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Dehulling and selected physical characteristics of Canadian dry bean (*Phaseolus vulgaris* L.) cultivars

B. Dave Oomah [a,*], Stuart Ward [a], Parthiba Balasubramanian [b]

[a] National Bioproducts and Bioprocesses Program, Pacific Agri-Food Research Centre, Agriculture and Agri-Food Canada, Summerland, British Columbia, Canada V0H 1Z0
[b] Crop Genetic Enhancement Program, Lethbridge Research Centre, Agriculture and Agri-Food Canada, 5403-1 Avenue South, P.O. Box 3000, Lethbridge, Alberta, Canada T1J 4B1

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ABSTRACT

The tangential abrasive dehulling device (TADD) was used to evaluate the dehulling properties of 13 dry bean cultivars from five market classes. Hull yield or percent kernel removed was cultivar dependent and increased linearly ($r^2 \geqslant 0.984$) as dehulling time increased from 30 to 120 s. Hull yield was significantly different within cultivars of great northern and pink bean market classes and there were no significant ($p < 0.05$) differences within black and pinto bean cultivars. Bean cultivars differed significantly in dehulling parameters–rate coefficient (RC) and abrasive hardness index (AHI), although the differences were small. Cluster analysis, based on dehulling parameters, segregated the cultivars into three major groups; AC Black Violet, AC Black Diamond, CDC Jet, and subgroup AC Resolute and AC Agrinto (AHI, 12.7–14.9 s); Othello, AC Early Rose and AC Polaris and the subgroup CDC Minto and Winchester (AHI, 11.7–12.5 s); and AC Redbond and Viva (AHI < 11 s). Black beans were the hardest to dehull since the longest time (928 s) was required to completely remove the hulls by abrading on average, 50 g/100 g seed. Multiple regression analysis showed that dehulling parameters were not related to any seed characteristics, although seed length, width, thickness and weight were highly correlated ($r^2 \geqslant 0.786$, $p < 0.005$).

1. Introduction

The seed coat performs a vital function in protecting the seed prior to germination and allows the seed to remain dormant or withstand mechanical damage. Legume seed coat, often referred as hull and the proper anatomical term 'testa', consists of parenchymal cells with sclerenchyma and an extensive vascular network system (Van Dongen, Ammerlaan, Wouterlood, Van Aelst, & Borstlap, 2003). Hull content of bean range from 7 to 13 g/100 g seed weight (Cardador-Martinez, Loarca-Piña, & Oomah, 2002; Deshpande, Sathe, Cornforth, & Salunkhe, 1982; Gutierrez-Uribe, 2005; Reichert, Oomah, & Youngs, 1984). Although the hull is a relatively small portion of the seed on a weight basis, it is rich in dietary fiber (Aguilera, Lusas, Uebersax, & Zabik, 1982; Anton, Ross, Beta, Fulcher, & Arntfield, 2008), minerals, particularly calcium (Moraghan, Etchevers, & Padilla, 2006), and phenolic compounds exhibiting strong antioxidant activity (Cardador-Martinez et al., 2002; Oomah, Cardador-Martinez, & Loarca-Piña, 2005) essential for development of novel food products. The polyphenolic-rich bean hull inhibits Caco-2 iron bioavailability (Ariza-Nieto, Blair, Welch, & Glahn, 2007) that potentially has detrimental nutritional implications particularly in low income bean consuming populations. Furthermore, bean consumers prefer thin hulls because of its association with fast imbibition and cooking time.

Bean hull, rich in dietary fiber and bioactives, offers physiological health benefits crucial in fulfilling the increasing need and demand for a diversified functional food base. For example, bean hull extract supplementation can reduce the incidence of azoxymethane induced colon cancer in rats (Hangen & Bennink, 2002), and prevent DNA damage or liver injury in mice (Azevedo et al., 2003; Han et al., 2004). Extracts of hulls obtained by abrasive dehulling of black beans were generally more effective than whole-seed extracts against colon, breast and prostate cancer cell proliferation (Gutierrez-Uribe, 2005). While the benefits of bean hulls have been known for some time, their large-scale incorporation into foods is nonexistent, due to the lack of efficient hull extraction platforms. Therefore, bean components must be separated efficiently to ensure their economic potential, particularly bean hull as a source of dietary fiber with demonstrated physiological benefits.

Pulse milling constitutes two major steps: loosening of the hull, followed by its removal in suitable milling machine (Narasimha, Ramakrishnaiah, & Pratape, 2003). Dehulling is an important primary process in pulse milling effectively separating the high dietary fiber hulls to obtain dehulled cotyledons with reduced tannin contents, better appearance, texture, and cooking qualities, palatability and digestibility (Deshpande et al., 1982; Ehiwe &

* Corresponding author. Tel.: +1 250 494 6399.
E-mail address: oomahd@agr.gc.ca (B.D. Oomah).

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Reichert, 1987; Towo, Svanberg, & Ndossi, 2003). Beans and pulses such as red, green and black grams, are considered difficult to mill and are generally processed in large-scale pulse mills using dry premilling treatments (Narasimha et al., 2003). Abrasive-type disk hullers developed by Reichert et al. (1984) are used in Africa for milling various pulses and commercial dehulling of pulses consumed in Asia has been reviewed previously (Narasimha et al., 2003). Dehulling has been investigated as a physical treatment suitable to modify and improve functional properties of bean proteins (Deshpande et al., 1982). In that context, manual dehulling improved the water absorption capacity of bean cultivars and the hull contributed positively to the foam and emulsion stability of bean flours due to the presence of complex carbohydrates. Manual dehulling has been used as a preliminary step in some food preparations (Paredes-Lopez & Harry, 1989) or protein studies (Montoya et al., 2008).

Navy bean hulls, rich in dietary fiber (40 g/100 g) have been prepared by roasting, cracking seeds in a disc attrition mill followed by aspiration. The process loosened hull and produced fines resulting in 7–13 g/100 g yield of hull (Aguilera et al., 1982). Abrasive dehulling has been evaluated with intermediate-sized dehuller (Reichert et al., 1984) demonstrating seed hardness as the primary factor responsible for the variability in dehulling efficiency of legumes. This characteristics was termed abrasive hardness index (AHI) defined as the time in seconds to abrade 1 g/100 g of the kernel as fines. Thus, AHI of legumes ranged from 7.6 s (mung bean) to 19.4 s (kidney bean) with only 2 min residence time required in the dehuller to remove over 90 g/100 g of kidney bean hull (Reichert et al., 1984). The tangential abrasive dehulling device (TADD) has been used in evaluating the large variability in dehulling quality of green gram, cowpea, chickpea, and pigeon pea cultivars (Ehiwe & Reichert, 1987; Singh, Santosa, & Rao, 1992). However, mechanical dehulling of dry bean seed has been limited, resulting in inadequate innovation and utilization of bean hulls as an attractive novel functional foods and nutraceutical ingredient.

Beans are not commercially dehulled yet, although other pulses are processed in large- and small-scale mills, particularly in India (Narasimha et al., 2003). Dehulling characteristics of pulses are governed by seed morphology (Reichert et al., 1984), seed size, shape, volume and uniformity and even hydration or soaking ability that may be required as pre-treatment before dehulling (Singh, 1995). This study was prompted by the need to economically obtain bean hulls with the least amount of cotyledon contamination. Another objective of the present study was to determine the variability in dehulling quality among bean cultivars and identify cultivars with acceptable dehulling characteristics. The relationship between dehulling and seed characteristics was also investigated to provide information on improving the dehulling quality of beans in a plant breeding program. This investigation extend our previous study on bean pearling (Cardador-Martinez et al., 2002) and describes the application of the TADD in evaluating the dehulling characteristics of Canadian dry bean cultivars. It also provides a useful tool desperately needed by plant breeders to monitor bean crops for grain hardness, an important attribute related to quality and end-use characteristics.

2. Materials and methods

Seeds of dry beans (*Phaseolus vulgaris* L.) lines used in this study were grown and harvested at Lethbridge, a semi-arid location in Southern Alberta. Dry bean seeds from 2006 to 2007 were kindly provided by Agriculture and Agri-Food Canada (Lethbridge, AB). The 13 cultivars used in this study included five bean market classes, black (AC Black Diamond, AC Black Violet, and CDC Jet), great northern (AC Alert, AC Polaris, and AC Resolute), pink (AC Early Rose and Viva), pinto (AC Agrinto, CDC Minto, Othello, and Winchester), and small red (AC Redbond). The name of the cultivars is used hereafter without the prefix.

2.1. Seed characteristics

Seed dimensions were determined from 25 randomly drawn seed samples. The length, width and thickness of 25 randomly selected seeds, for each sample were measured to 0.05 mm using a Digimatic Caliper (Mitutoyo Canada Inc., Mississauga, ON). Kernel or seed weights were determined with an analytical balance, reading weights in grams to four decimal places with an accuracy of ±0.2 mg and expressed as thousand seed weight. Sphericity was evaluated because of the difference in the shape, form and geometry of the bean seeds that may potentially affect dehulling quality. It was estimated based on length and width as sphericity (%) = $[(b/a)^{1/2}] \times 100$, where a and b are the seed length and width (mm), respectively, according to Bhattacharya, Narasimha, and Bhattacharya (2005).

Water hydration capacity was determined by soaking 50 seeds in deionized water at 1:4 (sample: water, w/w) ratio at room temperature for 16 h in accordance with the AACC 56-35 method (AACC, 2000). After the water was drained, the soaked seeds were blotted dry with a paper towel and weighed. Hydration capacity and unhydrated (stone) seeds were expressed on weight percent basis in accordance with the AACC method (AACC, 2000). The stone is a measure of the proportion of seeds that do not swell after soaking in the water absorption test and their number is recorded from the 50 seeds. The assay was duplicated for each sample.

2.2. Abrasive dehulling

Moisture content of beans at the time of dehulling was measured in duplicate according to the AOAC, (2005) vacuum oven method. Abrasive dehulling was carried out on a model 4E-230 TADD (Venables Machine Works Ltd., Saskatoon, SK, Canada) with an eight-cup cover plate. Details of machine design and operation were described earlier (Reichert et al., 1986). A 120-grit disk (Merit Abrasive Products Inc., Compton, CA, USA) fixed to an aluminum disk was used as the abrasive. Dehulling characteristics of bean cultivars were determined with 25 g of bean each in two of the cups. After dehulling for a given time interval, seeds were removed from the sample cups using the vacuum aspirating device described previously (Oomah, Reichert, & Youngs, 1981). The dehulled seeds and hulls, separated by air aspiration, were weighed and the weight loss calculated as (g/100 g) = [Initial weight–weight of aspirated kernels/initial weight] × 100, was designated as the yield of hulls. Dehulling was performed for successive time intervals of 30 s for a total of 120 s to generate the dehulling curve. The dehulling process was continued until the seed coat was completely removed from the cotyledon and the hull yield at that time was denoted CHR (Table 2).

Kernel hardness as rate constant was determined by the method of Lawton and Faubion (1989) using percent kernel weight loss during dehulling as a first-order decay model. The abrasive hardness index (AHI), which gives the time in seconds to abrade 1 g/100 g of seed was calculated on the basis of the slope obtained by plotting retention time against hull yield (Oomah et al., 1981). Dehulling was duplicated for each sample with three samples per bean cultivar.

2.3. Statistical analysis

Data were subjected to analysis of variance according to the general linear models (GLM), means comparison by Duncan's test, Pearson correlation, variance components and Bartlett's test using