LWT - Food Science and Technology 50 (2013) 215–219

Contents lists available at SciVerse ScienceDirect

LWT - Food Science and Technology

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

Functional properties of flour from low-temperature extruded navy and pinto beans (*Phaseolus vulgaris* L.)

M. Siddiq[a,*], S. Kelkar[b], J.B. Harte[a], K.D. Dolan[a,b], G. Nyombaire[b]

[a] *Department of Food Science & Human Nutrition, Michigan State University, East Lansing, MI 48824, USA*

[b] *Department of Biosystems & Agricultural Engineering, Michigan State University, East Lansing, MI 48824, USA*

ARTICLE INFO

Article history:
Received 5 February 2012
Received in revised form
25 May 2012
Accepted 30 May 2012

Keywords:
Beans
Extruded flour
Viscosity
Water absorption
Cookie sensory

ABSTRACT

This study assessed the feasibility of using low-temperature (85 °C) extrusion to process navy and pinto beans flours for gluten-free products. Bean flours were extruded using a twin-screw extruder and ground (250 μm particle size). Extruded (EXT) flours physical properties were compared with raw and 82 °C steam-cooked (STC) bean flours and cookies quality from EXT and STC flours also was evaluated. The EXT bean flours demonstrated better physical and functional characteristics, i.e., a significant increase in water absorption index, from 2.10 in STC to 2.73 in EXT navy flour and water solubility index, 13.33 to 25.56 (navy) and 13.35 to 21.19 (pinto) over STC bean flours. Extrusion cooking affected Hunter color "a" and "b" values significantly for navy and pinto bean flours, whereas, a mixed trend was observed for color "L" values. Extrusion decreased peak and final viscosities of navy and pinto flours when compared to raw or STC bean flours. The cookie diameter, height, and spread factor were comparable between EXT and STC flour cookies. Cookies from EXT flour scored >6 (1–9 hedonic scale) for flavor, texture, and overall acceptability which were higher than STC flour. Over seven-eighths (94/107) of the panelists could not detect beany flavor in the cookies.

1. Introduction

Dry beans (*Phaseolus vulgaris* L.) are an important constituent of the diet in many countries because of their high protein and soluble fiber content (Reyes-Moreno & Paredes-López, 1993; Sgarbieri, 1989; Wu et al., 2004). Consumption of beans potentially has been linked with reduction in cholesterol levels (Winham, Hutchins, & Johnston, 2007). Besides these nutritional benefits, beans are also gluten-free, so products made from bean flours provide alternatives to wheat flour based products.

Of the various bean processing techniques, extrusion has been used for processing of many legumes and offers the advantages of high productivity, shorter cooking times, energy efficiency, and relatively lower operating costs (Balandran-Quintana, Barbosa-Canovas, Zazueta-Morales, Anzaldua-Morales, & Quintero-Ramos, 1998; Rocha-Guzmán et al., 2006). Extrusion has also been shown to be the most effective method for improving protein and starch digestibility when compared with dehulling, soaking and germination (Alonso, Aguirre, & Marzo, 2000; Batista, Prudêncio, & Fernandes, 2010) and lowers flatulence-causing oligosaccharides (Borejszo & Khan, 1992). Although extrusion of various beans at temperatures of 145 °C or higher has been reported, the consumer acceptability of products made from extruded bean flours has not been explored (Batista et al., 2010; Coffey, Uebersax, Hosfield, & Bennink, 1993; Edwards, Becker, Mossman, Gray, & Whitehand, 1994; Van Der Poel, 1990).

Observations from a preliminary study with extruded navy and pinto beans showed that high temperature (>100 °C) processing may produce undesirable functional and sensory properties in bean flours (Nyombaire et al., 2007). There is limited information in the literature that describes the effects of process variables on the functional properties of extruded beans. The reason for the lack of such studies is that most of the extrusion processing technology applications have been in the development of cereal- and soybean-based products (Bhattacharya, 1997). However, the gluten-free and high-protein nature of dry beans and legumes offer opportunities for application of extrusion to develop bean-based products. Flours from dry beans have the potential to expand bean consumption beyond traditional uses. One market segment where dry beans can make a significant contribution is the increased demand for gluten-free products that has been driven by people suffering from celiac disease and wheat allergies or other conditions. Sales of gluten-free products are projected to grow at an annual rate of 25% for the next several years (Clemens & Dubost, 2008). Besides gluten-free food

* Corresponding author. Tel.: +1 517 355 8474; fax: +1 517 353 8963.
E-mail addresses: siddiq@anr.msu.edu, siddiq@msu.edu (M. Siddiq).

0023-6438/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.lwt.2012.05.024

applications, bean flours also have a great potential for use in weight-management diets, due to their lower carbohydrates and higher protein contents compared to wheat flour (Pelembe, Erasmus, & Taylor, 2002; Zhang, Shi, Ilic, Jun, & Kakuda, 2008).

Navy and pinto, the two most largely consumed beans in the U.S. (USDA-ERS, 2009), were selected for the present study. The objectives of the present study were to: 1) assess the feasibility of producing low-temperature extruded navy and pinto bean flours and analyze their functional properties, and 2) evaluate physical and sensory quality of cookies prepared using these flours. Extrusion at 85 °C was chosen since it was shown to be effective against reducing lectins and oligosaccharides (Kelkar et al., 2012).

2. Materials and methods

Navy and pinto beans (*P. vulgaris* L.), stored at 20 °C for 3 months, were obtained from Bayside Best Beans, LLC (Sebewiang, Michigan, U.S.A.). The beans were hand-sorted to remove splits, wrinkled seeds, and any debris and stored at 5 °C until needed for processing or analysis. For comparison, commercial steam-cooked (STC) navy and pinto bean flours were used that were processed by 82 °C steam pre-treatment (Commercial Finest, Hillman, Michigan, U.S.A.).

2.1. Extruded bean flour preparation

Navy and pinto bean seeds, after cleaning and washing, were soaked in water at 25 ± 1 °C for 8 h (at beans-to-water ratio of 1:2, g/mL). Soaked beans were dried in an oven at 65 ± 2 °C for 12 h and ground using a hammer mill, Model D Comminuting Machine (W. J. Fitzpatrick Company, Chicago, U.S.A.). Resulting bean meals were extruded in a lab-scale, co-rotating twin-screw extruder (Model JS30A, Qitong Chemical Industry Equipment Co. Ltd., China). The extruder screws were 30-mm in diameter and the barrel had a length-to-diameter ratio of 14.

Pinto and navy beans were extruded at 85 °C (die-end temperature), 36 g/100 g moisture content (wet-basis) and a feed rate of 120 g/min. The die used was a thick plate with a 7-mm circular hole. The bean extrudates were dried overnight (80 ± 5 °C) in a cabinet dryer and ground using a hammer mill to pass through a 250-μm screen (W.S. Tyler, Mentor, Ohio, U.S.A.). The extruded (EXT) bean flours were stored in sealed polyethylene bags at 5 °C until further analysis or use.

In a preliminary study, with extrusion at 85, 100 and 120 °C (die-end temperatures), extrusion at 120 °C produced flours with a darker, less desirable color. Bean flours extruded at 100 °C or 120 °C were inferior to STC bean flour in terms of pasting viscosity and cookies made from those flours exhibited poor baking performance (low spread, decreased diameter and increased thickness) when compared with cookies made with 82 °C STC or 85 °C EXT bean flours. Bean flours extruded at 100 °C and above were considered inferior for baking quality and not used in the present study.

2.2. Bean flour functional properties

2.2.1. Color

The color of the bean flours was measured in duplicate with a Hunter Color Meter (Model: D25 L optical sensor, Hunter Associates Lab., Reston, Virginia, U.S.A.). Approximately 50 g of flour was placed in the sample cup and color values “L,” “a,” and “b” were recorded. For the cookie color measurement, cookies were broken down to 8 ± 2 mm random shape pieces, placed in the sample cup to about 25 mm height, and color values “L,” “a,” and “b” were recorded.

2.2.2. Pasting viscosity

The pasting viscosity of raw, STC and EXT bean flours was determined by Rapid Visco-Analyzer (RVA, Newport Scientific, New Brunswick, New Jersey, U.S.A.) according to the AACC method 61–02 (AACC, 1995). The data from the RVA were processed by the Thermocline software, version 1.2 (Newport Scientific Inc., New Brunswick, New Jersey, U.S.A.). Pasting profiles of the flours were established by controlling their sample weight at 14 g/100 g moisture basis at a constant weight of 5 g. Samples were adjusted for water content based on their moisture content using their equivalent sample mass.

Bean flour samples (5 g) were weighed into aluminum canisters and mixed with 25 mL water. After putting a stirring paddle into the canister, the canister was placed into the heating chamber. A programed heating/cooling cycle was used, where the samples were equilibrated at 25 °C for 2 min, heated to 95 °C at a rate of 9 °C/min, held at 95 °C for 2.5 min and cooled to 25 °C at the same rate. Stirring speed was 160 rpm over the same period of time. From the viscosity–time curve the values of peak viscosity, final viscosity, and pasting temperature were recorded for all samples.

2.2.3. Water absorption index (WAI) and water solubility index (WSI)

Water absorption index (WAI) was determined using the method of Kaur and Singh (2006). Briefly, 3 g flour sample was dispersed in 30 mL of distilled water and heated at 90 ± 1 °C for 15 min in a water bath. The cooked paste was cooled to 25 ± 1 °C and transferred to pre-weighed 50-mL centrifuge tubes. The contents were then centrifuged at 3000 rpm for 10 min. The sediment was weighed after the supernatant was decanted for determination of its solid content into an evaporating dish. The weight of dry solids was determined by evaporating the supernatant overnight. The WSI and WAI were calculated as follows:

WAI = Weight of sediment/weight of dry solids

WSI = Weight of dissolved solids in supernatant/weight of dry solids × 100

2.3. Sensory quality of cookies

Cookies prepared from EXT bean flours were compared to those with the STC bean flour. A formulation of gluten-free cinnamon sugar cookies was chosen to compare the functionality of STC and EXT bean flours. Cookies were made using the following formulation: bean flour (150 g), oil (46 g), sugar, (208 g), cinnamon powder (7 g), salt (2 g), baking soda (2.6 g), xanthan gum (4 g), and vanilla extract (7 g). Cookies were baked at 180 °C (350 °F) for 14 min. Raw navy and pinto bean flours, i.e., without any heat treatment, may be unsafe for consumption, thus cookies were prepared from STC and EXT bean flours only.

2.3.1. Cookie color

Cookie color was measured using the method described in Section 2.2.1. The cookies were broken into small pieces and 100-g samples were used for Hunter Color “L,” “a,” and “b” values measurement.

2.3.2. Cookie diameter, height, and spread

Cookie spread was evaluated from the diameter and thickness of the cookies using AACC Method, 10-50D (AACC, 2000). Six cookies were placed edge-to-edge in a straight line and their total diameter or width (W) was measured using a ruler. The average diameter was recorded. To determine the thickness (T), six cookies were stacked on top of one another and the height was measured. Spread factor, in duplicate, was measured by rotating cookies at an angle of 90° and using the following equation: Spread factor = W/T × 10.