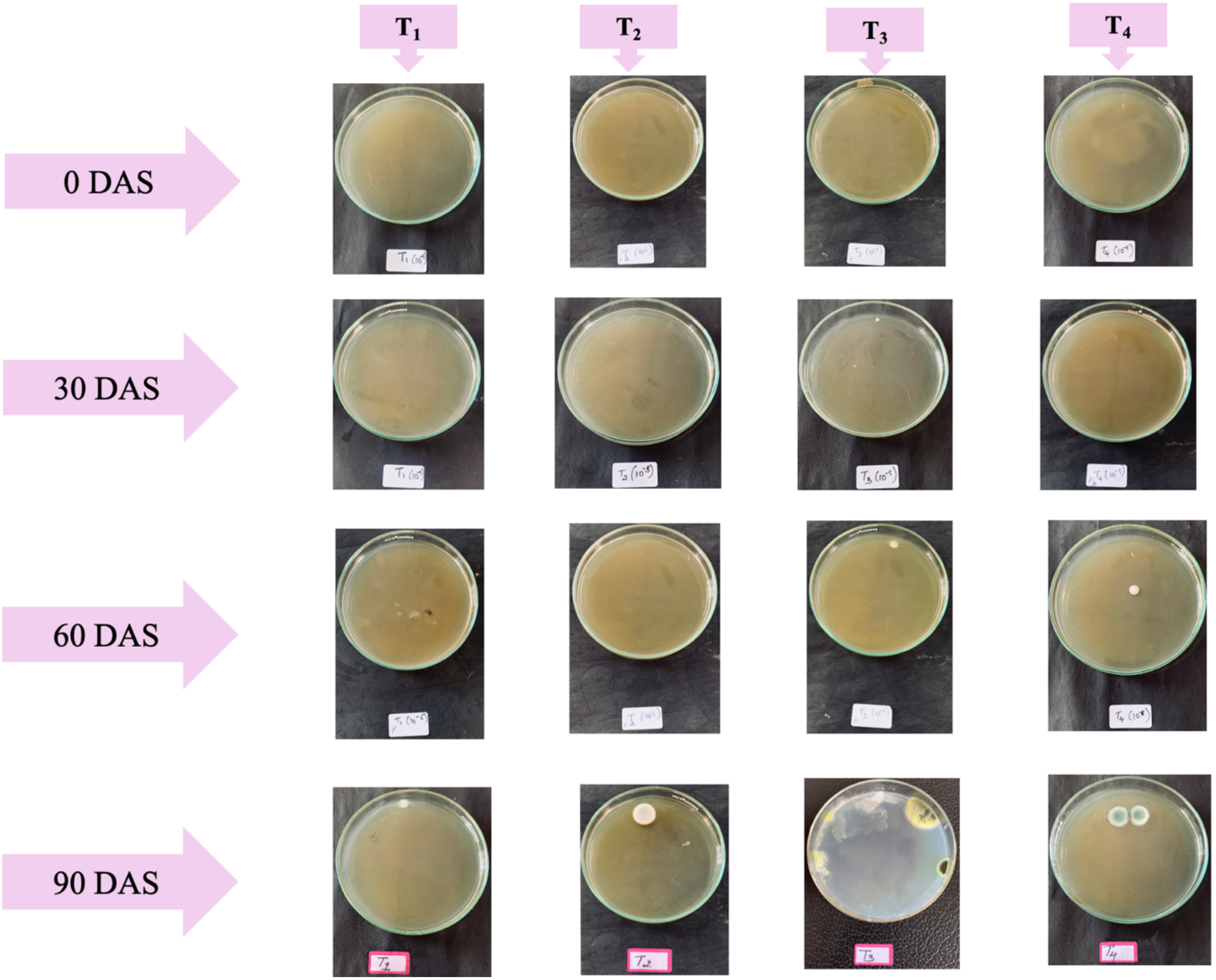


Plate 19: Effect of harvesting stages on Microbial count of (x10^5 cfu/ml) in Dragon fruit RTS

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present investigation, entitled "**Effect of different harvesting stages and wrapping materials on post-harvest quality, shelf life and value addition of Dragon fruit (*Hylocereus polyrhizus*)**" was carried out for two consecutive years during 2020-2022 in a private dragon fruit farm located at Seithekema-A village, Chümoukedima district, Nagaland and post-harvest quality analysis was conducted at Department of Horticulture, School of Agricultural Sciences, Nagaland University. The first experiment was laid out in Factorial Randomized Block Design replicated three times, consisting of three harvesting stages and five wrapping materials and the second experiment was laid out in Completely Randomized Design with four harvesting stages and five replications to study the physiological and biochemical changes of dragon fruit as influenced by maturity stages and wrapping materials for processing and post-harvest life.

The data thus obtained was subjected to suitable statistical analysis as per requirement of the design and the salient findings and results are summarized below:

5.1.1 To study the effect of harvesting stages and wrapping materials on post-harvest quality and shelf life of Dragon fruit.

5.1.1.1 Fruit morphological changes during storage

The pooled data of 2020-22 showed maximum retention of firmness, shelf life and minimum Physiological Loss of Weight (PLW) and post-harvest spoilage during storage in fruits harvested at 25 DAA (H_1) and in shrink wrapping (W_5). In case of interaction effect between the two aspects studied, the maximum retention of firmness, shelf life and minimum Physiological Loss of Weight (PLW) and post-harvest spoilage during storage was recorded in H_1W_5 (25 DAA, shrink wrapping) with 8.23 kg/cm^2 firmness, 11.27 days of shelf life, 1.78% PLW and 7.24% post-harvest spoilage on the last day of observation.

5.1.1.2 Physico-chemical changes

The effect of harvesting stages and wrapping materials significantly influenced the physio-chemical properties of dragon fruit during storage. Among the harvesting stages, fruits harvested at 30 DAA (H_2) retained the highest TSS, total sugar, reducing sugar, non-reducing sugar and betacyanin content with minimum reduction in values from the onset of storage. On the last day of observation, titratable acidity, ascorbic acid and total phenolic content were found to be highest in fruits harvested at 25 DAA (H_1). In regard to wrapping materials, the maximum content of TSS, titratable acidity, total sugar, reducing sugar, non-reducing sugar, ascorbic acid, total phenolic content, betacyanin and pectin content were found to be in Shrink wrapping (W_5). Analysis on interaction effect showed that fruits harvested at 30 DAA and stored with shrink wrapping (H_2W_5) exhibit more stability during the storage period and retained higher values at the end of storage in terms of TSS (12.27 ºB), total sugar (8.02%), reducing sugar (5.25%), non-reducing sugar (2.63%) and betacyanin in peel (35.42 mg/100g). Ascorbic acid (9.12), titratable acidity (0.33%), total phenolic content in peel (13.60 mg GAE/g) and pulp (5.28 mg GAE/g) and pectin (5.11%) were found to be higher in H_1W_5 (25 DAA, shrink wrapping), while betacyanin in pulp (35.34 mg/100g) was found to be higher in H_3W_5 (35 DAA, shrink wrapping).

5.1.1.3 Sensory evaluation

In terms of flavor, taste and overall acceptability, on the day of harvest, fruits harvested at 35 DAA had maximum score with mean rating of 8.2, 8.2 and 8.3 respectively, followed by 30 DAA with average score of 8.0, 8.0 and 8.1 respectively. Till day 4 of storage, fruits of 25 DAA and 30 DAA harvest had an increasing trend in scores whereas the rating for 35 DAA declined after day 2. At the end of storage, the highest scores for flavor, color, taste and overall acceptability were recorded in H_2W_5 (30 DAA, shrink wrapping) with a pooled average of 7.5, 7.7, 7.6 and 7.6 respectively.

5.1.2 To study the best harvest stage of Dragon fruit to prepare Ready-to-Serve (RTS) beverage.

5.1.2.1 Biochemical changes during storage

The study on RTS beverage prepared from different harvesting stages of dragon fruit depicted significant variation. During the 90 days of storage, TSS, pH, total sugar and reducing sugar content were found to be higher in the treatment of later harvest, while titratable acidity and ascorbic acid were found to be higher in the initial harvest treatments. At the end of observation period, the maximum TSS and total sugar were reported in H_3 (35 DAA) with 13.84 ºB and 12.00% respectively, whereby, maximum titratable acidity (0.47%) and ascorbic acid (0.51 mg/100mL) in H_1 (25 DAA) and reducing sugar (3.0%) and pH (4.11) in T_4 (40 DAA) were recorded.

5.1.2.2 Organoleptic test

The organoleptic quality was adjudged in terms of appearance, taste, odour and overall acceptability where maximum scores were found to be allocated to T_3 (35 DAA) with 5.29, 7.65, 6.36 and 7.06 scores respectively, on the last day of observation.

5.1.2.3 Microbial study

The microbial count in terms of bacteria and fungi were found to increase during the storage period. At the end of storage, minimum bacterial and fungal count was recorded in T_1 (25 DAA) with 6.30 and 4.40 x10^5 cfu/ml respectively.

5.2 Conclusion

Based on the results obtained from the present study, conclusions may be drawn as follows:

- Harvesting stage is crucial in ensuring optimum post-harvest quality and shelf life of dragon fruit. Physiochemical factors such as fruit size, fruit firmness, TSS, titratable acidity, sugar content etc. were recorded to be optimum at 30 DAA with maximum retention of quality attributes at ambient temperature. Also, at this stage the fruit indicate optimum degree of ripeness and better eating quality, though storability was found better in 25 DAA, fruits at this stage or earlier have not reached optimum intrinsic and extrinsic quality and fruits may be labelled as bland and flavorless. The maximum retention of betacyanin pigment was recorded in 30 DAA, while total phenolic content and pectin had higher concentration in fruits harvested at 25 DAA.

- It was observed that individual wrapping of fruits reduced the magnitude of deterioration during storage and retain physio-chemical quality for longer period of time. Among the wrapping materials, shrink wrapping was more effective in maintaining the optimum physio-chemical characteristics and overall acceptability of dragon fruit. Thus, dragon fruit harvested at 30 DAA and stored using shrink wrapping technology yielded the best physiological, biochemical, sensory and shelf life result.
- Brown paper wrapping was effective to some extent in preserving the quality and shelf life of dragon fruit and may be more beneficial in short- term storage during transportation. Using half dried banana leaves which is economical and a locally available material was slightly better than control, if not in preserving the quality but it provides effective cushioning effect. However, proper cleaning and sterilization is recommended to avoid microbial spoilage. EPE foam mesh net gave a snug fit form and enhanced quality with its ability to absorb large amount of shock and provide ample protection.
- RTS beverage prepared from different harvesting stages of dragon fruit was found to be aesthetically attractive and fulfil nutritional requirement, as such this product holds immense potential to be a consumer favorite. RTS beverage prepared from 35 DAA was found to be best in terms of quality and sensory evaluation.
- It was observed that premature harvesting of dragon fruit for processing does not yield the adequate sensory and nutritional properties for preparing superior product. Also, blending of dragon fruit juice with other fruits may be a more economical option and may enhance the flavor of the rich colored and nutritious dragon fruit juice for a greater consumer satisfaction.

Future line of work

Indian farmers are currently establishing a niche in the country's horticulture spectrum for dragon fruit production with the help and recognition from government as an asset to boost the economy and assist in achieving nutritional stability in the country. However, research studies on dragon fruit specific to our country's ecosystem is limited. Maturity indices is crucial for optimizing the correct stage of harvest so also, post-harvest management and processing, thus this work was taken up to shed light on the developmental nature of dragon fruit grown in the mid-hills of Nagaland. Some of the important aspects identified for future line of work are as follows:

- In depth study on location based cultivation technology, ripening and development mechanism and post-harvest preservation technology of dragon fruit.
- In-depth study on genomics to identify economically important traits.
- Identification of disease affecting the growth and storage of dragon fruit and screening out cultivars or varieties with good resistance.
- Effect of low-temperature, controlled atmospheric storage, film coating and biological preservation methods or combination of it all needs to be explored.
- Study on influence of different cultural, physical and chemical pre-harvest treatments on dragon fruit.
- Optimization of fruiting period by studying off season production techniques to avoid overlap of flowering and fruiting period with the monsoon rain which causes heavy loss to farmers.
- Production of different processed products and standardization of recipes.
- In-depth study on extraction and use of betacyanin as natural coloring agent.

CHAPTER VI

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REFERENCES

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