FOOD AND BIOPRODUCTS PROCESSING XXX (2014) XXX–XXX

Contents lists available at ScienceDirect

Food and Bioproducts Processing

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

Optimization of spray drying process in cheese powder production

Zafer Erbay[a], *Nurcan Koca*[b,*], *Figen Kaymak-Ertekin*[b], *Mustafa Ucuncu*[b]

[a] *Department of Food Engineering, Faculty of Engineering and Natural Sciences, Adana Science and Technology University, 01180 Adana, Turkey*
[b] *Department of Food Engineering, Faculty of Engineering, Ege University, 35100 Izmir, Turkey*

ABSTRACT

In this study, white cheese powder was produced using a pilot scale spray drier and response surface methodology was used to optimize the operating conditions of spray drying. The independent variables were inlet drying temperature, atomization pressure and outlet drying temperature, while drying experiments were carried out with an inlet drying air temperature range of 160–230 °C, an outlet drying air temperature range of 60–100 °C and an atomization pressure range of 294–588 kPa. The responses were nonenzymatic browning index, free fat content, solubility index, bulk density of cheese powder and exergy efficiency of the spray drying process. Optimum operating conditions were found to be an inlet drying temperature of 174 °C, atomization pressure of 354 kPa, and an outlet drying temperature of 68 °C. At this optimum condition, nonenzymatic browning index, free fat content, solubility index, bulk density and exergy efficiency were found to be 0.123 OD/g dm, 40.7%, 82.7%, 252 kg/m^3 and 4.81%, respectively.

Keywords: Spray drying; Optimization; Cheese powder; Free fat; Exergy

1. Introduction

Cheese is one of the most important dairy products with more than 1000 different varieties (Fox, 2011). Apart from the direct consumption of cheese, it can be used as a food ingredient for its functional properties such as flavor delivery, mouthfeel, appearance and adhesive properties. To obtain these functional properties, cheese needs be processed and the most effective industrial process is drying (Fox et al., 2000; Guinee and Kilcawley, 2004; Guinee, 2011). One of the most important dehydrated cheese products is cheese powder. Today, cheese powder finds widespread use in industrial sectors primarily as a flavoring agent and/or nutritional supplement in a variety of foods, and recent market analyses indicate that the consumption of cheese as an ingredient is growing rapidly (Guinee, 2011).

Drying of food materials is complicated because physical, chemical and biochemical transformations may occur during drying, some of which may be desirable. So, in practice, a dryer is considerably more complex than a device that merely removes moisture and for every dryer, the process conditions must be determined based on the feed, the product being produced, the purpose of the drying and methods being employed (Mujumdar and Law, 2010).

Spray drying is a suspended particle processing technique that has become one of the most important methods for drying fluid foods, especially in the dairy industry (Filkova et al., 2006). Dairy powders are generally characterized by their physical properties such as bulk density, reconstitution properties and free fat content; and these properties are directly affected by the spray drying process (Schuck, 2002).

Bulk density is one of the properties used as part of the specifications for final product and it is used by the industry to arrange storage, processing, packaging and distribution conditions (Barbosa-Canovas et al., 2005). Solubility is a key feature for overall reconstitution quality and food powders should be able to provide good solubility to be useful and functional (Barbosa-Canovas et al., 2005; Baldwin and Truong,

* Corresponding author at: Department of Food Engineering, Faculty of Engineering, Ege University, 35100 Bornova, Izmir, Turkey. Tel.: +90 232 3113029; fax: +90 232 342 7592.
E-mail addresses: zafererbay@yahoo.com (Z. Erbay), nurcan.koca@ege.edu.tr, nurkoca@yahoo.com (N. Koca), figen.ertekin@ege.edu.tr (F. Kaymak-Ertekin), mustafa.ucuncu@ege.edu.tr (M. Ucuncu).
Received 8 April 2013; Received in revised form 27 November 2013; Accepted 20 December 2013

http://dx.doi.org/10.1016/j.fbp.2013.12.008

2007). Additionally, free-fat that is defined as the fraction of fat which is not protected by protein film is very important during and after processing as it leads to off-flavors, poor rehydration and flowing properties (Farkye, 2006). Apart from these, considerable quality concerns for powdered products are the degradation of flavor, color and texture of the product during processing or storage. Nonenzymatic browning, known as Maillard reaction, is one of the major detrimental reactions that causes the formation of chemically stable and nutritionally unavailable derivatives for dairy powders (Palombo et al., 1984; Kilic et al., 1997), because of that, it should be minimized during spray drying.

Furthermore, drying is one of the most energy-intensive unit operations and the most energy-intensive method for drying is spray drying with the sole exception of freeze drying (Mujumdar and Huang, 2007). In the dairy industry, spray drying operations are the primary drying operations and they are the most important processes with regards to energy consumption (IDF, 2005). An important tool to analyze, optimize and improve the energy efficiency of the spray drying process and spray driers can be exergy analysis. Several studies have been undertaken on exergy analysis of different kinds of drying processes of food materials (Erbay and Icier, 2011; Gungor et al., 2011), while studies focused on exergetic assessment of spray drying process have recently begun (Jin and Chen, 2011; Erbay and Koca, 2012; Aghbashlo et al., 2012).

The main objective of this study was to determine the optimum process conditions for spray drying in white cheese powder production by investigating the effects of drying process variables on product quality.

2. Materials and methods

2.1. Materials

White cheese that was ripened for 7 months was supplied from Sütaş Dairy Company (Bursa, Turkey). Water, fat, protein, ash and salt content of white cheese used in this study were 52.0%, 24.4%, 18.4%, 4.9% and 4.3%, respectively. White cheese blocks were ground into small pieces. The ground cheese was put into air- and water-tight durable polypropylene plastic containers, stored at 2 °C and processed within 48 h.

Before drying, white cheese slurry composed of ground white cheese, water and Joha emulsifying salts (Kipa Chemical Company, Istanbul, Turkey) was prepared. In cheese slurry preparation, 3% (based on cheese) emulsifying salts were used. The slurry was heated and sheared with a blender (model LB10S, Waring, Torrington, CT). Firstly, the slurry was sheared at 6000 rpm for 1 min. Then, slurry heated in a water bath to 80 °C and sheared again at 6000 rpm for 10 min. The slurry, having 25% dry matter based on cheese, was fed to the spray drier at 45 °C.

2.2. Drying procedure

The white cheese slurry was dried in a pilot scale spray drier (Mobile Minor Niro-Atomizer, Soeborg, Denmark). The schematic illustration of the spray drier was shown in a previous study (Erbay and Koca, 2012). The cheese slurry was pumped with a peristaltic pump (model BT600-2J, Longer Precision Pump, Baoding, Hebei, China) to the atomizer and atomized with a rotary atomizer into a drying cabinet with dimensions of 1.2 m height and 0.87 m diameter. The feed rate was adjusted due to the inlet and outlet drying air temperatures. The rotary atomizer was driven by an air turbine wheel and its speed was between 20,000 rpm and 31,500 rpm. The atomizer wheel had a 50 mm diameter with 24 vanes to create a perfect and uniform atomization. Atomization pressure affects the droplet dimensions sprayed into the drying cabinet; therefore it is an important factor that causes effects on the drying rate and powder dimensions. Experiments were carried out at the inlet drying air temperature range of 160–230 °C, outlet drying air temperature range of 60–100 °C and with an atomization pressure range of 294–588 kPa. The air flow was co-current and the mass flow rate of air was 0.08 kg/s. The cheese powder samples were packaged in PET/Al/LDPE, than analyzed within 48 h. Before starting any experiment, the system was run for at least half an hour to obtain steady-state conditions.

2.3. Moisture content

The moisture contents of white cheese powders were determined by using gravimetric method (IDF, 1982). Two grams of samples were placed in an oven at 102 °C until constant weight was obtained. Masses were measured using a digital balance (model UX4200H, Shimadzu, Kyoto, Japan).

2.4. Browning index

The browning index values of white cheese powder samples were measured by an enzymatic digestion method (Palombo et al., 1984; Kilic et al., 1997). The method was based on pronase proteolysis that releases the brown pigments. One gram of white cheese powder was used during analysis and the absorbance of the samples were read at 420 (A_{420}) and 550 (A_{550}) nm by using a spectrophotometer (Varian, Cary 50 Bio UV/Visible Spectrophotometer, Palo Alto, CA) and the optical density (OD) of the samples were calculated as

$$\mathrm{OD} = A_{420} - A_{550} \tag{1}$$

The browning index (*BI*) values for each sample were expressed as OD/g dry matter.

2.5. Free fat content

The free fat content of dairy powders is commonly quantified by the solvent extraction method (Vignolles et al., 2007). In this study, the modified solvent extraction method described in A/S Niro Atomizer (2005) was used and the results were expressed as the percentage of free-fat content.

2.6. Solubility index

The solubility index of white cheese powder samples were measured by the Haenni method (Hawthorne, 1944). 1 g of powder was placed into a stoppered test tube with 5 mL of 5% sodium chloride solution (m/v). The solution was shaken and mixed with a vortex mixer. The refractive index values of the dispersed sample and sodium chloride solution were measured by using a refractometer (model RFM 330, Bellingham Stanley Ltd., Kent, UK). The solubility index (*SI*) values were calculated as:

$$Haenni\,value = y = (RI_{\mathrm{sample}} - RI_{\mathrm{NaCl}}) \times 1000 \tag{2}$$