Journal of Food Engineering 186 (2016) 34–41

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Effect of sieve particle size on functional, thermal, rheological and pasting properties of Indian and Turkish lentil flour

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ARTICLE INFO

Article history:
Received 22 June 2015
Received in revised form
12 December 2015
Accepted 5 April 2016
Available online 13 April 2016

Keywords:
Lentil
Particle size distribution
Complex viscosity
Gelatinization
Glass transition temperature
Microstructure

ABSTRACT

The influence of particle size (74–210 μm) on compositional, functional, rheological, thermal and pasting properties of two commercial lentil flour samples (Indian and Turkish) was investigated. Reduction of particle size significantly affected the composition of the flour. Turkish lentil flour fractions had higher bulk density (480–600 kg/m^3) than Indian one. Particle size did not influence the water holding capacity of flour, however, the process temperature increased those parameters significantly. Instrumental color parameters *a* and *b* reduced abruptly and the lightness value, *L* increased while the particle size was reduced from 210 to 74 μm. Laser diffraction analysis showed bimodal particle size distributions of lentil flour. Two distinct thermal transitions exhibited by lentil samples and the glass transition temperature varied among samples. Non-isothermal heating of lentil particle dispersions demonstrated a gradual decrease in the peak complex viscosity with decreasing particle size. Pasting parameters and micrographs of lentil fractions showed a significant difference between two samples. The obtained results could be useful for the food industry to manufacture lentil-based food products with a defined particle size to obtain desirable functional and rheological characteristics.

1. Introduction

Recently, there is a growing interest in plant proteins such as legume proteins among consumers', because of their potential health benefits such as reduced risk of cardiovascular disease, cancer, diabetes, osteoporosis, hypertension, gastrointestinal disorders, reduction of LDL cholesterol and obesity (Hu, 2003; Jacobs and Gallaher, 2004; McCrory et al., 2010; Zhang et al., 2015). Lentil *(Lens culinaris)* - the most studied among legumes is an excellent sources of proteins, dietary fibres and complex carbohydrates and also good sources of vitamins and minerals (de Almeida Costa et al., 2006). Lentil has one of the lowest glycaemic index (GI) among major staple foods (Jenkins et al., 1980), and numerous studies have illustrated the benefits of low GI foods in managing type 2 diabetes (Brand-Miller et al., 2003). Furthermore, the lentil does not contain gluten, and therefore, it is a good choice to develop speciality foods for celiac patients.

Mostly, lentil is used as whole seed or in split form, and as such there is no standard for milled flour used by the food industry. The flour has been used in various food applications like baked food products, snacks, soups, beverages, salad dressings, and others. In addition, lentil flour (LF) has been incorporated into various food formulation either as an ingredient or as a substitute for other types of flour (wheat or semolina flour) to produce baked and extruded snack products.

Particle size is a decisive parameter that influences inherent flour properties, and eventually the quality of the finished food product. Effect of flour particle size on its inherent properties and/or on the quality of the finished food products has been well documented. While working on particle size of rice flour, de la Hera et al. (2013a, 2013b) observed that the finer flour particles were more suitable for rice cakes over the rice bread. However, finer particles of sorghum flour showed better *in vitro* starch digestibility (Mahasukhonthachat et al., 2010). Recently, Ahmed and his group (Ahmed, 2014; Ahmed et al., 2014, 2015a,b) extensively evaluated role of particle size on functional, rheological and pasting properties of various flour samples, and found there was no regular trends between particle size and food properties, and the behavior is

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http://dx.doi.org/10.1016/j.jfoodeng.2016.04.008
0260-8774/

purely product specific. Therefore, each powdered food requires a special attention and sought detailed study on particle size and its influence on functional and structural properties to elucidate its further use in food product development and process engineering.

Plenty of literature is available on lentil flour and its functional, rheological, pasting properties. However, no attempt has been made to study the effects of lentil flour (LF) particle size on its intrinsic characteristics and related properties. The objective of this study was to evaluate and compare the effect of particle size on compositional, functional, rheological, and structural (macro and micro) properties of two commercially available lentil seeds.

2. Materials and methods

2.1. Raw materials

Two types of commercially available split red lentil seeds from two different countries (Indian Cv. L-4076 and Turkish Cv. *Çiftçi)* were procured from a local market in the state of Kuwait and used in this study. Both samples were collected from a single lot (20 kg each); stored at room temperature (20 ± 2 °C) in PET containers before use.

2.2. Sieve analysis

Split lentils were ground in a laboratory roller mill (Quadrumat® Junior, Brabender, Germany), and passed through a series of U.S. Standard sieve numbers 70-mesh (210-μm), 100-mesh (149-μm), 140-mesh (105-μm), 200-mesh (74-μm), and 230-mesh (63-μm) (Endecotts, London, UK), following the method described by Ahmed (2014). The fractions retained in each sieve after the sieving were designated as: 210 (−70; +100), 149 (−100; +140), 105 (−140; +200) and 74 (−200; +230) μm. The fractionation process was performed in triplicate.

2.3. Particle size distribution using light scattering

The particle-size distribution of the LF was measured by laser light scattering using a Malvern Mastersizer 3000 instrument (Malvern Instruments Ltd, Worcestershire, UK) with Hydro EV Flexible volume wet dispersion. The particle size distributions (PSDs), i.e., particle size at 10% (D_v10), 50% ((D_v50), median diameter), and 90% (D_v90) of the volume distribution were calculated using the Mastersizer 3000 software (version 5.54). The measurement was carried out in triplicates.

2.4. Scanning electron microscope

The microstructure and particle dimension of LF fractions were examined through a scanning electron microscope (SEM) (JEOL, JSM-5410LV, Tokyo, Japan). Each sample was coated with gold in a sputter coater (Structure Probe, West Chester, PA) before being scanned and photographed at various magnifications (450×). Particle size was measured by the software attached to the instrument which allowed for the measurement. About 50 particles were chosen randomly for the particle size measurement.

2.5. Physiochemical analysis

Proximate compositions (moisture, ash, protein and fat contents) of the LF fractions were determined according to AOAC methods (AOAC, 2002). Total dietary fiber of fat-free sample was estimated following AOAC method (method 991.43) using an automated Ankom^{TDF} Dietary Fiber Analyzer (Ankom Technology Corp., Macedon, NY).

2.5.1. Bulk density

Bulk density was expressed as weight of the flour sample in kg per unit volume of the flour (kg/m^3) (ASTM D7481 -09).

2.5.2. Total starch content

The total starch content of LF was determined by AACC (2000) method 76.13.01 (approved Nov. 3, 1999) using Megazyme Total Starch Assay Kits (Megazyme International, Wicklow, Ireland) following the method described in the instructions.

2.5.3. Color

The color was measured using a Hunter Colorflex™ Lab Calorimeter (Hunter Associates, Reston, VA). The instrument (45°/0° geometry, 10°observer) was calibrated with a standard black and white tile before the measurements. The color profile in terms of *L*, *a* and *b* values were measured according to the CIE color system (International Commission on Illumination).

2.5.4. Water holding capacity, oil holding capacity and water solubility index

The water holding capacity (WHC) and oil holding capacity (OHC) of each fraction was determined according to the method described by McConnell et al. (1974). The WHC (25 and 70 °C) and OHC (25 °C) were expressed as the volume of water/oil held in mL per gram dry matter of sample analyzed. The water solubility index (% WSI) was calculated as the dry residue weight to original dry sample weight multiplied by 100. All measurements were performed in triplicates.

2.5.5. Sediment volume fraction

The volume fraction (ϕ) was measured using a simple centrifugation technique as described by Hemar et al. (2011) with some modification at 25 and 70 °C as described elsewhere (Ahmed, 2014). The volume fraction determination was performed at least in duplicate.

2.6. Pasting properties

Pasting properties of LF particle fractions were studied using a Brabender Micro-Visco-Amylograph (Brabender, Duisburg, Germany) as described earlier (Ahmed et al., 2015b). The suspensions (15% w/v) were heated to 95 °C at a rate of 3 °C/min, held at 95 °C for 15 min, and cooled to 50 °C at a rate of 3 °C/min at a rotational speed of 250 rpm. The peak viscosity (PV), hot paste viscosity (HPV), cold paste viscosity (CPV) and their derivative parameters breakdown, setback, pasting temperature and peak time were obtained from the instrument software (Viscograph version 2.3.7).

2.7. Thermal properties

Thermal properties were measured using a Differential scanning calorimeter (DSC) (Q2000, TA Instruments, New Castle, DE) equipped with a refrigerated cooling system. The DSC was calibrated with indium and sapphire for temperature and heat capacity. The samples (10–12 mg) (Flour to Water ratio = 1:4) were run at a 10 °C/min heating/cooling ramp in heating–cooling cycles from −20 to 150 °C in a nitrogen atmosphere (flow rate 50 mL/min). The DSC measurements were done in triplicate. The enthalpy (ΔH) of the thermal transitions was calculated from the area of the peak endotherm using the Universal Analysis Software (version 4.5A, TA Instruments, New Castle, DE, USA).

2.8. Rheological measurement

Oscillatory rheological measurements of fractionated LF dough