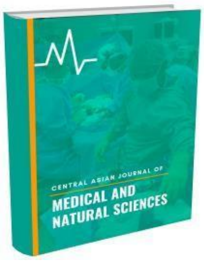

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Article

Effect of Packaging Type and Storage Temperature on Some Qualitative Traits of Two Apple Varieties: *Golden Delicious* and *Mutsu*

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Abstract: The objective of this study was to assess the influence of different types of packaging and storage temperature on some qualitative characteristics of two apples varieties (Golden Delicious and Mutsu) during 45-day storage time. The purpose of the experiment was to determine the best storage conditions to ensure fruit quality and reduce fruit losses after harvest.All factors, variety, packaging type, storage temperatures and interaction of them influenced significantly most of the measured characteristics. The results showed that storage time was correlated with reduction of fruit weight, total carbohydrate, total acidity, nitrogen, phosphorus and potassium. On the other hand, the total soluble solids percentage rose as a result of physiological and chemical changes after harvest, with the longer the storage times. The results indicated that the refrigerator storage was more efficient than room temperature storage in maintaining fruit quality by minimizing weight loss, maintenance of chemical composition, and slowing down the metabolic changes during storage. Packaging was also important as a preservative of fruit quality since nylon bags gave the best results for most of the studied traits when compared with the other packaging and the control treatment. The impact of the interaction indicated that the best conditions for maintaining apple quality was a combination of refrigerated storage and nylon bagging, whereas treatments involving room storage without packaging had the lowest scores for most traits. In most of the evaluated traits, the ability to maintain fruit quality was also different between the two varieties and was superior for Mutsu than for Golden Delicious when the fruits were stored. The study findings suggest that the application of nylon bags in refrigerated storage is an effective way of improving the quality of apples and extending their shelf life and thus help to reduce the post production losses and help to maintain fruit market value and nutritional value.

Keywords: storage temperature; Golden Delicious; Mutsu; nutritional value; nylon bags.

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1. Introduction

Apples (Malus domestica Borkh) are one of the most prominent and popular deciduous fruit crops in the world because of their nutritional and economic value: they have sugars, organic acids, dietary fibre, vitamin C, phenolic compounds and antioxidants, which are beneficial for human health. Apart from their long shelf life, apples are also one of the most traded fruits in the local and international markets as well as used for various food industries applications. However, after harvesting, the fruit continues to respire and produce ethylene, accelerating ripening and aging processes and causing physiological and chemical changes that negatively impact fruit quality and marketability. This requires the use of suitable techniques to reduce these changes and to ensure fruit quality during storage [1].

Golden Delicious apples are a popular variety, known for their golden yellow skin, sweet flavor, plump flesh and their use for both eating and cooking. It is a cross between the Golden Delicious and Indo varieties and is known as the Mutsu (Crispin) variety, and has large fruit size, high firmness and high juice and soluble solids content. Its sensitivity to storage conditions is, however, very different from that of other varieties, and its storage behaviour needs to be studied for better post harvest programs and enhancing fruit quality [2]. One of the most significant influences on the post-harvest storage of apple quality is storage temperature. Reducing the temperature slows down the rate of respiration, ethylene production rate, enzyme activity and water loss, leading to an improvement in weight, firmness and chemical properties and an increase in shelf life. However, the different responses of varieties to low temperatures require the selection of an appropriate temperature for each variety to avoid chilling damage and a decrease in quality during storage [1].

Apart from temperature, one of the major methods used to reduce post harvest losses is packaging. It slows down the release of moisture and the exchange of gases around the fruit and retards the rate of respiration, ripening and the loss of physical and chemical properties of the fruit. The most common way of apple quality preservation is plastic or paper bagging which creates an appropriate environment for preservation which can reduce weight loss and weight change, firmness, TSS and acidity compared to the unwrapped fruit [3]. Recent research has demonstrated that the benefits of packaging are to a large extent dependent on storage conditions. The combination of suitable storage temperature and suitable packaging resulted in a synergistic effect, which not only maintained the quality of fruits but also prolonged their storage life due to decreased weight loss and lowered incidence of physiological changes and post-harvest rot compared to the individual effect of each factor [4]. All of these are synergistic and contribute to fruit quality and marketability. Although several studies have investigated the impact of either storage temperature or packaging material alone, not much information is available on how different packaging materials combine with storage temperature to impact the quality characteristics of the Golden Delicious and Mutso apple varieties, especially locally [2]. More studies are needed to establish the best storage methods to maintain fruit quality and marketability. Therefore, this study aimed to evaluate the impact of packaging type and storage temperature on certain quality characteristics of the Golden Delicious and Mutso apple varieties, with the goal of identifying the best storage practices for maintaining fruit quality and minimizing post-harvest losses [5].

2. Materials and Methods

2.1. Experimental Location

Experimental Location: This study was conducted in the Plant Physiology Laboratory at Tikrit University, College of Agriculture, Department of Horticulture and Post-Harvest Landscape Engineering, during the years 2025-2026. The aim was to investigate the effect of packaging type and storage temperature on certain quality characteristics of two apple varieties: Golden Delicious and Mutsu.

2.2. Plant Samples

Plant Samples: Full-ripe, marketable apples of the Golden Delicious and Mutsu varieties were collected from a nearby market in Tikrit. Selected fruits were uniform in size, color, and ripeness, and free from mechanical and disease damage. They were then transported to the Plant Physiology Laboratory, washed with distilled water, and left to air dry at room temperature.

2.3. Experimental Factors

Experimental Factors: include two factores:- First Factor: Apple variety, divided into two levels:

1. Golden Delicious S1.

2. Mutsu S2.

The second factor: Packaging type, which is categorized into three levels:

1. Unpackaged (Control) T1.

2. Packaged in nylon bags T2.

3. Packaged in paper bags T3.

Measurements were taken under two storage conditions: room temperature and refrigerated storage at 4°C. Measurements were also taken on two dates: the first day of storage and 45 days after storage.

2.4. The studied characteristics:

1. Fruit weight: The weight of the fruits was measured using a digital electronic balance with an accuracy of 0.01 grams. The fruits were weighed individually before the start of storage (day one), and then the same fruits were weighed again after the end of the storage period (days). The weight was recorded in grams (g), and the average fruit weight per treatment was calculated according to the method adopted by [3].

2. Estimation of Total Carbohydrates (%): Carbohydrates were estimated according to the method described by [6] 0.5 g of the fresh, homogenized sample was weighed, and the carbohydrates were extracted with distilled water and filtered. One milliliter of the filtrate was taken and one milliliter of 5% phenol solution was added, followed by the rapid addition of 5 milliliters of concentrated sulfuric acid. The tubes were shaken well and left to stand for 20–30 minutes at room temperature until a yellow-orange color developed. The optical absorption was measured using a spectrophotometer at a wavelength of 490 nm, and the total carbohydrate concentration was calculated using a standard curve prepared with a standard glucose solution. The following equation was then used:

Total Carbohydrate (mg/100 g fresh weight) = (C × V × DF × 100) ÷ W …….(1)

Where:

C = Carbohydrate concentration read from the standard curve (mg/mL).

V = Total volume of extract (mL).

DF = Dilution factor, if any.

W = Weight of sample used for extraction (g).

When expressing the results as a percentage (%), the values were converted using the following equation:

Total carbohydrates (%) = Total carbohydrates (mg/100 g) ÷ 100 ………. (2)

3. Total Acidity (%): Total acidity (TA) was determined according to [7]. 10 mL of apple juice was placed in a 250 mL conical flask and diluted with 50 mL of distilled water. Two to three drops of phenolphthalein indicator were added, and the sample was titrated with 0.1 N sodium hydroxide (NaOH) solution until a light pink color appeared and remained stable for 30 seconds. Total acidity was calculated and the results expressed as a percentage of citric acid. Total acidity was calculated using the following equation:

TA (%) = (V × N × 0.064 × 100) / W ……….. (3)

Where:

V = Volume of sodium hydroxide consumed in the titration (mL).

N = Num of sodium hydroxide.

0.064. = Weight equivalent of citric acid

W = Volume or weight of the sample used.

4. Total Dissolved Solids Percentage: TSS% The percentage of total dissolved solids in apple fruits was estimated using a refractometer, by taking a few drops of fruit juice and placing them on the prism of the device, then reading the percentage of total dissolved solids directly, and the results were expressed in the unit % (°Brix).

5. Nitrogen (N%): Nitrogen was determined using a Microkjeldahl spectrometer as described in [8].

6. Phosphorus (P) (ppm): Phosphorus was determined using ammonium molybdate and ascorbic acid with a UV-VIS Spectrophotometer, model 80D, at a wavelength of 662 nm [9].

7. Potassium (K%): Potassium was determined using a Flame photometer as described in [10].

8. Statistical Analysis: The arithmetic means of the treatments were compared using Duncan's multiple range test at a probability level of 0.05 to determine the significance of the differences between the means.

3. Results and Discussion

3.1. Fruit Weight: The results presented in the table above (Table 1) indicated that there were significant differences in fruit weight among the various treatments of the study. The fruit weights on the first day of storage varied from 84.59 to 133.32 gram and after 45 days of storage, the fruit weights varied from 78.67 to 115.41 gram, showing a reduction of weight of the fruit at the end of storage. The initial weight for the Golden Delicious variety ranged from 96.83 to 131.00 grams, while after 45 days the weight of the variety was between 79.41 and 107.41 grams. The weight of Mutsu ranged from 84.59 to 133.32 g at the start of the experiment and from 78.67 to 115.41 g after 45 days. The results also indicated that the different packaging treatments had an effect on fruit weight maintenance. The highest fruit weight after 45 days was achieved in the Mutsu variety treatment by nylon bags and room temperature storage (115.41 g); and the lowest was achieved in the Golden Delicious variety treatment by paper bags and refrigerated storage (79.41 g). This means that the fruit reaction to weight maintenance is not uniform across different package types, varieties and temperatures [11]. As for interaction between the factors studied, the highest weight was obtained from the Mutsu variety treated with nylon bags with room temperature storage, and the lowest weight was obtained from the Golden Delicious variety treated with paper bags and refrigerated storage, which were 115.41 g and 79.41 g, respectively. This means that the response of the fruit was different from type of fruit, packaging and storage temperature.

Table (1) Effect of packaging type and storage temperature on some qualitative characteristics of two apple varieties, Golden Delicious and Mutsu, in terms of fruit weight.

Physicochemical properties	**Samples**	**Treatments**	**Storage for 1 Day**		**Storage for 45 Day**	
			Room temperature	Refrigerated storage	Room temperature	Refrigerated storage
Weight Fruit	Apple Golden Delicious	Control	121.37 BAC	102.76 EBDGCF	106.81 EBDAGCF	90.42 EDGF
		Nylon Bags	112.86 EBDA	103.98 EBDGCF	107.21 EBDAGCF	98.78 EDGCF
		Paper Bags	131.00 BA	96.83 EDGCF	107.41 EBDAGCF	79.41 GF
	Apple Mutsu	Control	117.46BDAC	84.59 EFG	109.24 EBDACF	78.67 G
		Nylon Bags	118.98 BDAC	96.44 EDGCF	115.41 BDAC	93.55 EDGCF

Paper Bags	133.32 A	99.24 EDGCF	114.09 EBDAC	89.32 EDGF

The means for different letter combinations within the factor or interaction were significantly different at a probability level of 0.05 according to Duncan's test.

Control: E0

Nylon Bags:E1

Paper Bags: E2

The fruit weight under the study treatments was found to be significantly different. Variety, packaging type, storage temp and the interaction between variety x packaging type x storage temp significantly influenced the fruit weight. Also, fruit weight gradually reduced after 45 days of storage as compared to the initial measurement. This is attributed to the transpiration of water and respiration, which causes the loss of weight in the plant as storage time increases, and to the consumption of some organic matter as a result of metabolic processes, which also results in weight loss as the storage time increases [12]. It was also observed that the refrigerated storage is more effective in weight conservation of the fruit than the room temperature storage [13]. This is believed to be due to the lower rates of respiration and transpiration at low temperatures that reduce moisture loss and delay post-harvest physiological changes. This is consistent with the results of Hasan et al [11], who showed that the refrigeration method was the most significant technique in minimizing weight loss and quality deterioration of apples during storage. In terms of the packaging type, the nylon bags proved to be the most effective in maintaining fruit weight, when compared with paper bags and the control treatment. This is due to the fact they create a high relative humidity inside the fruit, and prevent the loss of water vapor, keeping the fruit fresh for the duration of storage. Mahajan and others also found this to be true in their study on the effect of various fruit packing methods on fruit quality after harvest. Variety x Packaging type x Storage temp indicated that Mutsu variety kept in nylon packaging and refrigerated conditions gave the highest fruit weight after storage, whereas Golden Delicious variety kept at room temperature without any packaging gave the lowest fruit weight after storage. This is also due to the complementary effect of refrigeration and packaging in moisture loss reduction, and slowing down of physiological processes, along with the difference in genetic response between the two varieties to retain moisture and to tolerate the storage condition as observed in the study [14].

3.2. Carbohydrates: In the first day of storage, there are significant differences observed in the carbohydrate content ranging from 13.89% to 14.27% as shown in Table (2). Refrigerated Mutsu fruit packaged in nylon bags had the highest value (14.27%) and Golden Delicious fruit had the lowest value (13.89%) that was not packaged. The carbohydrate difference between the treatments remained after 45 days' storage, 11.935 to 14.435%. The highest value (14.435%) was found in Mutsu fruit packed in nylon bags and refrigerated while the lowest value (11.935%) was recorded in Golden Delicious fruit which was unpackaged and kept at room temperature. After 45 days of storage, results indicated that carbohydrate content was reduced in most of treatments than 1st day. The decrease in the amount, however, was different among varieties, packaging, and storage temperatures. Carbohydrate content was highly influenced by the interaction of the studied factors. After 45 days of storage, the Mutsu variety × nylon bags × refrigeration treatment had the highest level of carbohydrates, and the Golden Delicious variety × no packaging × room temperature treatment had the lowest level. This means the varieties responded differently to the carbohydrate preservation depending on the variety, method of packaging and storage temperature.

Table (2) shows the effect of packaging type and storage temperature on some qualitative characteristics of two apple varieties, Golden Delicious and Mutsu, specifically their carbohydrate content.

Physicochemical properties	**Samples**	**Treatments**	**Storage for 1 Day**		**Storage for 45 Day**	
			Room temperature	Refrigerated storage	Room temperature	Refrigerated storage
Carbohydrates	Apple Golden Delicious	Control	13.89 fe	13.91 fe	11.935 m	13.025 kj
		Nylon Bags	14.145bedg	14.173 bdc	13.635 hg	14.14 bedc
		Paper Bags	13.98 fed	14.01 fcdc	12.865 k	13.57 hi
	Apple Mutsu	Control	14.01 fedc	14.04 fbedc	12.30 l	13.36 i
		Nylon Bags	14.24 bac	14.27 ba	13.895 fe	14.435 a
		Paper Bags	13.935 fed	13.96 fed	13.135 j	13.835 fg

Duncan's test at a probability level of 0.05 indicated the means of the factors with different letters within the equation or interaction differed significantly.

The results indicated that the variety, packaging type, storage temperature and variety by packaging interaction significantly influenced the total carbohydrate content. Most treatments showed a reduction in carbohydrate values with storage time. This is due to the fact that physiological activity will persist after harvest, with carbohydrate being the first choice of energy in respiration, causing gradual losses in carbohydrate content with time. In addition, sugars and carbohydrates breakdown during storage because of the continuous ripening and ageing process that continues in the fruit during storage [15, 16]. The results also indicated that the carbohydrates content were better maintained under refrigerated conditions than room temperature conditions. This is thought to be due to the effect of lower temperatures, which slow down ethylene production, the respiration rate and the activity of enzymes, consequently resulting in slower carbohydrate consumption and longer preservation. The results are consistent with those [1] and Wright who showed that reducing the storage temperature plays a significant role in slowing down the rate of physiological and chemical changes in apples and the loss of their various nutrients. Concerning packaging type, packaging, especially nylon bags, helped to maintain carbohydrate content of fruit in comparison to the unpackaged fruit. This is due to its ability to lower the rate of moisture evaporation and provide a high relative humidity in the storage environment around the fruit, as well as decrease the intensity of gas exchange and respiration rate, which decreases the amount of carbohydrates consumed in storage. The use of suitable packaging material has been reported to help in maintaining the quality and in retarding the post harvest metabolic changes in apple [17, 14]. Variety x Packaging x Storage Temp. showed a definite effect on the preservation of the carbohydrates. The combination of refrigeration and packaging produced the maximum carbohydrate content after storage, and room temperature storage without packaging produced the minimum carbohydrate content. This is believed to be due to the synergic effect of lower temperature and reduced moisture loss through the packaging, which reduced metabolic activities and helped to maintain carbohydrates. Another cause for this difference between Golden Delicious and Mutso may be the genetic differences in respiration rate and carbohydrate utilization during storage [14].

3.3. Total Acidity % : From the first day of storage, there was significant difference between the treatments (Table 3), where the acidity value were within the range of 0.485% to 0.525%. Golden Delicious fruit packaged in paper bags and refrigerated was the top value (0.525%) and Mutsu fruit packaged in nylon bags and refrigerated was the lowest value (0.485%). The total acidity after 45 days storage was reduced in majority of the treatments ranging from 0.325% to 0.510%. For Mutsu fruit, the highest value, 0.510%, was obtained for fruit packed in nylon bags and refrigerated and the lowest value, 0.325%, was obtained for the unpacked fruit at room temperature. The results also revealed that there were significant differences between treatments on the first day of storage, ranging from 0.325 to 0.510% in acidity. It appears that total acidity in most treatments decreased after 45 days of storage from the initial acidity measurement. The loss, however, was different for each variety and each type of packaging, and with different storage temperatures. Moreover,the effect of the studied factors was significant. The Mutsu variety × nylon bags × refrigerated treatment × 45 days treatment showed the highest value of acidity at 0.510% and Golden Delicious variety × unpackaged × room temperature × 45 days treatment showed the lowest value of acidity at 0.325%. This means that the response to storage conditions varies between the two varieties as a function of packaging and storage temperature.

Table (3) shows the effect of packaging type and storage temperature on some qualitative characteristics of two apple varieties: Golden Delicious and Mutsu. Specifically, the acidity content of the fruit.

Physicochemical properties	**Samples**	**Treatments**	**Storage for 1 Day**		**Storage for 45 Day**	
			Room temperature	Refrigerated storage	Room temperature	**Refrigerated storage**
Acidity	Apple	Control	0.510 bdac	0.505 bdac	0.325 l	**0.40 ij**
	Golden	Nylon Bags	0.500 bdac	0.495 ebdac	0.42 ih	**0.48 ed**
	Delicious	Paper Bags	0.515 bac	0.525 a	0.38 kj	**0.45 gf**
	Apple	Control	0.495 ebdac	0.495 ebdac	0.36 k	**0.43 gh**
	Mutsu	Nylon Bags	0.490 ebdc	0.485 edc	0.45 gf	**0.51 bdac**
		Paper Bags	0.505 bdac	0.520 ba	0.41 ih	**0.47 ef**

The means for different letters within the factor or interaction were significantly different at a probability level of 0.05 according to Duncan's test.

The results indicated that the total acidity was significantly different between the treatments. Variety, packaging type, storage temperature and interaction of these affected the acidity. In general, acidity values gradually decreased as the storage period increased in all the treatments. This is believed to be due to the use of organic acids, in particular malic acid, the principal acid in apples, as a major part of respiration processes, so that the acid content diminishes with time. It can also be observed that refrigerated storage has been more effective in preserving the total acidity than the room temperature storage [12]. This has been related to the slower rates of respiration and slower utilization of organic acids at lower temperatures, which helps to maintain flavor and chemical quality of the fruit. This is in accordance with the effect of storage conditions on the chemical properties of apples revealed by [12]. As for packaging type, nylon bags had the most effective results in maintaining acidity when compared to paper bags and the control. This is due to their ability to minimize moisture loss, and to decrease the rate of gas exchange which reduces respiration and organic acid consumption, and therefore acidity for a longer storage time. This was confirmed by Mahajan and his group in their study on preservation of quality of horticultural products after harvest using packaging techniques.

The interaction of variety, packaging type and storage temperature revealed that the highest acidity value after storage was observed in the Mutsu variety packaged in nylon bags stored under refrigeration condition while the lowest acidity value was observed in the Golden Delicious variety which was not packaged and stored under room temperature. The complementary effect of refrigeration and packaging on the slowdown of the metabolic processes and the reduction of organic acids consumption, and the different physiological response of the two varieties in their ability to preserve the acidity during storage are in accordance with the results of [17, 18].

3.4. Total Dissolved Solids (TSS): In the Table 4 indicates that in nearly all treatments, the TSS content had increased following storage, compared to the initial storage level. But the increase was different for different varieties, packaging and storage temperatures. In terms of variety, Golden Delicious had the highest TSS of 14.295% after 45 days storage at room temperature in the control treatment. For the same treatment, the highest was recorded by Mutsu at 14.055%. With respect to the packages, the average TSS values for the control (unpackaged) treatment were the highest after the storage period, followed by the paper bag. The Nylon bags showed the lowest values in most of the treatments, thus showing the effect that they have in reducing the TSS increase during storage. The results also indicated that the storage at room temperature led to higher total soluble solid (TSS) than the refrigerate storage. The highest value (14.295%) was recorded in Golden Delicious variety, and the values in refrigerated fruit was reduced to 12.711% to 13.330% after 45 days of storage.

As for the interaction of variety, packing type and storage temperature, the interaction of Golden Delicious variety × nylon bags × room temperature storage (45 d) was statistically significant, and the treatment had the highest TSS value of 14.295%, while the treatment of Mutsu variety × plastic bags × refrigerated storage (45 d) had the lowest TSS value of 12.711%. This suggests that the interaction of the factors studied affected the response of TSS.

Table (4) shows the effect of packaging type and storage temperature on some qualitative characteristics of two apple varieties, Golden Delicious and Mutsu, specifically the fruit TSS content.

Physicochemical properties	Samples	Treatments	Storage for 1 Day		Storage for 45 Day	
			Room temperature	Refrigerated storage	Room temperature	Refrigerated storage
TSS	Apple	Control	12.495 lnm	12.525 lknm	14.295 a	13.33 de
	Golden	Nylon Bags	12.76 likhj	12.79 ikhg	13.58 dc	12.935 fhg
	Delicious	Paper Bags	12.595lkhjm	12.63 liknjm	13.915 b	13.13 feg
	Apple	Control	12.54 lknm	12.57 lknm	14.055 ba	13.159 fe
	Mutsu	Nylon Bags	12.85 ihj	12.88 ihg	13.33 de	12.71likhjm
		Paper Bags	12.40 n	12.435 nm	13.67 c	12.79 fhg

According to Duncan's test, the means identified with different letters in the study and interaction are significantly different at the 0.05 probability level.

The data indicated that there were significant differences between the total soluble solids (TSS) percentage of the experimental treatments. The variety, packaging method, storage temperature and the interaction of these factors influenced TSS. In most treatments, it showed a gradual increase in its values as the storage time went up. This is due to the conversion of complex carbohydrates (such as starch) into simple soluble carbohydrates and evaporation of water from transpiration. This results in more soluble solids in the fruit tissues. The storage temperature influences these changes, which are part of the physiological and chemical processes occurring during storage, and can be retarded by storage at lower temperatures [1]. The results indicated that the TSS values were also maintained in suitable range by refrigerated storage as compared to room temperature storage. The lower temperature slowed the respiration and metabolic processes thus reducing rate of changes in sugars and soluble solids and maintaining fruit quality for longer time. This is consistent with [1] who concluded that the storage temperature is crucial to the prevention of physiological and chemical changes in apples. Regarding packages types, it was found that the control treatment had the highest percentage of total soluble solids (TSS) than nylon bags or paper bags. The treatment with the greatest amount of TSS was the control treatment, and the least was the nylon bags. This is attributed to the nylon bagging that reduced moisture loss and created a more stable gaseous micro-environment around the fruit, that may have slowed down the changes of various soluble compounds and ripening associated with the fruit ripening process. This, in turn, minimises what might increase the total dissolved solids (TDS) in the stored product, which is in line with the findings of [14] which explained the importance of packaging techniques in controlling the environment around the horticultural product and minimising post harvest physiological changes.

The interaction between variety, packaging type, and storage temperature showed that the Mutsu variety, packaged in nylon bags and stored under refrigeration, achieved the best TDS values after storage, while the Golden Delicious variety, unpackaged and stored at room temperature, recorded the lowest values. This reflects the complementary effect of refrigeration and packaging in reducing metabolic changes and preserving soluble sugars, as well as the difference in response between the two varieties in terms of ripening rate and chemical changes associated with storage, which is consistent with the findings of [17].

3.5. **Nitrogen Content of Fruits (%)**: In the table (5) shows significant differences in nitrogen content on the first day of storage, ranging from 0.410% to 0.445%. The highest value, 0.445%, was recorded in Mutsu fruit wrapped in nylon bags and stored at room temperature, while the lowest value, 0.410%, was recorded in Golden Delicious fruit wrapped in paper bags and stored refrigerated, as well as in Mutsu fruit wrapped in paper bags and stored at room temperature. After 45 days of storage, nitrogen content decreased in all treatments compared to the initial measurement, with values ranging from 0.290% to 0.440%. The highest value, 0.440%, was recorded in Mutsu variety fruits packaged in nylon bags and stored under refrigeration, while the lowest value, 0.290%, was recorded in Golden Delicious variety fruits that were unpackaged and stored at room temperature. The results also showed that the decrease in nitrogen content was less pronounced in the refrigerated and nylon-bag-stored treatments compared to the other treatments. The interaction between the studied factors was significant. The Mutsu variety × nylon bags × refrigerated × treatment after 45 days showed the highest nitrogen content, while the Golden Delicious variety × unpackaged × room temperature × treatment after 45 days showed the lowest content. This indicates that the response of the fruits varied according to the variety, packaging type, and storage temperature.

Table (5) Effect of packaging type and storage temperature on some qualitative characteristics of two apple varieties, Golden Delicious and Mutsu varieties. Fruit nitrogen content%.

Physicochemical properties	**Samples**	**Treatments**	**Storage for 1 Day**		**Storage for 45 Day**	
			Room temperature	Refrigerated storage	Room temperature	Refrigerated storage
N %	Apple	Control	0.42 ^{bac}	0.415 ^{bac}	0.29 ^{i}	0.35 ^{fg}
	Golden	Nylon Bags	0.425 ^{bac}	0.43 ^{bac}	0.37 ^{ef}	0.41 ^{bc}
	Delicious	Paper Bags	0.42 ^{bac}	0.41 ^{bc}	0.34 ^{hg}	0.38 ^{ed}
	Apple	Control	0.415 ^{bac}	0.425 ^{bac}	0.32 ^{h}	0.37 ^{ef}
	Mutsu	Nylon Bags	0.445 ^{a}	0.42 ^{bac}	0.40 ^{dc}	0.44^{ba}
		Paper Bags	0.41 ^{bc}	0.415 ^{bac}	0.36 ^{efg}	0.40 ^{dc}

The means of the factors with different letters within the study or interaction differed significantly at a probability level of 0.05 according to Duncan's test.

The results indicated significant differences in nitrogen content among the studied treatments. Nitrogen content was affected by the variety, packaging type, storage temperature, and the interaction between these factors. The value gradually decreased with increasing storage time in most treatments. This is attributed to the continuation of physiological processes after harvest and the accompanying changes in nitrogen compounds and metabolic activity within the fruit, which may lead to a decrease in nitrogen content during storage [15].

Results also revealed that refrigerated storage was more effective in retaining the nitrogen content than room temperature storage. This is thought to be because the respiration rate is lower, aging processes slow down and the enzymes' activity is also reduced, meaning that less protein is broken down and more nitrogenous components are retained within the fruit tissues. This is consistent with the results obtained by [11] on the effects of storage conditions on the chemical composition of apples. As far as packaging type is concerned, nylon bags had a higher nitrogen content than paper bags and the control treatment. It is believed that this is due to their ability to decrease moisture loss and prevent the extremes of metabolic activity, thereby helping to maintain the proteins and nitrogenous compounds and slow down the changes during storage. This was observed by [14] while determining the effect of various packaging materials on fruit quality after harvest. Furthermore, variety x packaging x storage temperature was significant. The mutsu variety in which the packages were nylon and the storage temperature was refrigerated gave the highest nitrogen content after storage, and the Golden Delicious variety in which the packages were not used and the storage temperature was room temperature gave the lowest nitrogen content after storage. This is believed to be a synergistic effect of both the low temperature and packaging that retards the physiological processes and metabolic activity of the fruit and thus aids in maintaining a fruit's nitrogenous components in storage. In addition, the two varieties showed different responses to storage conditions [11].

3.6. Phosphorus content of the fruit(%): The results in Table (6) indicated that there were significant differences between the different studied treatments in terms of phosphorus content. Variety, packaging type, storage temperature and variety × packaging type were significant factors influencing phosphorus content. In general, the lower the storage time, the more phosphorus was removed from the product in most treatments, but the amount of phosphorus removed depended on the variety, packaging, and storage temperature. The control treatment, for instance, with room temperature, reduced the phosphorus level in the Golden Delicious variety from 0.083% to 0.061%, while it fell from 0.0845% to 0.0761% with nylon bags. Similarly, the P content dropped significantly from 0.0835% to 0.067% (from 0.0855% to 0.080%) in the Mutsu variety under room temperature and nylon bag treatments, respectively. The results also indicated that the percentage retention of phosphorus was higher in the refrigerated storage than refrigerated storage at room temperature. Overall, the phosphorus in the room temperature treatments was lower than in the refrigerated treatments after 45 days. This was particularly noted in the Mutsu × nylon bag treatment, which had a phosphorus content of 0.086% after 45 days of refrigeration, while it was 0.080% at room temperature. With respect to packaging type, nylon bags showed superior capacity for retaining the phosphorus content than did the control treatment and paper bags in some storage situations. This is due to minimal moisture loss and the low fluctuations in the environment to which the fruit is exposed during storage, which could restrict physiological changes during storage. The interaction between variety and packaging type and storage temperature was as follows: The Mutsu × nylon bag × refrigeration treatment had the highest level of phosphorus (0.086%) after 45 days, while the Golden Delicious × unpackaged × room temperature treatment had the lowest level of phosphorus (0.061%). This suggests that, mutually, the Mutsu variety, the nylon bag packaging and the refrigeration method worked best to maintain the content of phosphorus in the storage period.

Table (6) Effect of packaging type and storage temperature on some qualitative characteristics of two apple varieties, Golden Delicious and Mutsu varieties. Fruit phosphorus content (%).

Physicochemical properties	**Samples**	**Treatments**	**Storage for 1 Day**		**Storage for 45 Day**	
			Room temperature	Refrigerated storage	Room temperature	Refrigerated storage
P %	Apple	Control	0.083 edfc	0.082 egdf	0.061 o	0.071 lm
	Golden	Nylon Bags	0.0845 bdac	0.0855 bac	0.076 j	0.082 egdf
	Delicious	Paper Bags	0.0815 egfh	0.0825 egdf	0.07 m	0.0 77 ji
	Apple	Control	0.0835 ebdc	0.084 ebdac	0.067 n	0.075 jk
	Mutsu	Nylon Bags	0.0855 bac	0.0865 a	0.080 gh	0.086 ba
		Paper Bags	0.0805 gfh	0.0815 egfh	0.073 lk	0.079 ih

The means of the factors with different letters within the study or interaction differed significantly at a probability level of 0.05 according to Duncan's test.

The results revealed that there were significant differences in levels of phosphorus between the treatments being compared. Variety, packaging type, storage temperature, and variety x packaging type were significant for the phosphorus content. In addition, most of the treatments had lower phosphorus levels after a longer storage time. This is due to the ongoing metabolism in fruit after harvest that is associated with changes in the levels of phosphorus-based compounds during respiration and metabolic activity, resulting in a progressive loss of phosphorus over storage [19, 15]. The results also showed that refrigeration storage had better preservation of phosphorus content than room temperature storage. This is believed to be due to a decrease in respiration and enzyme activity that slows metabolic reactions and thus minimises changes in mineral content of the fruit during storage [1]. As for packaging material, nylon bags proved better than paper bags and the control treatment for the retention of phosphorus. This is due to their ability to reduce moisture loss and to maintain a more stable internal environment, thus reducing the intensity of the physiological processes, and delaying the post-harvest chemical changes in fruit. That is in line with the findings of [17] on Modified Packaging Techniques and Preservation of Fruit and Vegetable Quality. The variety × packaging type × storage temperature interaction revealed that the highest storage was found for Mutsu × nylon bag × refrigeration treatment and the lowest storage was observed for Golden Delicious × no packaging × room temperature treatment after 45 days of storage. It is indicative of the complementary effect of refrigeration and packaging in decreasing the metabolic activity and retaining mineral status in addition to genetic variation between the two varieties in their response to storage conditions [15, 17].

3.7. Potassium content of the fruit (%): The potassium content of the treatments studied is significantly different as seen in Table (7). Variety, packaging type, storage temperature, and variety × packaging type effects on potassium content were observed. Most treatments showed a decline of potassium with storage time. For example, in the Golden Delicious variety, it decreased from 0.92% to 0.725% in the control treatment at room temperature, and from 0.93% to 0.855% when using nylon bags. Similarly, in the Mutsu variety, it decreased from 0.925% to 0.775% in the control treatment and from 0.945% to 0.905% when using nylon bags at room temperature. This is due to the ongoing metabolic and physiological activities after harvest, which are accompanied by changes in ionic balance and movement of nutrients within the tissues during storage.

The results also indicated that refrigerated storage maintained better potassium levels than room temperature storage with the decreases of most refrigerated treatments being less than room temperature storage. This was especially true for the Golden Delicious variety in nylon bags (which dropped from 0.935% to 0.925%) or paper bags (which dropped from 0.910% to 0.905%) for the Mutsu variety. This is attributed to decreased respiration rate and physiological and chemical changes at lower temperatures which limit the rate of physiological and chemical changes that occur during storage. In terms of packaging type, all of the nylon packagings kept more potassium than the paper bags and the control treatment in several treatments, particularly during refrigerated storage. One such factor is the moisture barrier that nylon bags provide, which helps to keep the environment around the fruit more stable, which can help reduce physiological changes in fruit during storage. As to the interaction effect of variety×packaging type×storage temperature treatment, the Mutsu treatment obtained the highest potassium content after 45 days, at 0.975%, while the Golden Delicious treatment got the lowest potassium content, at 0.725%. This means that the Mutsu variety, nylon bag-packaging and refrigerated storage was more efficient for retaining potassium content throughout the storage time.

***Table (7) Effect of packaging type and storage temperature on some qualitative characteristics of two apple varieties and Fruit potassium content* (%).**

Physicochemical properties	Samples	Treatments	Storage for 1 Day		Storage for 45 Day	
			Room temperature	Refrigerated storage	Room temperature	Refrigerated storage
K %	Apple Golden Delicious	Control	0.92 bc	0.91 bcd	0.725 k	0.825 ih
		Nylon Bags	0.93 bc	0.935 bc	0.855 gfh	0.925 bc
		Paper Bags	0.92 ba	0.905 becd	0.805ji	0.875 efd
	Apple Mutsu	Control	0.925 bc	0.519 bcd	0.775 j	0.865 gef
		Nylon Bags	0.945 ba	0.930 bc	0.905 becd	0.975 a
		Paper Bags	0.895 ecd	0,910 bcd	0.835 gih	0.905 becd

Duncan's test used at 0.05 probability level indicated that the means of the factors having different letters in the study or interaction were significantly different.

The results indicated that there was significant difference among the potsassium content in the treatments studied. Variety, packaging type, storage temperature, and the variety×packaging type interaction all had an effect on potassium content. In addition, most treatments saw a decrease in potassium content with longer storage times. This is due to the ongoing metabolic activities and physiological processes in the fruit after harvesting, as well as changes in the permeability of membranes, the movement of ions, and the redistribution of minerals in the tissues during storage, resulting in losses of potassium [19]. In addition, the results indicated that potassium was better preserved under refrigerated storage than room temperature storage. It is believed that this is caused by slower metabolisms and respiration at lower temperatures, which decrease the speed of physiological and chemical changes and prevent loss of minerals during storage [1]. On the packaging type, results demonstrated that nylon bags preserved the content of potassium better than paper bags and the control treatment. This is because the functions of the packaging prevent the loss of moisture and regulate the diffusion of gases in and out of the fruit, which slows down physiological and metabolic activity and help maintain mineral components in the fruit during storage [17]. Furthermore, variety x packaging type x storage temperature was significant. The Mutsu variety, packed in nylon bags, refrigerated, had the highest potassium content after 45 days of storage, the Golden Delicious variety, un-packed and stored at room temperature, had the lowest. This can be attributed to the complementary effect of both cooling and packaging which slow down the physiology and metabolic processes of the fruit during storage as well as the differing responses of the two varieties to storage [19, 17].

4. Conclusion

Fruit weight, carbohydrates content, acidity, nitrogen, phosphorus and potassium decreased and percentage TSS increased after 1-Storage for 45 days as compared to the initial period of storage. The Golden Delicious variety was not as successful as 2-The Mutsu variety in preserving most of the quality parameters of the apple during storage. Refrigerated storage maintained apple quality in comparison with room temperature storage and resulted in less weight loss, loss of carbohydrate, acidity and nutrient losses, and delayed storage physiological changes. Fruit quality was greatly preserved by packaging. The nylon bags gave the lowest value compared with paper bags and the control treatment for the quality changes during storage. The Combining refrigerated storage and nylon bag packaging exhibited the greatest improvement in most of the parameters studied when compared to the other treatments. Moreover, variety x packaging type x storage temperature had significant effect on most of the studied traits, suggesting that fruit response is different from variety to type of packaging to storage temperature. The nylon bag treatment can be regarded as the best one for quality preservation, shelf-life and quality reduction of apples in Refrigerated storage. Our recommendation that use of refrigerated storage has been recommended to preserve apples because of the ability to preserve quality characteristics and reduce physiological changes during storage. Also, wrap apples with nylon bags before storage since it has been found to be more effective in maintaining fruit quality than paper bags or non-wrapped fruit. Nylon bags combined with refrigerated storage is recommended for storage because this combination has been useful in maintaining the quality of apples and increasing the storage life. Further research is recommended to investigate the improvement of apple quality in extended storage periods using other modern packaging materials such as biofilms and smart packaging. Investigate the influence of various storage temperatures and storage duration on fruit quality post harvest for the best possible fruit quality. Test other apple varieties with other storage treatments and packaging systems. Research on the effect of various post harvest activities like natural treatments or use of safe chemicals along with refrigeration and packaging on fruit quality and shelf life.

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