Contents lists available at ScienceDirect

Food and Bioproducts Processing

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

Enhancement of physicochemical properties of sugar beet fibres affected by chemical modification and vacuum drying

Dragana Šoronja-Simović[a], *Zita Šereš*[a], *Nikola Maravić*[a], *Marijana Djordjević*[a], *Miljana Djordjević*[a,*], *Jadranka Luković*[b], *Aleksandra Tepić*[c]

[a] *Department of Carbohydrate Food Engineering, Faculty of Technology, University of Novi Sad, Bul. cara Lazara 1, 21000 Novi Sad, Serbia*

[b] *Department of Biology, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia*

[c] *Department of Food Preservation Engineering, Faculty of Technology, University of Novi Sad, Bul. cara Lazara 1, 21000 Novi Sad, Serbia*

ARTICLE INFO

Article history:
Received 22 February 2016
Received in revised form 7 September 2016
Accepted 16 September 2016
Available online 22 September 2016

Keywords:
Sugar beet fibres
Alkaline hydrogen peroxide
Vacuum drying
Colour
Hydration properties

ABSTRACT

The effects of chemical modification with hydrogen peroxide and different temperatures of vacuum drying (55, 65 and 75 °C) on content of soluble and insoluble dietary fibres, physicochemical properties (colour, structure, water binding and swelling capacity) and drying kinetics of sugar beet fibres were studied. An increase in soluble and insoluble fibre ratio for 20–40% and fibre brightness for approximately 25% was achieved by chemical modification compared to the non-modified fibres. Further, swelling and water binding capacities of fibres, after conducting chemical modification, were three to four times higher than for non-modified fibres. Uniform reduction of a drying time with a rising temperature and fluctuating drying rate decrease were observed in modified fibres samples. The mentioned effects are explained by changes in fibre structure upon chemical modification. The whole study indicates that chemical modification and vacuum drying are suitable for sugar beet fibres and that modified fibres can be used as additives in food industry in order to fortify the diet.

1. Introduction

An increased awareness of a diet related health problems has intensified consumers' demand for natural ingredients which are expected to be biologically-active and health-promoting (Schieber et al., 2001). A large number of studies indicate positive health effects of dietary fibre (DF) intake (Anderson et al., 2009; Giacco et al., 2002; Liu et al., 2002; Pereira and Ludwig, 2001). The intake of DF helps prevention of various health problems such as obesity, type 2 diabetes, hypertension, cardiovascular diseases and some forms of cancer (Kendall et al., 2010). The recommended daily intake of total dietary fibre (TDF) depends on gender and age and ranges between 25–38 g, but the average intake is much lower than the recommended value (Slavin, 2003). DF can be classified in two main groups, soluble dietary fibre (SDF) (pectin, β-glucan, gums) and insoluble dietary fibre (IDF) (cellulose, hemicelluloses, lignin) (Papathanasopoulos and Camilleri, 2010). From the physiological role viewpoint, besides the amount of TDF, the ratio of SDF and IDF is also very important (Ishizuka et al., 1999). In for-

Abbreviations: DF, dietary fibre; TDF, total dietary fibre; SDF, soluble dietary fibre; IDF, insoluble dietary fibre; NMF, non-modified fibres; MF, modified fibres; SEM, scanning electron microscopy; WBC, water binding capacity; SC, swelling capacity.

* *Corresponding author.*
E-mail addresses: djordjevicmiljanatf@yahoo.com, miljanadj@tf.uns.ac.rs (M. Djordjević).

http://dx.doi.org/10.1016/j.fbp.2016.09.003
0960-3085/

mulations of certain food products, besides health effects, important are some functional properties of fibres such as water binding capacity (WBC), swelling capacity (SC), increasing viscosity or gel formation (Oreopoulou and Tzia, 2007).

Nowadays, an increasing number of studies are dealing with numerous by-products of different industries in order to explore possible materials that can be used for commercial production of DF. Sugar beet pulp as a fibrous by-product obtained from sugar production is an important source of dietary fibre (TDF 75–80%), but thus far mainly underutilized in food manufacturing. The extracted sugar beet pulp is rich in SDF and IDF, with approximately one-third of cellulose, hemicellulose and pectin (Dinand et al., 1999). Preferred SDF/IDF ratio, low level of phytate, and high water binding/holding capacity make sugar beet fibres more attractive than fibres originating from the cereal bran (Graf, 1986; Stauffer, 1993). Despite the evidence on health effects of fibre-rich foods, most consumers avoid them because they perceive the textural and sensory properties to be less attractive than conventional foods. In order to improve perceived attractiveness of healthy foods with sugar beet fibres, chemical modification with alkaline hydrogen peroxide can be conducted. Chemical modification of fibres from sugar beet involves eliminating or reducing the intensity of grey colour, unpleasant taste and odour (Dongowski, 1993). This treatment affects lignocellulosic materials such as sugar beet pulp, by solubilizing a portion of the lignin which is a part of the lignocellulosic matrix, resulting in higher water absorbency, improved softening and swelling characteristics of cell wall material (Dreher, 1999). Moreover, to allow easier manipulation and treatment, fibres must be dried and ground first in order to be used as an ingredient in food products.

In this research, vacuum drying was selected due to its favourable characteristics of lower pressure drying, which allows reduction of drying temperatures and therefore preserves the quality (taste, aroma) and appearance (colour, shape) of dried product when compared with the conventional air drying (Arévalo-Pinedo and Xidieh Murr, 2007). There is a lack of information documenting the combined effect of chemical modification and contact vacuum drying on composition and hydration properties of sugar beet fibres. The aim of this study was to evaluate the influence of chemical modification and different temperatures of contact vacuum drying of sugar beet fibres on: content of SDF and IDF, drying kinetic, colour, structural properties and hydration properties (water binding and swelling capacity).

2. Materials and methods

Sugar beet pulp used in this research was obtained in the technological process of sugar production from the Sugar Factory "Crvenka" (Crvenka, Serbia) with initial moisture content of 10–12% from 2014 year campaign. The sugar beet pulp was dried in the sugar factory using a rotating drum drier with a hot air stream of approximately 800 °C. For the purpose of the further research, dried beet pulp was treated and modified accordingly, in order to obtain the samples of non-modified and modified beet fibres.

2.1. Production of non-modified fibres

Dried sugar beet pulp was hydrated in laboratory vessels by adding 9 L of water per 1 kg of dry pulp and holding for a period of 24 h at room temperature. After hydration step, part of the water (60%) was removed mechanically in a laboratory press. Obtained pressed pulp was packed and frozen at −20 °C. The remaining water from the pulp was evaporated in a contact vacuum oven. After the drying process, pulp was ground in a laboratory mill (type WZ-1 "Spolem", ZBPP, Bydgoszoz, Poland) and sieved through a laboratory sieve (type SZ-1, ZBPP, Bydgoszoz, Poland). Obtained fractions with particle size in the range from 95 to 150 μm were used in further analysis. These fibres were, in further research, considered as non-modified fibres (NMF).

2.2. Production of modified fibres

NMF were pressed and treated with hydrogen peroxide solution (H_2O_2, concentration of 30%), followed by the successive and gradual addition of 10 mol L^{-1} NaOH in the reaction mixture until pH 11 was reached (Fig. 1). The reaction mixture was neutralised with 35% HCl, 24 h after chemical treatment, until the pH reached the value between 6 and 7. Following the neutralisation process, fibres were rinsed with distilled water, pressed and frozen at −20 °C. The obtained fibres were referred to as modified fibres (MF). After the freezing step, MF were treated following the same procedure as previously described for NMF.

2.3. Drying procedure and equipment

The dryer consist of a stainless-steel cylindrical vacuum chamber with total volume of 70 L. Inside the chamber condenser and the aluminium heating surface were placed and connected with the corresponding scale and a vacuum pump. Frozen sugar beet fibres were dried in a vacuum chamber at three different temperature values (55 °C, 65 °C and 75 °C) at an absolute pressure of 100 Pa. Drying was performed to a constant mass, and the fibre mass changes were recorded every 10 min. Several thin-layer drying models were used for fitting of obtained drying curves, for both NMF and MF.

2.4. Mathematical modelling of drying curves

The relative moisture content (MC) of DF samples throughout drying experiments was calculated using Eq. (1).

$$MC = \frac{M_t}{M_0} \quad (1)$$

where M_t represents moisture content at the specific time t, and M_0 is initial moisture content of the sample. The drying rate (DR) of DF samples throughout drying experiments was calculated from the dry basis moisture contents.

Fitting of drying curves of NMF and MF samples was performed with 3 commonly used thin-layer drying models and the best fit was achieved using modified Midilli et al. model (2002) according to Eq. (2):

$$MR = a\ e^{kt} + ct \quad (2)$$

where a and c are empirical constants in model, and k is the empirical coefficient in model.

2.5. Chemical composition of dietary fibres

The TDF content was determined using AOAC method 991.43 (1991) and AACC (1995) method 32-07, the IDF and SDF content was determined by AACC (2000) method 32-21 using commercially available test kits (Megazyme International Ireland Ltd., Wikclow, Ireland). The protein content was determined in accordance with AACC (2000) procedure 46-13 using the Kjeldahl method and the factor 6.25 × N for conversion. DF ash content was determined in dry sediment, which was obtained during the determination of TDF by annealing at 525 °C for 5 h (AOAC, 1990).