EFFECT OF AIR SPEED AND SIZE VENT AREA ON THE PRECOOLING CYCLE FOR CANTALOUPE FRUITS

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ABSTRACT

Cantaloupe is one of the important crops in Egypt a long time ago. Now a day there is a high increase in cantaloupe's production especially in the new reclaimed areas. Large amount of production is exported to international markets which represents a good income and a new source for hard currency. Removing heat from the product is required to prevent fruits deterioration and loss of its value. Forced-air cooling is considered an improved technique compared with other cooling methods such as room cooling since the cold air is forced through produce packed in boxes or ballet bins via its venting areas. In the present work, the fruits were analyzed for physiological properties such as loss in weight as well as the ostensibly properties. Three ranges of air speed were used: 2.5, 3.75 and 5 m/s and two sidewall vent area: 5%, 10% to examine the effect of increasing air speed and sidewall vent area on the precooling cycle and weight loss for cantaloupe fruits. The results indicated that, the air flow rate, total opening area and opening size show a significant effect on cooling efficiency and the quality of the cantaloupes fruits. Cooling temperature can extend the period of fresh appearance of the product, also increasing air flow rate and increasing side wall vent area has a good effect on the quality of the fruits.

INTRODUCTION

Fruits and vegetables begin to deteriorate after they are harvested and separated from their growing environment. To preserve the quality of fruits and vegetables and maximize profits for growers, it is critical to control the temperature of fresh produce and minimize the amount of time that products are exposed to detrimental temperatures. Precooling constitutes is the first link in the cold chain for food products. Of the various precooling techniques, air cooling is the most commonly adopted one **(Abdul Majeed, et al., 1980).**

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Pankaj et al. (2012) indicated that the temperature is one of the most important factors affecting the postharvest life of fruit as it influences to a large extent the physiological and biological changes taking place after harvest. **Elansari (2009)** indicated that, forced-air cooling is an improved technique compared by other methods, since the cold air is forced through produce packed boxes or pallet bins via its venting areas. He also added that, the way of packaging and the packaging materials should be properly selected to avoid any blockage of air passage and allow good air flow to achieve the cooling rate desired. **Tator and Elansari (1998)** showed that, forced-air cooling is considered as an industrial process which operates under significantly sever conditions. **Abdul Majeed, et al. (1980)** presented an analysis of the cooling characteristics of food products in air. They showed the coupled effects of heat and moisture transfer at the surface are included and the one-dimensional heat conduction equation in rectangular, spherical and cylindrical coordinates is solved. **Wijewardane et al. (2009)** have reported that, a number of researchers have made attempts to enhance the storage life of the cantaloupe using different substances at the pre or postharvest stages. **Abdul Majeed et al. (1980**) indicated that, the transient cooling of food products in refrigerated air is complicated due to the accompanying moisture transfer from the product surface. This surface moisture can be either due to the usual washing treatments or as a result of the inherent loss of free water from within the product. **Kaynas and Sivritepe (1995**) indicated that, the temperature of the produce is proportional to the deterioration by decay and senescence and consequently, to the potential storage life. Pre-cooling facilities good temperature management for prevention of ripening and effectively delaying the set of senescence. Besides growth of most disease organisms and their spread is greatly reduced at lower temperatures. Thus, maintenance of low product temperature is essential in reducing water loss and subsequent product shriveling. **Robbins and Patrick (1992**) indicated that, the fruits were exposed to 5, 10 and 20 °C for 45 days and then kept at ambient temperature for 25 days. The results indicated that, disease incidence and prevalence of *Penecillium digitatum* were higher in fruits stored at 5 and 20 °C and were lower at 10 °C. Weight loss was higher in the fruits stored

at 20 °C followed by 5 °C and was lower at 10 °C. The effect of delayed pre-cooling on fresh red raspberry fruit during storage was determined. They reported that, pre-cooling was delayed for 0.5 to 12 hour, followed by cold storage for 8 days, with subsequent storage at 20 °C for 24 hour. Weight loss was greater with increasing delays of precooling. **Robbins and Patrick (1992)** indicated that, in 1989, weight loss during the delay increased linearly with increasing delay for all cultivars. This was a result of more hours at the higher temperature and in a greater percentage of weight loss per hour with increasing delay. This differs from the results of (**Robinson et al., 1975**) who reported weight loss was more rapid immediately after harvest, with the rate falling to a fairly steady value for fruit stored at a constant temperature. The weight loss in citrus fruits was significantly affected by storage temperature. It increased with increase in post-storage incubation at ambient temperature. **Abdur rab et al. (2012**) referred that, the weight loss significantly increased from 1.039% to 8.014% with each 5 days interval from 0 to 25 days post storage incubation. **Kader and Saltveit (2003)** indicated that, the optimum temperature to store cantaloupe is ranged between 2 and 7°C. **Kader (2002)** indicated that**,** boxes should have about 5% sidewall vent area to accommodate airflow without excessive pressure drop across the box. **Mitchell, et al. (1972)** indicated that, the recommended pattern of vents for box cartons used to hold produce that is to be forced-air cooled should make up 5% of the total surface area, and should be located 5 to 7.5 cm away from the corners. A few large vents (1.3 cm wide or more) are better than many small vents.

Abdul Majeed, et al. (1980) indicated that, most of the analysis does not take into account the effect of moisture transfer during cooling. However, a few attempts have been made to account for the combined heat and mass transfer during the process. **Trevor et al. (1997)** indicated that, cantaloupes are harvested by maturity and not by size. Commercial maturity is ideally at the firm-ripe stage or "3/4 to full-slip". Cantaloupes ripen after harvest but not increase in sugar content. Cultivars vary in their external color at this stage of maturity and may retain a greenish cast. This skin color typically transitions from gray to dull green when immature, deep uniform green at maturity, and light yellow at full

ripeness. Raised and well-rounded netting on the fruit surface is another indicator of proper commercial maturity**.** He also added that, the essential thing is that the crates be sufficiently open so that the cooling fluid comes in contact with the entire surface of the cantaloupe.

In the present work, the fruits were analyzed for physiological and ostensibly properties. The effect of increasing air speed flow rate and sidewall vent area on the precooling cycle and weight loss of cantaloupe fruits were examined.

MATERIALS AND METHODS

To study the influent of changing air speed flow rate and side vent area on cantaloupe fruits, an experiment was carried out at Alex post-harvest laboratory, faculty of Agriculture, Alexandria University. The cantaloupe fruits, which used in the experiment, were approximately similar size (10-12 cm diameter) and maturity. The experimental room has a fixed temperature of 6 ℃, and RH of 85-90%, the ambient temperature outside was ranged between 25 and 27 ℃ during 6 days of experiments.
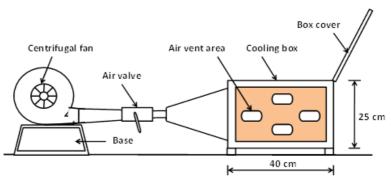
Cooling system:

The system consists of two parts: cooling box and centrifugal fan and all parts were put inside a refrigeration room (2 m×1.80 m) which was adjusted at 6℃. This cooling temperature agreed with the optimum temperature to store cantaloupe (**Kader and Saltveit, 2003**).

1. Cooling box:

The cooling box **(Figure 1, 2)** made of wood with 40 cm × 30 cm × 25 cm and the side wall can be changed with 5% or 10% sidewall vent area as agreed with (**Kader, 2002**). The box connected with an air flow rate fan through a metal part. Packed produce with airflow restricting materials should be taken in consideration when sizing the system air flow and static head pressure of the fans.

2. Centrifugal fan:

A centrifugal fan (power 1/2 hp.) was used in the experiment to provide the cooling box with cold air. The quantity of air flow was determined by using a flow-rate tap which adjusts to give 1/2, 3/4 and full quantity of air or 2.5, 3.75 and 5 m/sec.
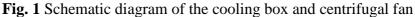
Fig. 1 Schematic diagram of the cooling box and centrifugal fan

Fig. 2. A photo of the cooling system

Temperature measurements:

The temperature of fruits was automatically measured daily for 5 hours by using a data logger DL2 version 5.0, Data-T Devices Cambridge-England as shown in **Figure (3)**. PC software Ls2Win was first used to program the logger. Sensors probe (Copper-Constantan wire) were inserted under surface and near the center of fruit to measure its surface and center temperature. On the other side the logger was connected with computer to save and record data. After 5 hours, the fruits get out from the cooling box and ostensibly examined and weighted.

Fig. 3. Data logger DL2 version 5.0 connect with PC

Air speed:

The speed of the air rate passing through the cooling box was measured by using an air velocity meter, (Tri-Sence Model No. 37000-00, Cole-Parmer Instrument Co.) as shown in **Figure (4)**.

Fig. 4. Air velocity meter and its probe.

Statistical analysis:

The experiments were carried out using analysis of variance appropriate for RCB with three replicates. Each replicate consisted of 6 fruits. Means were separated using Least Significant Difference (LSD) at 5% level of probability when the F-values were significant (SAS version 9.1.3 portable).

RESULT AND DISSCUSION

It's important to mention that, the heat inside the product have to be remove from the product to prevent fruits deterioration. The amount of heat to be removed depends on the produce and the required storage temperatures. Proper design fast cooling temperature and relative humidity control in cooling environment can extend the period of fresh appearance of the product. The results of the experiments are given in **Figure (2)** and **Tables (1, 2, 3)** as a function of precooling treatments and air flow-rate levels and sidewall vent area.

Tables (1) shows that: the percentage of weight loss (**WL, %**) ranged between 0.079 to 0.179 % at air speed (**AS**) of 2.5 m/s, and at side vent area (**SVA**) of 10%, however, the percentage of **WL** ranged between 0.079 to 0.22 % at **AS** of 2.5 m/s, and at **SVA** of 10%.

Table (2) shows that: the percentage of **WL, %** ranged between 0.134 to 0.270 % at **AS** of 3.75 m/s, and at **SVA** of 10%, however, the percentage of **WL** ranged between 0.090 to 0.186% at **AS** of 2.5 m/s, and at **SVA** of 10%.

Table (3) shows that: the percentage of **WL,** ranged between 0.271 to 0.426 % at **AS** of 5 m/s, and at **SVA** of 10%, however, the percentage of **WL** ranged between 0.22 to 0.268%, at **AS** of 5 m/s, and at **SVA** of 10%.

Table 1. The percentage of **WL** of cantaloupe fruits at **(AS)** of 2.5 m/s and **SVA of** 10% and 5%

No. of fruit	(AS) 2.5 m/s and (SVA) 10%			(AS) 2.5 m/s and (SVA) 5%		
	Weight before cooling, g	Weight after cooling, g	WL,%	Weight before cooling, g	Weight after cooling, g	WL,%
1	734.1	733.0	0.150	863.8	861.9	0.220
2	698.9	697.8	0.157	777.0	776.3	0.090
3	672.0	670.8	0.179	769.4	768.3	0.143
4	658.6	657.8	0.121	758.2	757.6	0.079
5	631.4	630.9	0.079	750.3	748.9	0.187
6	606.9	605.9	0.165	744.5	743.5	0.134

Table 2. The percentage of **WL** of cantaloupe fruits at **(AS)** of 3.75 m/s and **SVA of** 10% and 5%

No. of fruit	(AS) 3.75 m/s and (SVA) 10%			(AS) 3.75 m/s and (SVA) 5%		
	Weight before cooling, g	Weight after cooling, g	WL,%	Weight before cooling, g	Weight after cooling, g	WL,%
1	810.7	809.1	0.197	1134.1	1132.4	0.150
2	740.6	739.1	0.203	971.0	969.8	0.124
3	741.5	739.5	0.270	965.2	963.4	0.186
4	735.7	734.2	0.204	903.7	902.6	0.122
5	673.2	672.3	0.134	887.0	886.2	0.090
6	664.5	663.2	0.196	876.7	875.8	0.103

Table 3. The percentage of **WL** of cantaloupe fruits at **(AS)** of 5 m/s and **SVA of** 10% and 5%

No. of fruit	(AS) 5 m/s and (SVA) 10%			(AS) 5 m/s and (SVA) 5%		
	Weight before cooling, g	Weight after cooling, g	WL,%	Weight before cooling, g	Weight After cooling, g	WL,%
1	756.8	754.2	0.344	782.7	780.6	0.268
2	718.5	716.1	0.334	731.9	730.2	0.232
3	712.9	710.6	0.323	725.8	724.2	0.220
4	680.9	678.0	0.426	675.6	674.1	0.222
5	665.2	663.4	0.271	643.0	641.4	0.249
6	652.0	650.1	0.291	634.6	632.9	0.268

Table (4) gives a conclusion of the weight loss percentage and the average at various values of air speed and side vent area.

Table 4. The percentage of weight loss fruits at various air speed and sidewall vent area

Air speed and sidewall vent area	Weight loss, %	Average, %
2.5 m/s and 10% sidewall vent area	0.079 ~ 0.179	0.129
2.5 m/s and 5% sidewall vent area	0.079 ~ 0.220	0.150
3.75 m/s and 10% sidewall vent area	0.134 ~ 0.270	0.202
3.75 m/s and 5% sidewall vent area	0.090 ~ 0.186	0.138
5 m/s and 10% sidewall vent area	0.271 ~ 0.426	0.349
5 m/s and 5% sidewall vent area	0.220 ~ 0.268	0.244

The previous data indicated that, cooling temperature is important to extend the period of fresh appearance of the cantaloupe fruits. It assists in maintaining quality by reducing the rate of metabolic activities such as respiration, transpiration. Also increasing cooling air speed or increasing air flow rate does not effect the quality and ostensibly properties probable due to hard skin of the fruits and/or the cooling temperature was not very low although many researchers reported that, plants of tropical and sub-tropical origin, and some tissues from plants of temperate origin are injured by exposure to non-freezing temperature below 12°C (**Bramlage 1982, Couey 1982, Lyons 1973, Saltveit and Morris 1990**). **Alexander et al. (2012)** indicated that, chilling temperatures (**1–10ºC**) lead to numerous physiological disturbances in the cells of chilling-sensitive plants and result in chilling injury and death of tropical and subtropical plants.

The weight loss can be calculated as percent of original weight. For this purpose initial and final weight of the fruits was determined at time zero and after storage inside the refrigerator with the help of an electronic balance. The percentage of weight loss was calculated using the following formula (**Abdur Rab et al. 2012**):

$$Weight\,loss\ (\%) = \frac{Weight\,of\ fresh\ fruit - Weight\,after\ \mathrm{int}erval}{Weight\,of\ fresh\ fruit} \times 100 \quad (1)$$

Rapid cooling of the produce to safe storage or transportation temperature is imperative in preservation of quality and increase the shelf life by arresting the deteriorative changes caused by physiological and pathological agencies. The harvested produce contains substantial amount of heat associated with the product temperature and is known as

field heat, a significant part of cooling load. Precooling is the rapid extraction of heat from the product before transport, storage, and processing. Depending on the temperature, the product will lose its quality in no time unless promptly and appropriately cooled.

Temperature ratio (T_r):

Temperature data of cantaloupe fruits were plotted on graphs for different air speed flow rate and side vent area to find the optimum condition for fast cooling to protect the quality deterioration. The ultimate use of the experimental data for Cantaloupe can be made general by use of the temperature ratio concept. Fast cooling responses for any desired initial cantaloupe temperature can be calculated from experimental data obtained at a different initial product temperature. The temperatures ratio, T_r, at any time during the fast cooling of cantaloupe for the set of experiments can be presented by the following formula (**Ansari and Afaq, 1986**).
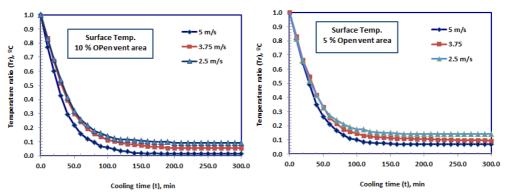
$$T_r = \frac{T - T_0}{T_{in} - T_0} \qquad (2)$$

Where:

T = Temperature of cantaloupe at both center (T_c), and surface or under skin (T_s), for different sizes, ºC.

T_o = Air refrigeration temperature, ºC.

T_{in} = Initial cantaloupe temperature after harvesting, ºC.

According to the previous formula, **Figure (3)** shows the relationship between temperature ratio, (T_r) and cooling time, (t) for three speeds of air (2.5, 3.75 and 5 m/s) and for 10 and 5% side vent area under skin (surface) of the cantaloupe fruits. The graph shows that temperature ratio decrease with increase of cooling time for all speed of air. The surface temperature of cantaloupe has a sharp decrease with increase of air speed in the first one hour of cooling, and after that the temperature slightly decreased during the left four hours, where the average temperature was (6.33, 7.27, 8.21 ºC) at 5, 3.75 and 2.5m/s at 10% side vent area and was (7.6, 8.3, 9.73 ºC) at 5, 3.75 and 2.5m/s at 5% side vent area respectively.

Fig. 3. Temperature ratio of cantaloupe fruit' surface versus cooling time at different air cooling speed and open vent area.

Figure (4) shows the relationship between temperature ratio, (T_r) and cooling time, (t) for three speeds of air (2.5, 3.75 and 5 m/s) and for 10 and 5% side vent area of the cantaloupe fruits center. The graph shows that temperature ratio decrease with increase of cooling time for all speed of air. The surface temperature of cantaloupe has a sharp decrease with increase of air speed in the first one hour of cooling, and after that the temperature slightly decreased during the left four hours, where the average temperature was (7.9, 8.5, 9.75 ℃) at 5, 3.75 and 2.5m/s at 10% side vent area and was (8.8, 9.26, 9.88 ℃) at 5, 3.75 and 2.5m/s at 5% side vent area respectively.
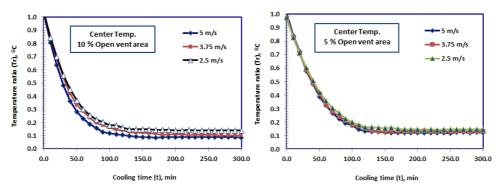

Fig. 4. Temperature ratio of cantaloupe fruit' center versus cooling time at different air cooling speed and open vent area.

The previous figures show the relation chip between temperature and cooling time, cantaloupe temperature's inside cooling box started at about 30 ℃ and rabid decreased to become constant at a temperature ranged

between 6.54 to 9.11 ℃ after 3 hours from starting the experiment. **Table (5)** shows more details of the results.

The trends of the curves in all figures were almost identical, while the weight loss was limited and it ranged between 0.129 to 0.349 % as shown in **Table (4)**. The small of weight loss due to small stored time (5 hours) and maybe some weight loss was occurring after harvesting.

Table 5. Final surface and center temperature of cantaloupe fruits under different air speed and sidewall vent area

Air speed and sidewall vent area	Final surface Temperature, ℃	Final center Temperature, ℃
2.5 m/s and 10% sidewall vent area	8.203	9.753
2.5 m/s and 5% sidewall vent area	9.737	9.870
3.75 m/s and 10% sidewall vent area	7.267	8.540
3.75 m/s and 5% sidewall vent area	8.190	9.260
5 m/s and 10% sidewall vent area	6.337	8.797
5 m/s and 5% sidewall vent area	7.613	7.967

Statistical analysis:

The data were statistically analyzed using analysis of variance appropriate for RCB design and means were compared using LSD test at 5% level of probability when the F-values were significant (SAS version 9.1.3 portable) and the results are shown below.

Var1 (surface)

SOURCE	DF	Anova SS	Mean Square	F Value	Pr>F
Time	10	8425.218800	842.521880	8866.63	<0.0001
Area	1	85.774255	85.774255	902.68	<0.0001
Speed	2	167.726910	83.863455	882.57	<0.0001
		The ANOVA Procedure			

Var2 (center)

SOURCE	DF	Anova SS	Mean Square	F Value	Pr>F
Time	10	8557.314371	855.731437	2823.60	<0.0001
Area	1	15.798813	15.798813	52.13	<0.0001
Speed	2	129.175476	64.587738	213.12	<0.0001
		The ANOVA Procedure			

From the previous tables, a significant differences between the means of the independent parameters speed and area.

CONCLUSION

Forced-air cooling is considered an improved technique compared with other cooling methods such as room cooling since the cold air is forced through produce packed in boxes or ballet bins via its venting areas. The versatility of forced-air coolers that allows for cooling of almost any fruit or vegetable and can function as a precooling unit and a room cooler. The fruits were analyzed for physicochemical and physiological such as loss in weight. In the present work, three ranges of air speed were used: 2.5, 3.75 and 5 m/s and sidewall vent area of 5%, 10% to examine the effect of increasing the air speed and sidewall vent area on the weight loss and precooling cycle for cantaloupe fruits. The results indicated that, the weight loss in cantaloupe fruits is slightly affected by air speed and sidewall vent area. The weight loss ranged between 0.129 to 0.349 % during the 5 hours daily.

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الملخص العربى

تأثير سرعة الهواء ومساحة الفتحات على التبريد السريع لثمار الكانتالوب

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تعتبر المحافظة علي جودة الخضروات والفاكهة من أهم العمليات التي يجب السعي الدائم لها بغرض تقليل الفاقد والتالف منها حيث انها تعتبر مواد حية تستمر بها العمليات الحيوية بعد حصادها فهي تتنفس وتفقد جزء من مائها ومن ثم تكون عرضة للتدهور والذبول وتظهر عليها اعراض الشيخوخة مالم تتوفر لها ظروف تداول ونقل وتعبئة وتخزين وعرض مناسبة تعمل علي الحفاظ علي جودتها وإطالة العمر التخزيني لها. ويعتبر التبريد السريع من أهم الوسائل والطرق المستخدمة فى حفظ الثمار و الخضراوات حيث أنها تؤدى الى إبطاء معدل التنفس وتقليل فقد الماء من الثمار أثناء النقل والتداول والتخزين كما انها تقلل من نشاط الكائنات الحية الدقيقة التى تهاجم الثمار. وفى هذا البحث تم تخزين ثمار الكانتالوب عند درجة حرارة ٦ درجات مئوية داخل الثلاجة مع دفع تيار هوائى على الثمار بمعدلات ٢.٥ متر/ث، ٣.٧٥ متر/ث و ٥ متر/ث مع استخدام نوعان من الفتحات لصندوق التخزين ٥% و ١٠% من المساحة الكلية لجانب الصندوق وذلك بغرض دراسة تأثير تغييرمعدل سرعة الهواء على جودة ثمار الكانتالوب وإطالة العمر التخزيني لها وكذلك الانخفاض فى الوزن نتيجة لانخفاض محتواها الرطوبى. وقد لوحظ أنه حدث انخفاض فى الوزن خلال تغيير معدل التهوية تراوح بين ٠.١٢٩ و٠.٣٤٩ % مما يعنى أن تغيير سرعة الهواء و زيادة الفتحات كان له تأثير إيجابى على الحفاظ على جودة ونضارة ثمار الكانتالوب. تم تحليل بيانات التجارب إحصائيا بإستخدام برنامج الساس عند مستوى معنوية ٥% وكانت زيادة سرعة الهواء وزيادة نسبة الفتحات ذو معنوية عالية.

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