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Trends in table olive production

Elaboration of table olives

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RESUMEN

Elaboración de aceitunas de mesa

Las aceitunas de mesa son uno de los principales encurtidos que se preparan actualmente a nivel mundial. España es el primer país productor y exportador. El objetivo de cualquier proceso de elaboración es eliminar el amargor natural de los frutos debido a la presencia de la oeuropeína. Los tipos de preparaciones más importantes son: Verdes Estilo Español, Negras Naturales y Negras (ennegrecidas por oxidación). En el presente trabajo se resumen los tres procesos de elaboración, revisándose la situación actual del conocimiento en cada una de las fases de los distintos procesos productivos.

PALABRAS-CLAVE: Aceituna de mesa - Estilo Español - Negra (madura) - Negra Natural.

SUMMARY

Elaboration of table olives

Table olives are one of the main pickled products prepared throughout the world. Spain is the first producing and exporting country. In general, any processing method aims to remove the natural bitterness of this fruit, caused by the glucoside oleuropein. The most common types of preparation are: Spanish Style Green, Natural Black and Black (Ripe) Olives (darkened by oxidation). In this paper the three elaboration processes are summarized, reviewing the current situation of the different phases of the production process for each one.

KEY-WORDS: Black Ripe - Natural Black - Spanish Style - Table olive.

1. INTRODUCTION: TRADE PREPARATIONS

"Table olives are the sound fruit of varieties of the cultivated olive trees (*Olea europaea* L.) that are chosen for their production of olives whose volume, shape, flesh-to-stone ratio, fine flesh taste, firmness and ease of detachment from the stone make them particularly suitable for processing; treated to remove its bitterness and preserved by natural fermentation; or by heat treatment, with or without the addition of preservatives; packed with or without covering liquid" (IOOC, 2004).

In general, any processing method aims to remove the natural bitterness of this fruit, caused by the glucoside oleuropein.

A complete definition of all Trade Preparations can be found in the "Trade Standard Applying to Table Olives" (IOOC, 2004). The main commercial preparations are described below:

Treated olives. "Green olives, olives turning colour or black olives that have undergone alkaline treatment, then placed in a brine where they undergo complete or partial fermentation, and preserved or not by the addition of acidifying agents". The most common preparation is "treated green olives in brine" also known as "Spanish style" or "Seville style".

Natural olives. "Green olives, olives turning colour or black olives are placed directly in brine in which they undergo complete or partial fermentation, preserved or not by the addition of acidifying agents". The most prevalent preparation is "natural black olives" also known as "Greek style".

Olives darkened by oxidation. "Green olives or olives turning colour are preserved in brine, fermented or not, darkened by oxidation in an alkaline medium and preserved in hermetically sealed containers subjected to heat sterilisation; they shall be a uniform black colour". These are also known as "ripe olives" or "black olives".

There are other trade preparations such as: dehydrated and/or shrivelling olives and specialities prepared in different forms.

2. SPANISH STYLE GREEN OLIVES

The Spanish "Reglamentación Técnico Sanitaria para la elaboración, circulación y venta de las aceitunas de mesa" (BOE, 2001) distinguishes four elaboration typies according to surface colour: green, turning colour, natural black and ripe olives. Green olives are those obtained from fully developed green fruits during the ripening period, prior to colouring. Such olives must be firm, sound, resistant to a slight pressure between the fingers, and without marks other than natural pigmentation. The colour of the fruits may vary from green to straw yellow.

One of the basic elaboration processes used to remove bitterness is the treatment with lye or “aderezo”. This denomination is given to any of the previous types of olives when they are treated with lye and then immersed in brine where the fruits undergo a partial or complete fermentation. A scheme of the “aderezo” process is given in Fig. 1 (Fernández-Díez *et al.*, 1985).

This process is characterized, in the case of green olives, by the fruits being transported to elaboration industries, sorted, partially graded by size, and finally treated with a dilute 2.0-5.0 % (w/v) sodium hydroxide solution (lye) to chemically remove bitterness. After this treatment, olives are washed with tap water several times for variable periods of time, to eliminate the excess of alkali. Later, olives are brined (10%, w/v, approximately) where they undergo a typical lactic fermentation. When the active fermentation has finished, fruits are sorted and graded by size again and, finally, conditioned to be packed as plain (whole), pitted, or stuffed with diverse products.

The criteria for choosing a cultivar as appropriate for green table olives are the following: good size and proper shape, high relationship flesh/stone, ease in releasing the pit as well as good colour and texture in the final product. The most popular cultivars used in Spain to prepare green olives are: Gordal, Manzanilla (or Cararrasqueña) and Hojiblanca. Other cultivars also devoted to this style but produced in lower proportions are Cacereña, Morona, Aloreña, Verdial, etc. Among the cultivars used in other countries, the following can be mentioned: Sigoise (Argeria); Arauco (Argentina); Konservolia, Kalamata (Greece); Ascolana (Italy); Picholine Marocaine (Maroco); Meski (Tunisia); and Domat (Turkey) (COI, 2000).

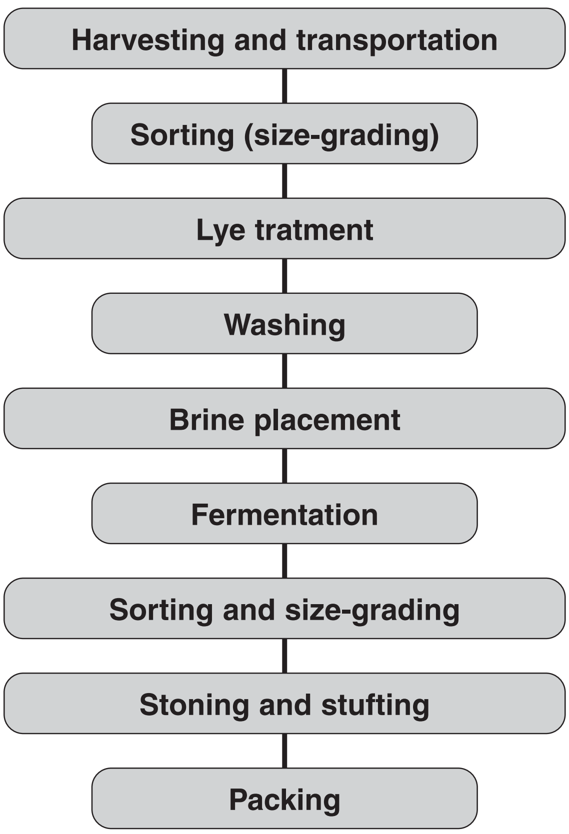

Figure 1
Elaboration process of grean table olives.

2.1. Harvesting and transportation

Green olives must be picked when the fruits have reached their maximum development (size) and prior to the colouring (pink colour).

To prevent olive damage, fruits are picked by hand (the so-called ordeño), and carefully placed in special padded baskets which are hung by their neck (“macaco”). Olive transportation is carried out in perforated plastic containers with an approximate capacity of 20 kg or in containers with a maximum capacity of 500 kg. These containers have plastic netting as walls (supported by an iron structure). The perforated walls permit the aeration of the fruits and the reduced weight also contributes to minimizing the fruit’s damage (“molestado”). Sometimes, olives are also transported in bulk, although this transportation system is not recommended because it increases the proportion of damaged olives.

Bearing in mind the contribution of hand harvesting to the high cost of the raw material and the recent developments in mechanical harvesting, conditions for both operations and transportation have been established so that the damage could be minimized. Application of this technology leads to final products of even better quality than those picked by hand (Rejano y Sánchez, 2004; Vega *et al.*, 2005). According to these authors, transportation in dilute sodium hydroxide solutions (0.3-0.4%, w/v) prevents the development of brown colour in the damage zones of the fruits. This technique also avoids the peeling of olives during the following debittering with lye, which is a problem that is observed in some cultivars when the lye is applied to fruits not subjected to a resting period of 24-48 hours before treatment. The only disadvantage of the process is that the maximum time olives can be immersed in lye is about 3 hours. After this period, fruits develop greenish spots around the stomas (“apulgarado”). However, this period can be prolonged when the lye is substituted by water. This technology is applicable to most situations that can be found during harvesting and transportation from the orchards to the elaboration factories.

It is also possible to store green olives for several weeks, before their preparation as Spanish green olives, using cold rooms and controlled atmospheres (Nanos *et al.*, 2002).

2.2. Lye treatment, washing, and brining

The lye treatment with a diluted solution of NaOH, also called “cocido” or “quemado”, is the essential step for green olive processing. Its main objective is the elimination of the bitter taste of the fresh fruits, which is achieved by the chemical hydrolysis of the oleuropein. Some cultivars require a previous resting period of 24-48 hours to avoid peeling. As mentioned above the treatment with dilute lyes, as usually applied during transportation of mechanically picked olives, can substitute this prior resting.

The concentration of the lye is adjusted, keeping room temperature in mind, so that the treatment lasts a certain period of time which is different for each cultivar. The energy of the treatment increases with the lye concentration and room temperature. Strong treatments lead to a higher permeability of the skin (El-Makhzangy Abdel-Rhman, 1999). The penetration of the lye into the flesh is considered sufficient when the chemical reaches about 2/3 of the distance from the exterior to the pit. To facilitate a homogeneous penetration, it is advisable that the olives in the batch have similar size and maturation degree. Lye treatment is normally achieved in 10,000 kg tanks. The diffusion coefficient of the NaOH though the skin ranges from 43.3 to 9.32×10^{-12} while through the flesh is $7{,}18 \times 10^{-11}$ to $1{,}18 \times 10^{-9}$ m^2/s, (respectively) (Maldonado y Zuritz, 2003; Maldonado y Zuritz, 2004). Currently, there is a tendency to apply the lye treatment at a controlled temperature, about 18°C, to avoid peeling (Sánchez *et al*., 1990) and permit a more homogeneous lye penetration.

Lye is a heavily polluted solution. Nowadays, lye re-use is a widely extended practice to decrease the environmental impact of these solutions. Lye recuperation is achieved by simply incorporating the NaOH content which has been used during the previous treatment into the solution. Then, this reconstituted solution can be used normally. On a pilot scale level, these lyes were re-used for up to 14 cycles (Garrido *et al*., 1979). However, the current industrial practice is to re-use them from 5 to 7 cycles.

When the lye treatments finish, the alkaline solution is removed and olives are covered with tap water (“lavado”). The main objective of this washing is the elimination of the excess of the alkali that penetrated into the flesh. An excessive washing period is not advisable because it may cause losses of diverse soluble compounds which will be later required for an appropriate fermentation (Borbolla y Alcalá y Rejano, 1978).

The number and the time devoted to washing waters varies, although the current trend is to reduce them to only one, which can last from 12 to 15 hours. This practice is, in part, due to the progressive water shortage and the high pollutant impact of the washing waters, similar to that produce by used lyes. The re-use of washing waters, after their neutralization and addition of an amount of acid which is equivalent to one or two washing waters, is not an affective system for the reduction of combined acidity (Rejano *et al.,* 1986) because the acidified (with HCl, phosphoric, or fermentation brines) solutions which are put into contact with fruits decrease the efficiency of such solutions to remove alkali. The use of warm water does not improve the release of alkali either (Sánchez, *et al*., 1995). The washing step may also be suppressed all together or be substituted by the addition of HCl in concentrations of up to 0.07 eq/l in the equilibrium. The HCl efficiency when the acid is added in these conditions is only about 81-87% of the theoretical yield (de Castro *et al*., 1989). This proportion of acid is not detected by a sensory panel or consumers; however, general preference increases in proportion to the number of washing waters given to the alkali treated olives.

When the washing waters are removed, olives are immersed in a 10-11% (w/v) brine in which olives are maintained during the fermentation and storage periods. Normally, fermentation is achieved in underground fermenters. Brine stabilization is fairly rapid and in a few days the NaCl concentration stabilizes at a level of 5-6%. In Tunisia, working with olives of Meski cultivar, the best debittering conditions were established as: 2.00% (w/v) NaOH lye concentration and a brine concentration of 9.0% (Chammen *et al*., 2005). Under these conditions, a good fermentation and a fairly good final quality were possible.

2.3. Fermentation and storage

At the beginning of the brining process, the pH of the brine shows values higher than 10 units due to the alkali that is released by the fruits. The development of a series of successive organisms produces different acids and lowers the pH to values around 4.0 units, mainly due to the growth of lactic acid bacteria. The fermentation is still spontaneous in most cases since, currently, the use of starter cultures is not a common practice in this and other fermented vegetable products. However, the use of resistant to alkaline pH (around 9 units) *Lactobacillus pentosus* 5138 starter culture initiates and accelerates the fermentative process (Sánchez *et al*., 2001). This inoculation reduces the *Enterobacteriaceae* population, and consequently the risk of potential spoilage, giving rise to a rapid brine acidification and decrease of pH levels in comparison with control treatments without inoculation. Other alternative inoculation system may consist of a sequential inoculation of *Enterococcus casseliflavus* cc45 and *Lactobacillus pentosus* CECT 5138, which leads to a rapid acidification during the first two days of brining, with a fast consumption of the fermentable sugars and a marked pH decrease pH (de Castro *et al*., 2002). During fermentation, there is a slow hydrolysis of the elenolic acid glucoside with the production of elenolic acid and glucose which is also used by the microorganisms present in the brine and maintains the microbial activity for a longer period of time (Brenes and de Castro, 1998).

The main differences among the physicochemical characteristics and the composition of the fermented products are mainly due to cultivars and elaboration practices in each industry rather than variations due

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to seasons. Thus, in general, Hojiblanca cultivar shows higher pH, combined acidity, and volatile acidity than Manzanilla and Gordal (Montaño *et al*., 2003). However, the volatile acidity/total acidity rate is the same regardless of the cultivar and season but is strongly related to propionic fermentation. When the sugars are exhausted, the fermentation period can be considered finished and the storage period begins. During this time, one may observe the growth of bacteria of the *Propionibacterium* genera which increases the pH because of the production of acetic and propionic acids using the lactic acid produced during the previous phase of active fermentation as substrate. (Cancho *et al*., 1980). If this process were extensive it could cause the spoilage known as "zapateria". This can be avoided by increasing the NaCl concentrations at the end of the main lactic fermentation up to 9% (w/v).

2.4. Packing and pasteurization

By the end of fermentation, olives must have reached the proper physicochemical characteristics so as to permit the packing and consumption of the product. Nevertheless, green fermented olives must undergo a series of complementary operations to adapt them to the different commercial presentations. Usually, they consist of passing the olives over conveyor belts where defective fruits are removed. Then olives are also subjected to grading by size which is achieved by passing the olives over a series of divergent cables. An olive falls down when the distance between cables is equal to its transversal diameter. Currently, most of the factories use automatic machines for sorting defective olives (Díaz *et al*., 2000, 2004). The sizes are grouped and preserved in plastic drums of about 300 kg where the fruits are kept until they are packed. These operations are also used to reduce variability among the pH, free acidity, and NaCl which normally present certain dispersion when they are the fermenters. These operations lead to the obtaining of olives which are similar in size, have uniform organolpetic characteristics and the same levels of NaCl and free acidity. Usually, these levels are high enough so as to assure product stability during the commercial life of the product. Pitted or stuffed olives are prepared just before packing to assure the preservation of the most outstanding quality.

In the past, the packed olives were stabilized only by their physicochemical characteristics, high values of free acidity and NaCl (0.5-0.7 and 5-7, respectively) and low pH (<3.5 units). In fact, the commercialization of these products requires pH values from 3.2- to 3.3. Otherwise the growth of microorganims is very probable. However, the progressive preference of consumers for low NaCl levels has modified such conditions and the stabilization of the final product under the lower NaCl concentrations requires the use of pasteurization. The microorganisms of reference for this process are the propionic bacteria because these are the germs with highest thermal resistance of all potential flora able to grow in the packed product (González Pellisó *et al*., 1982). The minimum value of lethality units established for a proper preservation of the product was fixed at 15, based on the thermal destruction studies carried out by these authors. When pasteurization used temperatures above 80°C, the quality of the olives remains practically unaltered. The degradation of the colour and texture as a consequence of such treatments were studied by Sánchez *et al*., (1991). In any case, one must always use fermented olives of the highest quality for obtaining a sound final product because there is a progressive degradation (first order kinetic) of texture with self life time (Sánchez *et al*., 1997).

In general, the final packing is achieved with fresh brine; but the re-use of fermentation brine is also possible for this operation. Brine regeneration through a cut off of 4000 daltons membrane produced packed anchovy stuffed olives of acceptable quality (Rejano *et al*., 1995).

Plastic pouches are frequently used as packing material, especially for local brands. However, they cannot be pasteurized because the heat accelerates the polymerization of ortho-diphenols and a progressive browning of the product (Sánchez *et al*., 1991).

Another popular product nowadays is the so-called anchovy flavoured olive, which is obtained by the addition of sodium glutamate to the packing brine. One must be careful with this preparation because the incorporation of this chemical increases the buffer capacity of the solution and the final pH obtained with respect to those without it. It is advisable to subject these olives to an intense washing before packing to counteract the effect of such an addition. In any case, a high quality product requires the use of moderate NaCl level and a relatively high pH level. So, the product requires pasteurization (Rejano y Sánchez, 1996).

3. NATURAL BLACK OLIVES

For preparing this type of olives, the fruit should be completely ripe but not overripe because olives picked at the end of the season retain an excellent colour after processing but their texture is not firm.

3.1. Brining and Fermentation

3.1.1. Anaerobic conditions

Traditionally the olives are placed into brine with a salt concentration between 8 and 10 % (w/v), although in colder areas lower concentrations (about 6 %) are used. The fermentation process takes a long time because diffusion of fermentable compounds through the skin, when the olives have not been treated with alkali, is slow. In this process the elimination of the bitterness in olives is achieved only by solubilisation of the oleuropein into the brine and equilibrium is reached in 8-12 months.

During the first days Gram-negative bacteria are present, the population reaches its maximum 3rd -4th day of brining and disappears after 7-15 days. The main genus present is: *Citrobacter, Klebsiella, Achromobacter, Aeromonas* and *Scherichia* (González *et al.*, 1975). However, in this spontaneous fermentation yeasts dominate. They start growing during the first few days of brining, reach their maximum population after 10-25 days and are present throughout the whole time that the olives are kept in the fermenters. *Saccharomyces oleaginosus* and *Hansenula anomala* can be considered the most representative species of this fermentation, followed by *Torulopsis candida, Debariomyces hansenii, Candida didensii* and *Picchia membranaefaciens* (Durán y González, 1977). With certain varieties (Gordal, Hojiblanca, etc.) and low salt concentration (below 5%) Gram-positive lactic cocci, *Pediococcus* and *Leuconostoc* genus are detected during the first days; also, *lactobacillus* growth during the whole fermentation period, if the salt concentration is not raised above 8.0 % (Garrido *et al.*, 1987).

The elimination of bitterness in olives is achieved by solubilisation of the oleuropein into the brine and the equilibrium is slow, it is reached in 8-12 months (Fernández *et al.*, 1985).

Once the fermented fruits under anaerobic conditions are ready to be marketed (bitterness removed), they are oxidized (darkened) by exposure to air in boxes of no more than 20 kg; this process improves the skin colour (Fernández *et al.*, 1972). The maximum length of this treatment should not to surpass 48 hours to avoid wrinkles in the olives.

During the fermentation of the olives in anaerobic conditions a variable proportion of fruits with “gas-pocket” spoilage (also it is called “fish eye”, “alambrado” in Spain) are produced. This spoilage is characterized by the development of blisters in the flesh of olives which may extend to the pits of the fruits. This is due to the CO_2 accumulation that is produced by the effect of olive respiration and the activity of the responsible microorganisms during the fermentative process (García *et al.*, 1982).

3.1.2. Aerobic conditions

To avoid the appearance of “gas pocket” spoilage, fermentation under aerobic conditions is carried out. The fermenter should be modified by introducing a central column through which air is bubbled (Figure 2) (García *et al.*, 1985).

The air removes the CO_2 produced by fruit respiration and microbial metabolism. The rate of air injection depends on the technical design of the factory and the column, but may range between 0.1-0.3 volumes per fermenter volume per hour (Garrido *et al.*, 1985a). Air bubbling maintains a certain percentage of dissolved oxygen in the brine that induces the growth of facultative instead of fermentative microorganisms

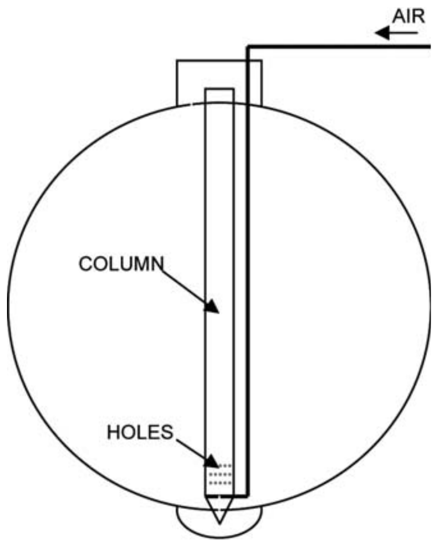

Figure 2
Fermentation vessel fitted with the aeration column

The species of Gram-negative bacteria found are the same family (Enterobacteriaceae) as those found in the traditional process. Yeasts are present during the whole fermentation process with a higher population than under anaerobic conditions. The most representative species identified with facultative metabolism have been: *Torulopsis candida, Debaryomices hansenii, Hansenula anomala* and *Candida diddensii*; with oxidative metabolism: *Pichia membranaefaciens, Hansenula mrakii* and *Candida bodinii* (García *et al.*, 1985). Lactic acid bacteria grow only when the salt concentration is below 8 %; at the beginning they are almost exclusively *Leuconosto*c and *Pediococcus*, but after 20 days *lactobacillus* predominate (Durán *et al.*, 1986).

3.1.3. Fermentation control

Fermentation under aerobic or anaerobic conditions is influenced by the initial pH and NaCl concentration. In order to prevent excessive growth of Gram-negative bacteria, acetic acid must be added to the brining solution to reduce the pH to below 4.5. If the pH is maintained high, the population of Gram-negative bacteria is excessive and produces a great volume of CO_2, which causes gas-pocket spoilage in the olives (Fernández *et al.*, 1985).

The NaCl concentration is also fixed according to the type of fermentation required. If only we aim for yeasts, the percentage of salt must be maintained in higher values than the 8%. The low acidity development (0,2-0.4%, as lactic acid) and the relatively high pH (4.3-4.5) mean that the salt concentration should be 8-10% to ensure adequate preservation. If growth of lactobacillus is preferred the initial NaCl concentration must be 3-6 % and when fermentation is concluded, salt should be added to reach 6-8% in the equilibrium. The final pH is lower (3.9-4.1) than with high NaCl percentages and the acid concentration higher than 0.6 % (expressed as lactic acid) (Garrido *et al.*, 1987).

When air is bubbled, the flux is controlled by a flow meter adapted to the air inlet of a fermenter. Usually, the flux is fixed on the basis of past experience.

When the active fermentation process is ended (3-4 months), aeration is only necessary if the CO_2 concentration is increasing and is characterized by the increase of brine volume during processing (Garrido *et al.*, 1985b).

The main advantages of the aerobic process compared with anaerobic fermentation are: (i) a lower incidence of gas-pocket spoilage; (ii) the elimination of the shrivelling of fruits; (iii) a reduction in the length of the process because air bubbling provokes a continuous brine recirculation that causes a rapid diffusion of sugars and bitter compounds into the liquid, making the fermentation faster and the organoleptic characteristics (bitterness) of the olive available for consumption in only 3 months (Garrido *et al.*, 1987b); (iiii) improved colour as a consequence of the different anthocyanin polymerization (Romero *et al.*, 2004), flavour and texture.

3.2. Packing

Until some years ago, these olives were not packed but were sold in bulk. Glass jars or cans are rarely used for this product, although nowadays there is an increasing demand for them. Usually, there are two presentation forms: naturally black olives in brine (Greek style) and Kalamata style. In the first, the most frequent values for commercial products are: pH about 4.0-4.2 and salt concentration between 6-8%. For Kalamata style, the pH values are lower because wine vinegar must be added and, furthermore, olive oil (García *et al.*, 1986)

To assure good conservation of the packed product pasteurization can be employed (in similar conditions to green olives) or the addition of sodium sorbate to reach a level of 0.05 % (as sorbic acid) in the equilibrium (García *et al.*, 1986).

4. BLACK (RIPE) OLIVES

The different phases of the elaboration process of this commercial preparation are summarized in the Figure 3.

The optimum colour for harvesting olives to be elaborated according to this preparation is when the fruit has a yellow-straw tone with light differences according to varieties (Fernández *et al.*, 1972) However, nowadays, they are collected when the fruit has a green colour, practically at the same time as those intended for elaboration as Spanish style.

To produce ripe olives, fruits can pass directly to the oxidation process, without any preservation. However, not all the fruits can be processed immediately, because factories do not have the

Figure 3
Flow scheme of ripe black olive elaboration process

required capacity and because it is not desirable to keep large amounts of canned merchandise in stock.

Also, it is possible to employ green Spanish style olives as raw matter, though the working conditions for obtaining a good final product are different (García *et al.*, 1987).

4.1. Storage

In Spain the procedure normally used for this stage was similar to that used for naturally ripe (black) olives. Briefly, it consisted of putting the olives into fermentation vessels in 4-6 % NaCl (w/v) brine. This concentration was increased progressively to 8-9 % salt which was maintained throughout the storage stage (Fernandez *et al.*, 1985)

However, this system leads to serious damage to the fruits, shrivelling and gas-pocket (“alambrado”) formation, produced by the accumulation of respiratory gases (CO_2) of the olives themselves (García *et al.*, 1995; Romero *et al.*, 1996), and the activity of Gram-negative bacteria and yeast responsible for this fermentation (Fernández *et al.*, 1985).

Modification to this method was introduced to prevent both types of spoilage. Correcting the initial pH of brines to 3.8-4.0 while acetic acid can inhibit the growth of Gram-negative rod and CO_2 accumulation are prevented by aeration in a similar fashion to naturally black olives (Brenes *et al.*, 1986).

The process was characterized by the maintenance of pH values, a slow sugar consumption and very low content of CO_2. (Garrido *et al*., 1993). The salt concentration must be increased to 6-7% to assure conservation when temperatures increase (spring, summer). The most representative germs of this fermentation were the yeasts, whose population grew rapidly from brining (at a higher rate as the salt content was lower). They remained throughout storage, although after 180 days a decreasing tendency was observed. The most representative species were: *Pichia membranaefaciens*, *Pichia fermentans* and *Hansenula polymorpha* (Fernández *et al*., 1992).

The development of a lactic fermentation is very difficult (García *et al*., 1992a; Durán *et al*., 1994 a; Durán *et al*., 1994 b) due to the inhibiting effect of the phenolic compounds (Ruiz *et al*., 1993; Durán *et al*., 1993) which are spread from the flesh of the olives to the brine (Brenes *et al*., 1993a).

In the USA a salt-free storage of olives combining acidulated water (lactic and acetic acid) in anaerobic conditions is used. This method was developed to alleviate the problem of brine disposal and sodium benzoate is also required and calcium chloride is usually added to the liquid to improve the olive texture (Vaughn, 1969).

In Spain, acid conservation is accomplished initially adding an acetic acid concentration between 1.5-3.0 %. In some instances, $CaCl_2$ (0.1-0.3 %, w/v) is added to prevent deterioration of the texture (Brenes *et al*., 1994) and the brine is aired to avoid the appearance of wrinkling and/or gas-pocket spoilage.

4.2. Darkening

This process is performed in horizontal stainless steel or polyester and fibber glass cylindrical containers. Pressurized air is introduced through a network of pipes so that the oxidation process is uniform (Fernández *et al*., 1985).

4.2.1. Lye treatments and air oxidation

The industrial procedure for the production of ripe olives consists of successive treatments with dilute NaOH solution (lye). During the intervals between lye treatments the fruits are suspended in water through which air is bubbled. Throughout this operation the olives darken progressively owing to the oxidation of ortodiphenols, hydroxytyrosol (3.-, 4 dihydroxyphenil ethanol) and caffeic acid (Brenes *et al*., 1992; García *et al*., 1992b).

The number of lye treatments is generally between 2 and 5. Penetration into the fruits is controlled so that the NaOH of the first treatment merely passes through the skin. Subsequent treatments are applied so that they penetrate deeper into the flesh. The final lye treatment must reach the stone (Fernández *et al*., 1985). It is possible to make only one lye treatment. The concentration of sodium hydroxide in the lye solution (between 1-4 %, w/v) depends on the ripeness of the fruit, its variety, preservation system, the environmental temperature and the desired penetration speed.

After each NaOH treatment, water was added to complete a 24 hour cycle. To reduce wastewater it is possible to reuse the storage liquid diluted with tap water (Brenes *et al*., 1998).

It is possible improve the colour of ripe olives and accelerate the oxidation rate by the addition of manganese cations (Brenes *et al*., 1995; García *et al*., 1996; Romero *et al*., 1998; Romero *et al*., 2000; Romero *et al*., 2001). The addition of manganese lactate or manganese gluconate is considered a processing aid by the IOOC (2004).

4.2.2. Washing (neutralization)

After the last lye treatment, olives are washed several times with water to remove most of the NaOH and lower the pH in the flesh to around 8 (Fernández *et al*., 1985). It is possible to diminish the number of washes by means of added food-grade HCl to the liquid or by injecting CO_2 into the containers (Brenes *et al*., 1993b).

4.2.3. Colour fixation

The black surface colour obtained is not stable and fades progressively after oxidation and during the shelf life of the packed product. To prevent this deterioration, only the use of ferrous gluconate and ferrous lactate is legally permitted for ripe olive processing (García *et al*., 1986a). Normally, ferrous salts were added at a concentration of 100 ppm (parts per million) of iron in the liquid. Iron diffusion into the flesh is complete in about 10 hours, but normally, this phase is prolonged to about 24 hours (García *et al*., 2001).

4.3. Canning and sterilization

The black (ripe) olives (whole, pitted, slices, quarters or paste) are packed in cans varnished on the inside or glass containers with a liquid that contains 2-4 % of NaCl and 10-40 ppm of iron to prevent deterioration of their black colour (Garrido *et al*., 1995). The best final colours are obtained when the pH of the olive flesh is around 7.0 (Brenes *et al*., 1995b). The addition of calcium caused a substantial increase in ripe olive firmness (García *et al.,* 1994; Romero *et al*., 1995)

Whatever the employed container, once closed it should be sterilized in a retort. To assure proper conservation it should reach a minimum value of accrued lethality of 15 F_0. Generally, the thermal treatment is accomplished at 121-126°C.

Ripe olives could be packed as acidified foods (pH< 4.6) in plastic pouches by lactic o gluconic acid additions, applying pasteurization for preservation (García *et al*., 1999).

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