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RESEARCH

Reducing Losses of Strawberry (*Fragaria X Ananassa* Duch. Var. Honor) and Tomato (*Solanum lycopersicum* L. Var. Newton) at Domestic Storage

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ABSTRACT

Purpose: *This study aimed to evaluate and compare the effectiveness of Cold Storage and Modified Atmosphere Packaging in minimizing weight loss and preserving the quality of strawberry and tomato fruits.*

Research Method: *Strawberries and tomatoes fruits were stored under two different conditions: cold storage and modified atmosphere packaging (two treatments) in five different refrigerators (five replications). Cold Storage involved placing fruits in uncovered small plastic containers. While Modified Atmosphere Packaging involved packaging the fruits in the same plastic containers, however, on this occasion, the containers were sealed with a shrink-wrap. Then containers were stored at low temperatures in the lower part of the refrigerator until wilting or rotting symptoms were observed.*

Findings and Values: *Modified atmosphere packaging demonstrated superior preservation of both strawberry and tomato fruit quality, extended storage duration, and reduced weight loss compared to cold storage. This underscores the potential of Modified atmosphere packaging as a valuable supplement for maintaining optimal storage conditions and preserving the quality of freshly harvested strawberry and tomato fruits. By embracing these practices, such as Modified atmosphere packaging, individuals can play a proactive role in reducing food waste and minimizing the necessity for additional purchases, thereby helping to alleviate the depletion of natural resources and advancing sustainability objectives.*

Keywords: *Cold storage, Modified atmosphere packaging, Storage days, Soluble solids, Titratable acidity.*

INTRODUCTION

Many Jordanians tend to buy more food than they need because it is more economical to purchase in large quantities. Unfortunately, significant amounts of freshly harvested strawberry and tomato fruits end up going to waste, with estimated post-harvest losses at 8% and 22.2%, respectively. A considerable portion of these losses occurs in households, leading to an increased need to purchase even more food.

This creates a demand for higher production levels, which ultimately depletes natural resources and undermines sustainability efforts (Khatun & Rahman 2018, Qurashi *et al.* 2023). Strawberry and tomato fruits are highly prized crops, yet they are vulnerable to mechanical injury and dehydration if not stored and cooled at suitable temperatures. These fruits can be preserved through controlled atmosphere,

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modified atmosphere packaging, or cold air storage methods (Abu-Zahra & Tahboub 2008).

Effective handling practices and the utilization of proper fruit packaging during storage can mitigate the detrimental loss of fruit quality, as it involves creating an atmosphere modification (Manleitner *et al.* 2002). Packaging fruits in polyethylene bags has been shown to decrease respiration rates, shield against mechanical damage, prevent moisture loss, maintain freshness, uphold quality, and prolong shelf life (Krivorot & Dris 2002).

Unpackaged berries experienced weight loss ranging from 2–4% per day, whereas packaged fruits showed significantly lower losses at 0.05–0.6% per day (Krivorot & Dris 2002). Gidado *et al.* (2024) note that fruits risk losing their commercial value if their water content decreases by 5% or more. Covering fruits with (PVC) film maintained fruit firmness and total soluble solids content but resulted in a decrease in total titratable acidity (Ferreira *et al.* 1994). Storage temperature is a key factor influencing physiological and biological changes, thus exerting a significant impact on the shelf life of fruits (Pathare *et al.* 2012).

To address the issue of food waste and promote sustainability, Jordanians need to adopt a new approach to purchasing food. It is important to shift away from the mindset of buying in excess and instead focus on buying only what is needed (Abu-Zahra 2017). Additionally, proper storage methods should be utilized to extend the shelf life of produce and maintain its quality. By taking these steps, we can reduce post-harvest losses and minimize the need for excessive production, thereby helping to preserve natural resources and promote sustainability (Abu-Zahra *et al.* 2007).

Existing methods of fruit storage, such as traditional cold storage, have been essential but often insufficient in maintaining the quality and extending the shelf life of fruits like strawberries and tomatoes. Cold storage generally involves refrigeration at low temperatures, which slows down metabolic processes and microbial growth, thereby delaying ripening and decay. However, it does not completely halt physiological and biochemical changes, leading to eventual deterioration in texture, flavor, and nutritional quality over time (Gwanpua *et al.* 2014).

Modified Atmosphere Packaging (MAP) has emerged as an alternative method to extend shelf life by controlling the atmosphere around the fruit. This technique involves packaging fruits in films or containers with modified gas compositions, typically reducing oxygen levels and sometimes adjusting carbon dioxide levels. By doing so, MAP can slow down respiration rates and reduce ethylene production, which are key factors in fruit ripening and senescence (Crisosto & Crisosto 2000).

However, both traditional cold storage and MAP have their limitations. Cold storage may lead to chilling injury, especially in sensitive fruits like strawberries and tomatoes, where low temperatures can cause tissue damage and affect flavor and texture negatively (Perez *et al.* 1997, Vaka *et al.* 2020). On the other hand, MAP requires careful optimization of gas compositions and packaging materials to avoid issues such as anaerobic respiration or excessive moisture buildup, which can promote microbial growth and accelerate decay (Oms-Oliu *et al.* 2008).

The study investigating the impact of both cold storage and MAP on the postharvest life and quality of strawberry and tomato fruits aims to address these limitations by providing a comparative analysis of these two storage methods. By directly comparing their effects on fruit quality parameters such as firmness, color, flavor, and nutritional content, the study can elucidate which method or combination of methods is more effective in preserving fruit quality over an extended period.

For instance, cold storage (CS) might be effective in maintaining firmness but could compromise flavor, while MAP might better preserve flavor but require careful management to avoid undesirable effects on texture or microbial spoilage. By studying both methods under controlled conditions, the researchers can provide insights into their respective strengths and weaknesses, helping to optimize storage protocols and potentially develop hybrid approaches that combine the benefits of both techniques.

In conclusion, while existing methods like cold storage and MAP have contributed significantly to fruit preservation, they each have drawbacks that limit their effectiveness in maintaining optimal quality over prolonged periods. This study aims to bridge these gaps by evaluating and comparing the impacts of cold storage and MAP on strawberry and tomato fruits, offering valuable data to improve storage practices and enhance the shelf life and quality of these fruits.

Choosing a suitable storage method can aid in minimizing postharvest losses and preserving fruit quality, which will result in reducing the need to purchase more food, decrease the need for intensifying production and help to protect natural resources, thereby promoting the sustainability of food systems. This project was aimed at comparing the efficacy of CS and MAP in reducing weight loss and preserving quality in fruits would improve readability.

MATERIALS AND METHODS

An experiment was carried out with strawberries (*Fragaria X Ananassa Duch.*), Honor variety, and tomato (*Solanum lycopersicum*), Newton variety fruits, grown in Jordan. The fruits were purchased from local markets in Jordan on 9th March 2023. Fruits were meticulously chosen to ensure consistent size and color, as well as to guarantee freedom from soil, mechanical damage, and defects. This helped to ensure that the fruits were of similar quality and had similar storage requirements.

To carry out the experiment, the fruits were stored in five different refrigerators located at the mentor's (Professor) and four students' homes. The storage temperature of each refrigerator was recorded daily, and the average temperature readings were considered. The temperature range of the refrigerators was maintained between 3 to 8 °C, which is the optimal range for the storage of most fruits and vegetables. The relative humidity of the refrigerators ranged from 50–80%, which differed because of the different refrigerators.

The experiment involved storing the fruit under two different conditions:

Cold storage (CS)

The first storage method involved placing strawberry and tomato fruits in uncovered small plastic containers with a capacity of 1 kg. These containers were then stored at low temperatures in the lower part of the refrigerator. The temperature varied between the different refrigerators used in the experiment.

Modified atmosphere packaging (MAP)

The second storage method involved packaging the fruits in the same 1 kg plastic containers as the CS treatment; however, on this occasion, the containers were sealed with a shrink-wrap composed of LLD-polyethylene resin, which is certified as pollution-free.

In fresh produce like strawberries stored in passive MA films, the product's own respiration gradually reduces O_2 and raises CO_2 inside the sealed package, slowing bacterial growth and extending shelf life (Brockelt *et al.* 2025). The wrapped containers were then stored at low temperatures in the lower part of the refrigerator. Again, the temperature varied between the different refrigerators used in the experiment.

Prior to commencing the storage period, the weight of every container and the fruit contained in each replication were recorded with the aim of identifying any weight changes that may take place at the conclusion of the storage period.

Parameters measured

Each container, holding strawberry and tomato fruits, was taken out of the storage refrigerator as soon as any signs of wilting or rot were observed on the fruits. Measurements and analyses were conducted either before or after the storage duration.

Table 1. A summary of the fruit types, treatments administered, and the replication counts for each treatment.

Fruit type	Treatment type	No. of Replications
Strawberry	Cold Storage	5
	MAP	5
Tomato	Cold Storage	5
	MAP	5

The following is a summary of the different fruit types used in the experiment, the treatments applied for each fruit type, and the number of replications for each treatment, as shown in Table 1.

Storage Period: The duration of the storage period was determined by tracking the number of days from the initial storage date until the appearance of wilting symptoms on the strawberry or tomato fruits, which remained within acceptable consumption standards, or until any instances of fruit rot were observed.

Weight Loss: To assess weight loss, the initial weight of the strawberry and tomato fruits in each container was measured before storage. Subsequently, at the conclusion of the storage period, the fruits' weights were measured once more, and the resulting weight loss was calculated and documented for each replication.

Total Soluble Solids (TSS) Percentage: Before and at the conclusion of each storage method replication, the soluble solids percentage was assessed. The samples of strawberry and tomato fruits were ground and filtered through a cloth sheet, with a few drops subsequently utilized to measure soluble solids using a refractometer instrument (Abu-Zahra 2017).

Total Titratable Acidity (TTA) Percentage: It was assessed both before storage and at the end of each storage method replication. Strawberry and tomato fruit samples underwent grinding and filtration through a cloth sheet, after which five milliliters of the filtrate were used for titration to determine acidity, utilizing 0.1 N NaOH (Abu-Zahra *et al.* 2007).

Statistical analysis

A Randomized Complete Block Design (RCBD) was used, featuring two treatments: Cold Storage and Modified Atmosphere Packaging. Each treatment was replicated five times, with five containers assigned per treatment, each placed in a separate refrigerator for each fruit type. Data underwent analysis of variance (ANOVA) following procedures outlined by Steel & Torrie (1980). Mean separation was accomplished using the Least Significant Difference through the SAS program. Significance was attributed to differences with a probability value of 0.05 or less.

RESULTS AND DISCUSSION

Results of TSS% and TTA% before storage, and the storage temperature were recorded in Table 2.

Strawberry results

Both storage methods exhibited an increase in soluble solids percentage (TSS%); however, MAP maintained a higher TSS% compared to CS, which resulted in the lowest significant increase in TSS% (Table 2 & 3).

This suggests that wrapping fruits helps preserve TSS during storage, aligning with the findings of Kitazawa *et al.* (2013), who observed increased soluble solids in strawberry fruits after both cold and MAP storage methods, with the highest increase seen in MAP storage. Additionally, titratable acidity percentage (TTA%) decreased from 0.51 (Table 2) to 0.37 and 0.28 in CS and MAP, respectively (Table 3). MAP demonstrated the greatest decline in acidity compared to cold

Table 2. Results of the analysis conducted on both strawberry and tomato fruits before storage.

Fruit type	TSS (%)	TTA (%)	Av. Daily Temp. (°C)
Strawberry	5.12	0.51	5.3
Tomato	3.6	0.35	5.3

Table 3. The outcomes of quality evaluations performed on strawberry fruits post-storage.

Treatment type	TSS (%)	TSS change (%)	TTA (%)	TTA change (%)
CS	5.12 b	-1.15 b	0.37 a	-0.195 a
MAP	6.28 a	0.01 a	0.28 b	-0.281 b
LSD 0.05	0.84	0.53	0.084	0.084

storage, which exhibited the lowest decline. Similar results were reported by Ferreira *et al.* (1994), who wrapped berry fruits with PVC film and compared them with cold-stored fruits.

The implementation of MAP notably prolonged the storage duration, extending it from 8.8 days for cold-stored fruits left uncovered to 20.8 days for fruits covered with MAP (Table 4). The application of shrink-wrap aided in preserving fruit quality by minimizing moisture losses and reducing respiration, consequently extending their postharvest life (Abu-Zahra 2017). A significant decrease in weight loss was observed in CS fruits, with a daily rate of 1.082% (Table 4). Nonetheless, wrapping the fruits alleviated this weight loss and maintained fruit quality, as the shrink-wrap covering reduced transpiration and respiration.

Tomato results

Both treatments (CS and MAP) showed an increase in the TSS%, but the highest increase was obtained by the MAP (Table 5).

So, wrapping fruits could encourage ripening more than CS by stimulating an increase in fruit TSS. On the other hand, TTA% decreased from 0.35 (Table 2) to 0.22 and 0.19 in CS and MAP, respectively (Table 5). Additionally, MAP demonstrated the most significant decrease in acidity compared to CS, which exhibited the least decline.

These findings align with those of Al-Dairi *et al.* (2021), who observed a notable rise in TSS% from 4.1 to 4.9 Brix alongside a significant decrease in TA% (0.25%) over a 12-day period of cold storage. The increase in TSS and reduction in TA are primarily attributed to carbohydrate conversion and biosynthesis occurring during the ongoing ripening process of tomato fruits in storage conditions. Additionally, ripening contributes to the breakdown of pectin substances into simple sugars (oligosaccharides), thereby resulting in a gradual increase in TSS over time (Munhuewyi 2012).

The results of the storage conditions indicated that employing MAP extended the storage duration from 14.4 days for uncovered tomato fruits to 24.4 days for covered tomato fruits (Table 6). MAP contributed to reduced weight losses by effectively decreasing both respiration and transpiration rates compared to the CS method, thereby extending the storage period of tomato fruits under MAP beyond that of cold-stored tomato fruits (Lafuente *et al.* 2005). The greatest weight loss was noted in CS fruits at a rate of 0.62% per day (Table 6). However, wrapping the fruits reduced this weight loss and maintained fruit quality. This effect can be attributed to the covering of fruits, which decreased both transpiration and respiration rates, as suggested by Rana & Siddiqui (2018).

Based on the findings of this project, it is

Table 4. Findings concerning the storage duration of strawberry fruits and their corresponding weight loss.

Treatment type	Storage days	Weight loss (%)	Av. Daily wt. loss (%)
CS	8.8 b	9.56 a	1.082 a
MAP	20.8 a	4.07 b	0.198 b
LSD 0.05	1.96	1.89	0.136

Table 5. The outcomes of quality evaluations performed on tomato fruits post-storage.

Treatment type	TSS (%)	TSS change (%)	TTA (%)	TTA change (%)
CS	3.88 b	-0.36 b	0.22 a	-0.13 a
MAP	4.20 a	-0.22 a	0.19 b	-0.16 b
LSD 0.05	0.31	0.032	0.028	0.027

Table 6. Findings concerning the storage duration of tomato fruits and their corresponding weight loss.

Treatment type	Storage days	Weight loss (%)	Av. Daily wt. loss (%)
CS	14.4^{b}	8.85^{a}	0.62^{a}
MAP	24.4^{a}	2.69^{b}	0.11^{b}
LSD 0.05	2.15	1.73	0.05

recommended that consumers take the following steps to minimize food waste and save money: purchase only the amount of food that can be consumed without any leftovers, and when buying food in bulk to take advantage of lower prices, it is advisable to portion it into smaller containers based on their consumption and seal them with shrink-wrap to preserve their quality for a longer period.

CONCLUSION

This study demonstrated that Modified Atmosphere Packaging (MAP) is a more effective storage method than traditional cold storage for strawberries and tomatoes. MAP significantly extended the storage duration, reduced weight loss, and better preserved fruit quality by maintaining higher total soluble solids (TSS) and lower titratable acidity (TTA). These results highlight the potential of MAP to reduce food spoilage, minimize the need for frequent repurchasing, and contribute to more sustainable consumption practices.

Looking ahead, further research should focus on exploring a wider range of produce types and alternative storage technologies such as Controlled Atmosphere (CA) storage, which allows for precise regulation of oxygen and carbon dioxide levels. Investigating underutilized fruits and vegetables and advancing storage innovations can help diversify agricultural systems, reduce food waste, and improve access to fresh, nutritious food throughout the year—ultimately supporting global sustainability goals.

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