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المجلة العراقية لبحوث السوق
وحماية المستهلك

USING EVAPORATIVE COOLING AND PACKAGING TO STORE GREEN PEPPER

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ABSTRACT

Green bell peppers, a staple in kitchens worldwide, are notorious for their short shelf life. Fortunately, a simple technology of an evaporative cooling system can offer a promising solution to extend their freshness and reduce spoilage. Extensive studies have been conducted to measure the shelf life of crops during cold storage by using different techniques, that control relative humidity. Evaporative cooling, air speed, and packaging used to store green pepper and compared with sustainability methods and non-packaging. The aim of the study was prolonging shelf life for at least seven days. The characteristics included weight loss (%), temperature (ºC), relative humidity (%), and shelf-life (days). An air cooler with a volume of 2000 cu ft/s was used. An evaporative air cooler and the box are assemblage by a thermal insulating tube. The temperatures and humidity inside and outside the box were measured using the Arduino system using the DHT-22 temperature and humidity sensor. By measuring the percentage of weight loss and the storage period, evaporative cooling increased the green pepper's shelf life by extending the crop's life and reducing the percentage of weight loss when using evaporative cooling and packing. It was noted that there was a strong relationship between the decrease in the percentage of weight loss and packing.

Keywords: Packaging, temperature, weight loss, sustainability, postharvest loss.

استخدام التبريد التبخيري والتعبئة لخزن الفلفل الاخضر

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الخلاصة

يشتهر الفلفل الأخضر، وهو عنصر أساسي في المطابخ في جميع أنحاء العالم، بفترة صلاحيته القصيرة. ولحسن الحظ، يمكن لتقنية بسيطة لنظام التبريد التبخيري أن تقدم حلاً واعدًا لإطالة نضارتها وتقليل تلفها. تم إجراء دراسات موسعة لقياس العمر الافتراضي للمحاصيل أثناء التخزين البارد باستخدام تقنيات مختلفة للتحكم في الرطوبة النسبية. التبريد التبخيري وسرعة الهواء والتعبئة المستخدمة لتخزين الفلفل الأخضر ومقارنتها بطرق الاستدامة وعدم التعبئة والتغليف. وكان الهدف من الدراسة إطالة مدة الصلاحية لمدة سبعة أيام على الأقل. وشملت الخصائص فقدان الوزن (٪)، ودرجة الحرارة (C)، والرطوبة النسبية (٪)، وأيام العمر الافتراضي. تم استخدام مبرد هواء بحجم 2000 قدم مكعب في

[*]**This article is taken from the first researcher's master's thesis.**

الثانية. يتم تجميع مبرد الهواء التبخيري والصندوق بواسطة أنبوب عازل حراري. تم قياس درجات الحرارة والرطوبة داخل الصندوق وخارجه باستخدام نظام Arduino باستخدام مستشعر درجة الحرارة والرطوبة DHT-22. ومن خلال قياس نسبة فقدان الوزن وفترة التخزين، تبين أن التبريد بالتبخير أدى إلى زيادة العمر الافتراضي للفلفل الأخضر من خلال إطالة عمر المحصول وتقليل نسبة فقدان الوزن عند استخدام التبريد التبخيري والتعبئة. ولوحظ أن هناك علاقة قوية بين انخفاض نسبة فقدان الوزن والتعبئة.

الكلمات المفتاحية : التغليف، درجة الحرارة، فقدان الوزن، الاستدامة، فقدان ما بعد الحصاد.

INTRODUCTION

The sweet green pepper crop is considered perishable after harvest and cold storage can decrease postharvest loss which reduces poverty and hunger these two goals related to the UN vision 2023. There is a stereotype related to the origin of vitamin C, which is the more prevalent in green bell pepper, however vitamin C content was greater in green bell paper which is confirm by **(Muhamad & AL- Badri, 2021)**. The optimal storage temperature varies among fruits and vegetables **(Khater & Afify, 2021)**.Preharvest treatment influences postharvest storage conditions **(Wang, *et al.*, 2018)**. An air cooler is used in Iraq during the hot summer **(Al-Badri & AL-Makhul, 2019)**; increase the relative humidity **(Abdul-Munaim, 2006; Al-Badri & Abdul-Abass, 2014)**.Compared with ambient conditions, evaporative cooling extend the shelf life of green pepper by four-fold **(Al-Badri S. B., 2019)**. It reduces weight loss and preserves marketability for a longer period **(Awole, & Workneh, 2013)**. The storage period for the pepper crop was 14 days when the temperature ranged between 25-28°C and the relative humidity was between 70-90% and reduces weight loss **(Al-Badri, 2019)** and shelf-life day was 15 days when using evaporative cooling with temperature 21C and75% relative humidity and weight loss was 12% **(Najam & AL-Badri, 2024)** . The storage period of the sweet pepper crop was 4 weeks at a temperature of 10C and 90% relative humidity **(Lim, & Woolf, 2007)**. The shelf life of the pepper crop was 3-5 weeks when stored at 7.5°C and 90-95% relative humidity **(Gonzalez & Wang, 1999)**. The number of the shelf-life days storage is affected by relative humidity **(Byeon, *et al.*, 2023)**.Therefore, evaporative cooling is a low-cost technology for storing fruits and vegetables. The evaporative cooler performance depends on the humidity of the outside environment **(Kale & Sundaram, 2014)** and shelf life day effect by relative humidity **(Kasampalis, *et al.*, 2022)** .Very dry air can absorb too much moisture, resulting in greater cooling. Evaporative cooling systems can be used to store fruits and vegetables for a short period of time after harvest, as confirmed by **(Bayogan, & Acosta, 2017; Sangeeta, *et al.*, 2022)**. Plastic has been developed and widely used in the field of food packaging due to its excellent insulating properties and low cost **(Chamas, *et al.*, 2020)** . Packaging plays a very important role in terms of: providing protection from dust, reducing microbial contamination from the surrounding environment and helping to maintain the freshness of the products **(Sirivatanapa, 2006)** . Packaging works to extend the shelf life of fruits and vegetables after harvest. This increases the sales of fresh products. The role of packaging in food marketing continues to develop to meet the growing needs of the market and consumers **(Alsoufi, & Obaid, 2020b)**.The industry has resorted to constantly improving the shape of the packaging, ensuring that it does not affect consumers' perceptions and providing all the information that consumers need **(Alsoufi, 2021)**. Storage at low temperatures is generally the most effective way to maintain the quality of horticultural crops after harvest and is the most widely used post-harvest technique **(Endo, & Imahori, 2019)**, however, storage green pepper at a temperature below 7°C, or storage between of 5 to 8°C reduces water loss and ripening, but after two weeks chilling injury occurs **(Singh, & Kotwaliwale, 2014)**. A lower relative humidity results in more moisture loss in vegetables. This will cause it to shrink, wilt, and lose freshness. High relative humidity causes vegetables to rot. This makes vegetables more vulnerable to attack by microorganisms **(Kale & Sundaram, 2014)**.This study tried to control relative humidity in the range of 90-95% under evaporative cooling system. The first factor is air speed (speed1vs speed2), the second factor is packaging vs nonpackaging and the third factor includes the storage location inside the evaporative cooling box vs the sustainability methods which simulate the local market.

MATERIALS AND METHODS

MATERIALS

The box used for the storage green paper was designed and tested by **(Najam & AL-Badri, 2024) .** The following materials were used in the field experiment.

- Evaporative air cooler: An Iranian evaporative air cooler with a size of 2000 ft3/s was used, shown in Figure (1).
- A transparent, perforated polyethylene box was used to store the pepper crop, as shown in Figure (2).
- An Arduino system with two DHT-22 temperature and humidity sensors was used to measure the temperature and humidity outside and inside the wooden box shown in Figure (3).
- A digital scale, type SF-400, was used to measure weight loss in the pepper crop before entering it into the special equation to calculate the percentage of weight loss shown in Figure (4).

Figure. (1): Evaporative cooler with wooden box.

Figure. (2): The plastic box used to package the pepper crop.

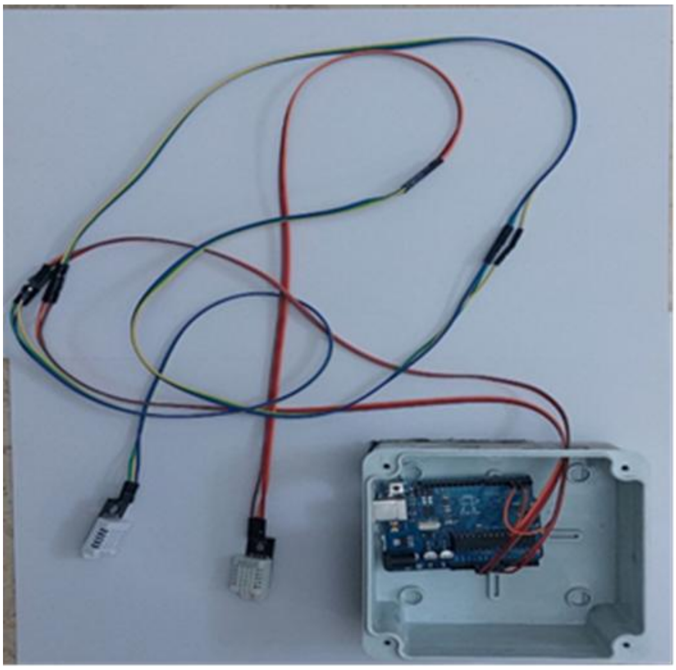


Figure. (3): Arduino system for measuring temperature and humidity.

Figure. (4): Digital scale type SF-400.

Figure. (5): The wooden box containing the pepper crop.

Table (1): Specifications of the evaporative cooling used in the experiment.

Type, Made	PAK KHAZAR, IRAN
Engine power H. P	¼
Fuel tank (L)	22 liters of water
R.P.M for engine S1	1290
R.P.M for engine S2	1320

METHODS

• Experimental Field:

The experiment was carried out according to a randomized complete block design (RCBD). Three replications were used. Two air speeds were allocated to the main scheme, and filling was allocated to the subplans, and the averages of the treatments were compared using Tukey selection with a probability of 0.05.

The experiment was conducted in Baghdad Governorate, which is geographically located at latitude 33.3128057 and longitude 44.3614875, in the Karrada region for the period from February 27, 2024 to April 17, 2024. The Carisma F1 pepper crop from the Spanish company Fito was used.

• Experimental Design:
Three factors were used. The first factor represents air speed as the main factor and has two levels.
A - The initial air speed is 3.6 m/s represented by (S1)
B – Second air speed 4.3 m/s represented by (S2)
The second factor with two levels, packaging and nonpackaging
A - Packing the pepper crop with the plastic box represented (P)
B - Without filling the pepper crop represented by (NP)
Finally: Colling and non-cooling used.
The experiment included 8 treatments,2×2×2, with three replications. The result was 24 experimental units. The data were analyzed using three-way ANOVA by using orginPro 2018.

• Experimental Execution Method:
A - The box is installed and connected with the pipe to the evaporative cooler. The evaporative cooler was operated at the first speed of air (S1) until the samples reached a weight loss rate of 12%. New samples of the crop are placed and the cooler is operated at the second speed (S2).
B - The weights of the crop samples is taken using the scale shown in Figure (4) every day throughout the storage period to determine the percentage of weight loss.
C - The samples are placed inside the box in plastic boxes and the changes you get are monitored. Also, samples without packaging are placed inside the box and the changes you get are monitored.
D - The storage period is calculated for the stored crop until the percentage of weight loss reaches 12%.

3 - Theoretical Calculations of the Studied Properties:

• Percentage of weight loss
The following equation was used to calculate the percentage of weight loss used before **(Al-Badri S. B., 2019)** .

$$\text{Weight Loss (\%)} = \frac{\text{lnitial weight} - \text{final weight}}{\text{lnitial weight}} \times 100$$

RESULTS

The results in Table 2 shows that the overall of the shelf life day of the samples was At the 0.05 level, the population means of A are significantly different ; At the 0.05 level, the population means of B are significantly different,and At the 0.05 level, the population means of C are significantly different .

The intreaction between the two factoers shown that At the 0.05 level, the population means of A * B are significantly different . At the 0.05 level, the population means of A * C are significantly different. At the 0.05 level, the population means of B * C are significantly different , and Finally the intreaction among the three factors shown that At the 0.05 level, the population means of A*B * C are significantly different .

Table(2): illustrated the Overall ANOVA of the three factoers for shelf life day.

Overall ANOVA

	DF	Sum of Squares	Mean Square	F Value	P Value
A	1	620.16667	620.16667	620.16667	3.17524E-14
B	1	150	150	150	1.52989E-9
C	1	20.16667	20.16667	20.16667	3.70576E-4
A * B	1	10.66667	10.66667	10.66667	0.00485
A * C	1	104.16667	104.16667	104.16667	2.06621E-8
B * C	1	0.66667	0.66667	0.66667	0.42621
A * B * C	1	32.66667	32.66667	32.66667	3.18854E-5
Model	7	938.5	134.07143	134.07143	5.33129E-13
Error	16	16	1	0	0
Corrected Total	23	954.5	0	0	0

A= represnted Cooling and non-coling
B= represnted P vs NP, C = S1 vs S2

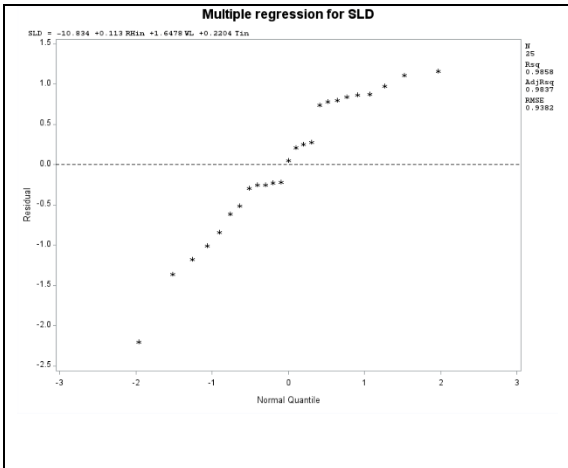
The shelf life day SLD was siginficantly different for most of the data due to storage , packaging and air speed, which play important roles in extending the self life day for CPS1 to 22 days vs CPS2 to14 days, and for no-packaging the shelf life day was CNPS1 for 13.66 VS CNPS2 was 9.66days. However,the shelf life of the NC was decreased to less than 9 days with packaging for S1, which was was related to the lack of envieront condation such as lower temperatures and high relative humidiy, as well as the presence of water vapor surrounding the green pepper, which is enhanced the shelf life by increasing the relative humidiy insdie the packaging box. These resluts were better than the results obtained by **(Najam & AL-Badri, 2024)**, because the packaging extended the shelf life for an average 22 days, while they extended the shelf life for 14 days.

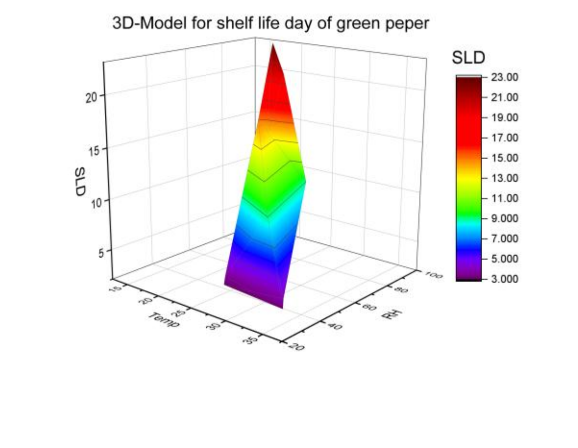
Table(3): illustrated the means Comparisons of the three factores.

A * B * C

			N	Mean	SD	SEM	Variance	Missing	NonMissing
C	P	S1	3	22	1.73205	1	3	0	3
		S2	3	14	1.73205	1	3	0	3
	NP	S1	3	13.66667	1.1547	0.66667	1.33333	0	3
		S2	3	9.66667	0.57735	0.33333	0.33333	0	3
NC	P	S1	3	4	0	0	0	0	3
		S2	3	9	0	0	0	0	3
	NP	S1	3	3	0	0	0	0	3
		S2	3	2.66667	0.57735	0.33333	0.33333	0	3

Table (3) shows that CPS1 which was cooling with packaging at speed , had the longest mean shelf life of 22 days, while at speed 2 , it had a shelf life of 14 days. This indicates that a air speed results in longer shelf life day. This may be related to the long contact between the air and the crops, which removed heat and increased the relative humidity around the crops. These information was confirmed by **(Al-Badri S. B., 2019)** and **(Najam & AL-Badri, 2024)**.





a)The result for multaple regression modle shown that R-square=0.985 AdjRes=0.9837, and RMSE=0.9382 The modle explain most of the data	b)The optimazation modle illistrated the shelf life day with temperatuer and humidity R-square=0.8481 RMSE=3.2239

Figure. (6): show the optimization model for the shelf life day.

The 3D shape in Figure 6 show the relationships between temperature, relative humidity and shelf life day.Temperatuer is the most important factor in this study due to its small cofficient,followed by relative humidity.

Table (4) shown that :At 0.05 level, the population means of A are not signifacntly different.At 0.05 level, the population means of B are not signifacntly different.At 0.05 level, the population means of C are signifacntly different.At 0.05 level, the population means of A*B are not signifacntly different.At 0.05 level, the population means of A*C are signifacntly different.At 0.05 level, the population means of B*C are not signifacntly different.At 0.05 level, the population means of A*B*C are signifacntly different.As we can see from the result that the intreaction between cooling methed and air speed are signifacntly different in matine WL of the green papper. The intreaction between cooling, packgaing and air speed also significantly different

Table(4): illustrated the Overall ANOVA of the three factoers for WL%.

ANOVA

Overall ANOVA

	DF	Sum of Squares	Mean Square	F Value	P Value
A	1	0.33429	0.33429	0.40126	0.53539
B	1	6.08284E-4	6.08284E-4	7.3014E-4	0.97878
C	1	12.50675	12.50675	15.01221	0.00134
A * B	1	3.52755	3.52755	4.23422	0.05629
A * C	1	17.78515	17.78515	21.34803	2.8361E-4
B * C	1	2.1346	2.1346	2.56223	0.129
A * B * C	1	6.49018	6.49018	7.79035	0.01308
Model	7	42.77915	6.11131	7.33558	4.98802E-4
Error	16	13.32969	0.83311	0	0
Corrected Total	23	56.10883	0	0	0

Table(5) shows that :At 0.05 level, the population means of A are significantly different.At 0.05 level, the population means of B are significantly different.At 0.05 level, the population means of C are significantly different.At 0.05 level, the population means of A*B are significantly different.At 0.05 level, the population means of A*C are significantly different.At 0.05 level, the population means of B*C are significantly different.At 0.05 level, the population means of A*B*C are significantly different.

Table(5): illustrated the Overall ANOVA of the three factoers for RH %.

Overall ANOVA

	DF	Sum of Squares	Mean Square	F Value	P Value
A	1	17899.77271	17899.77271	43332.80596	0
B	1	113.53758	113.53758	274.85834	1.68849E-11
C	1	250.8442	250.8442	607.25816	3.75255E-14
A * B	1	40.31559	40.31559	97.5983	3.25214E-8
A * C	1	107.18309	107.18309	259.47502	2.61167E-11
B * C	1	44.7509	44.7509	108.33556	1.5693E-8
A * B * C	1	108.946	108.946	263.74279	2.30846E-11
Model	7	18565.35006	2652.19287	6420.58202	0
Error	16	6.60923	0.41308	0	0
Corrected Total	23	18571.95929	0	0	0

The resuletes related to the relative humidity emply that factor A which was cooling the most importint factor influince the results to extended the shelf life days and decline the weight loss.

The results for temperature at table (6) shown that At 0.05 level, the population means of A are significantly different.At 0.05 level, the population means of B are significantly different.At 0.05 level, the population means of C are significantly different.At 0.05 level, the population means of A*B are significantly different.At 0.05 level, the population means of A*C are significantly different.At 0.05 level, the population means of B*C are not significantly different.At 0.05 level, the population means of A*B*C are significantly different.

Table(6): illustrated the Overall ANOVA of the three factoers for Temperature.

Overall ANOVA

	DF	Sum of Squares	Mean Square	F Value	P Value
A	1	787.93178	787.93178	2238.14373	0
B	1	2.27579	2.27579	6.46445	0.02173
C	1	30.47844	30.47844	86.57493	7.41636E-8
A * B	1	2.89719	2.89719	8.22954	0.01114
A * C	1	198.63134	198.63134	564.21826	6.65024E-14
B * C	1	0.00424	0.00424	0.01204	0.91399
A * B * C	1	8.70028	8.70028	24.71341	1.38685E-4
Model	7	1030.91906	147.27415	418.33662	0
Error	16	5.63275	0.35205	0	0
Corrected Total	23	1036.55181	0	0	0

The resuletes related to the tmeperatuer emply that factor A which was cooling wasthe most importint factor impact the results to extended the shelf life days and decline the weight loss.

CONCLUSION

The effectiveness of evaporative cooling systems can be affected by external factors such as climate variance, which may impact their performance and efficiency; thus, further research is needed to improve their capabilities. While evaporative cooling offers potential for applications in the short-term preservation of produce soon after harvest, challenges such as the lack of knowledge on the potential benefits and importance of these methods among farmers and industries have limited their widespread adoption. In conclusion, evaporative cooling plays a critical role in extending the shelf life of green pepper by reducing temperature and increasing relative humidity, thereby improving economic value, reducing postharvest losses, and offering environmental benefits. However, challenges such as limited adoption and the need for further research to enhance the effectiveness of evaporative cooling systems remain. Finally, this research indicates that cooling with packaging and using lower air speeds enhance the shelf-life day with minimum weight loss because the evaporative cooling system enhances the environment by increasing relative humidity and decreasing the temperature. Further studies needs to apply by using UV light disinfection techniques needed to extend the shelf life of green bell peppers for addional days.

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