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Research Paper

Olive oil quality improvement using a natural sedimentation plant at industrial scale

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Olive oil extraction is mainly carried out using continuous extraction by decanter centrifuge with efficiency of approximately 80–90%. After centrifugal extraction, olive oil is generally cleaned using a vertical disc stack centrifuge separator, which is suspected of being the major cause of decreased final olive oil quality. Experiments were carried out at industrial scale to compare the olive oil properties after improved processes of sedimentation (*Sedoil*) or centrifugation (*Cenoil*) with respect to raw olive oil obtained at the decanter exit (*Control*). Peroxide, polyphenol, chlorophyll, carotenoid, turbidity and K_{232} average values were significantly different between *Sedoil* and *Cenoil*, which confirmed that the use of disc stack centrifuges represents an important source of oxidative reactions. Analysis showed that storage time dramatically affects the oxidation level of the olive oil. All parameters used to monitor the oxidation level (i.e., free acidity, peroxide value and K_{232}) increased after 180 d of storage, and the content of natural antioxidants and pigments decreased as expected. The residual presence of water during long-term storage represented the most important source of oxidation, and an effective cleaning operation is necessary to preserve oil quality during its storage life. The analyses performed using ^{1}H and ^{13}C NMR showed that *Sedoil* was more similar in composition to *Control* than to *Cenoil*. The use of sedimentation plant allows the employment of the disk stack centrifuge to be reduced improving both energy saving and the quality of clean olive oil.

1. Introduction

Olive oil is a vegetable oil obtained directly from olive fruits (*Olea europaea*) by mechanical extraction. It is essential to the "Mediterranean diet" and is rich in triacylglycerol, glyceridic compounds and polyphenols.

At present, mainly due to economic pressures, the evolution of the oil extraction process has led to the replacement of traditional discontinuous pressure systems with continuous centrifugal extraction. The mechanical oil extraction is mainly carried out using a continuous process based on centrifugation by decanter centrifuge (a horizontal centrifuge with screw conveyor and rotating bowl), and it has an extraction

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Nomenclature

NMR	nuclear magnetic resonance
^{1}H NMR	hydrogen-1 nuclear magnetic resonance
^{13}C NMR	carbon-13 nuclear magnetic resonance
PID	proportional integral derivative
VFD	variable frequency driver
FWER	familywise error rate
FA	free acidity (g (100 g)$^{-1}$)
PV	peroxide value (meq kg^{-1})
K_{232} or K232	specific extinction coefficient at 232 nm
K_{270} or K270	specific extinction coefficient at 270 nm
Vph	volume (ml) of solution titrated with potassium hydroxide
c	concentration (mol l^{-1}) of the solution of potassium hydroxide
M	molar weight (g mol^{-1}) of oleic acid (= 282)
m	mass of sample of olive oil (g)
Vts	volume of the sodium thiosulphate solution (ml)
T	normality of the sodium thiosulphate solution (N)
CHLO	chlorophyll content (mg kg^{-1})
CAR	carotenoid content (mg kg^{-1})
UV	ultraviolet
E_0	coefficient for specific extinction
A_{670}	absorbance at 670 nm
A_{470}	absorbance at 470 nm
A	absorbance
d	optical path length
POLYPH	total polyphenol content (mg l^{-1})
TUR	turbidity
PCA	principal component analysis
PC1	first axis of the principal component analysis
PC2	second axis of the principal component analysis
AVGDIST	"mean Euclidean distance" between paired samples after principal component analysis
H0	null hypothesis

efficiency of approximately 80–90% of the oil contained in the fruit without any addition of other materials. The decanter is widely used in olive oil extraction and allows the processing of large amounts of olives in a short amount of time (Catalano, Pipitone, Calafatello, & Leone, 2003; Piacquadio, De Stefano, & Sciancalepore, 1998; Ranalli, De Mattia, & Ferrante, 1997).

Changes in olive paste rheological characteristics related to its water content, temperature, fruit variety and maturity level dramatically affect the extraction process quantitatively and even qualitatively (Boncinelli, Catalano, & Cini, 2013; Di Giovacchino, Sestili, & Di Vincenzo, 2002; Di Renzo & Colelli, 1997). Furthermore, the addition of lukewarm water to the olive paste during malaxation or extraction in the continuous extraction process by decanter centrifuge improves the separation of oil from vegetable water and husks (Amirante, Cini, Montel, & Pasqualone, 2001; Amirante, Di Renzo, & Colelli, 1995).

The final quality and extraction yield of olive oil are strictly related to both machine characteristics (e.g., type of crusher or decanter geometry) and processing parameters (e.g., the amount of added clean water, malaxing time and temperature, and amount of oxygen dissolved into the oil during the process) (Boskou, 2006; Del Caro, Vacca, Poiana, Fenu, & Piga, 2006; Di Giovacchino, Costantini, Ferrante, & Serraiocco, 2002; Ranalli, Cabras, Iannucci, & Contento, 2001; Salvador, Aranda, Gomez-Alonso, & Fregapane, 2003;).

Therefore, a correct control of the extraction process is essential to achieve both high extraction yields and olive oil quality (Altieri, 2010; Altieri, Di Renzo, & Genovese, 2013; Boncinelli, Daou, Cini, & Catalano, 2009; Furferi, Carfagni, & Daou, 2007; Jimenez, Beltran, Aguilera, & Uceda, 2008). In particular, the control of temperature and oxygen concentration during the malaxation phase has been demonstrated to have advantageous effects on both the extraction yield and the quality of the extracted olive oil (Aiello et al., 2012; Angerosa, Mostallino, Basti, & Vito, 2001; Catania et al., 2013; Servili, Selvaggini, Taticchi, Esposto, & Montedoro, 2003). Indeed the malaxing phase decreases the apparent viscosity of olive paste and enhances the enzymes activity, consequently affecting the volatile compounds, the phenolic composition and sensory quality of olive oil (Kalua et al., 2007). The initial volatile and non-volatile compounds composition establishes the olive oil shelf-life, which indeed is determined by the lipid oxidation reaction rate that cause the olive oil quality decrease at the expenses of the antioxidant content in the product (Gomez-Alonso, Mancebo-Campos, Salvador, & Fregapane, 2007).

The process consists of four phases:

1. Rupture of the olive fruits, which is carried out by several types of crushers. This operation produces a fluid composed of a mixture of two distinct liquid phases (raw oil and water) and an extremely heterogeneous solid phase (pit, skin, and pulp fragments);
2. Kneading of the paste to facilitate cohesion of smaller oil droplets into larger droplets that are easier to separate and to complete the tissue rupture using the action of the pit fragments;
3. Centrifugation to separate the different phases. This process occurs in a horizontal screw conveyor centrifuge with continuous discharge of the solid phase (i.e., a decanter);
4. Cleaning of the olive oil.

Final cleaning of the olive oil is required because the extracted oil still contains a certain amount of residual water and impurities. This further cleaning step is generally performed by a vertical disc stack centrifuge separator. Consider that there is a great interest, from a commercial point of view and on the basis of market requests, in minimally processed (raw) olive oil that does not shine because it is considered by consumers to be closer, in terms of composition, to the original oil present in the olive fruit (Boskou, 2006; Tsimidou, Georgiou, Koidis, & Boskou, 2005). Furthermore, the latest developments in decanter centrifuge design, modelling and construction (Altieri, 2010; Altieri et al., 2013; Amirante & Catalano, 2000, 1993; Boncinelli et al., 2009; Catalano et al., 2003; Daou, Furferi, Recchia, & Cini, 2007) allow the