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# Effects of processing methods and commercial storage conditions on the extra virgin olive oil quality indexes

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**RESUMEN**

**Efectos de los métodos de procesado y de las condiciones de almacenamiento comercial en los índices de calidad del aceite virgen extra**

El efecto de la maquinaria, el material de envasado y la intensidad de luz fue relacionado con los índices de deterioración oxidativa, índice de peróxidos (IP) y coeficientes de extinción $K_{232}$ y $K_{270}$ del aceite de oliva virgen extra durante una campaña de cosecha de aceituna en un esfuerzo por simular las condiciones de almacenamiento comercial. Esto reveló que durante el almacenamiento del aceite de oliva el índice de peróxidos fue afectado significativamente por el tipo de maquinaria de extracción, el material de envasado y la intensidad de luz. Es significativo que el aceite expuesto a la luz diaria difusa y a la artificial alcanzara el máximo IP en el segundo o tercer mes de almacenamiento, decreciendo a partir de este momento, mientras que las muestras almacenadas en oscuridad no alcanzaban su máximo IP hasta el sexto mes de conservación. Las muestras de aceite extraídas con centrífuga y mantenidas en contenedores vidrio en la oscuridad alcanzaron un IP mayor que las extraídas por el sistema clásico. Las velocidades de cambio del IP y de los $K_{232}$ y $K_{270}$ fueron también afectadas por el tipo de maquinaria extractora empleada, el material de envasado utilizado y la intensidad de luz recibida por el aceite durante su conservación.

*PALABRAS-CLAVE: Aceite de oliva virgen – Coeficiente de extinción – Índices de calidad – Índice de peróxidos – Sistemas de extracción.*

**SUMMARY**

**Effects of processing methods and commercial storage conditions on the extra virgin olive oil quality indexes.**

The effect of machinery groups, packing materials and light intensities was ascertained on indices of oxidative deterioration, peroxide value, and extinction coefficient $K_{232}$ and $K_{270}$ of extra virgin olive oil for one season of olive harvesting in an effort to simulate commercial storage conditions. It was revealed that during the storage of olive oil the peroxide value was significantly affected by the type of extraction machinery, packing material and light intensity. It is significant that oil exposed to diffused daylight and artificial light attained maximum PV in the second or third month of storage and decreased thereafter, while samples stored in the dark attained their maximum PV during the sixth month of storage. Oil samples extracted using the centrifugal type of machines and kept in glass containers in the dark had higher peroxide values than those extracted by the classic method. The rate of changes of the PV and the two indices $K_{232}$ and $K_{270}$ was also affected similarly by the type of machinery, packing material and light intensity.

*KEY-WORDS: Extinction coefficient – Extraction systems – Peroxide Value – Virgin olive oil quality indexes.*

## 1. INTRODUCTION

Olive oil has a unique position among edible oils due to its delicate flavor, stability and health benefits. Among the factors that significantly influence the preservation of olive oil quality are the extraction methods, the packing materials and the storage conditions. Today, the most interesting types of machineries used for oil extraction are the classic pressing and the continuous centrifugal systems. Pressing is the oldest (Boskou, 1996; Kiritsakis and Christie, 2000) but still a widespread method in use for oil extraction. Consequently, the technological progress has lead to a tendency for classic systems to be replaced by continuous centrifugation systems during the last twenty years. These systems require the addition of warm water to the oil paste to separate the oil from the other phases, resulting in the production of a considerable amount of vegetation water and a decrease in the content of the olive oil phenols. The polyphenols, except their effect on sensory and nutritional quality are also related to the resistance of virgin olive oil to autoxidation and is significantly affected by the extraction system (Vekiari and Koutsaftakis, 2002). Recently, because of consumers' return to biological products, efforts for coming back to traditional methods of extraction of the so called ecological olive oil extracted by the use of a stone mill press factories have been launched (Vekiari *et al.,* 2002).

The most significant factors affecting the olive oil quality after processing and during storage are environmental, temperature, exposure to light and contact with oxygen (Kiritsakis and Dugan, 1984; Allien, 1989; Leo, 1983). Much work has been done on the effect of storage conditions and packaging materials on olive oil quality. Papers concerning the behavior of various packaging materials have been published by Gutierrez *et al.* (1970; 1988), Mendez and Falque (2006), Koutsaftakis *et al.* (1999), Leo (1983). Kanavouras *et al.* (2004) studied selected characteristic flavor compounds evolved in extra virgin olive oil when packaged in various packaging materials and stored under different conditions. Pagliarini *et al.* (2000) has studied the stability of extra virgin olive oil by different types of bottles and under different commercial conditions and proved that it was not significantly influenced by different controlled bottling, transport and storage conditions in supermarkets. Several researchers have also worked on the effect of extraction methods on olive oil quality (Di Giovacchino *et al*.; 1994 and 2002; Martinez *et al.* 1974; De Felice *et al.*, 1979; Ranalli *et al.*, 2005). In the Greek market the most common material in use for olive oil packaging are plastic bottles (polyethylene and PVC), tins, transparent glass, or of green and brown color.

Kiritsakis *et al.* (1984) has investigated the effect of olive storage, processing systems, oil storage conditions and packaging materials on Greek olive oil quality. Vekiari *et al.* (2002 and 2003) have evaluated the influence of some representative continuous and classic machinery types on the virgin olive oil packed in polyethylene and other containers used in Greece. However, few studies (Vekiari *et al.* 2002; Martinez *et al.*, 1974) concerning the comparison between the traditional and centrifugal systems have been done.

The objective of the current multivariated study was to evaluate the extent of degradation in the quality of Cretan virgin olive oil of koroneiki, the most popular Greek variety, extracted by the classic and centrifugal machinery system and stored under conditions simulating those used in supermarkets. At the same time, the behavior against autoxidation of the commercial packaging materials, commonly in the Greek market (transparent glass and bottles of PVC) in combination with different light intensities was studied.

## 2. MATERIALS AND METHODS

Olive fruits of good quality and in the mature firm condition were harvested from the trees of the variety Koroneiki in the fields of the Institute of Subtropical Plants and Olives in Messara, on the island of Crete. The olive oil was extracted by two machineries: the classic system of Theocharis, MOLACER 14in and the centrifugal system of Alfa-Laval, COSI type with 314 three phase decanter.

Olive processing consisted of the following stages: milling and mixing (common in both systems), pressure or centrifugation for classic and centrifugal systems respectively and separation of the oil phase.

The conditions in the different systems were as follows: The mean temperature recorded was 27 °C for the classic system and 30 °C for the centrifugal. The mixing duration for the first system was 45 min while for the other it was 30 min. Nine trials from the same olive fruits under the same conditions were carried out for each extraction system. The extracted olive oil derived from them was mixed and was then filtered. The oil obtained from each system was initially analyzed for moisture, acidity, peroxide value, impurities, polyphenol content and absorption in UV (extinction coefficients $K_{232}$ and $K_{270}$). Then, it was packed in 1L plastic containers made of PVC (88% PVC, with stabilizers octylic Zn and a greasing mean), and transparent glass bottles and stored at the temperature of 28 °C under different light conditions for ten months. A separate container was used for each month. Three different light intensities were studied: a. intense artificial light, b. diffused daylight and c. dark. The samples for storage in the dark were put in paper boxes. The samples were stored in a room painted white, on shelves of 3m long and 20cm wide. Having in mind the intensity of light that falls on the shelves of supermarkets, a lightness of 1000 Lux was used. Five tubes of 40 Wat and 8 of 20 Wat were put opposite the samples. The intention of light was measured by Hjoki photometer.

During storage the extent of oxidation of the olive oil in plastic and glass bottles was determined by the measurement of the peroxide value and the extinction coefficients $K_{232}$ and $K_{270}$ (Official Journal of the European Communities, 1991) once a month. Three bottles for each case were used and each oil sample was analyzed in duplicate.

*Statistical analysis:* The multifactor ANOVA statistical analysis was applied to the data set using the statistical package Statgraphics, in order to study the influence of the different factors (extraction system, means of packaging and storage conditions) on the quality characteristics of olive oil, peroxide value and extinction coefficient $K_{232}$ and $K_{270}$.

## 3. RESULTS AND DISCUSSION

*Initial quality of olive oil:* Results for the initial analyses (average of nine trials) of olive oil samples obtained from the different extraction systems are presented in Table 1. Significant differences were found between the two systems in the characteristics of moisture, acidity, impurities, peroxide value (PV), UV absorbance and the polyphenol content. The mean PV measured for the classic system was higher in comparison to the centrifugal system and this may be due to the contact with the metal surface of the equipment of the former case. On the contrary, the polyphenol content was much lower in the centrifugal than in

Table 1
**The initial analyses (average of nine trials) of olive oil samples obtained from the different extraction systems.**

| | Productores | | | | | | |
|---|---|---|---|---|---|---|---|
| **Systems** | **Acidity %** | **PV meq/$O_2$** | **Polyphenols mg/L** | **Moisture %** | **Impurities %** | **$K_{232}$** | **$K_{270}$** |
| Centrifugal | 0,37a* | 2,75a | 130a | 0,321a | 0,218a | 1,39a | 0,127a |
| Classic | 0,49b | 3,37b | 196b | 0,39b | 0,431b | 1,40a | 0,131a |

Values followed by the same letter vertically do not differ statistically at the P = 0.05.

the classic system and this is in agreement with the literature (Vekiari and Koutsaftakis, 2002).

*Effect of extraction system, packing material and storage conditions on the olive oil quality characteristics:* According to the literature, hydroperoxides, the initial products of oxidation, comparatively unstable, are a very sensitive indicator of the early stages of oxidative deterioration and a good guide to the evaluation of olive oil quality while the specific absorption coefficients in the UV region (secondary oxidation products) provide information on the state of preservation of the oil (Kiritsakis and Christie, 2000; Allien, 1989).

In Figures 1-4 the changes of PV and UV absorbance in 270nm of virgin olive oil extracted by different machinery systems and stored in commercial packing materials under different light intensities are presented.

From Table 2 arises a significant influence of machinery type and light intensity on the PV as well as the extinction coefficient and also the rate of PV changes for the harvesting period.

The results obtained also indicated that the nature of the material has a notable influence on the way in which the indices studied are altered.

The highest values of PV and the rate of their change as well were measured in samples extracted by the centrifugal system and not in those of the classic system. This fact could be attributed to the protection of olive oil by the higher polyphenol content of the classic system, although values of acidity, peroxides and moisture were also higher in this system (Vekiari and Koutsaftakis, 2002). It was also found (Table 3, Figures 3, 4) that the oil extracted by the classic system and stored in the dark always had lower values in comparison with those of centrifugal in the dark in both means for

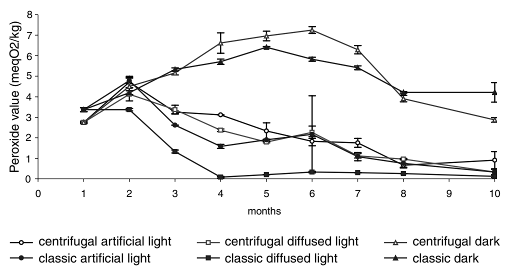


Figure 1
Evolution of PV (means of 3 trials in duplicate ± standard error) of olive oil stored in glass bottles for 10 months under artificial and diffused light and in the dark.

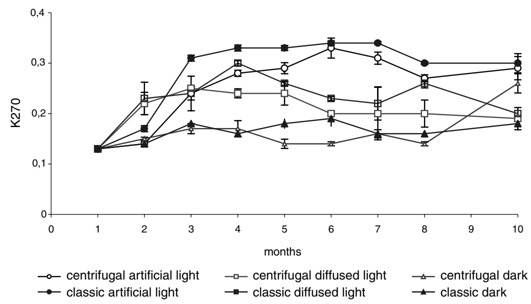


Figure 3
Changes of $K_{270}$ (means of 3 trials in duplicate ± standard error) of olive oil stored in glass bottles for 10 months under artificial and diffused light and in the dark.

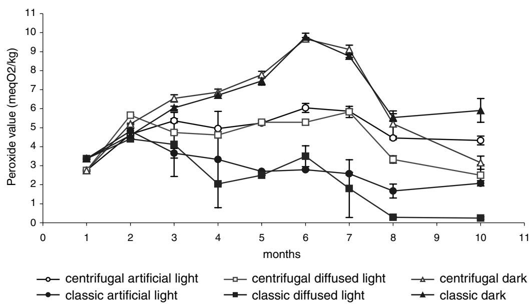


Figure 2
Evolution of PV (means of 3 trials in duplicate ± standard error) of olive oil stored in PVC containers for 10 months under artificial and diffused light and in the dark.

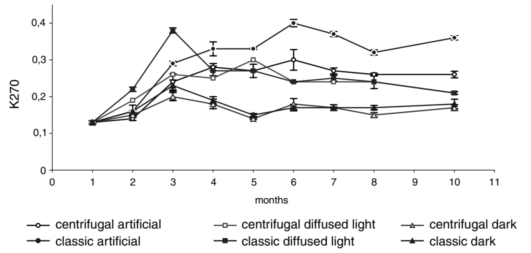


Figure 4
Changes of $K_{270}$ (means of 3 trials in duplicate ± standard error) of olive oil stored in PVC containers for 10 months under artificial and diffused light and in the dark.

Table 2
**Significant effects of all the factors on PV, $K_{232}$, $K_{270}$ (A) and their rate of change (B) in significance level P = 0,05.**

| | A | | B | | A | B |
|---|---|---|---|---|---|---|
| | $K_{232}$ | $K_{270}$ | $K_{232}$ | $K_{270}$ | PV | PV |
| **Systems** | *** | *** | * | *** | *** | *** |
| Centrifugal | 1,73 | 0,241 | 1,10 | 1,76 | 4,12 | 1,9 |
| Classic | 1,77 | 0,273 | 1,24 | 1,94 | 3,23 | 1,17 |
| **Packing material** | *** | *** | *** | *** | *** | *** |
| Glass | 1,712 | 0,251 | 1,08 | 1,809 | 2,72 | 1,06 |
| Plastic | 1,83 | 0,262 | 1,145 | 1,893 | 4,61 | 2,00 |
| **Light intensity** | ** | *** | ns | *** | *** | *** |
| Diffused light | 1,736 a | 0,260 a+ | 1,101 | 2,357 a | 2,4 a+ | 1,13 |
| Artificial light | 1,770 b | 0,322 b | 1,111 | 1,872 b | 2,8 b | 1,06 |
| Dark | 1,776 b | 0,188 c | 1,112 | 1,312 c | 5,83 c | 2,4 |

***, **, ***:** Significant influences of mean values at significance level 0.05, 0.01 and 0.001 .
+Value followed by the same letter vertically do not differ statistically at P = 0.05

$K_{270}$ but only in the glass for $K_{232}$. The same results were obtained when the rate of changes was used as criterion (Table 2).

It is worth mentioning that during storage, PV in all cases did not exceed the value of 20meq$O_2$ / kg of olive oil (Figures 1, 2), which is the maximum established by the Council for International Olive Oil in order for an oil to be considered as a virgin oil.

The samples packed in PVC presented higher peroxide values compared to those packed in glass containers and exposed to all the light intensities. These results are similar with other findings and point to the probable intrusion of oxygen as a consequence of the permeability of the plastic material (Kiritsakis and Dugan, 1984; Gutierrez *et al.*, 1970; Mendez and Falque, 2006). Generally, during the first months of storage, an increase in PV in both means was observed as a consequence of the action of both, diluted and headspace oxygen in the containers and the light that induce a rapid deterioration. Then, the PV was progressively reduced because of the degradation into secondary products, which was more obvious in the samples packed in glass containers and less in those packed in PVC bottles. This could be explained as the evolution of autoxidation which, except of the temperature, also depends on the light, and vacuum activity. The light in combination with the presence of air may cause serious alterations on olive oil quality while the absence of air and sunlight leads to the reduction of PV (Allien, 1989). The phenomenon is sharper as the influence of these factors is stronger. The higher decomposition of peroxides in glass was due to the natural vacuum over the oil surface when all the headspace oxygen had been spent. On the contrary, a high rate value was developed in samples packed in PVC containers, as oxygen is steadily being absorbed and peroxides are decomposing in secondary products more rapidly than they are being generated (Table 2). After some months of storage the PV was maintained rather stable in both means (fig.1, 2).

In samples exposed to artificial light and diffused daylight the maximum PV was measured during the $2^{nd}$ or $3^{rd}$ month and consequently it was reduced. On the contrary, samples stored in the dark and packed in both glass and plastic containers gave higher PV and the rate of change could be compared with those exposed to diffused daylight and artificial light. These samples attained their maximum PV during the sixth month of storage. This delay could be attributed to the absence of light.

On the other hand, the natural pigments of extra virgin olive oil (chlorophylls) act as antioxidant, synergistically with the phenol antioxidants inhibiting the evolution of autoxidation (Kiritsakis and Dugan, 1984).

Regarding the absorbance to UV, it was revealed that the $K_{232}$ values were maintained under the limit of 2.5 units which has been established by COI while the $K_{270}$ values in some cases exceeded the limit of 0.20 units during the ten months of storage. A sharp increase in $K_{232}$ was noticed at the beginning in all light intensities in the glass containers while for the $K_{270}$ this increase was observed in both packaging means.

In storage under light, a significant increase of $K_{270}$ was noticed to be faster at the beginning and then progressively decreased because of the small permeability of the means. The increase in oxidation confirmed by the increase in extinction coefficients occurred in both means due to the increase in the number of compounds resulting from peroxide degradation. Higher values of $K_{232}$ found in samples stored in plastic bottles could be due to the joint action of light and the permeability of this type of container to the oxygen that catalyzes the oxidation reaction. There was only one exception in the samples stored in the dark in both packing materials where the absorption in 232nm and 270 nm was much less, maintained under the permitted limit. This is in agreement with the literature (Caponio *et al.,* 2005) where it refers to the fact that oils kept in the dark contained mainly products of primary oxidation, while oils kept under

Table 3
**Changes of $K_{232}$ (means of 3 trials in duplicate ± standard error) of olive oil stored in glass bottles and PVC containers for 10 months under artificial and diffused light and in the dark.**

| | K232 / GLASS | | | | | | K232 / PVC | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | **centrifugal artificial light** | **centrifugal diffused light** | **centrifugal dark** | **classic artificial light** | **classic diffused light** | **classic dark** | **centrifugal artificial light** | **centrifugal diffused light** | **centrifugal dark** | **classic artificial light** | **classic diffused light** | **classic dark** |
| 1 | 1,39±0,02$^{a}$ | 1,39±0,02$^{a}$ | 1,39±0,02$^{a}$ | 1,40±0,01$^{a}$ | 1,40±0,01$^{a}$ | 1,40±0,01$^{a}$ | 1,39±0,01$^{a}$ | 1,39±0,01$^{a}$ | 1,39±0,01$^{a}$ | 1,40±0,02$^{a}$ | 1,40±0,02$^{a}$ | 1,40±0,02$^{a}$ |
| 2 | 1,41±0,01$^{b}$ | 1,47±0,03$^{bc}$ | 1,45±0,02$^{a}$ | 1,41±0,01$^{b}$ | 1,45±0,01$^{b}$ | 1,43±0,04$^{a}$ | 1,45±0,02$^{a}$ | 1,46±0,02$^{b}$ | 1,50±0,02$^{a}$ | 1,53±0,06$^{c}$ | 1,46±0,01$^{b}$ | 1,60±0,03$^{a}$ |
| 3 | 1,56±0,02$^{ab}$ | 1,58±0,02$^{ab}$ | 1,51±0,02$^{a}$ | 1,59±0,02$^{ab}$ | 1,59±0,01$^{ab}$ | 1,50±0,01$^{a}$ | 1,59±0,02$^{ab}$ | 1,62±0,03$^{b}$ | 1,60±0,02$^{ab}$ | 1,60±0,14$^{ab}$ | 2,07±0,05$^{ab}$ | 1,74±0,07$^{c}$ |
| 4 | 1,76±0,06$^{ab}$ | 1,66±0,05$^{a}$ | 1,69±0,04$^{a}$ | 1,69±0,03$^{a}$ | 1,72±0,05$^{ab}$ | 1,63±0,04$^{a}$ | 1,79±0,02$^{ab}$ | 1,66±0,04$^{a}$ | 1,76±0,04$^{ab}$ | 1,73±0,02$^{ab}$ | 1,77±0,09$^{ab}$ | 1,86±0,05$^{b}$ |
| 5 | 1,54±0,02$^{abc}$ | 1,54±0,01$^{abc}$ | 1,47±0,01$^{a}$ | 1,57±0,02$^{bc}$ | 1,5±0,03$^{ab}$ | 1,46±0,02$^{a}$ | 1,56±0,01$^{bc}$ | 1,54±0,02$^{abc}$ | 1,58±0,01$^{bc}$ | 1,57±0,03$^{bc}$ | 1,51±0,05$^{ab}$ | 1,59±0,01$^{c}$ |
| 6 | 1,55±0,05$^{bc}$ | 1,47±0,01$^{ab}$ | 1,44±0,01$^{a}$ | 1,62±0,01$^{cd}$ | 1,54±0,02$^{abc}$ | 1,5±0,03$^{ab}$ | 1,53±0,05$^{bcd}$ | 1,53±0,01$^{abc}$ | 1,62±0,05$^{cd}$ | 1,66±0,01$^{d}$ | 1,54±0,01$^{abc}$ | 1,61±0,03$^{cd}$ |
| 7 | 1,57±0,03$^{cd}$ | 1,43±0,03$^{ab}$ | 1,46±0,01$^{ab}$ | 1,58±0,02$^{cd}$ | 1,50±0,01$^{abc}$ | 1,40±0,04$^{a}$ | 1,52±0,03$^{bcd}$ | 1,43±0,01$^{ab}$ | 1,71±0,06$^{ef}$ | 1,62±0,03$^{de}$ | 1,54±0,05$^{abc}$ | 1,76±0,02$^{c}$ |
| 8 | 1,38±0,01$^{a}$ | 1,5±0,16$^{c}$ | 1,37±0,02$^{a}$ | 1,46±0,02$^{abc}$ | 1,44±0,02$^{ab}$ | 1,36±0,03$^{a}$ | 1,45±0,01$^{ab}$ | 1,35±0,01$^{a}$ | 1,50±0,09$^{abc}$ | 1,53±0,04$^{abc}$ | 1,35±0,03$^{ab}$ | 1,63±0,05$^{bc}$ |
| 10 | 1,47±0,05$^{bc}$ | 1,25±0,14$^{a}$ | 1,37±0,03$^{ab}$ | 1,45±0,05$^{bc}$ | 1,38±0,02$^{ab}$ | 1,36±0,01$^{ab}$ | 1,61±0,03$^{ab}$ | 1,42±0,02$^{ab}$ | 1,72±0,07$^{d}$ | 1,61±0,01$^{cd}$ | 1,45±0,01$^{ab}$ | 1,68±0,11$^{d}$ |

light contained products of secondary oxidation, as was shown by $K_{270}$ values exceeding the legal limits. The lesser oxidative alteration in the dark could be related to the antioxidant effect of the natural pigments acting synergistically with the phenols. It is worthwhile to note that the index $K_{232}$ increases with the PV while the decrease in PV is followed by the increase in $K_{270}$. It is characteristic also that $K_{232}$ and $K_{270}$ present the max value in different times.

Glass acts as a barrier to oxygen, which cannot pass through it, avoiding the loss of certain components that deteriorate under its presence but it allows the direct action of light on the olive oil and this could promote oxidative rancidity as a consequence of its sensibility to photo-oxidation. Therefore, the storage of extra virgin olive oil in PVC bottles, because of the action both of the light and the even small oxygen permeability, could not be suggested the most appropriate mean for maintaining the quality of the extra virgin olive oil.

Finally, as a consequence of the results reported herein, the packaging material should ensure protection from light in order to maintain the olive oil quality, especially when the oil is stored under the studied commercial conditions. This study has reaffirmed that glass bottles, stored in the dark conserve the oil obtained by classic machinery much better providing higher protection from oxidation compared to PVC containers.

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