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Influence of olive tree irrigation and the preservation system on the fruit characteristics of Hojiblanca black ripe olives

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Abstract

In this study, the effect of olive tree irrigation, the use of salt in preservation liquids and the reuse of sodium hydroxide solutions (lye) on the weight, shriveling, firmness and phenolic content of Hojiblanca processed olives was investigated. A weight loss in fruits of up to 5% during the preservation stage was observed, particularly for olives from irrigated trees and stored in brines. By contrast, a weight gain of up to 7% was achieved during the darkening stage, whose intensity was increased by using fruits from non-irrigated trees and preserved in a salt-free environment as well as fresh lye for the debittering step. Moreover, shriveling particularly appeared in fruits from non-irrigated olive trees, this defect being more intense if lye was reused. Firmness was also affected by the studied variables, and natural rainfed irrigation and the reuse of lye and salt in the preservation solutions gave rise to firmer olives. The content in phenolic compounds of black processed olives was higher in fruits from non-irrigated than irrigated trees, in particular those of hydroxytyrosol, tyrosol and luteolin 7-glucoside. Overall, these results will contribute to the knowledge of table olives processing and the industrial optimization of this sector.

Keywords: olive, weight, shriveling, firmness, phenolic

1. Introduction

Spain is the major producing country of table olives with ca. 500 million kilograms per year, about 40% of this production being obtained from the Hojiblanca variety, which is an emerging table olive variety worldwide. These fruits are mainly intended for black olives and are mechanically harvested because of their hard texture and low incidence of bruising.

The industrial production of black olives involves their harvesting at an early stage of maturation when they have a green/yellow color on the surface, their covering with an acidified brine and oxidation darkening under alkaline conditions (García, Brenes & Garrido, 1991). Considerable research has been carried out on the preservation and darkening process of Hojiblanca black olives (García, Brenes & Garrido, 1991; Brenes, García, Romero & Garrido, 1998; de Castro, García, Romero, Brenes & Garrido, 2007) but changes have been introduced in the process during the last years that make it necessary for industries to know their effects on the characteristics of the final product.

The influence of olive tree irrigation on the quality of this product has never been investigated. Indeed, there is limited information about the effect of tree irrigation on the quality of table olives in general (Proietti & Antognozzi, 1996; Marsilio et al., 2006). Besides, changes in olive weight during the preservation and darkening stages of black olive processing is a controversial matter because reliable data are not available. In fact, on many occasions, the processors themselves argue over contradictory data about the weight loss of olives during the preservation stage, which could be related to the presence of salt in the liquids (De Castro et al., 2007). It has been reported that olives of the Verdial variety gained weight during the darkening step (Garrido, Albi &

Fernández., 1973) but it was not related to the olive tree irrigation or the storage solution used. Also, the reuse of the sodium hydroxide solutions is another widespread industrial practice that could affect the fruit characteristics (Garrido, 1984).

It is well-documented that fruits from irrigated olive trees have lower contents in phenolic compounds (Patumi, d'Andria, Marsilio, Fontanazza, Morelli et al., 2002; Marsilio et al., 2006) than those from non-irrigated trees, as well as lower activity of enzymes involved in the biosynthetic routes of polyphenols (Tovar, Romero, Girona & Motilva, 2002). Irrigation also affects the level of phenolic compounds in olive oils (Stefanoudaki, Williams, Chartzoulakis, & Harwood, 2009) but the effect of water stress on the concentration of phenolic compounds in black olives has never been studied. Water deficit can also affect some table olive quality parameters such as the presence of shriveling on the surface of fruits or the firmness of the final product.

The aim of the current study was to provide reliable data about the influence of olive tree irrigation, the presence of salt in the preservation solution and the reuse of lye on some important characteristics of the Hojiblanca fruits such as their weight, presence of shriveling, firmness and content in phenolic compounds.

2. Materials and methods

2.1 Olives

Olives of the Hojiblanca variety were mechanically harvested at a maturity stage (green/yellow color on surface) suitable for processing in October 2009. Fruits were cultivated in Lora de Estepa and Casariche, two small towns in the province of Seville (Spain), under irrigation and non-irrigation conditions. The annual rainfall for 2009 was 540 mm, being abundant during the spring and autumn and almost insignificant during the summer. Farmers supplied the olives to two Cooperatives from irrigated or non-irrigated soils over four weeks in October. On arrival, leaves and small branches were removed and the fruits were washed.

2.2 Preservation stage

Olives were put in fiberglass underground tanks, which contained about 9500 kg of fruits and 5500 L of cover solution. During the four weeks of October, in the two Cooperatives, two different samples of olives from irrigated or non-irrigated trees were put into two tanks (duplicate) and covered with a 3.5 g/100 mL of NaCl and 1.6 g/100 mL of acetic acid solution or with just the 1.6 g/100 mL acetic acid solution. A total of 128 tanks were used for the experiments. All of the tanks were maintained under aerobic conditions by bubbling air from the bottom of the tank with a column as described elsewhere (De Castro et al., 2007).

To study the evolution of the weight of the olives during preservation, 4.0 kg of fruits were put into a plastic net and introduced at 1 m of depth into each tank with a plastic string. Periodically, at 1, 4, 7 and 10 months from preservation the plastic nets were removed from the tanks and the olives were weighed.

2.3 Darkening stage

The olives stored for 7-8 months were darkened as black ripe olives in 12 PVC cylindrical containers with conical bases (García, Brenes & Garrido, 1991). Three olive samples from each non-irrigated tree and brine storage, non-irrigated tree and salt-free storage, irrigated tree and brine storage, and irrigated tree and salt-free storage treatments were darkened. The process consisted of placing 1.5 kg of fruits in 1.5 L of 0.75 mol/L of NaOH solution (lye) for 4-5 h, sufficient time for the lye to reach the pit. The olives were then covered with tap water and air was bubbled through the mixture for 24 h. After draining, the olives were put in a new washing solution (tap water: preservation olive solution, 1:1), and air was bubbled for 24 h (Brenes et al., 1998). Finally, the liquid was poured off and the fruits were covered with a 0.1 g/100 mL of ferrous gluconate solution and aerated for another 24 h. Before packing, the weight of the olives was checked.

A weighed amount of whole (ca. 175 g) and pitted (ca. 145 g) fruits were bottled in cylindrical A314 jars (Juvasa, Seville, Spain) with 145 and 175 mL of a cover solution respectively, which had 3 g/100 mL of NaCl and 0.025 g/100 mL of ferrous gluconate. Calcium chloride (0.35 g/100 mL) was also added in the cover solution of half of the jars. All of them were sterilized at 121ºC for 15 min in a computer-controlled Steriflow retort (Madinox, Barcelona, Spain). One month from packing, they were opened and the olives were weighted. Firmness and shriveling were tested.

Olive samples from treatments reported above were also processed with reused lye supplied by the Agrosevilla SCA factory instead of fresh lye. The concentration of this reused lye was adjusted to 0.75 mol/L of NaOH.

2.4 Changes in volume of olives during lye treatment

One liter of tap water was put into a 2 L graduated cylinder, and 1 kg of olives was added. The increase in volume of the mixture was recorded. Then, fruits were treated with a 0.75 mol/L of NaOH solution until the alkaline solution reached the pit, which was monitored by adding a drop of phenolphtaleine ethanolic solution on the pulp of olives. Subsequently, the fruits were weighed and put into the graduated cylinder containing 1 L of water. The difference between the volume of olives before and after the lye treatment was recorded.

2.5 Quality analysis of olives

Firmness of olives was measured using a Kramer shear compression cell coupled to an Instron Universal Testing Machine Model 1001 (Canton, USA). The crosshead speed was 200 mm/min. Firmness was the mean of 10 replicate measurements, each of which was performed on 3 pitted olives, and expressed as N/100 g pitted olives. Analyses were made one month after packing.

The presence of olives with wrinkles that affected their appearance was tested by three table olive experts on 100 olive fruits one month after packing. This was expressed as % of shriveled fruits.

2.6 Polyphenols analysis

Pitted fruits were crushed with an Ultraturrax homogenizer, and 3 g of the paste were mixed with 18 ml of dimethyl sulfoxide (DMSO) (Romero-Segura, Sanz, & Pérez, 2009). After 1 min of agitation by vortex, the mixture was centrifugated at 6000 g for 5 min, and the supernatant was filtered through a 0.22 µm pore size nylon filter. An aliquot of 250 µL was mixed with 250 µL of internal standard (0.2 mmol/L of syringic acid in DMSO) and 500 µL of DMSO. Finally, 20 µL of the mixture were injected into the chromatograph. A Spherisorb ODS-2 (5 µm, 250 x 4.6 mm, Waters Inc.) column was used. The HPLC system consisted of a Waters 2695 Alliance (Waters Inc., Mildford, MA, USA) with a pump, column heater and autosampler included, the detection being performed with a Waters 996 diode array detector at 280 nm. Separation was achieved using an elution gradient with an initial composition of 90% water (pH adjusted to 2.3 with phosphoric acid) and 10% methanol. The concentration of the latter solvent was increased to 30% over 10 min and maintained for 20 min. Subsequently, the methanol % was raised to 40% over 10 min, maintained for 5 min and then increased to 50%. Finally, the methanol % was increased to 60%, 70% and 100% in 5 min intervals. The flow rate of 1 mL/min and a temperature of 35ºC were used (Medina et al., 2007).

2. 7 Statistics

Statistical comparisons of the mean values for each experiment were performed by one-way analysis of variance (ANOVA), followed by the Duncan's multiple range test ($p<0.05$) using Statistica software version 6.0 (Stat-Soft, 2001).

3. Results and discussion

There was a continuous weight loss of the fruits with time in all tanks (Fig. 1), although significant differences among the treatments were detected. Olives from non-irrigated trees lost weight to a lower extent than fruits from irrigated trees, and salt in the preservation solution gave rise to faster weight loss. After 10 months of preservation, the lowest (3.5%) and the highest (5.1%) weight loss was obtained for olives from non-irrigated trees and preserved in a salt-free solution, and olives from irrigated trees and preserved in acidified brine, respectively. Moreover, the time of harvesting did not show a statistically significant effect ($p<0.05$) on the weight loss (data no shown) but fruits harvested at the end of October tend to have higher weight loss than those picked during the first week of the month. It must be said that these results were obtained for the Hojiblanca variety and the intensity of the weight loss for other olive varieties could be different. However, we have collected sporadic data for years and the tendency was quite similar for all the varieties. The diffusion of substances from the olives to the preservation solution seems to explain the weight loss. Also, this phenomenon was more intense in olives submerged in brine because of the osmotic action of the salt.

In contrast to the weight loss found during the preservation stage, there was a significant weight gain in the darkening process, especially during the NaOH treatment (Fig. 2). Overall, olives gained about 5-7% of weight, a percentage higher than the weight loss which occurred during the preservation stage, although this gain depended on several factors. The use of fresh lye gave rise to a higher weight gain in olives than reused lye ($p<0.05$). Despite these results, factories must continue reusing the lye in order to reduce the environmental impact of table olive wastewaters. Significant weight gain differences were also found between olives from irrigated and non-irrigated trees, having gained the former a higher percentage of weight than the later. It must be remembered that olives from irrigated trees lost a higher percentage of weight than non-irrigated during the preservation stage. Moreover, the presence of salt in the preservation solution provoked a lower weight gain during darkening, which is another argument in favor of eliminating NaCl from the preservation solutions of black olives as well as its contribution to the mineral contamination of the table olive wastewaters.

There are only few previous data about the effect of the darkening process on the weight of olives (Garrido, Albi & Fernández, 1973) but no explanation for this phenomenon was offered. A very simple experiment was done to clarify this issue. One kilogram of olives was put in contact with an NaOH solution (0.75 mol/L) for 5 hours and a significant increase in weight (11.3%), as well as in volume, was observed. Additionally, fruits increased their volume from 0.6 L to 0.7 L (Fig. 3). It seems that the weight gain of olives during the darkening stage, in particular during the alkaline treatment, was due to the increase in volume of the fruits and, consequently, in weight.

It has been reported that the lye treatment affects both the skin and mesocarp textural characteristics (Georget, Smith, Waldron, & Rejano, 2003), it dissolves the epicuticular waxy coating and breaks the intercellular pectic material in the middle lamella causing the softening of tissues (Marsilio, Lanza & De Angelis, 1996). Moreover, changes in the intercellular volume of olives have also been reported as a consequence of gas diffusion (oxygen, nitrogen and carbon dioxide) during their preservation stage (Romero, Brenes, García & Garrido, 1996), and even the growth of lactic acid bacteria could provoke structural modification in tissues (Servili et al., 2008). However, an increase in cell volume due to the lye treatment has never been reported. Thus, it can be speculated that the volume gain of olives during this alkaline treatment, and therefore weight gain, could be due to cell separation because of pectic material solubilization of the middle lamella.

Olives also suffered small weight changes after packing and sterilization. Whole fruits lost weight (ca. 1.1%), whereas pitted olives gained weight (ca. 0.6%). Neither the preservation method nor the irrigation regime had a significant effect on the weight changes in the olives after packing (data not shown).

The presence of wrinkles on the surface of olives sometimes becomes a severe commercial defect that makes them unacceptable to consumers. This phenomenon is rare for Manzanilla olives but common for Hojiblanca fruits. Many variables can be involved in this damage, such as the preservation method. If anaerobic conditions are maintained, a very high concentration of carbon dioxide will be accumulated in the solutions and olives. This gas is released from the fruits when they are taken out of the fermenters and small wrinkles can appear on the olive surface. By contrast, the maintenance of aerobic conditions prevents this damage because carbon dioxide is constantly purged (Romero et al., 1996). In our industrial trials, aerobic conditions were used.

Other variables can also affect the presence of shriveling on fruits. Fig. 4 shows the influence of tree irrigation and type of lye on the percentage of shriveling on whole and pitted packed olives. First, we must say that the statistical analysis ruled out the presence of salt in the preservation solution as a key factor for shriveling on olives (data not shown). By contrast, the stress water of the olive trees exerted a significant effect on this alteration, in particular when lye was reused. Also, the effect was more severe on whole than pitted olives. We do not have an explanation for this phenomenon although Patumi et al. (2002) indicated that olive trees under water stress conditions produced fruits with a higher cuticular thickness to prevent the loss of water, and it could influence the presence of shriveling when olives are processed.

Results from our experiments also disclosed that firmness was another quality characteristic of olives influenced by the tree irrigation regime, the reuse of lye and the presence of salt in the preservation solution (Fig. 5). Fruits cultivated in irrigated trees had significantly lower firmness than those from rainfed trees, which is in accordance with previous works (Proietti & Antognozzi, 1996; Marsilio et al., 2006). In contrast to the results obtained by Garrido (1984), firmer olives were obtained when reusing the lye. Moreover, it was confirmed that the presence of a low level of salt in the preservation solution gave rise to harder olives (De Castro et al., 2007). Several studies have shown the positive effect of sodium ions on olive texture (García, Brenes & Garrido, 1994; De Castro et al., 2007) and other fermented vegetables (Fleming, McFeeters & Thompson, 1987). In the case of Hojiblanca fruits, firmness is not currently a key quality parameter because of their hard texture (Georget, Smith & Waldron, 2001), except when they are preserved in a very highly acidified medium free of salt. In order to solve this softening problem, calcium ions were added to the packing solutions of olives preserved in a salt-free environment, and they showed a similar texture to those stored in acidified brine without calcium added during packing (Fig. 6), thereby confirming the great influence that calcium ions can exert on the firmness of table olives (Romero, García, Brenes & Garrido, 1995; Tassou et al., 2007; De Castro et al., 2007).

Olive polyphenols play an important role in table olive characteristics since they contribute to their color, flavor and texture. Besides, these substances are powerful antioxidants and exert many beneficial effects on human health. The effects of tree irrigation, salt in the preservation solution and the reuse of lye on the phenolic content of packed black olives were studied. After the statistical analysis of the data, the irrigation regime only showed a significant effect on the concentration of these substances in olives (Fig. 7). The total content of phenolic compounds in olives from non-irrigated and irrigated trees was 602 and 501 mg/kg, respectively. Differences were found among all the individual compounds although they were only significant for hydroxytyrosol, salidroside, tyrosol and luteolin 7-glucoside. The effect of water stress on the phenolic content of olive fruits (Patumi et al., 2002; Tovar et al, 2002), olive oil (Stefanoudaki et al, 2009) and naturally green processed olives (Marsilio et al., 2006) is well-documented, the higher the irrigation regime the lower the content in phenolic compounds. With regard to black oxidized olives, we observed an increase of about 20% in phenolic concentration between fruits from irritated and non-irrigated olive trees. It is not a very high difference but it must be noted that olives suffered many water changes during processing.

4. Conclusions

The weight and volume of black olives during processing is affected by the type of olive tree irrigation, the use of salt in the preservation solution and the reuse of lye. Fruits lost and gained weight during the preservation and darkening steps respectively. These changes are dependent on the above mentioned variables. In addition, the non-irrigation of olive trees and the reuse of lye influenced the presence of shriveling on the surface of the olives to a great extent. All these data will contribute to the optimization of the black ripe olive processing, and to explain some changes that occur during this elaboration process at industrial scale.

Acknowledgements

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Figure legends

Fig. 1. The effects of tree irrigation and the presence of salt in the preservation solution on the weight loss of Hojiblanca olives during their storage before the darkening stage: (♦) non-irrigated trees and brine storage, (●) non-irrigated trees and salt-free storage, (▲) irrigated trees and brine storage, (■) irrigated trees and salt-free storage. The error bars represent the standard errors of 32 replicates.

Fig. 2. The effects of the reuse of lye, tree irrigation, and salt in the preservation solution on the weight gain of Hojiblanca olives during the darkening process. The error bars represent the standard errors of 12 replicates. Different letters mean significant differences according to a Duncan's multiple range test (P<0.05).

Fig. 3. The effect of the alkaline treatment on the weight and volume of Hojiblanca olives.

Fig. 4. The effects of tree irrigation and the reuse of lye on the shriveling defect of Hojiblanca black olives: irrigated trees and fresh lye, non-irrigated trees and fresh lye, irrigated trees and reused lye, non-irrigated trees and reused lye. Olive quality was tested after one month from olive packing. The error bars represent the standard errors of 6 replicates. Different letters mean significant differences according to a Duncan's multiple range test (P<0.05).

Fig. 5. The effects of the reuse of lye, tree irrigation and the presence of salt in the preservation solution on the firmness of Hojiblanca black olives. Measurements were made after one month from olive packing. The error bars represent the standard errors of 12 replicates. Different letters mean significant differences according to a Duncan's multiple range test (P<0.05).

Fig. 6. The effect of calcium addition in the packing solutions on the firmness of Hojiblanca black olives one month after sterilization. Analyses were made after one month from olive packing. The error bars represent the standard errors of 6 replicates. Different letters mean significant differences according to a Duncan's multiple range test (P<0.05).

Fig. 7. The effect of tree irrigation on the content of phenolic compounds in the Hojiblanca black olives. Analyses were made after one month from olive packing. The error bars represent the standard errors in triplicate. Different letters mean significant differences according to a Duncan's multiple range test (P<0.05).

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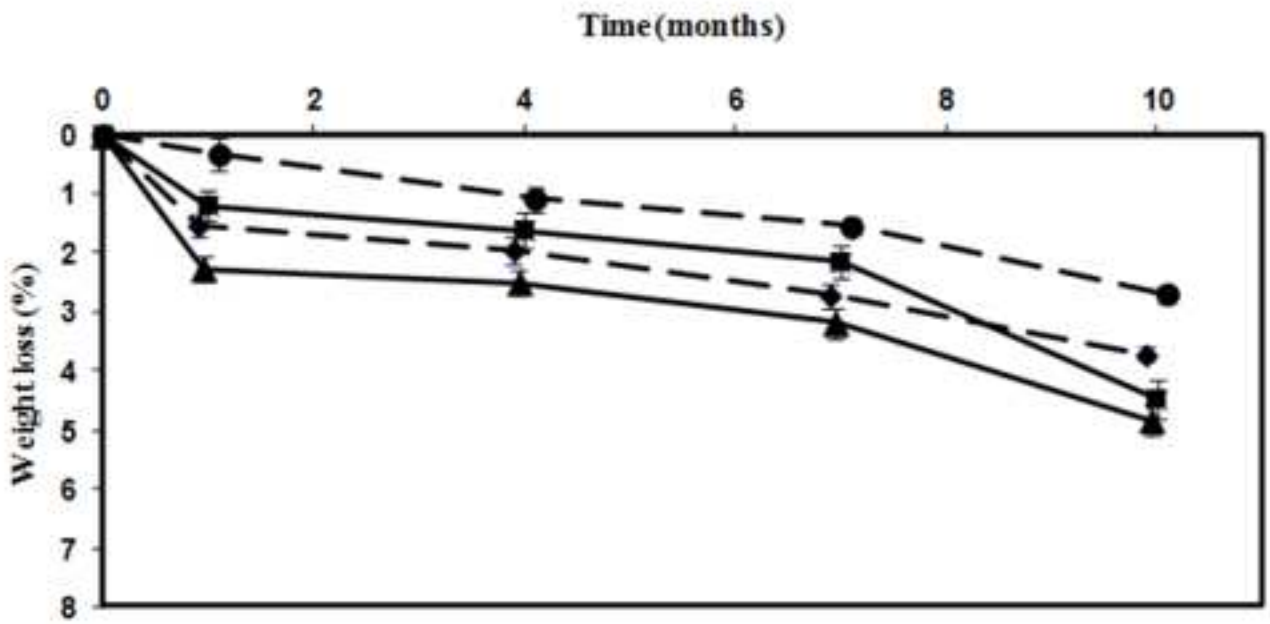

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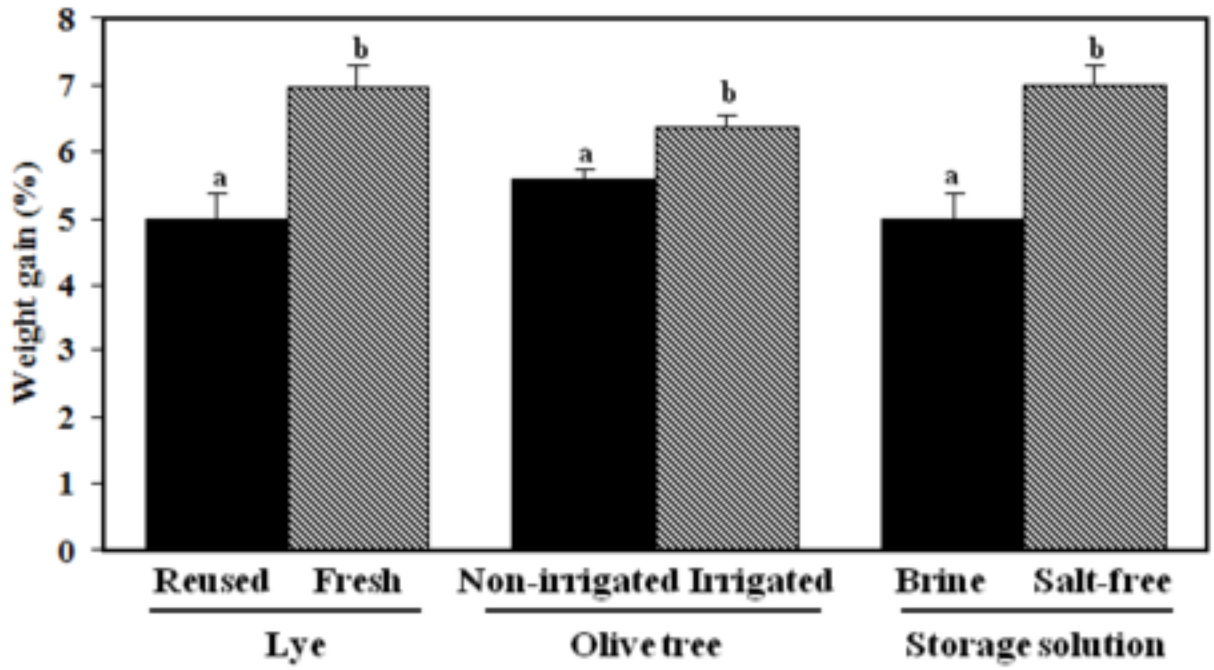

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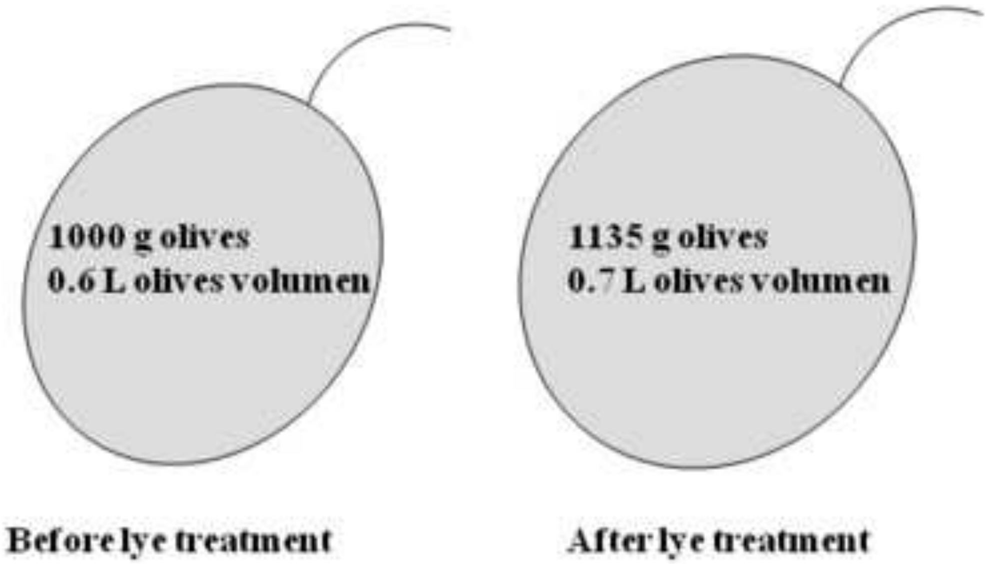

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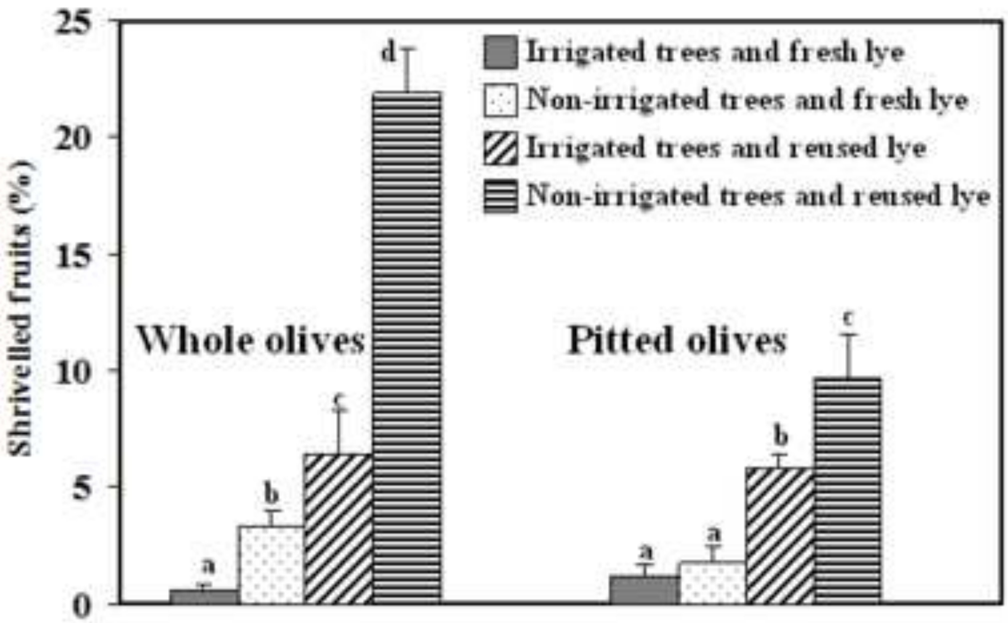

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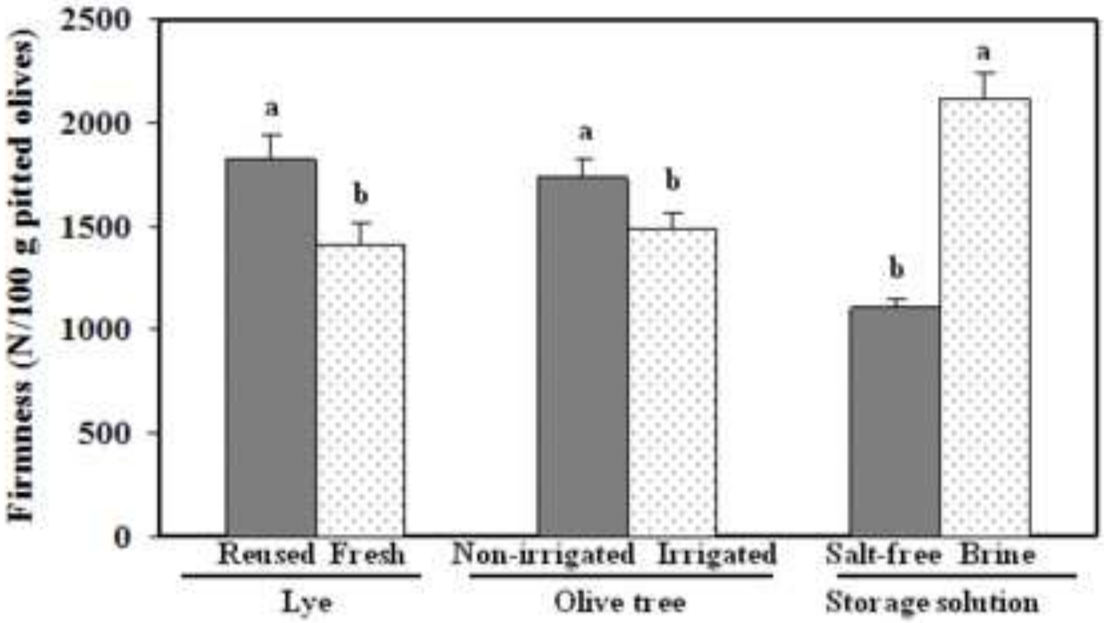

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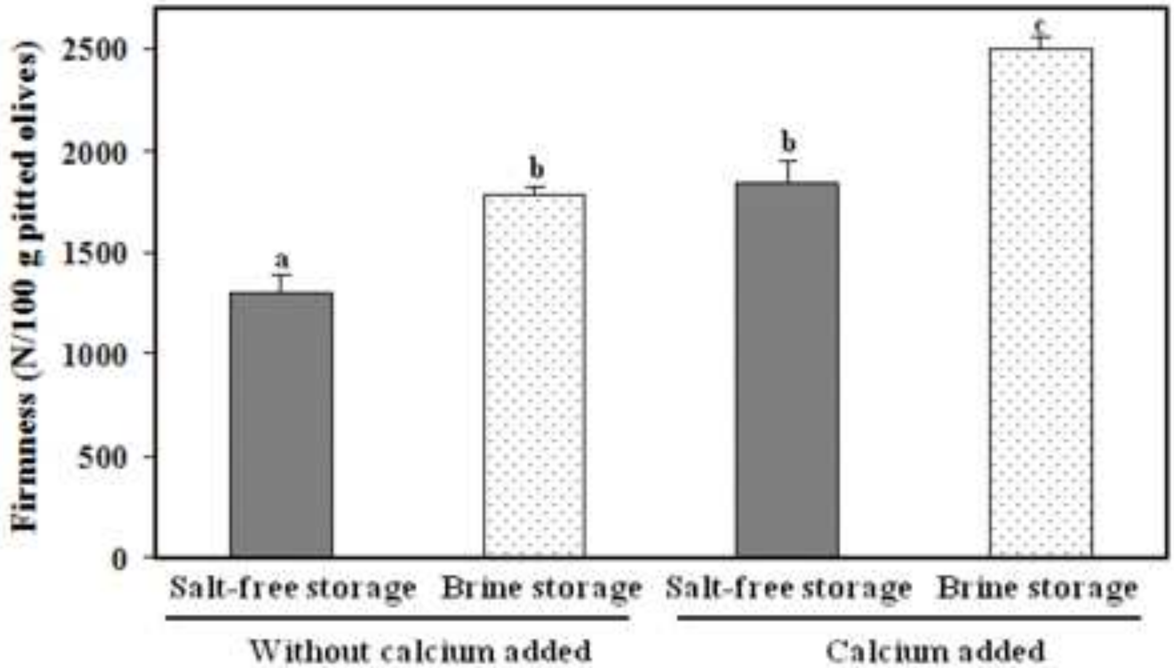

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