Food Hydrocolloids 51 (2015) 76–87

Contents lists available at ScienceDirect

Food Hydrocolloids

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

Effect of drying method on rheological, thermal, and structural properties of chestnut flour doughs

Jasim Ahmed*, Hasan Al-Attar

Food and Nutrition Program, Environment & Life Sciences Research Center, Kuwait Institute for Scientific Research, P.O. Box 24885, Safat 13109, Kuwait

ARTICLE INFO

Article history:
Received 30 July 2014
Received in revised form
18 April 2015
Accepted 27 April 2015
Available online 14 May 2015

Keywords:
Chestnut
Physicochemical properties
Thermal analysis
Pasting properties
Complex viscosity
Scanning electron microscopy

ABSTRACT

The objective of this work was to characterize the functional, thermal and rheological properties of chestnut flour doughs produced through freeze-drying (FD) and tray-drying (TD) process. Drying method did not influence the physicochemical properties (e.g. bulk density, water holding capacity and sediment volume fraction) of chestnut flour however affected both particle mass distribution and color values (*a* and *b*) significantly. Thermal analysis of chestnut doughs showed two distinct peaks attributed by starch gelatinization and melting of starch–lipid complex, respectively. Although there were only minor differences in the total starch contents between two chestnut flour, they displayed significant variability in pasting properties and oscillatory rheology during heating. The amylograms of the chestnut dispersions showed higher maximum viscosity and heat stability for the FD sample, as well as a higher tendency to the molecular re-association during cooling than for the TD flour. Pasting properties of chestnut doughs were well described by rheometric measurement and data obtained through both measurements are comparable. The chestnut doughs exhibited predominating solid-like property ($G' > G''$). The mechanical rigidity (G') of doughs significantly influenced by the concentration and the increase in G' with concentration was well described by a power-type relationship. The chestnut granules exhibited a range of shapes, varying from round, oval, rectangular to irregular. Average particle diameter of the tray-dried sample was larger than the freeze-dried sample. This study provides in-depth knowledge on structural/rheological properties of chestnut flour by two drying processes, which would be helpful for selection of ingredients and their application in food industries.

1. Introduction

Chestnut (*Castanea mollissima Bl.*) is an important seasonal nut with a total world production of 1.96 million tons in 2010 (FAOSTAT, 2012). Chestnut fruit is highly appreciated and extensively consumed throughout Europe, America, and Asia. The fruit is consumed as fresh, boiled, roasted or in processed forms. Recently, there is an increasing demand of chestnut flour for its gluten-free characteristic and low fat content compared with other nuts for the development of food products for celiacs and human health. Plenty of literature is available on the chestnut-based gluten-free food products development either individually or in combination. Chestnut has a large potential for commercial success as it is a good source of starch which can replace the conventional starch sources, like cereals and tubers (Correia & Beirao-da-Costa, 2010; Liu, Wang, Chang, & Wang, 2015; Moreira, Chenlo, Torres, & Rama, 2014) for modification of many food properties like texture, rheology, gelation, moisture retention, products homogeneity etc. (Rindlav-Westling, Stading, & Gatenholm, 2002). It is, therefore, a steady supply of chestnut with moderate cost is required to fulfill various industrial applications like development of thermoplastic starch, gluten-free and health related food products.

Chestnuts are seasonal fruits with high water content (≃50% wet basis) and available for a short period of time. Drying is one the best preservation methods that can extend the shelf life of chestnut fruits. Dried chestnuts can be further processed into a powder form (e.g. flour) which could be incorporated into various food formulations as a functional food additive with distinct flavor. Quality of dried flour depends upon type of drying, temperature used, duration, air velocity, tray loading and many other factors. Several drying methods have been reported in the literature so that high quality products are produced efficiently. Conventional hot-air tray drying is an inexpensive process, and the sample dries rapidly at selected heating condition (temperature, air flow rate and humidity). It has been reported that fruit drying temperatures affected the

* Corresponding author.
E-mail addresses: jahmed2k@yahoo.com, jaahmed@kisr.edu.kw (J. Ahmed).

http://dx.doi.org/10.1016/j.foodhyd.2015.04.030
0268-005X/

physicochemical properties of the fruit flour and consequently could influence functional properties (Correia, Leitão, & Beirão-da-Costa, 2009). However, the quality (e.g. color, rehydration capacity) of the dried product changes significantly. During hot-air drying, chestnut flour undergoes gelatinization in presence of water, and it is believed that mode of drying significantly affect the gelatinization and functionality. Furthermore, the extent of gelatinization depends on starch source, moisture content, drying temperature, the presence of other compounds (Chiotelli, Pilosio, & Le Meste, 2002) and also the amylose/amylopectin ratio (Correia & Beirão-da-Costa, 2012). It was observed that amylose/amylopectin ratio and resistant starch content altered during drying at temperatures 70 °C or less (Correia & Beirão-da-Costa, 2012); whereas Moreira, Chenlo, Torres, and Rama (2013) reported that chestnut flour dried at 85 °C absorbed more water content to obtain the desired consistency. On the other hand, freeze drying (FD) is one of the most advanced dehydration methods, which produces superior product quality (porous structure and minimum shrinkage) and often low throughput process and the operational cost of the process is very high. Mostly, pharmaceutical and nutraceutical industries can afford the FD process for their products whereas food industries always look for products with desired functional properties with a moderate cost. Therefore, a comparison between two drying processes could provide information on the physical and functional properties of chestnut flour. The obtained information can guide chestnut flour manufacturers and end users to select the appropriate process/product that can be beneficial for their operations or product formulation.

Rheology plays an important role for characterization of new ingredients especially starch-based products and to understand its functionality. During thermal processing, most of cereal and legume flour undergo starch gelatinization and protein denaturation in dispersion, and produce visco-elastic dough/gel. Viscoelastic properties of gluten-free dough, like chestnut flour (CNF) dough, can be influenced by the particle size and particle size distribution of flour and also by means of water absorption capacity of flour (Moreira et al., 2014). Those thermal transitions and structural behavior of CNF dough can be measured by various fundamental (e.g. oscillatory rheology, creep behavior, biaxial measurement) and empirical rheological techniques (e.g. penetration, viscoamylograph and uniaxial measurement). Rheology of dough is critical in optimizing product development, manufacture methodology or final product quality (Steffe, 1996) as well as it is useful to determine the stability of food materials. Rheological characterization of gluten-free dough like chestnut would be very interesting since it lacks gluten which is responsible for development of three-dimensional network. Moreira and his group (Moreira, Chenlo, Torres, & Prieto, 2010; Moreira, Chenlo, & Torres, 2011, 2012, Moreira et al., 2013, 2014) extensively studied rheological behavior of chestnut flour/starch individually or in combination with other additives. However, limited works have been done on mechanically dried chestnut and its effect on rheological and structural behavior of CNF dough. No information is available on functionality and rheological characteristics of freeze-drying chestnut flour.

The main objective of this work was to compare the functional, pasting, rheological, and thermal properties of chestnut flour doughs processed through freeze-drying and tray drying. Furthermore, microstructures of CNF doughs were also evaluated.

2. Materials and methods

2.1. Materials

A single batch (20 kg) of Chinese grown chestnut (unknown cultivation) samples was purchased from the local market in the state of Kuwait during the winter season of 2013–2014. Chestnuts with average moisture content (43.5 ± 1.3% wet basis) (AOAC, 2000) were stored at cold room (4 ± 1 °C for 7 days) until carrying out the drying experiments. Samples (10 kg) were washed thoroughly, peeled and cut into small pieces with a sharp knife followed by macerated into puree. Samples were divided into two batches for drying (tray loading 2 kg/m^2). The first batch was placed inside a tray dryer (Harvest Saver, Model R5A, Commercial Dehydrator Systems, Inc., OR, USA) for drying till the sample achieved constant moisture content. Drying was carried out at 60 °C with a relative humidity of 30% and an air velocity of 2.9 m s^{-1}. The drying time was about 14 h till it reaches to constant moisture content. The selection of the drying temperature was based on some preliminary runs at selected temperatures (50, 55, 60 and 65 °C), and visual observations on the dried products. It was found that the drying at 60 °C produced the best quality of chestnut flour. This observation has been well-supported by Correia et al., (2009); those authors found the optimum drying temperature for chestnut was 60 °C. The second batch was freeze-dried. The samples were frozen in a freezer, and later transferred to the freeze-drier (GAMMA 2-16 LSC; Martin Christ GmbH, Osterode am Harz, Germany) for 38 h at a temperature between −47 °C and −50 °C, and a pressure of 0.7 Pa. Both drying experiments were carried out in duplicate.

2.2. Sieve analysis

Dried chestnut samples were grinded in a laboratory size grinder (Robot Coupe R5, France), and passed through a series of United States (US) Standard sieve numbers 30-mesh (595-μm), 50-mesh (297-μm), 100-mesh (149-μm), 140-mesh (105-μm), 200-mesh (74-μm), 230-mesh (63-μm) and 270-mesh mesh (53-μm) (Endecotts, London, UK), manually. After sieving, the amount of the ground sample (g) retained in a defined sieve were designated as 595 (−30; +50), 297 (−50; +100), 149 (−100; +140), 105 (−140; +200), 74 (−200; +230) and 63 (−230; +270) μm. The −ve sign represents chestnut flour particles passed through the sieve and the retained particles are expressed through +ve sign. Fractionated samples were packed in amber glass bottles and stored at 5 °C until further use.

2.3. Particle size distribution using light scattering

The particle-size distribution of the CNF was measured by laser light scattering using a Malvern Mastersizer 3000 instrument (Malvern Instruments Ltd, Worcestershire, UK) with Aero S dry powder dispersion. The lens used had a focal length of 300 mm which allowed particle size measurement from 0.01 to 3500 μm. The particle size distributions (PSDs), i.e., particle size at 10% (D_v10), 50% ((D_v50), median diameter), 90% (D_v90) of the volume distribution were all calculated automatically using the Mastersizer 3000 software based on Fraunhofer theory. The measurement was carried out in triplicates.

2.4. Physico-chemical properties

The proximate compositions of the dried chestnut flour were analyzed according to AOAC methods (AOAC, 2002) for the determination of moisture, ash, and crude fat contents. Protein was calculated as nitrogen content (N) × 5.3. Protein for each particle fraction was estimated by the CHNS (carbon, hydrogen, nitrogen and sulfur) analysis based on combustion method (AOAC, 2002). The loose bulk density was determined by weighing the mass of the dried powder sample which freely was poured in a 100 mL graduated cylinder and expressed as weight per unit volume (kg/m^3) (American Society of Testing Materials, ASTM D7481 – 09). The