Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 24, Issue 4, 2024
PRINT ISSN 2284-7995, E-ISSN 2285-3952

INFLUENCE OF HYDRO-COOLING AND PACKAGING ON THE STORABILITY OF ROSEMARY PLANTS

Nermeen Mohammed TOLBA[1], Ahmed Mohammed ElTARAWY[2]

[1]Institute of Agricultural Engineering, Agricultural Research Center, Dokki District, Giza Governorate, Egypt, Phone: 01015749022; E-mail: nermenafk@gmail.com
[2]Kafr El-Shaikh University, Faculty of Agriculture, Horticulture Department, Kafr El-Shaikh, Egypt, Phone:01012010004; E-mail: tarawy100@gmail.com

Corresponding author: nermenafk@gmail.com

Abstract

Rosemary plants are regarded as one of Egypt's most valuable medicinal and aromatic herbs because they are used in a variety of food and medical industries. Because of medicinal and aromatic herbs are quickly affected by temperatures, the initial cooling process procedure is an essential stage in the treatment of these herbs. This process is carried out immediately after harvesting plants to remove the field heat and reduce microbial activity. Also, it keeps the final product fresh for a long period. Here, we investigated the influence of Hydro-cooling, packaging materials and storage temperatures on the quality and active components for rosemary plants. The plants were immersed in a mixture of ice and water at 5°C for 10 min and stored in two various bags (polyethylene – polyvinyl chloride shrink at 5 and 23°. The quality of rosemary plants such as fresh weight loss, chlorophyll content, respiration rate, volatile oil percentage and its compounds were measured. The obtained data showed that Hydro-cooling, packing in polyethylene bags and storage at 5 °C were the most suitable treatments when compared to the other treatments, as notified by the values of fresh weight loss, chlorophyll content, respiration rate, volatile oil % and its compounds. Hydro-cooling and storage at 5 °C decelerated leaf water loss, reduced respiration rate, and increased oil content, thus increasing the shelf life of rosemary plants by up to 28 days.

Key words: *hydro-cooling, Rosemary, storage, shelf life, volatile oil*

INTRODUCTION

Medicinal and aromatic herbs are very important in Egypt due to their various uses, including cooking and treating a variety of ailments. As a result, their productivity must be increased by increasing the area of agricultural land. Since these plants are sensitive to high temperatures, they must be handled with care after harvest. The field heat of medicinal and aromatic herbs and freshly harvested crops is ordinarily elevated and must be taken away as soon as possible before transportation, processing and storage to increase their shelf life and be available on demand whenever required. Precooling of agricultural crops shortly after harvest is a paramount component of the cool series, which ultimately influences the product's shelf life. Pre-cooling is typically viewed as a separate process that requires particular facilities but is complimentary to low temperature storage. Because impairment is proportional to the time agriculture products are risked to high temperatures, pre-cooling is effective even when produce is later reverted to ambient temperature [10]. Most highly perishable horticultural products, especially leafy and flowering vegetables, deteriorate faster when field heat is not removed before being stored in low temperatures [6]. Storage deteriorating after harvest is the major source of vegetable losses, resulting in substantial financial losses [30]. Leafy vegetables are very perishable and susceptible to water loss, which can be exacerbated by inappropriate temperature and air humidity management during store and trade areas, resulting in shorter usable life and higher end product costs for customers [2]. As a result, it's either consumed right away or used conservation strategies to reduce metabolic activity and extend shelf life. Postharvest wastage control methods are used to slow or minimize product impairment through various storage, shipping, and treatment processes, whereas hydro-cooling is useful for fresh vegetables [31]. Hydro-cooling is a process that uses ice or cold water and is simple, practical, and effective to reduce the temperature of vegetables before packing and refrigerating them. This approach eliminates heat from freshly harvested crops in the field, slowing metabolism and reducing crop degradation [12]. The freshness of most fruits and vegetables is influenced by water loss during storage, which is dependent on the temperature and relative humidity of the storage conditions. According to [16], Low temperature storage is the most effective way to preserve the quality of fruits and vegetables because it reduces respiration, ethylene production, ripening, senescence, and mold development. They also demonstrated that elevated temperatures increment the difference of vapor pressure between the fruit and its surroundings, which has the potential to accelerate moisture transport from the fruit to the atmosphere around it. Packing films have been demonstrated to extend the shelf life of perishable goods, creating a modified in-pack atmosphere with low O_2, elevate CO_2 and decreasing water loss [29]. The MA response of fresh Cymbopogon citrates was studied by [25] in relation to film packing and storage temperatures. At 5 and 0 degrees Celsius, fresh weight loss was substantially smaller than at higher temperatures. Many medicinal and aromatic plants' essential oil content and compounds were influenced by the period of store [4]. Most herbs, like mint, oregano, rosemary, thyme, and sage, preserved their apparent quality after keeping at 0°C for up to 4 weeks, whilst basil suffered from chilling harm, inclusive flavour loss, after stored period of 5 to 7 days at 7.5°C and just 2 days at 2°C, as indicated by [7].

The aim of this research is to study the effect of hydro-cooling, packing in two types of bags, and storage at 5 and 23 °C on fresh weight loss, chlorophyll content, respiration rate, volatile oil content, and its compounds for rosemary plants.

MATERIALS AND METHODS

This research was achieved at Horticulture. Department of the Faculty of Agriculture, Kafr El-Sheikh University to study the influence of Hydro-cooling and storage bags at storage temperatures 5 and 23 °C on the storability of *Rosmarinus officinalis*, L. plant in 2022. The quality of herbs was analyzed at the laboratory of the faculty.

Plants used in this study

Rosemary plants were acquired from the research farm of the Horticulture Department, Faculty of Agriculture, Kafr El-Sheikh University, in March 2022 and transported immediately to the laboratory. Plants were selected without any marks of fading, yellowing or the incidence of mold. The plants were divided in two groups (hydro-cooling and non-cooling). Hydro-cooling was adjusted at 5°C where plants were immersed in a blending of ice and water for 10 minutes and stored in two different bags (polyethylene and polyvinyl chloride shrink), then stored at two temperatures (23–5°C). Each bag contained 200 g of plants.

Measurements

Safe storage duration (days)

The parameters in which precooled and non-precooled fresh plants maintained acceptable quality until they began to deteriorate were measured. The following parameters have been included:

Fresh weight loss

The weights of the samples were measured by a digital balance with an accuracy of 0.01g and the proportion of fresh weight loss of each replicate was calculated in relation to its original weight according to the equation:

$$\frac{\text{First weight} - \text{plant weight on storage date}}{\text{First weight}} * 100$$

....(1)

Respiration rate

Plants weighing 100 grammes were placed in a dissector and linked to a tube holding 25 ml of 1.0 N KOH; CO_2 free air was introduced into the dissector via the KOH for one hour. KOH was titrated with 1.0 N HCL using thymol blue indicator, and CO_2 generation was measured as mg CO_2 $Kg^{-1}h^{-1}$ as described by [15].

Total chlorophyll

Each week, five plant samples were selected randomly from each packaging at each storage temperature; chlorophyll was measured using chlorophyll meter equipment, model Minolta SPAD 502.

Volatile oil content and its components

The volatile oil has been extracted from fresh herbs samples (50g) using Clevenger hydro-distillation devices, as indicated by the [26]. The volatile oil concentration was measured for each treatment on a weekly basis until each treatment's shelf life ended. The volatile oil extracted from the plants was analysed using gas liquid chromatography (GLC) to determine its constituents.

Plants temperature

Temperature changes in plants throughout the pre-cooling procedure was measured using a digital global temperature meter with a copper-constantan thermocouple.

Statistical analysis

The experiment was coordinated in a completely randomized block design and included eight treatments with three replicates for each treatment. All data were analysed statistically by analysis of variance (ANOVA) using CoStat version 6.303. The means of treatments were compared using Duncan's test.

RESULTS AND DISCUSSIONS

Fresh weight loss

Table 1 revealed that plants held at room temperature lost their fresh weights more quickly than those stocked in the refrigerator. According to [9], who evidenced similar results, fresh sweet basil and spearmint preserved at a higher temperature of 20 ºC lost more weight than those kept at 0 or 5 ºC. Furthermore, it is apparent that the Hydro-cooling process and storage temperatures have a significant impact on fresh weight loss. Using hydro-cooling and lowering the storage temperature from 23 to 5 °C produced a decrease in the loss of fresh weight for rosemary in general.

Similar results were achieved by [23] in coriander and [12] in parsley, which manifested that hydro-cooling lowered fresh leaf weight loss during storage. It was found that the non-hydro-cooling treatments resulted in the largest fresh weight loss compared with the hydro-cooling treatments, which recorded the lowest fresh weight loss.

Additionally, raising the storage temperatures from 5 to 23 °C resulted in a greater fresh weight loss. After 21 days, only hydro-cooling at 5 °C resulted in improved leaves turgescence.

This finding shows the relevance of hydro-cooling treatment, which is very efficient due to water's strong thermal conductivity, as well as the uniform contact between water and the product's surface, which enhances quick temperature decrease [32].

However, maintaining the cold chain extends the shelf life of the product by lowering the temperature difference between the plant and the environment, hence reducing water losses.

Also, we can notice that plants in two packages continued to lose their fresh weight as the duration of storage increased but this fresh weight loss was greater in storage temperature 23 °C than 5 °C.

This consequence can be attributable to the final condensation and water collecting within the package, which generate a high-moisture atmosphere.

The same result was found by [1], as he discovered considerable water collecting within the packages and ascribed it to high levels of transpiration in the leaves at room temperature.

Polyvinyl chloride shrink bag was recorded the highest fresh weights loss with and without hydro-cooling at storage temperature 23 °C for all storage periods compared with polyethylene bags in which storage continued, with a decrease in weight loss, up to 28 days at storage temperature 5 °C.

According to [34], who reported that the decrease in the proportion of quotidian fresh mass loss in the leaves was due to the increase and keeping of the border layer, the depression in the vapour pressure deficit between the leaves and the atmosphere surrounding the produce, and the formation of an adjusted atmosphere within the package.

Table 1. Influence of Hydro-cooling, packaging materials and storage temperatures on weight loss % of *Rosemarinus officinalis* plants

Packaging materials	**Storage temperatures, °C**	**7 days**		**14 days**		**21 days**		**28 days**	
		Without cooling	**With cooling**	**Without cooling**	**With cooling**	**Without cooling**	**With cooling**	**Without cooling**	**With cooling**
control	**23**	23.25 a	18.23 b	29.98 a	25.54 b	-	-	-	-
polyvinyl chloride shrink	**5**	2.76 g	0.02 h	5.23 g	1.05 h	7.19 e	3.03 f	9.35 e	5.15 f
	23	12.56 c	10.11 d	23.79 c	19.22 d	27.06 a	24.03 b	29.94a	26.08b
polyethylene	**5**	0.22 h	0.21 h	0.24 h	0.23 h	0.75 g	0.29 g	1.91 g	1.01 g
	23	10.01 e	8.56 f	15.5 e	12.6 f	21.79 c	17.31 d	24.73c	20.99d

Note: Data were expressed by mean as means in a column that are followed by the different letters indicate significant differences at the ($P\leq0.05$) level.
Source: Own results.

Respiration rate

Table 2 exhibited that the respiration rate of the rosemary plant upgraded with the storage period increment at 5 and 23 °C, as it was noticed that the large increase was at 23 °C while it slowed down by the low storage temperature of 5 °C. This result was in line with [22], who mentioned that low temperature storage slows down respiration rates in most products, but in chilly-sensitive produce, lower temperatures that cause chill injury will raise the rates of respiration. Also, the respiration rate at room temperature is higher than 5 °C and this is due to the cooling reduces the respiration rate and ethylene production. According to [17], who reported that cooling decreases the rate of respiration, ethylene generation, the degree of senescence, and microbial activity. On the other hand, it can be observed that the respiration rate of the untreated plants was higher than that of the plants treated with hydro-cooling, and this is due to the fact that the hydro-cooling process is an effective approach to decreasing the plant's metabolic activity, which slows the rate of respiration, resulting in a longer storage duration. According to [13], hydro-cooling was found to be a quick method for cooling minimally treated spinach in spring, reduced the rate of respiration , and improved quality in comparison with other cooling methods like traditional room cooling, forced-air cooling and vacuum cooling. In addition to packaging material had significant effect on respiration rate for rosemary plants at 5 and 23 °C.

Table 2. Influence of Hydro-cooling, packaging materials and storage temperatures on respiration rates CO_2 $Kg^{-1}h^{-1}$ of *Rosemarinus officinalis* plants

Packaging materials	**Storage temperatures, °C**	**7 days**		**14 days**		**21 days**		**28 days**	
		Without cooling	**With cooling**	**Without cooling**	**With cooling**	**Without cooling**	**With cooling**	**Without cooling**	**With cooling**
control	**23**	143.23a	133.62b	165.85 a	153.62 b	-	-	-	-
polyvinyl chloride shrink	**5**	123.65 d	83.63 h	138.32 d	87.06 h	148.65 b	98.79 g	162.45a	105.65c
	23	131.22bc	126.65c	140.63 c	138.52 d	157.88 a	146.33 c	-	-
polyethylene	**5**	90.65 f	72.22 i	106.52 f	76.23 i	136.23 d	81.35 h	152.41b	84.33d
	23	97.26 e	87.33 g	111.51 e	104.65 g	127.65 e	123.02 f	-	-

Note: Data were expressed by mean as means in a column that are followed by the different letters indicate significant differences at the ($P\leq0.05$) level.
Source: Own results.

Respiration rate values of polyvinyl chloride shrink bags were higher than polyethylene bags at 5 and 23 °C. [33] reported that when the temperature rises, the O_2 level in the package decreases while the CO_2 level grows, since the permeability of the package film to O_2 and CO_2 gases does not increase at the same extent as the produce's respiration rate, the low O_2 and high CO_2 concentrations are harmful to fresh fruit, producing physiological harm and bad flavours.

Total chlorophyll (SPAD)

Total content of chlorophyll reduced during the storage duration at 5 and 23 °C with or without hydro-cooling as illustrate in Table 3. The control herbs which preserved without packaging at room temperature lose the storability after storage period of 14 days but they listed the highest values of total chlorophyll content compared with treated herbs. This same findings was noticed in a peppermint investigate conducted by [3], who stated that the SPAD values in hydro-cooled branches were much lower than those in control branches, owing to the increment water in the tissues during the pre-cooling process, which effectively diluted the chlorophyll concentration. The highest values of chlorophyll content were observed at 5°C of the storage temperature. The result agrees with [28], who mentioned that samples stored in refrigeration at 5 ºC exhibited a higher SPAD index, as the low temperature prevented chlorophyll breakdown and resulted in green leaves at the end of storage. According to [2], pre-cooling followed by 5°C on parsley leaves (*Petroselinum crispum*) did not cause chlorophyll breakdown, as measured by the SPAD index. The extension of storage periods decreases total chlorophyll, which is probably attributable to some breakdown in plant tissues as storage duration increases [21]. The results also, illustrated that packaging materials had significant effect on total chlorophyll content. In accordance with [2], imperforated plastic packaging might cause CO_2 cumulation and minimise O_2 in the package, affecting the atmosphere and decreasing the formation and activity of ethylene and the enzymes that cause chlorophyll breakdown. In addition, our findings are similar to [20, 21], stated that using different packing materials under similar cooling temperatures influenced the total chlorophyll content, likewise influenced by different cooling temperatures under the same packaging materials. The highest values of total chlorophyll content recorded by using polyethylene bags at low temperature.

[12] reported similar results, as they attributed the keeping of chlorophyll in the leaves of lettuce to chilled packaging. Polyethylene bags are superior to polyvinyl chloride shrink bags in delaying degradation of chlorophyll, possibly due to their improved influence on CO_2 and O_2 inside the package.

Table 3. Influence of hydro-cooling, packaging materials and storage temperatures on total chlorophyll (SPAD) of *Rosemarinus officinalis* plants

Packaging materials	**Storage temperatures, °C**	**7 days**		**14 days**		**21 days**		**28 days**	
		Without cooling	**With cooling**	**Without cooling**	**With cooling**	**Without cooling**	**With cooling**	**Without cooling**	**With cooling**
control	**23**	1.39 a	1.23 b	1.25 a	1.14b	-	-	-	-
polyvinyl chloride shrink	**5**	1.13 d	0.84 f	1.09 c	0.65 h	0.97 b	0.53 f	0.92 b	0.49 e
	23	1.02 ef	0.82 g	0.99 e	0.63 i	0.81 c	0.51 g	0.42 f	0.31 h
polyethylene	**5**	1.21 c	0.85 f	1.15 b	0.76 f	1.03 a	0.64 d	0.96 a	0.58 c
	23	1.06 e	0.83 g	1.01 d	0.71 g	0.96 b	0.61 e	0.50 d	0.39 g

Note: Data were expressed by mean as means in a column that are followed by the different letters indicate significant differences at the (P≤0.05) level.
Source: Own results.

Volatile oil content

Hydro-cooling treatment showed the highest oil % compared with non cooling treatment for rosemary plants throughout storage period as shown in Table 4. Volatile oil content at 5 °C was higher than at 23 °C. As mentioned by [19], low temperature slows down changes in physiological, chemical and physical composition of the produce. According to [5], high temperature have an impact on respiration rates of product, organic matter breakdown, transpiration losses, exterior quality characteristics and the decrease in inactive components. In regard to the packaging types, the data revealed that the differences in oil content among the packaging types were negligible at the different storage periods. Whereas, the storability of control herbs was for only 14 days, which gave a slight increase in oil content over the other treatments. Also, the content of oil in different packaging was higher at a temperature of 5 °C as mentioned by [18] who showed the impact of packaging types on the oil quality of sweet basil and he found that oil quality was best by storage at 4 °C in plastic bags.

Table 4. Influence of hydro-cooling, packaging materials and storage temperatures on the volatile oil content % of *Rosemarinus officinalis* plants

Packaging materials	**Storage temperatures, °C**	**7 days**		**14 days**		**21 days**		**28 days**	
		Without cooling	**With cooling**	**Without cooling**	**With cooling**	**Without cooling**	**With cooling**	**Without cooling**	**With cooling**
Control	**23**	0.21bc	0.23a	0.22bc	0.25a	-	-	-	-
polyvinyl chloride shrink	**5**	0.18ef	0.20cd	0.20 de	0.21cd	0.21bc	0.22ab	0.22cd	0.24ab
	23	0.17f	0.19de	0.18e	0.20de	0.20cd	0.21bc	0.22cd	0.22cd
polyethylene	**5**	0.19de	0.21bc	0.21cd	0.22bc	0.22ab	0.23a	0.23bc	0.25a
	23	0.18ef	0.19de	0.19ef	0.21cd	0.21bc	0.22ab	0.22cd	0.23bc

Note: Data were expressed by mean as means in a column that are followed by the different letters indicate significant differences at the (P≤0.05) level.
Source: Own results.

Volatile oil components

The data in Table 5 demonstrate that 14 compounds accounted for 91.99% of the aromatic oil of rosemary herb after harvest (control). Compounds identified included α-pinene (12.33%), β-pinene (8.14%), limonene (4.21%), ρ-cymene (11.18%), camphene (8.24%), α-terpinolene (9.25%), 1,8 cineole (7.12%), linalool (6.61%), B-carophyllene (7.29%), borneol (4.56%), thymol (5.22%), camphor (3.19%), Eugenol (1.74%), and Bornyl acetate (4.52 %). [24] found similar findings, the oil of rosemary contains α-pinene, β-pinene, limonene, ρ-cymene, camphene, eugenol, linalool, borneol, and terpineol.

In general, the total proportion of oil components in samples treated with or without hydro-cooling declined after storage in comparison with the control. Total proportion of oil compounds for hydro-cooling treatments were higher than non cooling at different storage temperatures as they were 41.07 and 31.1 % at 23°C and 61.75 and 54.86 % at 5°C, respectively.

Table 5. Influence of hydro-cooling on volatile oil components (%) of rosemary after storage period (21 days) at different storage temperatures and polyethylene bags

Components	**Control**	**21 days**			
		Without cooling		**With cooling**	
		23 °C	**5 °C**	**23 °C**	**5 °C**
A – pinene	12.01	5.31	7.88	6.33	8.25
B – pinene	8.14	1.54	3.95	2.89	4.42
Limonene	4.21	0.99	1.89	1.16	2.65
ρ- cymene	11.18	4.21	6.69	5.89	7.65
Camphene	8.24	3.51	6.84	5.32	7.21
γ- terpinene	9.25	3.01	5.22	9.61	10.12
Thymol	5.22	1.79	2.98	2.75	3.65
1, 8 cineole	7.12	0.75	2.33	1.02	2.65
Linalool	6.11	2.94	4.98	3.56	5.02
Eugenol	1.74	0.42	1.36	0.55	0.89
borneol	4.06	1.13	2.01	4.47	5.31
B-carophyllene	7.00	3.66	4.94	4.03	5.12
camphor	3.19	0.62	1.23	0.84	1.63
Bornyl acetate	4.52	1.22	2.56	1.65	3.89
Total	91.99	31.1	54.86	50.07	68.46

Source: Own results.

In addition, the temperature of storage also influenced the percentages of oil components, as they were higher at 5 °C than at 23 °C. The findings are consistent with [7] observation that most herbs, including rosemary, keep acceptable quality after being kept for up to four weeks at a temperature of 0 °C.

In summary, regarding the global economic crises, we must look for ways to reduce post-harvest processes costs to obtain a product for marketing over longer distances with high quality and a longer shelf life at the lowest costs. Economic gains arise for precooling of fruit and vegetables from reduced spoilage and extended shelf life as precooling methods impact both quality and economics, making them critical considerations in the postharvest supply chain comparing with the lake of cooling [8, 27, 14]. Additionally, precooling minimizes food waste during long-distance transport. Also, hydrocooling is regarded as efficient because of the low application cost and high energy efficiency compared with other precooling methods. Moreover, hydrocooling is capable of cooling large quantities of fruit while disinfecting the fruit surface, as mentioned by [11]. This increases the economic return for both local and international market traders.

CONCLUSIONS

Hydro-cooling improved the shelf life of rosemary plants, mainly by minimizing fresh weight loss and maintaining a greater amount of water in the leaves throughout refrigerated storage. In addition to plastic packaging proved successful at maintaining relative water content. Polyethylene containers efficiently kept the leaves from fading for a long duration of time. The most effective treatments for quality upkeep postharvest rosemary were hydro-cooling, polyethylene bags and storage at 5 °C as they decreased the loss of fresh weight, increased the total chlorophyll, maintain respiration rates, oil content and its components.

ACKNOWLEDGEMENTS

The authors express their appreciation to the Agricultural Engineering Research Institute and Horticulture Department at Faculty of Agriculture, Kafr Elsheikh University for their assistance to conduct the research study. We sincerely thank Prof. Magdy Mohamed Khalafallah prof. at Horticulture Department, Faculty of Agriculture, Kafr El-Shaikh University, Kafr El-Shaikh, Egypt, for the language editing.

REFERENCES

[1]Alvares, V. d. S., Negreiros, J. R. da S., Ramos, P.A.S., Mapeli, A., M., Finger, F.L., 2010, Pré-resfriamento e embalagem na conservação de folhas de salsas. (Precooling and packaging in the conservation of parsley leaves). Brazilian Journal of Food Technology, Campinas, Vol.13(2), 107-111, abr./jun. 2010.

[2]Álvares, V. S., Finger, F., Raoul, C., Santos, A., R. C., Negreiros, S., Casali, V., 2007, Effect of pre-cooling on the postharvest of parsley leaves. Journal of Food Agriculture and Environment, Vol. 5, No. 31.

[3]Barbosa, C.K.R., Fonseca, M.C.M., Silva, T. P., Finger, F. L., Casali, V. W.D., Cecon, P. R., 2016, Effect of hydrocooling, packaging, and cold storage on the post-harvest quality of peppermint (*Mentha piperita* L.). Rev. Bras. plantas med. 18 (1 suppl 1), 248-255.

[4]Baritaux, O., Richard, H., Touche, J., Derbesy, M. J. F., Journal, F., 1992, Effects of drying and storage of herbs and spices on the essential oil, Part I. Basil, *Ocimum basilicum* L. Flavour and Fragrance Journal, 7(5), 267-271.

[5]Böttcher, H., Günther, I., Franke, R., 2001, Comparative studies in the postharvest responses of different medicinal and culinary herbs. (Conference paper): 2001, Vol. 6, No. 3, 129-137 ref. 12.

[6]Brosnan, T., Sun, D.W., 2001, Precooling techniques and applications for horticultural products - a review. International Journal of Refrigeration, 24(2), pp.154-170.

[7]Cantwell, M.I., Reid, M.S., 1993, Postharvest physiology and handling of fresh culinary herbs. Journal of Herbs, Spices & Medicinal Plants, 1(3), pp.93-127.

[8]de Souza, E.L., de Souza, A.L.K., Tiecher, A., Girardi, C.L., Nora, L., da Silva, J.A., Argenta, L.C., Rombaldi, C.V., 2011, Changes in enzymatic activity, accumulation of proteins and softening of persimmon (Diospyros kaki Thunb.) flesh as a function of pre-cooling acclimatization. Scientia Horticulturae, 127(3), pp.242-248.

[9]El-Kershi, A.A.G., 2003, Postharvest packaging and temperature-controlled storage of peppermint and sweet basil herbs destined for medicinal and aromatic uses, Ph.D. Thesis, Faculty of Agriculture, Alexandria University, Egypt.

[10]El-Ramady, H.R., Domokos-Szabolcsy, É., Abdalla, N.A., Taha, H.S., Fári, M., 2015, Postharvest management of fruits and vegetables storage. In: Lichtfouse, E., Ed., Sustainable Agriculture Reviews, Springer, Cham, 65-152. https://doi.org/10.1007/978-3-319-09132-7_2

[11]Ferreira, M.D., Sargent, S.A., Brecht, J.K., Chandler, C.K., 2009, Strawberry bruising sensitivity depends on the type of force applied, cooling method, and pulp temperature. HortScience horts, 44(7), 1953-1956. https://doi.org/10.21273/HORTSCI.44.7.1953

[12]França, C.F.M., Ribeiro, W.S., Silva, F.C., Costa, L.C., Rêgo, E.R., Finger, F.L., 2015, Hydrocooling on postharvest conservation of butter lettuce. Horticultura Brasileira, 33(3), pp.383-387. https://doi.org/10.1590/S0102-053620150000300018

[13]Garrido, Y., Tudela, J.A., Gil, M.I., 2015, Comparison of industrial precooling systems for minimally processed baby spinach. Postharvest Biology and Technology, 102, pp.1-8.

[14]Gross, C.K., Wang, C.Y., Saltveit, M., 2016, The commercial storage of fruits, vegetables, and florist and

nursery stocks (No. 66 Revised). US Department of Agriculture.

[15]Han, Q., Gao, H., Chen, H., Fang, X., Wu, W., 2017, Precooling and ozone treatments affects postharvest quality of black mulberry (*Morus nigra*) fruits. Food Chemistry, 221, 1947-1953.

[16]Haney, R.L., Brinton, W.F., Evans, E.R.I.C., 2008, Soil CO2 respiration: Comparison of chemical titration, CO2 IRGA analysis and the Solvita gel system. Renewable Agriculture and Food Systems, 23(2), 171-176.

[17]Hardenburg, R.E., Watada, A.E., Wang, C.Y., 1986, The commercial storage of fruits, vegetables, and florist and nursery stocks. Agricultural Handbook No. 66. US Department of Agriculture, Agricultural Research Service.

[18]Kalbasi-Ashtari, A., 2004, Effects of post-harvest pre-cooling processes and cyclical heat treatment on the physico-chemical properties of “Red Haven Peaches” and “Shahmiveh Pears” during cold storage. Agricultural Engineering International: CIGR Journal of Scientific Research Development.

[19]Karwowska, K., 1997, Influence of storage methods of fresh basil (*Ocimum basilicum* L.) and tarragon (*Artemisia dracunculus* L.) on their quality, Journal article: Annals of Warsaw Agricultural University SGGW, Horticulture, No. 18, 127-139 ref. 7

[20]Khorshidi, J., Tabatabaei, M.F., Ahmadi, F.M., 2010, Storage temperature effects on the postharvest quality of apple (*Malus domestica* Borkh. cv. Red Delicious). New York Science Journal, 3(3), pp.67-70.

[21]Lange, D.L., 2000, New film technologies for horticultural products. HortTechnology, 10(3), pp.487-490.

[22]Loaiza, J., Cantwell, M., 1997, Postharvest physiology and quality of cilantro (*Coriandrum sativum* L.). HortScience, 32(1), pp.104-107.

[23]Luengwilai, K., Beckles, D.M., 2013, Effect of low temperature storage on fruit physiology and carbohydrate accumulation in tomato ripening-inhibited mutants. Journal of Stored Products and Postharvest Research, 4(3), pp.35-43.

[24]Oliveira, L.S., Silva, T.P., Ferreira, A.P., Pereira, A.M., Finger, F.L., 2015, Effect of hydrocooling in the postharvest shelf life of coriander leaves. Horticultura Brasileira, 33, pp.448-452.

[25]Panda, H., 2000, Essential Oil Hand Book. National Institute of Industrial Research, Delhi, India, 73-86.

[26]Park, K.W., Kang, H.M., Kim, C.H., 2000, MA Strotage Response of Fresh Lemongrass Depending upon Film Source and Storage Temperature. Horticultural Science & Technology, 18(1), 18-21.

[27]Pharmacopoeia, E., 1984, Egyptian Pharmacopoeia, General Organization for Governmental. Printing Office, Ministry of Health, Cairo, Egypt, pp.31-33.

[28]Rab, A., Rehman, H., Haq, I., Sajid, M., Nawab, K., Ali, K., 2013, Harvest stages and pre-cooling influence the quality and storage life of tomato fruit. The Journal of Animal & Plant Sciences, 23, 1347-1352.

[29]Schvambach, M.I., Andriolli, B.V., Souza, P.F.D., Oliveira, J.L.B., Pescador, R., 2020, Conservation of crisp lettuce in different post-harvest storage conditions. Revista Ceres, 67(4), 256-262.

[30]Sharma, K.D., Cardona, J.A., Sibomana, M.S., Herrera, N.G.S., Nampeera, E., Fallik, E., 2018, Quality attributes of modified atmosphere packaged bell pepper (*Capsicum annuum* L.) during storage. Journal of Nutrition, Food Research and Technology, 1(2), 56-62.

[31]Sivakumar, D., Bautista-Baños, S., 2014, A review on the use of essential oils for postharvest decay control and maintenance of fruit quality during storage. Crop protection, 64, pp.27-37.

[32]Teixeira, D.A., Gomes, J.A.O., Bonfim, F.P.G., Pardo, P.I., Mayobre, M.T., 2016, Técnicas de conservação pós-colheita para o manjericão. Revista Brasileira de Plant as Medicinals, 18, pp.168-171.

[33]Tsang, M., Furutani, S., 2006, A low-cost hydrocooling unit for horticultural commodities. J. Hawaii Pac. Agric, 14(1).

[34]Vakkalanka, M.S., D’Souza, T., Ray, S., Yam, K.L., Mir, N., 2012, Emerging packaging technologies for fresh produce. In Emerging Food Packaging Technologies, Woodhead Publishing. 109-133.

[35]Wills, R., McGlasson, B., Graham, D., Joyce, D., Rushing, J.W., 1998, Postharvest: An introduction to the physiology and handling of fruit, vegetables and ornamentals. Journal of vegetable crop production, 4(2), 83-84.