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Physical and functional characteristics of selected dry bean (*Phaseolus vulgaris* L.) flours

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ABSTRACT

Many varieties of dry beans (*Phaseolus vulgaris* L.) are available with entirely different physico-chemical and sensory characteristics. Selected dry bean varieties (red kidney, small red kidney, cranberry and black) were processed into flour and analyzed for the physico-chemical and functional characteristics. The bulk density of the beans flours varied significantly ($p < 0.05$) from 0.515 g/ml for black bean flour to 0.556 g/ml for red kidney bean flour. The small red kidney bean flour had the highest water absorption capacity (2.65 g/g flour) while black bean flour showed the lowest at 2.23 g/g flour. Significant differences were observed for oil absorption capacities of bean flours, which ranged from 1.23 g/g for small red kidney bean flour to 1.52 g/g for red kidney bean flour. The bean flours emulsion capacity and stability and foaming capacity and stability also varied significantly and was variety-dependent. The highest apparent viscosity, 0.462 Pa.s, was recorded for small red kidney bean flour whereas black bean flour exhibited the lowest value of 0.073 Pa.s at 30 g/100 ml water content in the flour dispersions. The force-deformation curves for doughs from different bean flours showed that black bean flour had the highest peak force or hardness value of 90.7 N followed by doughs from cranberry, small red kidney and red kidney bean flours. The results of this study offer useful data on bean flours' potential uses in different food products.

1. Introduction

Legumes occupy an important place in human nutrition, especially among the low-income groups of populace in the developing countries. They provide a good source of protein, which is 2–3 times that of cereal grains, and are a rich source of dietary fiber, starch (Osorio-Diaz et al., 2003) minerals and vitamins (Kutos, Golob, Kac, & Plestenjak, 2002). The various types of beans are a staple food and a low-cost source of protein in many countries where protein energy malnutrition is prevalent widely (Van Heerden & Schonfeldt, 2004). Dry beans are rich in non-nutrient components, too; Wu et al. (2004) investigated the oxygen radical absorbance capacity (ORAC) of common foods consumed in the U.S. Their data showed that red kidney beans had the highest total antioxidant capacity per serving size as compared to all other foods, including many fruits commonly believed to be rich in antioxidants.

The inclusion of legumes in the daily diet has many beneficial physiological effects in controlling and preventing various metabolic diseases such as diabetes mellitus, coronary heart disease and colon cancer (Tharanathan & Mahadevamma, 2003). It has been reported that the protective effects of dry beans in disease prevention, such as against cancer, may not be entirely associated to dietary fiber, but to phenolics and other non-nutritive compounds (Oomah, Tiger, Olson, & Balasubramanian, 2006), as polyphenols from dry beans may possibly act as antioxidants, hindering the formation of free radicals (Boateng, Verghese, Walker, & Ogutu, 2008). In addition, legumes belong to the food group that elicits the lowest blood glucose response. The general consensus on healthy eating habits favors an increase in the proportion of legume-based polymeric plant carbohydrates including starch in the diet. The role of legumes as a therapeutic agent in the diets of persons suffering from metabolic disorders has been reported previously (Shehata, Darwish, Nahr, & Razek, 1988; Simpson et al., 1981).

Dry bean flours can be used as functional ingredients to improve the nutritional quality of a variety of processed food products (Horax, Hettiarachchy, Chen, & Jalauddin, 2004). One recent study reported on the use of pinto bean flour in tortillas (Anton, Lukow, Fulcher, & Arntfield, 2009). The application of various technological

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processes to legumes can increase their use as an ingredient in manufactured food products. Processing improves the nutritional quality of dry beans by reducing the content of anti-nutritional factors and, at the same time, diversifies their use as ingredients by altering their functional properties.

The fact that dry beans, apart from being nutrient-rich, are gluten-free offers significant opportunities for exploiting bean flour use in different food systems. The number of new gluten-free products introduced in the United States increased by five-fold, from 135 in 2003 to 832 in 2008 (Clemens & Dubost, 2008). They further reported that the sales of gluten-free products are projected to grow at an annual rate of 25% for the next several years. However, there is limited information published on bean flour's physico-chemical characteristics and functional properties, which eventually influence the product characteristics and, in turn, sensory quality and consumer acceptability. The present study was undertaken with an objective to produce flours from selected dry beans and to characterize selected functional properties of these flours.

2. Materials and methods

The red kidney, small red kidney, cranberry and black beans (*Phaseolus vulgaris* L.) were procured from Bayside Best Beans, LLC (Sebewiang, Michigan, U.S.A.) and stored at 4 °C until processed. The dry beans were analyzed for their proximate composition (Table 1), using two replicates; all the other analyses were done on three replicates.

2.1. Bean flour preparation

After cleaning and removal of any broken seeds, 1-kg portions of beans were washed and soaked in 4-times volume of water for 12 h to reduce flatulence-causing oligosaccharides by leaching them into the water. The soaked beans were then dried in an oven at 65 °C for 24 h. The dried beans were ground using a hammer mill (Model-D Comminuting Machine, W.J. Fitzpatrick Company, Chicago, Illinois, U.S.A.) followed by grinding in a NutriMill (Pleasant Hill Grains, Hampton, Nebraska, U.S.A.) so that the flour would pass through a 250 μm stainless steel sieve (W.S. Tyler Co., Mentor, Ohio, USA). The flour samples were stored in polyethylene bags at 4 °C until used for analysis.

2.2. Hunter color, hue, and chroma

The color of bean seeds and bean flours was measured with a Hunter Color Meter (Model: D25 L optical sensor, Hunter Associates Lab., Reston, Virginia, U.S.A.). The reason for measuring seed coat color was to see how flours from respective bean types would compare to whole beans color. A thick layer (approx. 50 g) of beans or flour was placed in the sample cup and color values were recorded as "L" (0, black; 100, white), "a" (−a, greenness; +a, redness), and "b" (−b, blueness; +b, yellowness). The Chroma and hue angle values were computed according to the method of Little (1975), as follows:

$$\text{Chroma} = \sqrt{a^2 + b^2} \quad (1)$$

$$\text{Hue angle}\left(h^\circ\right) = \tan^{-1}\left(\frac{b}{a}\right) \quad (2)$$

Table 1
Proximate composition (g/100 g) of different bean varieties.

Bean variety	Protein	Fat	Crude Fiber	Ash
Red kidney	23.32 ± 0.18a[a]	3.53 ± 0.07a	3.66 ± 0.11b	4.60 ± 0.09a
Small red kidney	20.93 ± 0.21b	3.14 ± 0.08b	4.14 ± 0.09a	4.67 ± 0.16a
Cranberry	23.62 ± 0.20a	3.46 ± 0.11ab	4.59 ± 0.13a	4.87 ± 0.16a
Black	23.24 ± 0.22a	3.62 ± 0.08a	3.38 ± 0.11b	5.00 ± 0.18a

Values are mean ± standard deviation.
[a] Means sharing the same letters in columns are not significantly different from each other (Tukey's HSD test, $p < 0.05$).

2.3. Bulk density, water and oil absorption capacity

Bulk density of bean flours was determined according to the method of Okaka and Potter (1977). A 50-g sample was filled into a 100-ml graduated measuring cylinder. The cylinder was tapped gently several times on a laboratory bench to a constant volume. The results for bulk density were reported as g/ml. Water absorption capacity of bean flours was measured by the centrifugation method of Kaur and Singh (2006). For the determination of oil absorption, the method of Lin, Humbert, and Sosulski (1974) was used. The water and oil absorption capacities were expressed as g of water or oil, absorbed per g of the sample on a dry-weight basis.

2.4. Foaming and emulsifying properties

Foaming properties were determined according to the method of Okaka and Potter (1977). One gram of flour was dispersed in 50 ml of distilled water, in a capped test tube, by shaking vigorously for 5 min followed by immediate pouring into a 250-ml graduated cylinder. The volume of the foam formed was then recorded as the foam capacity (ml/100 ml). A final observation was made after 60 min for recording the foam stability (ml/100 ml).

Emulsifying properties were determined by the method of Yasumatsu et al. (1972). A 0.5-g sample of bean flour was suspended in 3 ml of distilled water contained in a graduated tube followed by the addition of 3 ml of oil. The contents were then shaken vigorously for 5 min. The resulting emulsion was centrifuged at 2000 x *g* for 30 min. The volume of the emulsified layer divided by that of the whole slurry multiplied by 100 was taken as the emulsifying activity of the flour (ml/100 ml). To determine the emulsion stability, the homogenized mixture of flour, water, and oil was heated at 80 °C for 30 min before centrifugation at 2000 × *g* for 30 min. The emulsifying stability was then calculated as the volume of the emulsifying layer divided by that of the heated slurry multiplied by 100, reported as ml/100 ml.

2.5. Least gelation concentration

The least gelation concentration was determined by the method of Sathe and Salunkhe (1981). For each type of bean flour, dispersions of 2, 4, 6, 8, 10, 12, and 14 g flour/100 ml water were prepared in 5 ml of distilled water in test tubes and heated for one hour in a water bath at 95 ± 1 °C. The heated dispersions were cooled to 10 ± 1 °C. The least gelation concentration was determined based on visual observation whether any drops from the emulsion slipped out to the top or not in inverted tubes. The results were expressed as no (−), complete (+), or partial (±) gelation. The partial gelation depicted as a result of broken or irregular-shaped drop.

2.6. Apparent viscosity

Three concentrations were selected to determine the apparent viscosity of bean flour dispersions: 10, 20, and 30 g/100 ml. Their corresponding rheograms at 25 °C were obtained using a Haake Rotovisco viscometer (Model: VT55, RS100, Haake, Germany). A shear rate of 100 s^{-1} was selected to compare apparent viscosity of sample dispersions as per the method of Shama and Sherman (1973).