LWT - Food Science and Technology 77 (2017) 110–118

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Effect of microwave power coupled with hot air drying on process efficiency and physico-chemical properties of a new dietary fibre ingredient obtained from orange peel

Clara Talens [a], Juan Carlos Arboleya [a], Marta Castro-Giraldez [b, *], Pedro J. Fito [b]

[a] AZTI - Food Research, Parque Tecnológico de Bizkaia, Astondo Bidea, Edificio 609, 48160, Derio, Bizkaia, Spain
[b] Instituto Universitario de Ingeniería de Alimentos para el Desarrollo, Universidad Politécnica de Valencia, Camino de Vera s/n, 46022 Valencia, Spain

ARTICLE INFO

Article history:
Received 22 February 2016
Received in revised form
10 November 2016
Accepted 13 November 2016
Available online 14 November 2016

Keywords:
Microwave drying
Energy consumption
Citrus by-products
Orange fibre
Swelling capacity

ABSTRACT

Orange by-products are an excellent source of dietary fibre. The main objective of this work was to compare the physico-chemical and technological properties of fibres obtained from orange by-products by applying two different drying methods: hot air (HAD) and hot air coupled with microwave drying (HAD + MW). Process efficiency was also compared. 92% reduction in processing time and 77% reduction in energy consumption was achieved with HAD + MW. The drying treatment did not affect the physico-chemical properties of the fibres; however, the shrinkage-swelling phenomena that occurred during drying changed the rehydration properties of the fibre. HAD mainly affected the mechanical energy whereas HAD + MW affected the surface tension. An increase in particle size due to an increase in porosity during HAD + MW improved the fibre swelling capacity. HAD + MW can reduce drying time resulting in a more efficient drying process that positively affects the orange fibre's technological properties.

1. Introduction

One important source of citrus dietary fiber is the residue generated by the orange juice industry (Fava et al., 2013; O'Shea, Arendt, & Gallagher, 2012). The ability to swell after water absorption is the principal physiological effect of fiber. The physico-chemical properties the fibre may be altered during processing operations such as drying (Bocco, Cuvelier, Richard, & Berset, 1998; García Herrera, Sánchez-Mata, & Cámara, 2010).

The main disadvantage of conventional hot air drying (HAD) is that it takes a long time, even at high temperatures, which in turn may cause serious damage to the product's quality attributes, such as flavour, colour, texture, nutrient status and beneficial health substances (Nijhuis et al., 1998; Tsami, Krokida, & Drouzas, 1998). The application of coupled drying technologies such as hot air-microwave drying (HAD + MW) could reduce the drying time and preserve the quality of orange by-products (Fava et al., 2013; Talens, Castro-Giraldez, & Fito, 2016a). MW drying has achieved considerable attention in the recent past, gaining popularity because of its advantages over conventional heating such as reducing the drying time of biological material with small quality loss (Arslan & Ozcan, 2010; Sahraoui, Vian, El Maataoui, Boutekedjiret, & Chemat, 2011). The theoretical basis of drying treatments by hot air is to produce water fluxes from food sample to the air stream induced by a gradient of water chemical potential (Demirel & Sandler, 2001). The main drive of the water transport is the gradient between a_w and relative humidity (Traffano-Schiffo, Castro-Giráldez, Fito, & Balaguer, 2014). A common technique is to couple MW with hot air drying (Bergese, 2006; Kowalski, Rajewska, & Rybicki, 2005). Talens (2015) reported a higher expansion phenomenon in orange peels at 14% water content after HAD + MW drying at 6 W/g compared to HAD. One of the strategies used to improve the functionality of vegetable by-products is the expansion of fibrous materials which in turn increases its specific surface area, thus generating a greater retention of water (Bejar, Kechaou, & Mihoubi, 2011; Ghanem, Mihoubi, Kechaou, & Mihoubi, 2012; Santana and Gasparetto, 2009; Gu, Ruan, Chen, Wilcke, & Addis, 2001; Lundberg, 2005; Ruiz-Dıaz, Martı;nez-Monzó, Fito, & Chiralt, 2003; Turbak, Snyder, & Sandberg, 1983).

The objective of this study was to compare the energy consumption of hot air drying (HAD) *versus* hot air drying coupled with microwaves (HAD + MW) by analysing the physico-chemical and

* Corresponding author.
E-mail address: marcasgi@upv.es (M. Castro-Giraldez).

http://dx.doi.org/10.1016/j.lwt.2016.11.036
0023-6438/

Nomenclature

MW	microwave drying
HAD	hot air drying
WRC	water retention capacity
TDF	total dietary fibre
IDF	insoluble dietary fibre
SDF	soluble dietary fibre
SC	swelling capacity
dm	dry matter
φ	relative humidity (−)
M	mass per time in wet basis (kg s^{-1})
M'	mass per time in dry basis (kg s^{-1})
x	mass fraction (kg kg^{-1})
X	absolute moisture (kg water kg dry air $^{-1}$)
t	time (s)
h	specific enthalpy (J kg^{-1})
p_s	water saturation pressure (kPa)
C_p	heat capacity at constant pressure (W g^{-1} K^{-1})
ΔH	molar enthalpy (J mol^{-1})
ρ	density (kg m^{-3})
ν	velocity (m s^{-1})
s	section (m^2)
E	energy (kW or kWh)
W	microwave energy (W g^{-1})
P	absolute pressure (Pa)
T	temperature (K)
R	ideal gases universal constant (J mol^{-1} K^{-1})
Qc	isosteric heat
A	sample overall surface (m^2)
A^*	sample external surface (m^2)

Subscripts and superscripts

amb	ambient conditions
da	dry air
D	drying conditions
0	initial time
v	vapour
w	water
i	internal
e	external
P	protein
F	fat
A	ash
C	carbohydrates
S	sugar
T	total; CEL Cellulose; HEM Hemicellulose; L Lignin

technological properties of the dietary fibre obtained from orange by-products.

2. Materials and methods

2.1. Fibre production process

Orange peels (Citrus sinensis (L.) Osbeck var Lane Late) were obtained after juice extraction by using a rotary press machine (Zumex Z450, Zumex Group, Valencia, Spain). Orange by-products were minced to 0.5–1 cm particle size using a cutter (Stephan UMC-5, Stephan, Germany) and blanched in water (ratio of 1 kg of fresh orange peel per 4 L of distilled water) at 65 °C for 5 min. Afterwards, samples were centrifuged at 1 kg for 5 min using a high performance centrifugal machinery (Comteifa, Barcelona, Spain).

Blanched samples were treated in batches of 0.5 kg by two different drying methods in order to compare process efficiency and the physico-chemical and rheological characteristics of the fibre ingredient obtained. A pilot scale combined 2450 MHz electromagnetic MW and hot air drier equipment (MMP20T, Sairem S.A., Miribel, France) was used for HAD and HAD + MW treatments. Combined drying chamber dimensions were 0.66 m × 0.66 m x 0.83 m, air velocity was 7 m/s, hot air temperature was 55 °C (relative humidity = 6.5%), ambient temperature was 15 °C and relative humidity was 60%. For the energy consumption calculations, HAD, HAD+2 W/g, HAD+4 W/g and HAD+6 W/g were studied (the applied MW power was referred to the initial weight). The drying process was performed for each treatment until sample moisture was 0.01 kg_w/kg_T. Drying processes were stopped at different times in order to obtain the mass variation and moisture. Weight was measured by a precision balance Mettler Toledo AB304-S (±0.001 g). Experiments were carried out in triplicate.

For physico-chemical analysis, samples treated by HAD and HAD+6 W/g were compared after 190 min and 15 min of drying, respectively. This was the time needed to reach 0.01 kg_w/kg_T of final moisture in orange by-product. After drying, samples were milled using an ultracentrifuge mill (ZM 100, Retsch, Haan, Germany) with a sieve of 500 μm. At this stage, powder samples were sealed in plastic bags for further characterization.

2.2. Compositional analysis

Powder samples were analysed according to the ISO recommended standards. Moisture as in ISO 1442:1997 (ISO., 1997); ash as in ISO 936:1998 (ISO., 1998); protein content was analysed by using the Digestion Unit K-435 and a distillation unit B-324 (Buchi Labortechnik AG, Flawil, Switzerland). A correction factor of 6.25 was used as recommended by ISO 937:1978 (ISO., 1978). Crude fat was analysed as in ISO 1443:1973 (ISO., 1973). Total sugars were analysed by Luff–Schoorl method for reducing sugars (Lees, 1968). The carbohydrate content was determined by difference.

TDF, SDF, and IDF were determined by the AOAC enzymatic-gravimetric method, 991.43. Acid detergent fibre and acid detergent lignin was analysed by the gravimetric method AOAC 973.18. Cellulose content was calculated as the difference between acid detergent fibre and acid detergent lignin. Finally, hemicellulose content was determined according to NF V 18–122 (AFNOR., 1997).

2.3. Colour

Colour was measured following CIELab scale. L*, a* and b* parameters were measured using a Minolta CR-400 chromameter (Osaka, Japan), where L* is the parameter that measures lightness, a* the tendency towards red and b* the tendency towards yellow.

The meter was calibrated using the standard white plate provided by the manufacturer and powder samples were disposed over the whole surface of the plate for measurement in triplicate.

2.4. Particle size distribution

Analysis of the particle size distribution was carried out using a laser diffractometer Mastersizer 2000 (Malvern Instruments Ltd,