

Postharvest performance interpretation and storage temperature optimization in some newly introduced melon hybrids

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All relevant data are within the paper and its Supporting Information files.

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The authors declare no competing interests.

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Abstract: Temperature is a key factor in melon cold storage. Thus, optimizing storage temperature is an important goal in postharvest research. In this experiment, postharvest attributes of four inbred lines and five derivative hybrids were investigated under three storage temperatures (1, 4, and 12°C). Melon fruit were evaluated for their main characteristics directly after harvest and postharvest changes were monitored through cold storage period. Cluster analysis results showed that most of the hybrids clustered with their maternal parents illustrating the significant role of cytoplasmic inheritance for the studied traits. Similarly, principal component analysis clustered the studied types into three clusters according to their average postharvest behaviour. The best postharvest performance belonged to inodorus and cantalupensis netted melon with their intercrossing breeds. While the dudaim inbred line and its hybrid scored the highest postharvest changes. Response surface analysis showed that 1.8°C was the optimum storage temperature for inodorus and cantalupensis clusters, while 5.1°C was the best storage temperature of dudaim cluster. The results of the current study are similar to previous reports for optimum storage temperature in similar melon types.

1. Introduction

Melons (*Cucumis melo*) are among the most important fruit crop worldwide with a yearly production of more than 27 million tons (FAO, 2019). This fruit is of an exclusive importance in Mediterranean and Eastern Asia regions (Garcia-Mas *et al.*, 2012). Melons are usually perishable with short shelf life and low storability (Fukuta *et al.*, 2006; Briones *et al.*, 2012). Thus, these fruits do not maintain their marketability for longer than 10 days in room temperature conditions. Therefore, introducing new melon types with enhanced storability, longer shelf life, and better shipping potentials is among the main aims of melon breeders. Additionally, investigating postharvest behaviour and optimizing storage

variables of this fruit is of high importance.

Persian melons (*Cucumis melo* var. *inodorus*) are reported to be a valuable material in melon breeding for postharvest purposes. These types of melons have firmer mesocarps compared to cantalupensis types and thus, endure shipping and handling better (Welbaum, 2015). For instance, including the line 'Cm-UTKH' in breeding programs by crossing with other cantalupensis melons reportedly introduced new types with promising postharvest attributes (Alabboud *et al.*, 2020; Shajari *et al.*, 2021). Therefore, investigating these newly introduced intergroup hybrids for their postharvest potentials under different storage temperature might be of high importance.

Weight losses, firmness losses, soluble solids fluctuations and colour changes are the main postharvest attributes in stored melons. Furthermore, temperature is the main factor affecting these attributes throughout cold storage (De Arruda *et al.*, 2003; Yang *et al.*, 2003; Žnidarčič *et al.*, 2013; Hatami *et al.*, 2019). Therefore, minimizing postharvest changes through optimized storage temperature is the ultimate goal in cold storage research. However, monitoring these attributes in large populations can be a laborious quest especially when investigating optimum storage temperature. Thus, a more appropriate experimental method should be used in order to minimize experiment size and maintain an acceptable accuracy. For this purpose, principal component analysis (PCA) is considered a useful tool to explain diversity within a studied group of samples with minimum loss of information. Many researches implemented PCA for better understanding of melon fruit characteristics (Obando *et al.*, 2008; Maietti *et al.*, 2012; Farcuhi *et al.*, 2020). On the other hand, response surface method (RSM) is a direct application of regression theory to optimize an experimental

input (Barton, 2013) with fewer number of experiments (Wani *et al.*, 2012) which fits the goal of postharvest studies in melon.

Therefore, the main goals of this study were to investigate postharvest attributes of some newly introduced melon hybrids under different storage temperatures, and to find the optimum storage temperature for these hybrids through the application of response surface regression optimization.

2. Materials and Methods

Plant material

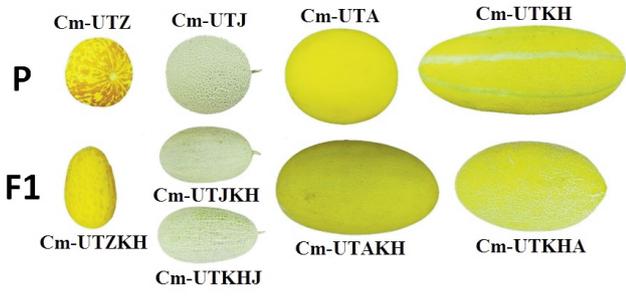
The experiment was carried out for the seasons of 2019 and 2020 at the Research Station of the Department of Horticultural Sciences (University of Tehran) in Karaj, Iran. Four melon inbred lines (Table 1) with five of the intercrossing hybrids were used in this experiment (Fig. 1). The seed of inbred lines and hybrids were planted in seedling trays in greenhouse and transferred to the field three weeks after germination. The seedlings were planted in rows with 1.5 m distance between rows and 0.8 m between plants on each row. Ripening was determined by the development of $\frac{1}{2}$ to $\frac{3}{4}$ of abscission layer in types that tend to develop an abscission layer and after 42 days post-anthesis in types that lacks the ability to develop an abscission layer. The fruit were harvested at ripening and transferred to the cold storage facility at the Department of Horticultural Sciences. The harvested fruit were stored under three different temperature (1, 5, and 12°C) and a relative humidity of 90-95% for a period of one month.

Fruit attributes monitoring

The main fruit characteristics were monitored

Table 1 - The morphological characterizations of the inbred lines used for the crosses

Line name	Group and origin	Climacteric behaviour	Fruit shape	Rind	Mesocarp	Volatiles	Origin
Cm-UTKH	Inodorus,	Non-climacteric	Oval elongated	Yellow-Shallow netted	Greenish white	Odourless	Khorasan (South-eastern part of Iran)
Cm-UTA	Cantaloupensis x Inodorus derived inbred line	Non-climacteric	Oval-Round	Dark yellow - Without net	White	Odorous (Medium)	Abadan (Southern part of Iran)
Cm-UTJ	Cantaloupensis	Non-climacteric	Ova -Round	Green - Netted	Green	Odourless	Alborz (North-western part of Iran)
Cm-UTZ	Dudaim	Climacteric	Round flatted	Dark yellow with orange areas - Without net	White	Odorous (High)	Kerman (South-eastern part of Iran)



Breed	Maternal parent	Paternal parent
Cm-UTKHA	Cm-UTKH	Cm-UTA
Cm-UTAKH	Cm-UTA	Cm-UTKH
Cm-UTKHJ	Cm-UTKH	Cm-UTJ
Cm-UTJKH	Cm-UTKH	Cm-UTJ
Cm-UTZKH	Cm-UTZ	Cm-UTKH

Fig. 1 - The studied melon inbred lines (P) and their hybrids (F1). The first part in each hybrid name represents the maternal parent while the second represent the male parent.

directly after harvest and throughout storage period in 10 days intervals (i.e. days 0, 10, 20, and 30). Fruit weight was measured using an electronic scale. TSS% in the juice of extracted from a longitudinal section of the fruit was measured using a handheld refractometer. Mesocarp firmness was measured using a handheld penetrometer equipped with an 8-mm tip. The firmness was expressed as an average of three reads along the longitudinal surface of the fruit after the removal of the rind. Rind colour was expressed in CIE-lab scale as lightness (L^*), chroma (C^*) and hue angle (h°) using a chromameter (Konica Minolta, Japan).

The changes in fruit attributes throughout storage were presented as percentages and were calculated using the following formulas:

$$\text{Weight loss (\%)} = (FWO - FWA)/FWO \quad (1)$$

$$\text{Firmness loss (\%)} = (MFO - MFA)/MFO \quad (2)$$

Where FWO and FWA are fruit weight (g) at harvest and at analysis time, respectively; while MFO and MFA are mesocarp firmness (Kg cm^{-2}) at harvest and at analysis time, respectively.

Colour changes were calculated using colour difference formulas according to Sharma *et al.* (2005) eq. 3 and using the same system described in Mohi-Alden *et al.* (2021).

$$\Delta C = [(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2]^{1/2} \quad (3)$$

where ΔC is colour changes during cold storage L_0^* , a_0^* and b_0^* are the values of colour parameters at harvest, and L^* , a^* and b^* are the values of colour parameters after cold storage.

Data analysis

The two-factor experiment (evaluation date and storage temperature) was carried out in a split plot design. Fruit attributes mean at harvest were compared using Fisher's LSD test ($P < 0.05$) with Minitab 19 software. Furthermore, fruit attributes were clustered using Ward's method on NCSS 12. The averages postharvest measurement for the studied lines and breeds were analysed using principal component analysis (PCA). The best Response surface method (RSM) was used to calculate the optimized storage temperature for each PCA cluster.

3. Results

Fruit characteristics and heterosis analysis

The main fruit characteristics of parents and F1 progeny were investigated (Table 2). The result showed that the parent 'Cm-UTKH' recorded the highest fruit length and fruit shape values and, the parent 'Cm-UTA' scored the highest results in terms of fruit diameter, mesocarp thickness, and cavity diameter. The highest firmness results were observed in 'Cm-UTJ' parent with 11.67 Kg cm^{-2} followed by its hybrid 'Cm-UTJKH' (10.98 Kg cm^{-2}), with no significant differences between the parent and the hybrid. The highest fruit weight, and TSS% were observed in the hybrids 'Cm-UTKHA' and 'Cm-UTJKH' with 2033.91 g and 15.3%, respectively. As for colour attributes, the highest L^* and hue values were recorded in the parent 'Cm-UTA', while the highest chroma values were observed in the hybrid 'Cm-UTJKH' and the reciprocal 'Cm-UTKHJ'.

Moderately low heterosis results were recorded for fruit diameter, cavity diameter, firmness, TSS, and colour attributes. However, F1 progeny expedited higher heterosis values levels for fruit length (33.17%), fruit shape (22.71%), mesocarp thickness (17.48%), and weight (29.35%).

Cluster analysis of fruit attributes

Ward linkage cluster analysis of fruit attributes at day 0 can be seen in figure 2. The studied genotypes were clustered in three clusters the first cluster contained the hybrid 'Cm-UTZKH' with its maternal parent. The second cluster contained 'Cm-UTJKH' with

Table 2 - Fruit characteristics for the studied melon types directly after harvest (Day 0 observation). FL (Fruit length), FD (Fruit diameter), FS (Fruit shape), MT (Mesocarp thickness), CD (Cavity diameter), W (weight), F (Firmness), TSS (Total soluble solids), L* (Lightness), H (Hue), C (Chroma)

Type	FL (cm)	FD (cm)	FS	MT (cm)	CD (cm)	W (g)	F (Kg cm ⁻²)	TSS (%)	L*	H	C
Cm-UTKH	27.77 a	11.33 cd	2.50 a	2.65 cd	6.09 b	1717.42 b	4.77 e	11.70 b	71.15 d	69.72 d	62.35 c
Cm-UTA	13.81 e	14.82 a	0.93 f	3.77 a	7.14 a	1520.51 c	9.84 b	6.33 e	78.24 a	78.77 a	60.37 d
Cm-UTJ	12.88 f	11.94 c	1.09 e	3.01 b	5.88 bc	1026.36 d	11.67 a	11.65 b	72.81 cd	22.06 e	65.21 b
Cm-UTD	6.21 g	7.57 e	0.80 f	1.05 e	5.44 c	201.84 f	5.63 de	6.67 e	68.72 e	70.99 cd	44.45 f
Cm-UTAKH	21.65 c	13.44 b	1.61 c	3.66 a	6.30 b	1738.41 b	7.46 c	8.70 d	74.23 c	75.76 b	60.13 d
Cm-UTKHA	22.29 c	13.15 b	1.69 c	3.54 a	5.98 bc	2033.91 a	6.51 cd	10.60 c	70.92 d	71.69 c	60.12 d
Cm-UTJKH	16.71 d	10.64 d	1.59 c	2.92 bc	4.82 d	917.40 de	10.98 ab	15.30 a	76.19 b	17.17 f	75.38 a
Cm-UTKHJ	25.98 b	13.79 b	1.95 b	2.78 bcd	6.97 a	1771.08 b	5.20 e	10.33 c	73.24 c	12.71 g	74.49 a
Cm-UTZKH	14.36 e	11.12 cd	1.32 d	2.49 d	6.16 b	760.31 e	7.38 c	6.80 e	72.74 cd	74.36 b	55.36 e
h%	33.17	8.87	22.71	17.48	-1.49	29.35	-5.91	13.85	1.01	-16.64	12.05

Types with similar letters in each column have no significant differences for the monitored trait in that column (P<0.05). h% represents heterosis in each trait compared to med-parents.

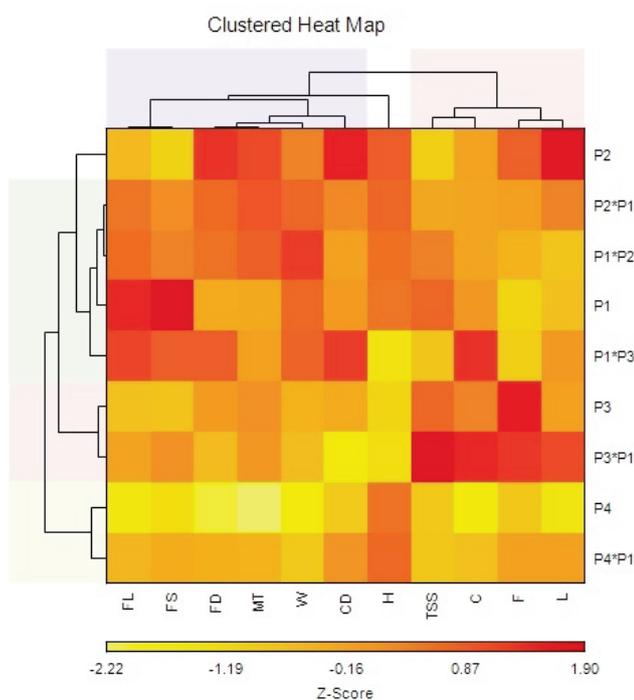


Fig. 2 - Ward's linkage cluster analysis for the studied melon types and their fruit characteristics. P1, P2, P3, and P4 represent the studied lines Cm-UTKH, Cm-UTA, Cm-UTJ, and Cm-UTZ, respectively while two letters genotypes represent F1 direct and reciprocal breeds. FL (Fruit length), FD (Fruit diameter), FS (Fruit shape), MT (Mesocarp thickness), CD (Cavity diameter), W (weight), F (Firmness), TSS (Total soluble solids), L* (Lightness), H (Hue), C (Chroma). The colors of the heat map represent the normalized values of raw data to Z score. Thus, red colors or yellow colors represent values higher or lower than the average value for each studied characteristic, respectively.

its maternal parent. While the final cluster constituted of the 'Cm-UTKHA', 'Cm-UTKHJ', and their maternal parent in addition to the hybrid 'Cm-UTAKH'. On the other hand, 'Cm-UTA' was not clustered with any of the studied types.

As for the studied fruit traits, two major clusters were noticed. The first contained TSS, chroma, firmness, and lightness (L). The second cluster contained the rest of the studied attributes (fruit length, fruit shape, fruit diameter, mesocarp thickness, weight, and cavity diameter), while hue was not clustered with any other attribute.

Principal component analysis results

The average postharvest performance data under three different storage temperature was subjected to principal component analysis (PCA) (Fig. 3). Scree distribution of factors showed that the first two factors were accounted for 68.7% of the total variance with 49.3% for the first factor (PC1) and 19.4% for the second (PC2). Additionally, the accumulated effect of the first three factors was accounted for 79.1% of the total variance among the studied types (Table 3). The most significant positive contributors to the PC1 were chroma, TSS, firmness, and colour changing index, while hue and firmness loss were the most significant negative contributors to this factor. On the other hand, PC2 was substantially positively influenced by fruit weight.

As for genotype clustering according to biplot of postharvest performance, three major clusters were noticed. The green cluster located on the positive

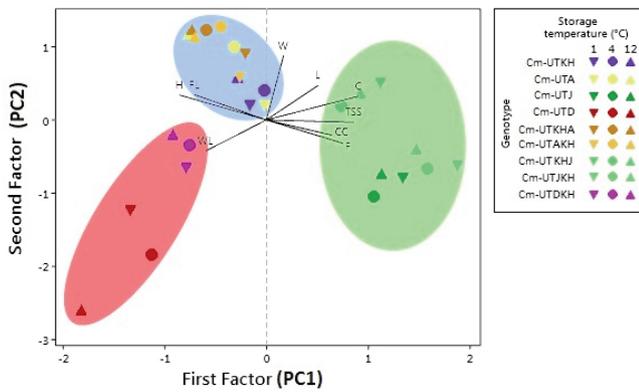


Fig. 3 - Principal component analysis for the studied melon. Loading factors represent the average performance of the studied types calculated as the mean for each loading variable of each type during storage period (the average of 0, 10, 20, and 30 days in cold storage). W (Weight), WL (Weight loss), F (Firmness), FL (Firmness loss). TSS (Total soluble solids), L (Lightness), H (Hue), C (Chroma), CC (Color changes).

quadrates of PC1 and contained ‘Cm-UTJ’ parent with its hybrid ‘Cm-UTJKH’ and reciprocal ‘Cm-UTKHJ’. The blue cluster located on the positive PC2 and negative PC2 quadrante and was constituted of the parents ‘Cm-UTKH’ and ‘Cm-UTA’ with their hybrids ‘Cm-UTKHA’ and ‘Cm-UTAKH’. The last cluster was located on the quadrante determined by negative PC1 and PC2 and contained the parent ‘Cm-UTZ’ and its hybrid ‘Cm-UTZKH’ (Fig. 3).

Table 3 - Principal component analysis unrotated factor loadings and communalities

Variable	Factor1	Factor2	Factor3
Weight	0.17	0.901	0.141
Weight loss	-0.594	-0.433	-0.418
Firmness	0.754	-0.328	-0.464
Firmness loss	-0.705	0.354	-0.139
TSS	0.868	-0.034	0.131
Lightness	0.51	0.484	-0.661
Hue	-0.852	0.347	-0.108
Chroma	0.911	0.334	-0.02
Colour changes	0.651	-0.215	0.2
% Var	49.3	19.4	10.4
Accumulated	49.3	68.7	79.1

Response surface analysis throughout storage period

Contour plotting was used to demonstrate fruit postharvest performance during cold storage period can be seen in figure 4 and figure 5. The most pronounced weight loss was observed in the parent ‘Cm-UTZ’ under 12°C and after 20 days in cold storage with more than 30% weight loss. On the other hand, the highest firmness losses were recorded under 12°C and after 30 days in cold storage with the line ‘Cm-UTA’ and its hybrids ‘Cm-UTAKH’ and ‘Cm-UTKHA’ with more than 80% firmness loss in the parent and more than 75% firmness loss in both hybrids.

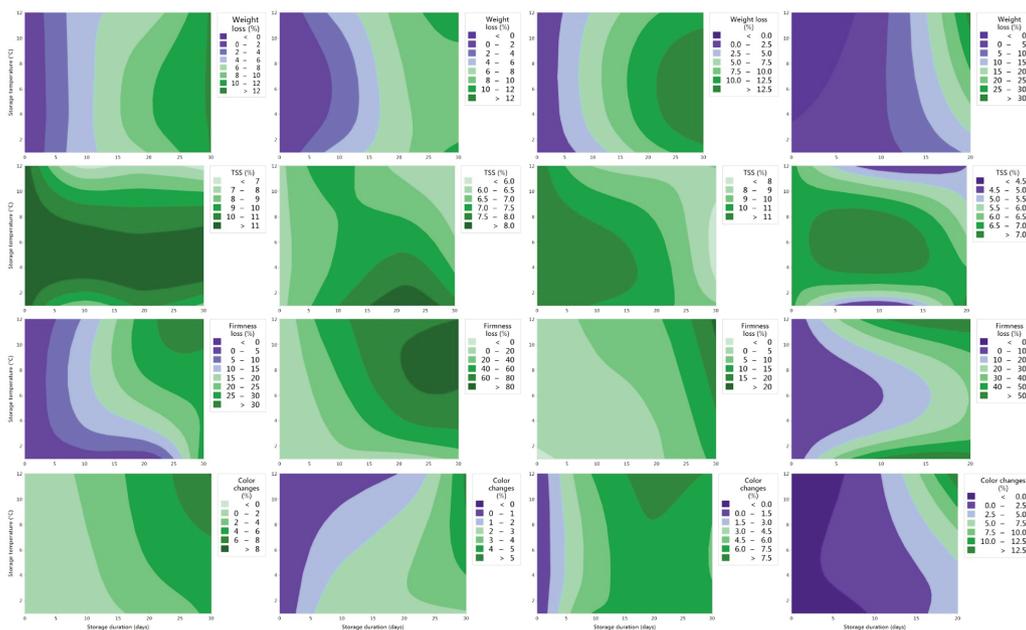


Fig. 4 - Contour plots of postharvest changes during cold storage period for the studied inbred lines. Each column of contour plots represents an inbred line (From left to right ‘Cm-UTKH’, ‘Cm-UTA’, ‘Cm-UTJ’, and ‘Cm-UTZ’, respectively). Each row of contour plots represents a postharvest attribute (From top to bottom Weight loss, TSS, Firmness loss, and Color changes, respectively). A significant difference between contour levels is present when the difference between contour levels are larger than 1.32, 1.67, 5.97, and 1.02 for Weight loss, TSS, Firmness loss, and Color changes, contours respectively (P<0.05).

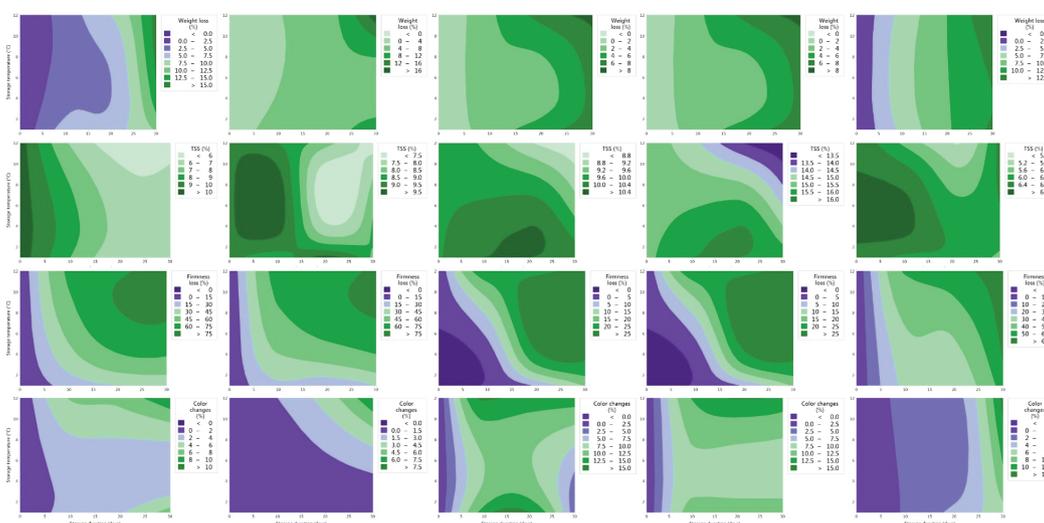


Fig. 5 - Contour plots of postharvest changes during cold storage period for the studied hybrids. Each column of contour plots represents a hybrid (From left to right 'Cm-UTKHA', 'Cm-UTAKH', 'Cm-UTKHJ', 'Cm-UTJKH', and 'Cm-UTZKH', respectively). Each row of contour plots represents a postharvest attribute (From top to bottom Weight loss, TSS, Firmness loss, and Color changes, respectively). A significant difference between contour levels is present when the difference between contour levels are larger than 1.32, 1.67, 5.97, and 1.02 for Weight loss, TSS, Firmness loss, and Color changes, contours respectively ($P < 0.05$).

There were no significant colour changes during the first 10 days of storage under any of storage temperature in any of the studied lines except for 'Cm-UTZ'. However, all the studied hybrids showed significant colour changes after 10 days in cold storage and under all temperature except for 'Cm-UTKHA' which showed significant colour changes only after 20 days in storage and under higher storage temperature ($>5^{\circ}\text{C}$). colour changes were steep and more pronounced in the hybrids 'Cm-UTKHJ' and 'Cm-UTJKH'.

There was no defined trend in TSS changes throughout storage period in the studied genotypes. A general decreasing trend was noticed in the lines 'Cm-UTJ' and 'Cm-UTZ' and similar decreasing overall trends were observed in all the studied hybrids. On the other hand, minimal TSS fluctuations were observed in the line 'Cm-UTA'. Furthermore, the line 'Cm-UTKH' experienced significant decrease in TSS during the first 10 days of storage under 12°C and then remained constant for the rest of storage duration. However, the line 'Cm-UTKH' kept an almost constant TSS under 4°C throughout storage period.

Response surface model was used in order to calculate the optimized storage temperature of the clusters obtained via PCA analysis. The monitoring date and storage temperature were set to be the continuous factors of the model, while weight loss (WL), firmness loss (FL), colour changes (CC), and TSS were set as responses. Stepwise method was used to omit unnecessary sources for better fit of each model

(Table 4). Then, the optimized storage temperature for each cluster was calculated by setting optimization goals of WL, FL, and CC to a minimum and TSS to a maximum. The results showed that the optimized temperatures were 1.8 for the green and blue clusters, and 5.1 for the red cluster.

4. Discussion and Conclusions

Fruit characteristics

Cluster analysis showed that fruit shape was more correlated with fruit length than diameter even though these three attributes were located in the same cluster (Fig. 2). This relation was also observable in (Table 2) since the line 'Cm-UTKH' recorded the highest FL and FS values, while the line 'Cm-UTZ' recorded the lowest. In fact, both these traits had also a high heterosis values with 33.17% and 22.71% for FL and FS, respectively, which is similar to Monforte *et al.* (2005) reports of significant correlation between fruit shape and length. The same research suggested that the heterosis in fruit shape is a function of fruit elongation.

On the other hand, the segregation fruit diameter, mesocarp thickness, fruit weight, and cavity diameter might indicate that the more rounded the melon is, the thicker the mesocarp and thus, the heavier fruit will be. The relatively high heterosis in mesocarp thickness and fruit weight (17.48% and 29.35%,

Table 4 - Storage temperature optimization results for the clusters obtained by principal component analysis using response surface method

Model	Response surface regression	Sources			Optimization goal	Optimized storage temperature
		Linear	Square	interaction		
Green cluster	WL	D	-	-	Minimize	1.8
	FL	D, T	T x T	D x T	Minimize	1.8
	CC	T	T x T	-	Minimize	1.8
	TSS	T	-	-	Maximize	1.8
Blue cluster	WL	D, T	D x D, T x T	D x T	Minimize	1.8
	FL	D, T	T x T	-	Minimize	1.8
	CC	D, T	T x T	D x T	Minimize	1.8
	TSS	D, T	T x T	-	Maximize	1.8
Red cluster	WL	D, T	D x D	-	Minimize	5.1
	FL	D, T	T x T	-	Minimize	5.1
	CC	D, T	-	D x T	Minimize	5.1
	TSS	T	T x T	-	Maximize	5.1

WL= Weight loss, FL= Firmness loss), CC= Colour changes, TSS =Total soluble solids, D= Test date, T= Storage temperature. Cluster colours (green, blue, and red) refer to the principal component analysis (PCA) clustering shown in figure 3.

respectively) and the low heterosis in cavity diameter might in favour of the previous debate. The current results showed that the hybrids 'Cm-UTKHA', 'Cm-UTAKH', and 'Cm-UTKHJ' scored positive weight heterosis values compared to best parents, while 'Cm-UTJKH' and 'Cm-UTZKH' that scored negative weight heterosis compared to mid parent results. This result is similar to Monforte *et al.* (2005) and Mohammadi *et al.* (2014) reports of positive to negative heterosis for melon fruit weight, while the general positive heterosis for fruit weight is similar to this reported by Feyzian *et al.* (2009). Furthermore, the results refer to the importance of the line 'Cm-UTKH' in breeding programs to increase average fruit weight.

It was noticed that each hybrid clustered with its maternal parent, except for the hybrid 'Cm-UTAKH' which was however the closest to its maternal parent 'Cm-UTA' although they were not clustered together (Fig. 2). This observation refers to the high maternal impact of the used lines and the cytoplasmic inheritance for the studied traits. The cytoplasmic inheritance and the high similarities between hybrids and maternal parents was previously reported for fruit length, fruit diameter, fruit shape, average fruit weight, mesocarp thickness, cavity diameter, TSS, and firmness (Y. Hassan Al-Hamdany, 2013; Shajari *et al.*, 2021) while other study reported a non-significant reciprocal effect for fruit weight (Feyzian *et al.*, 2009).

Postharvest performance

In the current work, PCA clustered the studied genotypes according to their average postharvest performance into three clusters with each hybrid clustered with its maternal parent. The high similarities in postharvest behaviour between hybrids and their maternal parent can be also attributed to the significant reciprocal effects for the studied traits, which were previously reported in similar population (Alabboud *et al.*, 2020).

By comparing loading variables to samples distribution, it can be concluded that the 'Cm-UTJ' line with its hybrid 'Cm-UTJKH' and reciprocal 'Cm-UTKHJ' had lower weight loss and firmness loss during cold storage compared to 'Cm-UTZ' and its hybrid 'Cm-UTZKH'. Thus, the former samples had a better postharvest performance compared later (Fig. 3) which can be also noticed in (Fig. 4) and (Fig. 5). colour changes in the line 'Cm-UTJ' and its hybrids are attributed to chroma increase which indicates more saturated colour during cold storage.

According to PCA biplot (Fig. 3), the samples with higher TSS content were characterized by lower weight and firmness losses during cold storage; therefore, the types with higher TSS content performed better throughout cold storage. Previously a negative correlation was reported between sucrose content in blueberry and Polygalacturonase activity (Wang *et al.*, 2020). Additionally, postharvest shelf

life of roquette leaves was extended in relation to higher sucrose content (Clarkson *et al.*, 2005). Furthermore, it was reported that sucrose can act as a protective signal in fresh cut melon against wounding signal (Wu *et al.*, 2020). Considering the fact that sucrose is the major component in melons' TSS content (Burger *et al.*, 2000), it can be assumed that the current observed correlation between TSS content and enhanced postharvest performance is related to a higher sucrose level. However, this relation should be investigated thoroughly.

Storage temperature optimization

The decrease in fruit weight and firmness in addition to colour changes are among the usual observations throughout cold storage of fruit and vegetables. Weight loss is mainly attributed to water evaporation during storage period (Ial Basediya *et al.*, 2013) which is supposed to increase by increasing storage temperature as can be seen in all the studied types (Fig. 4 and 5). The differences in weight loss between different types during storage phase should be correlated with fruit characteristics. For instance, the line 'Cm-UTJs' and its related hybrids are characterized with thicker rind and suberized periderm tissues which can efficiently block water evaporation (Nishizawa *et al.*, 2017) especially when considering the non-climacteric behaviour of the aforementioned types compared to other climacteric types such as 'Cm-UTZ'. Firmness loss is the result of cell wall deterioration due to various enzymes activity throughout storage (Qi *et al.*, 2011; Wu *et al.*, 2020). The current results showed lower and slower firmness loss under lower storage temperature, which is usually observed in stored melon (Hatami *et al.*, 2019) due to the slower overall metabolism and the lower enzymatic activity.

The currently observed fluctuation in TSS during cold storage phase was observed in full melon fruit (Hatami *et al.*, 2019) and in fresh cut slices (Chong *et al.*, 2015). In fact, most of the observations where TSS fluctuated were under lower storage temperature (1°C) (Fig. 4 and 5). Therefore, the most convincing explanation is that fruit metabolism under lower temperature was lower than that of higher storage temperature; therefore, water evaporation from fruit resulted in higher concentrations of soluble solids.

Response surface method (RSM) is a combination of experimental design, analysis of regression and stochastic response optimization (Barton, 2013). The main advantage of RSM analysis compared to other optimization methods is that fewer number of exper-

iments are needed to monitor the interaction of the independent variables on the response (Wani *et al.*, 2012). PCA clustering results were used to produce response surface models. The postharvest related data of each cluster members were the inputs while the target was to find the storage temperature which minimizes weight losses, firmness losses and color changes while maintaining the highest TSS possible. RSM analysis showed that the optimized storage temperature for both green (netted cantalupensis melon) and blue clusters (inodorus) members was 1.8°C. This result is similar to previous recommended storage temperature for various inodorus group cultivars (Yang *et al.*, 2003) where a storage temperature of 3°C was recommended, and netted cantalupensis group cultivars (De Arruda *et al.*, 2003; Žnidarčič *et al.*, 2013) where a storage temperature of 2-3°C resulted in the best storage outcomes. On the other hand, the optimum storage temperature for the red cluster (dudaim) was 5.1°C which is similar to the previous observations in dudaim group including the line 'Cm-UTZ' where 5°C resulted in better colour preservation and less weight, firmness, and TSS losses during cold storage period (Hatami *et al.*, 2019). Therefore, RSM can be considered a feasible method of storage temperature optimization especially in newly established populations and hybrids.

The current study showed that the hybrid melon types of inodorus x cantalupensis and dudaim x inodorus crosses had more similarities with their maternal parent. These similarities were obvious not only on fruit characteristics directly after harvest, but also in the later postharvest performance in cold storage. This result illustrated the importance of cytoplasmic inheritance in melon. The best postharvest performance was that of crosses between inodorus x netted cantaloupe, while the worst performance was related to 'Cm-UTZ' line of the group dudaim and its hybrid with the line 'Cm-UTKH'. The current reported work flow of using PCA followed by RSM showed promising results in optimizing storage temperature which was similar to previous literature. Therefore, the use of this workflow is highly recommended in optimizing postharvest inputs especially when testing for newly introduced hybrids where the experimental work volume might be overwhelming.

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