LWT - Food Science and Technology 55 (2014) 403–407

Contents lists available at SciVerse ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

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

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A R T I C L E I N F O

Article history:
Received 17 June 2011
Received in revised form
29 May 2013
Accepted 19 June 2013

Keywords:
Olive
Weight
Shriveling
Firmness
Phenolic

A B S T R A C T

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.

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 (Brenes, García, Romero, & Garrido, 1998; De Castro, García, Romero, Brenes, & Garrido, 2007; García et al., 1991) 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 (Marsilio et al., 2006; Proietti & Antognozzi, 1996). 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 (Marsilio et al., 2006; Patumi et al., 2002) 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

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0023-6438/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.lwt.2013.06.015

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 et al., 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 121 °C 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 × 4.6 mm, Waters Inc.) column was used. The HPLC system consisted of a Waters 2695 Alliance (Waters Inc., Milford, 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 mL of water (pH adjusted to 2.3 with phosphoric acid) and 10 mL of methanol. The concentration of the latter solvent was increased to 30 mL/70 mL (methanol/water) over 10 min and maintained for 20 min. Subsequently, the methanol concentration was raised to 40/60 (mL methanol/mL water) over 10 min, maintained for 5 min and then increased to 50/50 (methanol/water). Finally, the methanol concentration was increased to 60/40, 70/30 and 100% in 5 min intervals. The flow rate of 1 mL/min and a temperature of 35 °C were used (Medina, Brenes, Romero, García, & de Castro, 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