GRASAS Y ACEITES, 57 (1),
ENERO-MARZO, 16-24, 2006,
ISSN: 0017-3495

The postharvest of mill olives

By **José M. García** and **Khaled Yousfi**

Departamento de Fisiología y Tecnología de Productos Vegetales
Instituto de la Grasa, CSIC,
Avda. Padre García Tejero 4 - 41012 Sevilla, Spain.

RESUMEN

La postcosecha de aceituna de molino

El mayor deterioro del aceite de oliva es debido a la inadecuada manipulación de las aceitunas durante el tiempo que media entre su cosecha y su procesado. El almacenamiento de las aceitunas se lleva acabo mediante el simple amontonamiento del fruto, esperando su procesamiento. Estos frutos desarrollan toda clase de procesos degenerativos en un corto periodo de tiempo. Los aceites obtenidos a partir de estos frutos exhiben deterioros hidrolíticos y oxidativos característicos, confirmados por sus valores altos de acidez, de índice de peróxidos o de absorbancia en la región ultravioleta a 232 y 270 nm. Para evitar esta situación, la industria intenta reducir al máximo el intervalo entre la cosecha y el procesado del fruto, mediante un aumento de la capacidad de molturación. Sin embargo, el equipo necesario para prevenir la acumulación de fruto en Enero no se precisa para el resto de la campaña. En este capítulo, la refrigeración de las aceitunas o el uso de tratamientos físicos, que permiten el procesado de frutos poco maduros, son analizados como alternativas posibles.

PALABRAS-CLAVE: Aceite de oliva - Calidad - Olea europaea - Refrigeración - Tratamiento de calor.

SUMMARY

The postharvest of mill olives

The greatest deterioration of olive oil is due to poor handling of the olives during the time between harvesting and processing. Storage of olive fruits is carried out by simple heaping in fruit piles, waiting their processing. These fruits develop all kinds of degenerative processes in a short period of time. Oils obtained from them show characteristics hydrolytic and oxidative deteriorations confirmed by their high acidity values, peroxide value or ultraviolet absorbance at 232 and 270 nm. To avoid this situation, the industry is currently reducing the interval between harvesting and processing, through an increase in milling capacity. However, the equipment necessary for preventing the accumulation of fruit in January would be unnecessary for the rest of the season. In this chapter, refrigeration of the olive fruits, or the use of physical treatments, to allow the processing of unripe fruits, are analysed as possible alternatives.

KEY-WORDS: Heat treatment - Olive oil - Olea europaea - Quality - Refrigeration.

1. INTRODUCTION

Virgin olive oil is by definition the oil obtained from the olive fruit through physical procedures, which include the washing, grinding, beating, pressing, decantation, centrifugation or filtration, without being mixed with oils of another nature. In the same way, it seems logical to relate the quality of an orange juice to the physiological state of the fruits wherefrom it is obtained; the quality of virgin olive oil is directly related to the quality of the fruit from which it is extracted. In this chapter the consequences of the postharvest manipulation on the olive physiology and on the oil quality will be studied. In general, the postharvest period of a fruit includes all the processes that the olive is subjected to, from harvesting up to its sale in the market or its industrial transformation. Thus, normal activities such as packaging, transportation, selecting, sorting, cleaning, antifungal treatments, grading, or storage are all associated with this period. Traditionally, olives have been treated from the moment of harvesting until their processing with the same sensitivity that construction material such as sand or gravel might receive (Figure 1). The degree of excellence of virgin olive oil is directly related to the physiological state of the fruit at the moment of its processing, and this is the most determinant factor to its level of quality. Unfortunately, obtaining the best quality virgin olive oil is not rewarded by a sufficient increase in the market value of this oil in comparison to that reached for other virgin oils from a lower quality category (Fundación del Olivar, 2005a). Frequently, extra virgin olive oil is sold only about 3% more expensive than the so-called “lampante”, which can not be commercialized for human consumption without previous refining and, in fact, oil of the “virgin” category can reach a better price than “extra virgin” oil, in spite of its lower level of quality (Fundación del Olivar, 2005b). Therefore, to address the olive industry on the goal of obtaining a high quality olive oil



Figure 1
Olive pile. Source: J. Alba

may seem utopia. Nevertheless, it is an indisputable fact that olive oil will never be able to compete in price with other oils, due to the high cost of its harvesting and the scanty yield that is obtained from its physical extraction (25 % of the initial weight, at best). The competitiveness of olive oil comes from its intrinsic quality, superior to any another edible oil (Touzani 2004). The increasing value that the Mediterranean diet is acquiring among nutrition specialists has contributed to an international rise in the demand for virgin olive oil (Wahrburg et al. 2002). For this reason, in spite of the scarce profit margin rendered from its price, the production and sale of virgin olive oil is increasing systematically (Grapevines et al. 2003). Throughout this chapter the postharvest strategy that the olive industry has selected for obtaining a high quality product will be discussed and the utilization of other alternative systems will be proposed.

2. POSTHARVEST OF OLIVES: CURRENT SITUATION AND FUTURE TRENDS

Historically, the greatest deterioration of olive oil is due to poor handling of the olives during the time between harvesting and processing. After harvesting, which is normally done with the cheapest process called "vareo" (shaking the olive branches with rods), the olives, laying on the soil from the beaten branches, are picked up and put in dump truck boxes, sometimes even using digging machines (Figure 2). Storage of these olives is carried out by simple heaping in fruit piles on the courtyard of the olive mills, awaiting their processing. In these conditions all kinds of degenerative processes and pathogenic infections develop in the fruit in a short period of time. Anaerobic micro-organisms act in the internal zone of the pile and aerobic ones in the outermost areas. At the same time, the metabolism of the accumulated fruits results in a considerable increase in temperature in the pile, autocatalyzing the degenerative processes and accelerating fruit degradation. Normally, oils obtained from these fruits are characterized by presenting hydrolytic and oxidative deteriorations measured by their high acidity values, peroxide value or ultraviolet absorbance at 232 and 270 nm, produced respectively by lipases, lipoxygenases and liases of both olive and parasitic origin (González-Cancho, 1957; Mazuelos-Vela, 1972; García and Streif, 1991). The oil obtained also develops an undesirable sensory attribute called "atrojado" (fusty), due to the presence of a high content in volatile acids, such as acetic or butyric and in fat alcohols, such as 1-octen-3-ol and 2-octen-1-ol (Gutiérrez et al., 1981; Olías et al., 1988; Olías and García, 1997).

To avoid this physical and biological deterioration of the fruit, which determine the subsequent production of a low quality virgin oil, the industry is currently following a main strategy of reducing the interval between harvesting and processing, as much as possible and recommends three steps for the olive during this period: Firstly, the separation of harvested olives from the ones previously falling onto the soil is strongly recommended. For this purpose the use of canvases on the soil for the reception of the harvested fruits is commonly used. Secondly, the use of perforated boxes is recommended for keeping the olives: a larger format of 100 x 100 x 120 cm^3 for a short storage period ($\leq$ 48 h) (Figure 3) and a small one (50 x 30 x 40 cm^3) specially for longer periods of storage (Figure 4) (Tous et al. 2005). Finally, the main recommendation that the olive industry is following consists in an increase in milling capacity in order to avoid a wait period $\geq$ 24 h from the harvesting to the oil extraction (de Toro et al. 2002).

The separation of healthy from decayed fruit is one of the basic premises of postharvest technology in order to guarantee that it will arrive to the market or processing plant in good condition. It is especially important for the sensory quality of virgin oils. The human nose is very sensitive to the odours developed in infected olives. A small presence of these undesirable attributes could contaminate a large amount of oil, resulting in a serious loss of quality. On the other hand, these infected fruit randomly placed in the olive pile are infection nests from which the parasitic micro organisms, mainly fungi, can rapidly proliferate among the rest of the fruit. This progressive deterioration is accelerated by the presence of mechanically damaged fruits, which are especially



Figure 2
Digging machine used in olive harvesting.
Source: J. Alba.

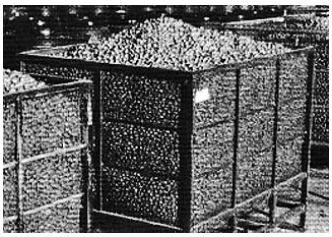


Figure 3
Container for table olives.
Source: P. García



Figure 4
Olives packed in a 22 kg able perforated plastic box.
Source: Tous et al. 2005

sensitive to the fungi infection. The use of "vareo" causes a high incidence of fruit damage and, indirectly, facilitates oil deterioration.

Unfortunately, the use of perforated plastic boxes to contain the olives during their postharvest period is not yet an extended practice. Normally, the use of boxes is limited to transporting the olives from harvesting to the dump truck boxes, but even this simple measure can suppose a considerable improvement in the maintaining fruit integrity in comparison to the use of diggers for this task. In addition to the reduction of mechanical damage, the main aim of this system is to avoid deterioration due to excessive fruit accumulation. The holes in the boxes are very important to allow for ventilation of the olives, delaying the fermentation processes in the stored fruit. The use of boxes for the storage of olives intended for oil would mean a significant improvement in quality for the olive oil industry. It implies the introduction of the palletization system, habitually used for other commodities, such as oranges, apples, pears, etc. For instance, palletization, in addition to a better preservation of the fruit to damage caused by handling , allows for quick cargo removal in minutes using a forklift, more efficient olive storage, higher quantity in a lower space, and better organization of the olives, which could be classified by their different characteristics: origin, quality, harvesting system, variety, etc. However, the main advantage of this system is that it would facilitate the traceability of the olive oil from the olive tree to the bottle of virgin olive oil. Thus, producers, who obtain the highest quality virgin olive oil, could sell their product at a higher price than other oils of inferior quality. This system should be an affective tool for securing the characteristic of quality of a determined denomination of origin.

The acceleration of fruit processing through the increase of milling capacity is the least imaginative and the most expensive solution to prevent olive oil deterioration caused by the use of damaged and/or decayed fruits, which have been stored in poor conditions. Historically, the olive oil industry has suffered two traditional impediments, which condition its quality production: Reduced harvesting time and olive tree alternation (Table 1). Olive harvesting is done during a relatively short period of time, when fruit offer a better yield for oil production. Thus, in the last five seasons, almost 40 % of oil production has been concentrated in the month of January. The machinery necessary for preventing the accumulation of fruit waiting oil extraction during peak production in January would be excessive for the rest of the season, when it would have to work at 50 or 60 % of its capacity. Furthermore, the olive crop is highly variable; one season with a high yield of olives will be followed by one with a very poor fruit production. For this reason, the processing capacity for a crop during a high production season to avoid fruit accumulation, would only work at 50% of its performance during seasons of lower fruit production.

3. COLD STORAGE. AN ALTERNATIVE

The use of refrigeration in fruit storage is based on the reduction of the speed of the metabolic processes induced by low temperatures. Thus, enzymatic activity such as celulases and galacturonases, responsible for fruit softening, or chlorophylases, which act in skin colour changes are delayed, allowing a longer commercial life for the commodity. However, the main metabolic effect of cool temperature is the decrease in the effectiveness of fruit respiration. This process supplies the energy necessary for the development of fruit maturation. A high level of respiration determines two undesirable effects: a shorter commercial life for the product stored and a loss in weight and nutritional value, because this process consumes energy metabolites such as sugars, lipids, or organic acids. Furthermore, refrigeration delays the deterioration activity of the pathogens, which are mainly responsible for postharvest loss of fruits. In olives, decreasing the temperature from 18 to 5 °C led to a decrease in CO_2 production of somewhat more than twenty-fold (García and Streif, 1991). This suggests that the lag provoked in all the

Table 1
Spanish olive oil production during five seasons. The alternation of production and its concentration in determined months was evident. Source: Spanish Ministerio de Agricultura, Pesca y Alimentación

	Spanish Olive Oil Production (Tm x 1000)						
Months	**2000/01**	**2001/02**	**2002/03**	**2003/04**	**2004/05**	**Total**	**%**
November	40	93	55	89	70	**347**	**6.1**
December	200	388	282	430	315	**1615**	**28.6**
January	270	535	324	568	422	**2119**	**37.5**
February	320	295	144	240	145	**1144**	**20.2**
March	110	67	48	71	26	**322**	**5.7**
April	30	27	5	16	4	**82**	**1.5**
May	5	8	3	3	1	**20**	**0.4**
Total	**975**	**1413**	**861**	**1417**	**983**	**5649**	**100.0**

metabolic activities that require energy produced by respiration should be equally delayed.

Some fruits are sensitive to low temperature and during cold storage develop a physiological disorder commonly named “chilling injury”. The cause of this problem has been attributed to a non programmed accumulation of succinic acid in the Krebs cycle. Succinic-dehydrogenase should be more affected by a low temperature than the other enzymes of this metabolic system and its toxic substrate would destroy the fruit cell (Kader, 1985). At the same time, low temperatures could affect the permeability of the plasmatic membranes, altering the physical properties of its main constituent, the phospholipids. In general, a fruit is considered cool-sensitive, if it develops chilling injuries at temperatures slightly higher than its freezing point. Unfortunately, the fruit of the *Olea europaea* is one of them. Chilling injury symptoms in olives begin as an internal browning of the flesh around the pit, subsequently, external pitting appears dull in colour on the skin of this area, browning becomes darker and, finally, progressively occupies all the internal flesh and the skin surface. The chilled olives are especially sensitive to fungi infection and rot rapidly (Kader 1996; Nanos 2002).

Maxie (1964), Woskow and Maxie (1965) and Kader (1989) in different works identified the temperature of 5° as the barrier for the cold storage for different table olives. Below this temperature these fruits developed severe chilling injury. Subsequently, García (1993a) found that this temperature was also useful for storing mature-green 'Picual' fruits, the most highly cultivated Spanish variety of olives intended for oil.. However, after a prolonged storage of 2 months at 5 °C this variety exhibited a 10 % incidence of chilling injury. For the storage of olives intended for oil, temperature is the main determining factor for maintaining physiological conditions of the fruit intact and, subsequently, to extract from it oil with the same level of quality as it had initially. During storage, the incidence of fruit decay increases in direct relationship with the temperature selected. After a week of storage the decay of ‘Picual’ olives stored at 12 °C was four times higher than at 8°C and eight times higher than at 5°C (García et al., 1996a). The increase of fruit decay determines a proportional increase in the acidity of the oil, due to the hydrolytic action of the lipases of the pathogens, which use this activity as the first step in metabolizing the oil contained in the infected fruits. Refrigeration at 5 °C delays fungi proliferation and, consequently, the acidity value of the oil is maintained within the limit established for the "extra" quality of the virgin olive oil ($\leq$ 0.8 %) for up to a period of 30 days. Similarly, quality parameters which evaluate the level of oil oxidation, exhibit a level of deterioration proportional to the storage temperature. Thus, the values of stability to oxidation of the oils obtained from olives stored at 5°C were better than the ones extracted from fruit kept at higher temperatures. In the same way, the panel test also showed the close relationship between the physiological state of olive fruit and the sensory evaluation of its oil. Storage at 5°C allows for maintaining the initial sensory quality of oils extracted from fruit stored for 30 days at laboratory scale (Gutiérrez et al. 1992; Garcia et al. 1996a, García et al. 1996b).

The sensitivity to low temperature diminishes with fruit maturity. Agar et al. (1999) did not appreciate any chilling injury incidence on black ripe ‘Manzanillo’ olives stored for up to 6 weeks at 0, 2.2, 5, or 16 °C. However, fruit of this maturity level decayed more rapidly than the green-mature one, and after 4 weeks of cold storage the oil obtained from those exceeded the limit value of acidity established for “extra” virgin category of quality.

Cold storage can be supplemented by the modification of the atmosphere within the room where the fruits are kept. Habitually, this modification consists of an increase in the concentration of CO_2 and/or a decrease of O_2. This system allows a better control of both: development of fruit maturation and pathogen proliferation, extending the commercial life of the stored product and better maintaining of its initial level of quality. Atmospheric manipulation can also be useful to delay the physiological changes due to chilling sensitive crops, as these cannot be stored for a long time at low temperatures. Nevertheless, the use of these atmospheres can induce other physiological disorders, or aggravate chilling injury, depending on the commodity (Kader, 1986; Nanos et al. 2002). If the new concentrations of these gases in the refrigerated room are permanently regulated, the system of storage is named “controlled atmosphere” (CA), whereas the absence of this control determines the use of a “modified atmosphere” (MA) storage.

CA storage has been tested in table olives in California and in Greece, obtaining different results according to the cultivar used. Thus, ‘Mission’ green-mature olives have benefited from CA storage at 5 °C, because these olives maintain their initial ripening stage and a good physiological and sensory quality after 10 weeks of storage under 2 to 5% O_2 and 2.5 to 10.5% CO_2 at 5°C. However, the use of CA increases the sensitivity to chilling injuries of Manzanillo’ olives, which show an appreciable incidence of chilled fruit after a storage period of 6 weeks at 10 °C under an atmosphere enriched with a concentration of 5% CO_2. The incidence of this disorder increased if the presence of O_2 was also diminished at up 2% in the storage atmosphere (Woskow and Maxie, 1965; Kader et al., 1989). More recently, Nanos et al. (2002) also obtained a different answer to storage conditions, according to the table variety tested, whereas ‘Conservolea’ olives can be stored at 7.5 °C under CA conditions for up to 22 days, ‘Chondrolia’ fruits resulted extraordinarily sensitive to chilling injury, even at this relatively high temperature.

Storage of mill olives under CA conditions has also been assayed. García and Streif (1991), using the table variety ‘Gordal’ tested the effect of refrigeration and CA conditions on the quality of the oil subsequently extracted. Both, O_2 reduction or CO_2

increasing induced chilling on fruit stored at 5 °C and the incidence of this disorder increased; when both CA conditions were combined. In contrast, fruit stored at the same temperature did not suffer any physiological damage. Affected fruit decayed rapidly and, in consequence, the best quality oil was obtained from the olives refrigerated in air. Subsequently, using 'Picual' olives the effects of CA conditions were studied on fruit physiology (Castellano et al., 1993; García, 1993a), on polyphenol content (Maestro et al., 1993) and oil quality (Gutiérrez et al., 1992; Pérez-Camino et al., 1992; García, 1993b) in the Instituto de la Grasa. As was previously observed in table olives, CA storage induced physiological disorders in olives intended for oil, being especially detrimental the use of high CO_2 concentrations (García, 1993a). In consequence, as the use of CA storage atmospheres does not provide any additional advantage over refrigeration in air at 5°C for the storage of mill olives, but inducing physiological disorders facilitates fruit decay and, afterwards, the obtaining of poor quality oils, which are characterized by a high acidity level and the presence of undesirable sensory attributes.

One of the main factors to take into account for the use of refrigeration for the storage of olives intended for oil is the selection of an adequate loading unit to contain the product. Of course, for the industry the use of the largest possible container supposes an important saving in costs. However, it may imply an excessive fruit accumulation, which does not allow for effective refrigeration of the unit. On the other hand, the use of small boxes facilitates that the stored fruit acquiring the desired temperature as soon as possible, but it can be expensive in practice. Garcia et al. (1994) studied the effect of the loading unit on fruit physiology and on the quality of the oil from it. A loading unit with a capacity of 400 kg of 'Picual' olives stored at 5 °C showed a real temperature of 25 °C in the inner zone of fruit accumulation. Consequently, the fruit stored under these conditions decayed rapidly and the oil extracted immediately exhibited a poor level of quality. In contrast, fruit placed in containers with a storage capacity of 60 Kg showed an internal temperature of 6 °C, only 1 °C higher than the refrigerated room where it was stored and the oils obtained from it exhibited a level of quality similar to its initial level for at up 30 days of fruit storage. In summary, the best possible loading unit should be one, while as big as possible, allows efficient refrigeration of the entire stored product. The perforated plastic boxes capable of holding 22 Kg of fruit, previously recommended for prolonged olive storage are perfectly useful for cold storage.

When considering the use of refrigeration for the storage of olives intended for oil, the industry must meet at least the following requirements: A cool room capable of storing the product that cannot be absorbed by the mill machinery. It should be equipped with cooling machinery able to refrigerate the product at the temperature required (normally 5 °C) over a period of time ≤ 12 hours, to immediately delay fruit deterioration due to internal or external factors. The air inside the room must be renewed often, to avoid undesirable accumulations of CO_2 due to fruit respiration. As the external aspect of the fruit is not relevant for mill olives, maintaining a high level of relative humidity (RH) is not necessary, but the level of fruit dryness could be easily controlled during fruit cold storage regulating the speed of ventilation and the RH inside the room. It would be interesting for future studies to clarify the effect of the level of fruit dryness induced by cold storage on oil quality. It can be a non-polluting system to reduce the production of waste water. All the material necessary for palletization required by the industry is also necessary, including boxes, pallets or forklifts and the machinery associated with it: Case inverters, case washing machines, etc. Finally, it is necessary to take into account that cold storage is not a fruit hospital. Only healthy fruit can be refrigerated to obtain a high quality olive oil. The refrigeration of damaged or rotten fruit only guarantees an oil of poor quality. Consequently, this system is only compatible with the careful harvesting, packing and transport of this product.

Refrigeration of olives intended for oil at 5°C has been successfully applied by the olive oil industry (García et al., 1996b; Canet and García, 1999). About 1000 Tm of olives ('Blanqueta' and 'Villalonga' cultivars) were hand harvested in Valle de Albaida (Valencia, Spain), packed in perforated plastic containers with a capacity of 14 Kg of olives and stored for 18 days at 5 °C (Figure 5). The commercial quality of the oil obtained (about 200 Tm) from the fruit stored under these conditions was evaluated as the best possible for virgin oils ("extra"), since the values of the quality parameters, which measure the level of quality of these oils, were inside the limits established for this category of quality (Table 2). The storage at 5 °C of the olive that could not be immediately processed allowed for the use of the mill machinery to full yield for 8 weeks (Figure 6). The hypothetical increase of double milling capacity would be not sufficient to absorb



Figure 5
Olives stored at 5 °C in Cooperativa Valle de Albaida (Valencia). Source: M. Canet.

Table 2
Evaluations reached by the oils obtained from olives of the varieties Blanqueta and Villalonga stored industrially for 18 days to 5°C in the parameters that define the level of quality of the virgin olive oil. [a]Mean value ± standard deviation of three determinations analysed in three different oil extractions. Source: Canet and García (1999

Quality parameter	'Blanqueta'	'Villalonga'
Acidity (% oleic)	0,53 ± 0,19[a]	0,44 ± 0.12
Peroxide value (mEq Oxygen/Kg oil)	3,50 ± 0,65	3,87 ± 0,98
K_{232}	1,68 ± 0,06	1,57 ± 0,09
K_{270}	0,12 ± 0,00	0,14 ± 0,02
Stability (hours)	51,13 ± 6,96	67,67 ± 9,59
Panel text ("1" the worst - "9" the best)	6,93 ± 0,37	7.30 ± 0,22

the harvest at highest production peak (Figure 7). An amount of 200 Tm of olives could not be processed in the sixth week of the season, and would be exposed to a serious risk of deterioration. On the other hand, under this milling capacity, the oil extraction machinery would work to full yield for only two weeks. Cold storage clearly facilitates a more economic use of disposable machinery. Considering that the next season the olive fruit production could suffer a reduction of the 50 %, due to the typical olive alternation (Figure 8). In this case, the actual milling capacity should be sufficient to process this reduced fruit production. An excessive milling capacity would be unproductive approximately every two seasons. Cold storage is more versatile and less restrictive than oil extraction machinery. It can be used for the refrigeration of multiple products and requires a lower maintenance cost. Furthermore, cold storage is more susceptible to renting than excess of oil extraction machinery, because at the moment of the peak production, when it is actually required, all the mills of a certain area would be occupied, working to full yield.

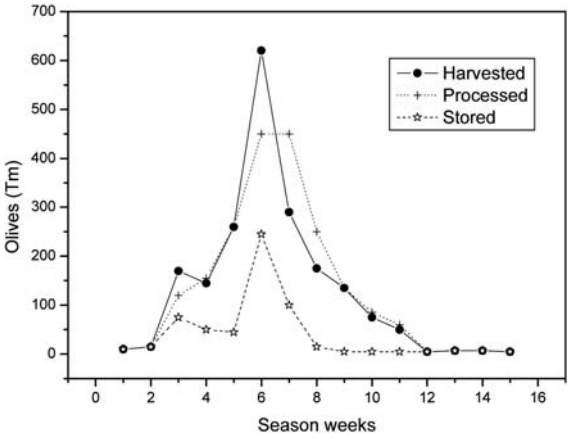


Figure 7
Estimated data of olive processing for virgin olive oil production supposing the use of a milling capacity of 64,000 kg/day in the Cooperativa Comarcal Valle de Albaida (Valencia, Spain) using as reference the season 1993-94. Source: Canet and García (1999).

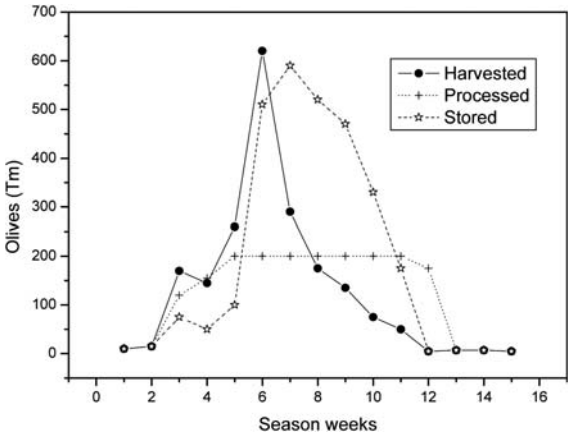


Figure 6
Data of the olive processing for virgin olive oil production using a milling capacity of 32,000 kg/day in the Cooperativa Comarcal Valle de Albaida (Valencia, Spain) during the season 1993-94. The olives were stored at 5 °C in boxes able for 14 kg fruits. Source: Canet and García (1999).

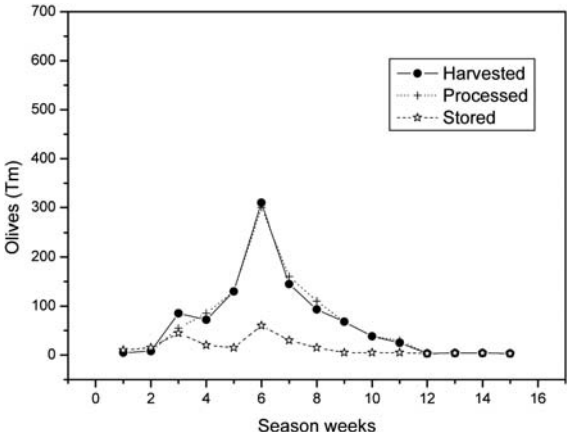


Figure 8
Estimated data of olive processing for virgin olive oil production supposing a 50 % reduction of the olive crop due to the olive alternation in the Cooperativa Comarcal Valle de Albaida (Valencia, Spain) using as reference the season 1993-94. Source: Canet and García (1999).

4. POSTHARVEST HEAT TREATMENT: A FUTURE POSSIBILITY

During olive ripening (from the green-mature to the black stage of maturity) the increase of the lipid content is scarce (Wodner et al. 1988). Coinciding with this observation, the changes in the oil biosynthesis during fruit growing and maturity, measured by the incorporation of ^{14}C acetate to the oil of 'Picual' and 'Gordal' olives, showed at 25 weeks after flowering (corresponding to the green-mature or spotted stages of olive ripening) the enzymatic machinery responsible for the oil synthesis lost its activity in both varieties (García and Mancha, 1992). This point of ripening can be considered, in a production perspective, as the suitable one by the beginning of the fruit harvesting, because after this maturity level the oil accumulation in the olives is interrupted. Furthermore, olive fruit cells have internal enzymatic activities, such as lipases, lipoxigenases or hydroperoxide liases, which can cause hydrolytic or oxidative alterations during fruit ripening or/and the milling and the malaxation of the oil extraction process (Olías. 1992). Obviously, as the olive matures, the possibility of these enzymes acting on the stored oil increases and, in consequence, the quality of the oils tends to decline. The oil of the variety 'Arbequina', for example, presented significantly higher acidity and ultraviolet absorbance when it was obtained from black fruits at the end of their ripening stage, than when was extracted from green-mature fruits, at the beginning of this physiological process (Garcia et al. 1996c, Yousfi et al. 2005). Furthermore, olives soften during fruit ripening, being riper fruits more susceptible to mechanical damage and fungal infection. Thus, green-mature olives resist postharvest handling better than the mature ones (García and Yousfi 2005). Nevertheless, in Spain the harvesting is normally carried out during the months of December, January or February, when fruit reaches a red or black skin colour (Table 1), due to four main reasons: Firstly, the harvesting is easier, because the resistance of the olive to fall down decreases fruit maturity. Secondly, although the oil content is only slightly higher in black olives, the physical extractability normally increases with the level of maturity. This fact is probably due to the softening of the ripe fruit which would facilitate the separation of the oil from the olive tissue. The third reason is the excess of bitterness and pungency that the oils extracted from green olives show. When their presence is too high, these sensory attributes can result in consumer rejection of the product. Especially sensitive to these attributes the consumers who are accustomed to the milder taste of refined oils such as those from important markets such as Japan, Canada, U.S.A. or the Northern European Countries. The green-mature stage of the ripening marks the beginning of a continuous reduction of the level of oil bitterness up to practically disappearing in the most advanced stages of olive maturity (Amiot et al. 1986 and 1989). Finally, perhaps the most important reason for the harvesting delay of olives intended for oil is tradition. In Andalusia, since perhaps the times of Roman domination, olive harvesting has begun on the same day, December the eighth (the day of the Immaculate Conception, according to the catholic calendar).

Both the first and the fourth reasons for harvesting delay are not in the scope of postharvest intervention and they are not treated in this chapter, but the other two arguments can be clear objectives susceptible to being solved by the development of an adequate postharvest technology in the same way that other fruits have been successfully treated to control sensory attributes, such as the elimination of kaki astringency or the degreening orange skin.

Oil bitterness is mainly due to of the secoiridoid derivatives of phenols (Mateos et al. 2004), these compounds, partially soluble in lipids, are given to the virgin oil during its extraction, through an unknown process, in which at least two kinds of enzymes, such as glycosidases and estearases, should be involved (Tsimidou et al. 1998). Glycosidases would break the glycosidic bond of the oleuropein, an extraordinarily bitter water-soluble glycoside characteristic of the *Olea europaea* leaves and fruits, yielding these secoiridoid derivatives of phenols. From oleuropein and/or secoiridoid derivatives the estearases would yield free phenols which are not bitter. A physical treatment previously applied to the fruit might alter the activities of these enzymes, probably inhibiting them partially or totally, and, consequently, controlling the level of bitter taste in the oil obtained. According to this work hypothesis Garcia et al. (2001) heated green-mature Manzanilla and Verdial olives at different temperatures (30 to 50 °C) for 24 to 72 hours in a thermostaticed room, observing that heating promotes a reduction of oil bitterness in direct relationship to the time and the temperature used, without any significant affect on the physical and chemical parameters, which are used to evaluate the level of quality of olive oil. As expected according to the proposal of an enzymatic inhibition, the phenol content of the oil decreased with the intensity of the treatment and, consequently, the stability against oxidation also decreased, although maintaining high absolute values. This result did not coincide with those published before by Farag et al. (1997), who obtained a stabilization of the olive oil by microwave heating of 'Picual' and 'Chemlalli' olives previous to oil extraction.

The heat treatment by temperature air transmission is difficult to adapt to the production lines of the olive oil extraction industry. It requires an equipped room, a relatively long treatment time, the use of boxes and is a discontinuous process that requires the loading and unloading of treated material.

Dipping in water allows for a more rapid and efficient transmission of the heat to the fruits. Using this method, the heat treatment could be carried out in only a few minutes, and its adaptation to the industrial production lines would be easier. It would only be necessary to add a heating system to the fruit washing process normally used in the oil

extraction lines of the industry. Following this idea the same investigation team tested hot water (60 to 72 °C) dipping of 'Manzanilla', 'Picual' and 'Verdial' olives to control the presence of bitter taste of the oil subsequently extracted (García et al. 2005). These treatments reached similar results of air heating, but with a considerable saving of time. However, an excess of intensity of the heat treatment can cause a detrimental effect on olive oil. It could produce emulsion of the oil during the subsequent extraction process, or inducing a sensory attribute defined as "cooked green beans", which is not unpleasant, but it can not be considered as common for virgin olive oils. Unfortunately, to establish a general optimal treatment condition has not yet been possible, because it changes from season to season for each variety, and, even, for each cultivation zone. Probably, as the enzymatic activity responsible for bitter taste, as well the structural properties of the fruit (humidity, ratio flesh/stone, fruit age, oil content, consistency, etc) responsible for the efficiency of the physical oil extraction are closely related with these factors, and the optimal intensity of the heat treatment should change according to these variables. Each olive mill industry would have to establish its own particular treatment conditions according to its own variety, seasonal, and cultivation characteristics.

An unexpected effect of heat treatment was the increase in oil pigmentation. The oils obtained from treated fruits showed approximately double the content of carotenes and chlorophylls, compared to that obtained from control olives in all the varieties tested. As a result, the oil acquired a more intense and darker green colour, which increased with the temperature used in the treatment. Thus, a paradoxical case was found in the oils obtained after heat treatment: The greenest oils, traditionally related by the consumers to those obtained from unripe fruits and, therefore, with high bitterness, actually presented the lowest intensity in this attribute.

This is probably due to the heat-induced inactivation of the enzymes responsible for the pigment degradation during the oil extraction process. Luaces et al. (2005) published a more detailed description of this phenomenon. The production of highly pigmented oils should be interesting for the industry. Carotenes have vitamin characteristics and are antioxidants, whereas chlorophylls are oxidants in the presence of light, and antioxidants in darkness (Kiritsakis et al. 1985). Maintaining these oils in darkness should improve their stability. Furthermore, to have this kind of oil available, greener and softer should mean many different mixing possibilities ("coupages") with other virgin olive oils for improving their colour without modifying their taste.

REFERENCES

Agar IT., Hess-Pierce B., Sourour MM., Kader AA. 1999. Identification of optimum preprocessing storage conditions to maintain quality of black ripe 'Manzanillo' olives. *Postharvest Biology and Technology* **15**, 53–64.

Amiot MJ., Fleuriet A., Macheix, JJ. 1986. Importance and evolution of phenolic compounds in olive during growth and maturation. *J. Agric. Food Chem*. **34**, 823-826.

Amiot MJ., Fleuriet A., Macheix JJ. 1989. Accumulation of oleuropein derivatives during olive maturation. *Phytochemistry* **28**, 67-69.

Canet M., García JM. 1999. Repercusión de la frigoconservación de la aceituna de molino en el proceso de producción de aceite de oliva virgen. *Grasas y Aceites* **50**, 181-184.

Castellano JM., García JM., Morilla A., Perdiguero S., Gutiérrez F. 1993. Quality of' Picual' olive fruits under controlled atmosphere. *J. Agric.and Food Chem*. **41**, 537-539.

Farag RS., El-Baroty G., Abd-El-Aziz N., Basuny AM. 1997. Stabilization of olive oil by microwave heating. *Int. J. Food Sc. Nutr*. **48**, 365-371.

Fundación del Olivar, 2005a: www.oliva.net/poolred/Comun/GrafEvolAnual.asp, 28/09/05

Fundación del Olivar, 2005b: www.oliva.net/poolred/Comun/precios.asp, 28/09/05

García JM., Streif J. 1991. The effect of controlled atmosphere storage on fruit and oil quality of 'Gordal' olives. *Gartenbauwissenschaft*, **56**, 233-238.

García JM., Mancha M. 1992. Evolución de la biosíntesis de lípidos durante la maduración de las variedades de aceituna Picual y Gordal. *Grasas y Aceites* **43**, 277-280.

García JM. (1993a). Efecto del CO_2 en la atmósfera de almacenamiento sobre la fisiología de la aceituna de molino. *Grasas y Aceites*. **44**:81-84.

García JM. 1993b. Efecto del CO_2 en la atmósfera de almacenamiento del fruto sobre la calidad del aceite de oliva. *Grasas y Aceites*. **44**, 169-174.

García JM. 1994. La conservación de la aceituna de molino. *Unaproliva* **1(4)**. 19-24.

García JM., Gutiérrez F., Castellano JM., Perdiguero S., Morilla A., Albi MA. 1994. Storage of olive destined for oil extraction. *Acta Horticulturae* **368** 673-681.

García JM., Gutiérrez F., Castellano,JM., Perdiguero S., Morilla A., Albi MA. 1996a. Influence of storage temperature on fruit ripening and olive oil quality. *J. Agric. Food Chem*. **44**, 264-267.

García JM., Gutiérrez F., Barrera M.J., Albi MA. 1996b. Storage of mill olives on an industrial scale. *J. Agric. and Food Chem*. **44**, 590-593.

García JM., Seller S., Pérez-Camino MC.1996c. Influence of fruit ripening on olive oil quality. *J. Agric. Food Chem.* **44**, 3516-3520.

García JM., Yousfi K., Mateos R., Olmo M., Cert A. 2001. Reduction of oil bitterness by heating of olive (*Olea europaea*) fruits. *J. Agric. Food Chem*. **49**, 4231- 4235.

García JM., Yousfi K. 2005. Non-destructive and objective methods for the evaluation of the maturation level of olive fruit. *Eur. Food Res. Technol*. **221**, 538-541 (2005)

García JM., Yousfi K, Oliva J, García-Diaz MT, Pérez-Camino MC. 2005. Hot Water Dipping of Olives for Virgin Oil Debittering. *J. Agric. Food Chem*. **53**, 8248-8252.

González-Cancho F. 1957. Investigaciones sobre la conservación de la aceituna de molino III. Población microbiana de los trojes. *Grasas y Aceites*. **8**, 55-63.

Grapevines M., Towers FJ., Senise O., López M. 2003. El sector oleícola español: diagnóstico y ejes de desarrollo Olivae 97, 26-40.

Gutiérrez R., Dobarganes MC., Gutierrez F., Olías JM. 1981. Componentes volátiles en el aroma del aceite de oliva virgen. V. Aceites obtenidos de frutos atrojados. *Grasas y Aceites* **32**, 299-303.

Gutiérrez F., Perdiguero S., García JM., Castellano JM. 1992. Quality of oils from olives stored under controlled atmosphere. *J. Am. Oil Chem. Soc.* **69,** 1215-1218.

Kader AA. 1985. An overview of the physiological and biochemical basis of CA effects on fresh horticultural crops. In: Controlled atmospheres for storage and transport of perishable agricultural commodities. Fourth Nat. Contr. Atm. Res. Conf. North Carolina State University. Pp: 1-9.

Kader AA. 1986. Biochemical and physiological basis for the effects of controlled and modified atmospheres on fruits and vegetables. *Food Technol*. **40**, 99–104.

Kader AA., Nanos GD., Kerbel EL. 1989. Responses of 'Manzanillo' olives to controlled atmospheres storage. *Proceeding 5th International Controlled Atmosphere Research Conference.* Wenatchee, WA. Vol. 2. pp 119-125.

Kader AA., 1996. Olive disorders. *Univ. California Perishables Handling Newsletter* **86**, 8–9.

Kiritsakis AK., Dugan LR. Studies in Photooxidación of Olive Oil. *. J. Am. Oil Chem. Soc.* **1985**, *62,* 892-896.

Luaces P., Pérez AG., García JM., Sanz C. 2005. Effects of Heat-Treatment of Olive Fruit on Pigment Composition of Virgin Olive Oil. *Food Chemistry* **90**, 169-174.

Maestro R., García JM., Castellano JM. 1993. Changes in Polyphenol content of olives stored in modified atmospheres. *HortScience* **28**, 749.

Mateos R, Cert A, Pérez-Camino MC, García JM. 2004. Evaluation of Virgin Olive Oil Bitterness by Quantification of Secoiridoid Derivatives.*J. Am. Oil Chem. Soc*. **81**, 71- 75

Maxie EC., 1964. Experiments on cold storage and controlled atmosphere. In: *the 43th. Annual Technical Report of the California Olive Association*. Davis (Cal.), USA. pp. 12-14.

Mazuelos-Vela F. 1972. La lipasa de hongo *Gloesporium olivarum* Alm. *Grasas y Aceites* **23**, 432-435.

Nanos GD., Kiritsakis AK., Sfakiotakis EM. 2002. Preprocessing storage conditions for green 'Conservolea' and 'Chondrolia' table olives *Postharvest Biology and Technology* **25**, 109–115.

Olías JM., Lozano MD., Rios, JJ., Gutierrez F.,Gutierrez R. 1988. Determinación de ácidos grasos volátiles en aceites de oliva vírgenes. *Grasas y Aceites*, **39**, 77-81.

Olías JM. 1992. Definition of extra virgin olive oils. International congress on olive oil quality. Florence. Italy.

Olías JM., García J.M. 1997. Olive. In *Postharvest physiology and storage of tropical and subtropical fruits.* Mitra S. Ed. CAD International. Wallingfort. UK. Pp: 225-239.

Pérez-Camino MC., García JM., Castellano,JM. 1992. Polar compound concentration in virgin oils from stored cultivar Picual olive fruits. *J. Agric. Food Chem*. **40**, 2260-2262.

de Toro MD., Sanchez MT., Montes F. 2002. Olives. Post-harvest quality. *Alimentacion Equipos y Tecnologia* **21** (174): 75-77

Tous J., Villamil J., Hermoso JF., Alber A. 2005. El olivo en Uruguay. *Olivae 103*, 56-61.

Touzani A. 2004. La calidad: importante objetivo del Consejo Oleícola Internacional. *Olivae* **100**, 34-38.

Tsimidou M. 1998. Polyphenols and quality of virgin olive oil in retrospect. *Ital. J. Food Sci*. **10**, 99-115.

Wahrburg U., Kratz M., Cullen P. 2002. Mediterranean diet, olive oil and health. *Eur. J. Lipid Sci. Technol.* **104**, 698-705.

Woskow M., Maxie EC. 1965. Cold storage studies with olives. In: *44th Annual Technical Report of the California Olive Association.* Davis (Cal.) USA. pp. 6-8.

Wodner M., Lavee S., Epstein E. 1988. Identification and seasonal changes of glucose, fructose and mannitol in relation to oil accumulation during fruit development in *Olea europaea* L. *Scientia Horticulturae*, **36**, 47-54.

Yousfi K., Cert RM., Garcia JM. 2005. Changes in quality and phenolic compounds of virgin olive oils during objectively described fruit maturation. *European Food Research and Technology*. In press.

Recibido: Septiembre 2005
Aceptado: Noviembre 2005