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Quality and Shelf Life of Lisboa Lemon within Polystyrene Containers in Refrigerated Chamber

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Abstract

The aim of this research was to knowing if it would improve the shelf life of the lemons that were stored in hermetically polystyrene containers closed, as same that were placed in a refrigerated chamber with temperature of 10˚C inside, high relative humidity (85%) and renovation of the air by action of the compressor of the chamber. Lemons cv "Lisboa" were cut directly from the orchard and washed with chlorinated water at 150 mg·L^{-1} sodium hypochlorite. The study variables were the color of the epicarp (shell) and the endocarp (pulp), polar and equatorial diameter, firmness of the pulp and total soluble solids concentration (˚Brix) in the endocarp. The tone and purity of the yellow color of the shell (epicarp) and pulp or endocarp of the oranges increased significantly within polystyrene containers and, consequently, its quality was preserved and its shelf life was extended to more than 100 days without that they have symptoms of deterioration, by losses polar and equatorial diameter or decrease in total soluble solids. Inside closed containers polystyrene the temperature decreased to 2.0˚C in the refrigerated chamber, so that the principle of thermal insulation polystyrene reaffirmed, and its functionality for packaging products, such as fruits, resolve some of their physiological problems themselves, to prolong its shelf life and improve its presentation.

Keywords

Variety "Lisboa", Polystyrene Containers, Weight, Shape, Color, Firmness, Total Soluble Solids

1. Introduction

Lemon Lisboa or Lisbon is one of these fruits that is grown in the Valley of Mexicali, Baja California, Mexico, where it occupies the second place in cultivated surface, since the first place corresponds to the lemon Eureka (Italian); while the third and fourth place is represented by lemon Colima and Persa, respectively [1].

Fruits and vegetables are important in human nutrition and are good sources of energy, fat, carbohydrates, calcium, phosphorus, iron, magnesium and vitamins such as A, B_6, B_{12}, C, thiamin, riboflavin and niacin. They provide more than 90% of vitamin C in human nutrition and are also excellent sources of fiber, a component of great importance in the diet [2].

The demand for minimally processed and refrigerated fruits and vegetables is continuous, which must be fresh, convenient, of high quality and safe for the health of the consumer [3]. Fresh cut fruits and vegetables are products that are partially prepared, so that no additional preparation is necessary for their consumption [4]. It is important that they have a fresh character, despite the cellular damage that this type of product suffers during the harvest [5]. Minimally processed fruits and vegetables are those products with living tissues or that their fresh condition has only been slightly modified in character and quality [6].

The storage techniques used after the harvest, once the fruits have been packaged for fresh commercialization, have the purpose of preserving the quality of the same, taking into account the adequate environmental conditions that allow to reducing the speed of the vital processes of these products, and dispose of them for longer periods than the normal ones, in addition to offering fresh products to distant markets and decreasing losses during their commercialization. Among the most widely used techniques for the conservation of fruits and vegetables are refrigeration, the use of controlled atmospheres, the use of ethylene absorbents, the application of covering films and the exogenous application of phytoregulators [7].

The technique of conservation in modified atmosphere (AM) consists of packing food products in materials with diffusion barrier gases, in which the gaseous environment has been modified to reduce the degree of respiration, reduce microbial growth and delay the enzymatic deterioration with the purpose of extending the useful life of the product. Inside a closed container, the gaseous atmosphere changes continuously throughout the storage period due to the influence of different factors such as the respiration of the packaged product and the biochemical changes [8].

After being harvested, fresh fruits and vegetables continue their metabolic processes, consume O_2, and produce CO_2 and water vapor. The modification of the atmosphere around the product is carried passively by the effect of breathing [9].

Depending on the requirements of the food to be packaged, an atmosphere with environments rich in CO_2 and poor in O_2 will be required, which reduces

the respiration process in the products, conserving their physicochemical, organoleptic and microbiological characteristics for a longer time [10].

Expanded polystyrene is used to package and pack food [11]. In such a way that in view of the increasing demands on the part of the consumer of fruits with quality, both from the export market and from the internal one, it is important the adequate selection of the material for packaging, since the appropriate packaging is the one that solves problems physiological characteristics of the fruit, protects it by prolonging its conservation and, at the same time, highlights its presentation without significantly increasing the price of the final product [12].

It has been shown that giant-bananas (AAA) Cavendish postharvest increase shelf life when stored in closed polystyrene containers inside a refrigerated chamber at temperatures of 10˚C - 12˚C [13].

The tone and purity of the yellow color of the epidermis and the pulp of the oranges increased significantly within the polystyrene containers and, consequently, their useful life lasted for more than 100 days, without any symptoms of deterioration losses of polar and equatorial diameter or by reduction of total soluble solids, compared with said characteristics of the oranges in the lower tray of a refrigerated chamber [14].

The objective of this investigation was to determine if the shelf life of lemons cv "Lisboa" is increased, when these are stored inside hermetically sealed polystyrene containers, placed in closed environments with a temperature of 10˚C, high relative humidity (85%) and frequent renewal of air in the storage space.

2. Materials and Methods

The experiment was carried out in the agricultural center of the University of Arizona in Yuma, AZ, USA, with coordinates 32˚42'45"N and 114˚42'18"W, in a laboratory equipped for storage of climacteric fruits. The orchard of lemons of the variety "Lisbon" is in the Mesa Station of the same university, located in Somerton, AZ, EU at 33˚24'54"N and 111˚49'53"W, from where the lemons were harvested with the necessary care (**Figure 1**) and subsequently washed with chlorinated water with 150 $mg \cdot L^{-1}$ of sodium hypochlorite, to prevent growth and development of fungi that usually grow on lemons. After drying, 20 lemons were confined in polystyrene containers with a capacity of 10 kg and hermetically sealed. Then the containers were placed inside a refrigerated chamber, where the temperature was 10˚C and the relative humidity 85%. The containers were opened at 8, 12 and 16 weeks after storage, and the control consisted of lemons placed in an open polystyrene container inside the refrigerated chamber.

The statistical analysis was made on the basis of experimental design of randomized complete blocks with four replications and five treatments: lemons freshly harvested and evaluated (week 0) before others were packed in containers, lemons confined in a closed polystyrene container which was opened at 8 weeks, another that opened at 12 and one more that was opened at 16 weeks, plus the witness that consisted of the lemons packed in the open container.

Figure 1. Lemons from the cultivar "Lisboa" harvested on 10/05/2015 in the vegetable garden located in La Mesa Station of the University of Arizona, Somerton, AZ, EU.

The study variables were fruit weight, equatorial diameter, shape, shell color (epicarp), firmness and Brix degrees (total soluble solids). The weight, shape and color of the shell were examined with the Autoline Fruit Sorting System. The equatorial diameter was measured with a vernier and firmness with a penetrometer fruit pressure tester mod. Ft. 011 on the surface of the lemons to obtain the values in pounds; while the total soluble solids were analyzed with a digital refractometer (PR 32, ATAGO, EU), by placing juice drops of the lemons in the refractometer receiver. The measurements were carried out from the day of packaging (week 0); likewise, at 8, 12 and 16 weeks.

The analysis of variance was made with the statistical program SAS version 5 [15], while the multiple comparison of means was performed with the Tukey test with $\alpha \leq 0.05$.

3. Results and Discussion

The analysis of variance of the weight of the lemons indicated highly significant differences ($P \leq 0.001$) with standard deviation of 9.22 g and a CV = 8.98%, in such a way that the multiple comparison of means shown in **Table 1**, allowed to notice that lemons checked at the end of eight weeks after being packed had 11.7% (11.1 g) more weight than controls, at 12 weeks the increase was 11.1% (10.5 g) and at 16 weeks of 7.4% (7.0 g), although without statistical difference with respect to the witness; however, at 16 weeks the lemons decreased their weight by 2.0% (2.0 g) compared to the one they had at the time of packaging.

Significant differences were found with the analysis of variance of the equatorial diameter of the lemons ($P \leq 0.052$), standard deviation of 0.13 in, and a CV = 5.75%. The multiple comparison of means indicated in **Table 1** made it

Table 1. Weight, equatorial diameter and shape of cv "Lisboa" lemons stored for 8, 12 and 16 weeks in polystyrene containers hermetically sealed and one open, placed in a refrigerated chamber.

Treatments	Weight (g)	Equatorial diameter (in)	Shape (sh)
Week 0	103.91 a	2.27 ab	0.72 ab
Week 8	105.99 a	2.33 a	0.71 b
Week 12	105.39 a	2.27 ab	0.80 a
Week 16	101.91 ab	2.24 ab	0.74 b
Control	94.88 b	2.21 b	0.70 b

Means with the same letter in each column are statistically equal (Tukey, $\alpha \leq 0.05$).

possible to note that, after eight weeks of being packed, the lemons had 5.4% (0.12 in) More of equatorial diameter than the controls, at 12 weeks the increase it was 2.7% (0.06 in), and at 16 weeks the increase was 1.34% (0.03 in), although without statistical difference with the control; however, at 16 weeks the diameter of the lemons decreased 1.3% (0.03 in) compared to the one they had when packaged, the appearance of the lemons can be seen in Figure 2.

The analysis of variance of the shape (sh) of the lemons indicated highly significant differences (P ≤ 0.010), with standard deviation of 0.093 (sh) and CV = 12.6%, in such a way that the multiple comparison of means shown in the Table 1 allowed to observe that, after eight weeks of being packed, the fruits had 1.4% (0.01 sh) better than the control, at 12 weeks it was 14.3% (0.10 sh), and at 16 weeks of 5.7% (0.04 sh); whereas compared to the shape of the initially packaged (week 0), this character was superior in 2.2% (0.02 sh), the shape can be seen in Figure 2.

The analysis of variance for the green-yellow (g/y) color of the epicarp indicated highly significant differences (P ≤ 0.000), standard deviation of 3.3 g/y and CV = 3.4%. The multiple comparison of means (Table 2) indicated that, at the end of eight weeks, the lemons were 0.10% (0.1 g/y) more green-yellow than the control ones, but without statistical difference; at 12 weeks were 0.20% (0.2 g/y) less green-yellow, also without statistical difference with the color of the control lemons; however, at 16 weeks they were 6.0% (5.9 g/y) less green-yellow than the control, with significant difference in relation to the control, and had a decrease of 1.92% (1.8 g/y) compared to when they were packed , color that can also be seen in Figure 2.

The firmness of the lemons occurred with highly significant differences (P ≤ 0.000), standard deviation 0.65 lb and a CV = 18%; the multiple comparison of means (Table 2) indicated that at eight weeks the lemons had 100% (2.2 lb) more firmness than the control, at 12 weeks the increase was 50% (1.1 lb), and at 16 weeks of 54.5% (1.2 lb), but until this total of weeks (16) the firmness increased 3.0% (0.1 lb) compared to what they had when they were packed (week 0).

(a) (b) (c)

Figure 2. Lemons CV "Lisboa" at 8 weeks (11/16/2015) (a), at 12 weeks (12/14/2015) (b) and at 16 weeks (01/11/2016) (c) of stored in closed polystyrene containers.

Table 2. Color green-yellow (g/y), firmness (lb) and degrees Brix of lemons cv "Lisboa", confined in closed polystyrene containers and in an open one, inside refrigerated chamber, during 8, 12 and 16 weeks.

Treatments	Color (green-yellow g/y)	Firmness (lb)	˚Brix
Week 0	93.9 b	3.3 b	7.2 c
Week 8	98.1 a	4.4 a	7.7 b
Week 12	97.8 a	3.3 b	7.5 bc
Week 16	92.1 b	3.4 b	7.2 c
Control	98.0 a	2.2 b	8.7 a

Means with the same letter in each column are statistically equal (Tukey, $\alpha \leq 0.05$).

The Brix degrees also occurred with highly significant differences ($P \leq 0.000$), standard deviation of 0.45 ˚Brix and CV = 5.85%; the multiple comparison of means (**Table 2**) indicated that at eight weeks there was a decrease of 11.5% (1.0 ˚Brix) that the control lemons, 12 weeks later were reduced 13.8% (1.2 ˚Brix), and at 16 weeks 17.2% (1.5 ˚Brix); however, compared to the ˚Brix they had when they were packed, at 16 weeks there was no significant difference.

These results coincide with those of Reyes *et al.* [13] and Obregón *et al.* [14], since the former found that the shelf life of Cavendish Giant bananas (AAA) increased when they were packed in closed polystyrene containers and placed inside a refrigerated chamber with a cool temperature of 10˚C - 12˚C; while the second ones observed that the shelf life of oranges cv "Valencia" also increased, to preserve its quality for more than 100 days inside closed polystyrene containers inside a refrigerated chamber with a temperature of 3˚C - 9˚C.

From these results, it can also be deduced that the use of polystyrene containers fulfilled the fact referred by Yildiz [3], regarding that the lemons were minimally processed, to be fresh, in a convenient condition, with high quality and they were safe for the health of the consumer. In such a way that the suggestion of Watada and Qi [4] was also fulfilled, which is that no additional preparation is necessary for its consumption. In addition, as recommended by Huxsoll and Bolin [5], lemons maintained a fresh character, despite the cellular damage they could suffer during harvest.

Likewise, these results will also complement the knowledge of the technicians

and producers so that, once the lemons have been packaged for fresh commercialization, they have the quality that the consumer demands, in the environmental conditions that the closed polystyrene containers give, with the which the speed of the vital processes of lemons can be reduced, and also have longer periods than normal, in addition to offering them fresh to distant markets and reducing losses during their commercialization, as they suggest Parikh *et al.* [7].

In addition, these results are related to what was reported by González [8], since this author discovered that with the procedure of packing food products in materials with a barrier to the diffusion of gases, the degree of respiration of fruits can be reduced, reduce the microbial growth and delay the enzymatic deterioration, with the purpose of extending the useful life of the product. Since inside a closed container, the gaseous atmosphere changes continuously throughout the storage period due to the influence of different factors such as the respiration of the packaged product and the biochemical changes.

With the closed polystyrene containers, the conditions suitable for the requirements of lemons are also provided, such as food to be packaged, since as Parry [10] refers, they will require a rich in carbon dioxide and poor in oxygen atmosphere, to reduce the breathing process, preserve its physicochemical, organoleptic and microbiological characteristics for a longer time.

Therefore, the use of hermetically sealed polystyrene containers to package lemons cv "Lisboa", confirmed what was reported by Perdomo [11], who mentioned that expanded polystyrene is used to package and pack food. Likewise, its use is related to what was mentioned by Raimondo and Espejo [12], since they have said that in view of the increasing demands on the part of the consumer of quality fruit, both in the export market and in the domestic market, it is important to adequate selection of the material for packaging, as the appropriate packaging is the one that solves the physiological problems of the fruit, protects it by prolonging its conservation and, at the same time, highlights its presentation without significantly increasing the price of the final product.

4. Conclusion

Among the evaluated variables that affect the quality of the lemons, 66.7% of them (weight, equatorial diameter, shape and firmness) of the lemons stored in the closed polystyrene containers, remained above those of the lemons confined in the open container inside the refrigerated chamber (control) until 16 weeks (120 days), while 33.3% of them (green-yellow color of the epicarp or shell and total soluble solids or ˚Brix) remained below those of the control, without the green-yellow being <90 or the ˚Brix ≥ 8.7 that indicate a decrease in acidity, so that both levels of the characteristics lead to the deterioration of the lemons. Since the shelf life of the lemons was prolonged, then the polystyrene containers can be another technology to conserve lemons for longer than usually considered (12 weeks) in the refrigerated chambers currently used by the producer.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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