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Development of microwave-assisted dynamic extraction by combination with centrifugal force for polyphenols extraction from lettuce

Alice Angoy[a,b,c,d], Marc Valat[b], Pascal Ginisty[a], Alain Sommier[b], Pascale Goupy[c], Catherine Caris-Veyrat[c], Farid Chemat[d,*]

[a] IFTS, 3 Rue Marcel Pagnol, 47510, Foulayronnes, France
[b] I2M (CNRS UMR 5295), Université de Bordeaux et Arts et Métiers ParisTech, 33400, Talence, France
[c] INRA, Université d'Avignon, UMR408, Sécurité et Qualité des Produits d'Origine Végétale, F-84914, Avignon, France
[d] Université d'Avignon et des Pays de Vaucluse, INRA, UMR408, GREEN Extraction Team, F-84000, Avignon, France

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ABSTRACT

A new process design and operation for the extraction of polyphenols from fresh lettuce was developed. Microwave assisted centrifugation (MW/C) is a combination of microwave heating to explode the internal cells of biological material containing secondary metabolites, and centrifugation to intensify diffusion, collection and separation. MW/C is performed at atmospheric pressure without adding any solvent or water. A detailed study concerning optimization of different operating parameters like microwave power, centrifugal force and extraction time, was performed. MW/C has been compared not only to the reference conventional solvent extraction (CSE) technique but also to microwave extraction assisted by low rotational speed (MW/R) to assess the synergy between centrifugation force and microwave heating. Extracts obtained by MW/C, MW/R and CSE method were compared for the recovery of polyphenols at different time of the process in optimized operating conditions. The new combined MW/C process provided reduction in the extraction time compared to MW/R process, with an enhancement in recovery of target compounds. Energetic and environmental impacts using this combined process were evaluated in a scale up perspective.

1. Introduction

Since 1986, microwave assisted extraction (MAE) is an active research area which impacts modern chemistry of natural products (Ganzler, Salgó, & Valkó, 1986). All the reported applications have shown that MAE is an alternative to conventional extraction techniques with a faster extraction rate, less or no solvents, a more effective energy use, an intensification phenomena with increased mass and heat transfer, and a reduction of processing steps. Different MAE techniques have been developed such as microwave-assisted solvent extraction (MASE) (Paré, 1992), compressed air microwave distillation (CAMD) (Craveiro, Matos, Alencar, & Plumel, 1989), microwave hydrodistillation (MWHD) (Stashenko, Jaramillo & Martinez, 2004), solvent free microwave hydrodistillation (SFME) (Lucchesi, Chemat & Smadja,. 2004) and microwave hydrodiffusion and gravity (MHG) (Vian, Fernandez, Visinoni, & Chemat, 2008). All these studies pointed the effectiveness of the proposed techniques but also observed the presence of hot spots in the plant matrices during microwave process which induces burning at high microwave power and degradation of valuable metabolites. It was reported that imposing rotation during microwave extraction allows homogenizing the temperature field and therefore limit hot spots phenomena to occur (Geedipalli, Rakesh, & Datta, 2007; Périno, Pierson, Ruiz, Cravotto, & Chemat, 2016). Furthermore, Michel, Destandau, and Elfakir (2011) show that the use of centrifugation cycles during extraction improved the yield and extract quality.

In a previous work (Apaolaza, Valat, Ginisty, Sommier & Jomaa, 2015), a semi-industrial pilot centrifuge was modified in order to enable application of microwaves during the separation process for drying purposes. Combination of high rotational speeds and microwaves was a real technical challenge and demonstrated that energetic cost of drying could be significantly decreased through this combination of mechanical and thermal effects. In this study, we modified the semi-industrial pilot combining centrifugal force and microwave heating initially designed for drying to perform extraction of natural products and to allow the collection of the extracts by gravity.

All modifications and adaptations were performed to permit several possibilities for MW/C extraction with maximum linear speed of the basket wall at 4000 rpm of about 230 km/h, maximum MW power of

* Corresponding author.
E-mail address: farid.chemat@univ-avignon.fr (F. Chemat).

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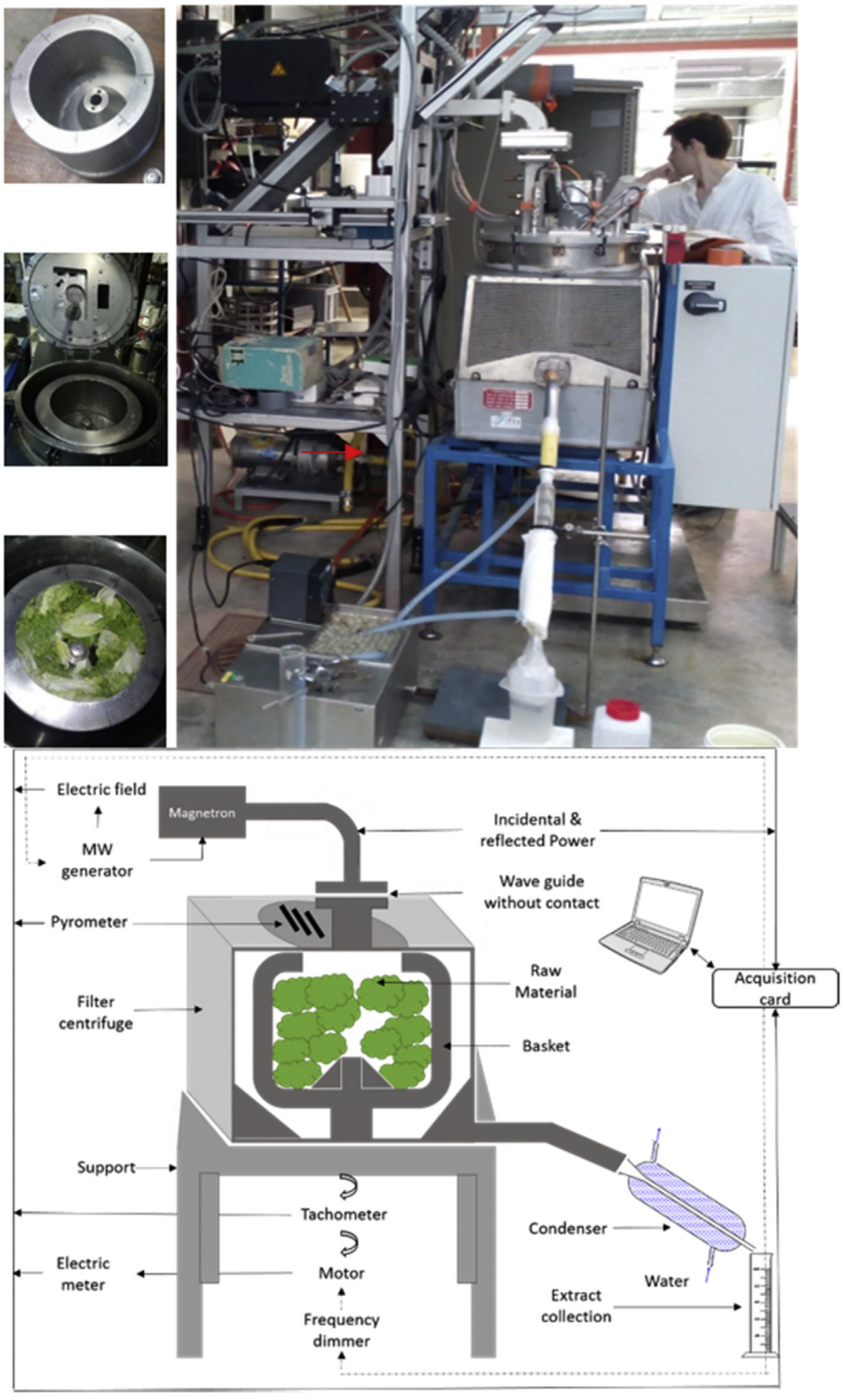

Fig. 1. Microwave-assisted dynamic extraction by combination with centrifugal force.

1.2 kW, with the possibility of injecting directly steam or fluid during the process and forcing ventilation of air with temperature and humidity control. Furthermore, to demonstrate the synergy of thermal (microwave heating) and mechanical (centrifugal gravity force) combination, MW/C semi-industrial pilot was equipped with different sensors which measure surface temperature of the product, energy consumption of microwave and rotational speed, incident and reflected microwave power.

The aim of this study is also to prove that subsequent combinations of non-conventional processes such as MW and centrifugation technologies will permit the development of new operating conditions and driving forces, and consequently of a new extraction continuous technique with high affinity, high intensification level, and possibility to scale up or down.

In this work, we studied extraction of polyphenolic compounds from the by-products of common lettuce (*Lactuca sativa* L.) used as a model product by MW/C. The different extraction parameters such as microwave power, centrifugal gravity force and extraction time were