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Research Paper

Microwave-assisted treatment for continuous olive paste conditioning: Impact on olive oil quality and yield

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ARTICLE INFO

Article history:
Received 1 July 2014
Received in revised form
17 August 2014
Accepted 26 August 2014
Published online 16 September 2014

Keywords:
Microware treatment
Olive oil extraction plant
Innovation
Malaxer
Phenols content
Volatile compounds

Olive paste conditioning using microwave technology was integrated into an olive oil extraction plant using industrial-scale microwave-assisted apparatus. This first effort at integrating microwave technology contributed significantly to the continuous conditioning of the olive paste. The components of the equipment were designed and sized for optimal efficiency in an earlier preliminary study. With the aim of improving the operation of the extraction plants towards providing a continuous management of the process, an investigation of effects of optimal scheduling on olive oil quality was conducted. The objective was to evaluate the impact of the microwave treatment used to condition the olive paste on olive oil quality and yield and comparing it with the conventional industrial malaxation. The short process time of the rapid microwave treatment resulted in a low oxidation of the olive oil and consequently a reduction in the peroxide value compared with the conventional method. Using the microwave treatment, a higher concentration of volatile compounds in the oil was obtained with a lower content of phenolic compounds that are associated with spicy and bitter notes. No significant differences were found with extraction yield. Microwave processing was therefore confirmed as an attractive alternative to the conventional malaxation, with the main advantages being the rapid processing time and the high olive oil quality.

1. Introduction

The main objectives for the designers of food equipment include reductions in process time, improvements in energy efficiency, reductions in labour, heat distribution uniformity, process control and the modularity and flexibility of the plants (Rodgers, 2007). In the olive oil extraction process, the focus for the introduction of new technologies is towards a reduction in malaxing time and improvements in operations

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http://dx.doi.org/10.1016/j.biosystemseng.2014.08.015
1537-5110/

Nomenclature

EVOO	extra virgin olive oil
PLC	programmable logic controller
Q_u	mass flow rate of the modular unit (kg s^{-1})
P_{MW}	microwave power required (W)
η_c	cavity efficiency
C_p	specific heat of olive paste (J kg^{-1} K^{-1})
ΔT	temperature difference (K)
V_p	volume of the modular pipe (ml)
t	residence time (s)
γ	specific mass of the olive paste (kg ml^{-1})
EY	extraction yield (%)
W_{oil}	mass of the extracted oil (kg)
W_{olives}	mass of processed olives (kg)
SPME	solid-phase micro-extraction
PDMS/DVB	polydimethylsiloxane/divinylbenzene
MSD	mass selective detector
amu	atomic mass unit
LOX	lipoxygenase
HPL	hydroperoxide lyase

management leading towards the continuous management of the entire process. These aims are closely linked to the production of high-quality olive oil and high extraction yields. Another important aspect that must be taken into account is the reduction in the energy needs of the process, thereby decreasing both environmental and financial costs.

Historically, many significant breakthroughs have originated at the interfaces between different fields of technology. Microwave technology is an example of a new technology that is used in many food processing applications, which has led to significant improvements in these processes (Catalano, Fucci, Giametta, Penna, & La Fianza, 2013; Chandrasekaran, Ramanathan, & Basak, 2013; Dogan-Halkman, Yücel, & Halkman, 2014; Koné et al., 2013; Reyes, Cerón, Zúñiga, & Moyano, 2007; Schiffmann, 2010; Xanthakis, Le-Bail, & Ramaswamy, 2014). The principle of microwave heating is based on the transformation of electromagnetic energy into thermal energy through the direct interaction of the former with polar molecules in a reaction mixture (Venkatesh & Raghavan, 2004). This volumetric heating principle of microwaves can partially address current heat transfer limitations. Microwave heating can reduce heat-up time and can better preserve thermo-labile constituents (Coronel, Simunovic, & Sandeep, 2003). The significant retention of the quality attributes of foods treated by continuous flow microwave systems has been previously reported (Coronel et al., 2003; Gentry & Roberts, 2005). In addition, microwave heating has certain peculiarities compared with conventional heating that are related not only to the rapid microwave heating rate but also to the non-uniformity of the local applied electric field, which serves to accelerate temperature homogeneity within the material (Cheng, Raghavan, Ngadi, & Wang, 2006).

Malaxation is a complex phase of the olive oil extraction process that cannot be attributed solely to either a simple "heating" phase or to a simple "kneading" phase (Tamborrino, 2014). The combined actions of the time, temperature and kneading lead to important changes in the olive paste microstructure and in the chemical and biochemical interactions between the substrates until a pre-defined quality profile of the extracted olive oil is obtained (Amirante, Clodoveo, Leone, & Tamborrino, 2012; Angerosa et al., 2004; Leone, Romaniello, Zagaria, & Tamborrino, 2014; Pastore et al., 2014; Reboredo-Rodríguez, González-Barreiro, Cancho-Grande, & Simal-Gándara, 2014; Servili et al., 2004; Tamborrino, 2014; Tamborrino, Pati, et al., 2014; Taticchi et al., 2013). Although microwave radiation has wide uses in various applications in the field of food processing, research-aimed improvements in certain fields remain to be explored, especially in processes in which the recovery of final food products with well-defined sensorial and healthy characteristics is required, as is the case of the olive oil.

The concept of utilising microwave heating to condition olive paste through the use of an industrial-sized microwave-assisted apparatus, thereby replacing the conventional malaxation process, has recently been reported by the authors (Leone, Tamborrino, Romaniello, Zagaria, & Sabella, 2014). In the present study, an approach for guaranteeing control of the microwave apparatus was developed to ensure product quality, flexibility and efficiency through the implementation of a feedback control system.

Improvements in the thermal energy transfer efficiency during the olive paste-conditioning process and reductions in processing time while still obtaining high-quality olive oil have been the main challenges of this research. The aim of the application of the microwave technology in the olive oil industry manufacturing sector is to modify the process, which normally consists of a discontinuous conditioning of the olive paste (the malaxation process), by the introduction of a continuous process to improve the performance of the mechanical extraction plant, thus saving malaxation time, and to develop system-integrated machines that perform active functions related to the disruption of the water–oil emulsion, promoting coalescence. In the specific field of olive oil extraction plants, the innovative equipment solutions should only be considered after careful assessments of the potential impacts on the quality of the olive oil produced. The goal of this work was to address microwave applications during the olive oil extraction process to highlight factors that affect innovative approaches to olive oil extraction plants and to investigate the adequacy of microwave plant design parameters by assessing the olive oil quality and yield. In this regard, extraction yields, the chemical characteristics of the olive oil were investigated, and minor compounds such as phenols content and volatile compounds were evaluated. The sizing of a modular unit of a microwave-assisted plant was carried out, by improving a prototype microwave-assisted plant developed in a previous research (Leone, Tamborrino, et al., 2014). In spite of the complex nature of microwave–food interactions, the results of this study should be useful for a better understanding of the process and for future industrial applications.