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Novel method and machine for dehulling of guar seeds and optimisation of dehulling process

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ABSTRACT

Traditional guar processing method to produce guar gum splits comprises of splitting, germ separation, heating and dehulling heated splits through cutting and scratching in which 12–17% endosperm are lost. A novel pretreatment method and machine was developed to dehull guar seeds prior to splitting. The process involved steeping seeds in ethanol solution (0.2–0.4% concentration), conditioning for 5 min followed by dehulling through compressive- shear- and abrasive-forces applied simultaneously using the developed machine. The machine comprised of hopper, feed regulator, under-runner discs of wire mesh for dehulling pretreated seeds, and aspirator to separate hull. Pretreated guar seeds moved between discs in compressed condition, thus subjected to abrasive and shear forces to remove hull. Dehulling efficiency increased with moisture content and rotational speed up to 75.8 ± 1.7% (d.b.) and 90 rpm, respectively and then decreased. Second order polynomial model described the relationship between dehulling efficiency, moisture content and rotational speed. Process conditions were optimised using surface plot and contour plot. Optimum range of moisture content and peripheral speed were 74–80% (d.b.) and 2.76–3.2 ms^{-1} (88–102 rpm), respectively at which a dehulling efficiency of 91.67 ± 5% was observed with 3.48% split formation. Capacity of the machine was 80 $kg\,h^{-1}$ pretreated seeds at 90 rpm.

1. Introduction

Guar (*Cyamopsis tetragonoloba*), until recently remained a minor crop, seems destined to assume a larger role among the cultivated plants that caters the commercial needs of human being. The discovery that guar seed endosperm could be a source of useful industrial gum brought this little known crop world recognition and paved its way to the crop of major prominence (Yadav and Ray, 2002). Now guar gum is one of the most important agricultural produce of India on account of its very high export potential (APEDA, 2015). However, systematic research work on efficient dehulling of guar seed is lacking.

Guar seeds are light pale to brown in colour and oval to round in shape. It is a pulse crop rich in protein, lipids and minerals. The seed parts include hull or seed coat (14–17%), endosperm (32–42%), and germ and embryo (43–47%) (Singh et al., 1968; Goldstein et al., 1973). Endosperm contains about 78–82% galactomannan gum (Goldstein et al., 1973). The endosperm is used for producing guar gum powder whereas germ, embryo and hull are used as animal feed. The guar gum powder is a good water binder and emulsifier. In addition to food processing, guar gum is used in textiles, paper, oil well drilling, explosives, ore floatation, tobacco, electrical and telephone, varnish and coatings, ceramics, fire fighting, building

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construction, water purification, pharmaceuticals, cosmetics, etc.

Dehulling of guar seeds is aimed to obtain endosperm free of germ and hull. Splitting and dehulling of the seed is reported to be done by two processes namely dry processing, and dehulling after wet pre-treatment (Gunjal and Kadam, 1989). In dry processing, the guar seeds are split into two halves using horizontal burr mill and then germ is separated using pin mill followed by screening. The composites of endosperm and hull are heated to soften the hull and fed into a machine where the hull is removed from endosperm by cutting, scratching and abrasive action (Vishwakarma et al., 2009). Vacher (1985) patented a process for dehulling hard seeds (guar, carob, and tara) claiming that infra-red treatment prior to dehulling facilitates isolation of the seed endosperm. However, guar seed was not included in the details of the process and claims. Mercandelli (2001) described the commercial method of processing of guar gum from guar seeds, which is basically the dry processing method. Guar processing industries of India use high carbon steel blades mounted on a cylinder to remove hull from heated unhulled guar splits (Vishwakarma et al., 2009). This machine does not remove the hull completely and substantial portion of the endosperm (12–17%) is lost in the form of brokens and powder (Vishwakarma et al., 2009). Further, hull of about 10% cotyledons is not removed by the machine (APEDA, 2011).

In wet pretreatment method, the guar seeds are boiled in aqueous solution of sodium bicarbonate (0.5%) and urea (0.05%). Seeds are then washed with water and then dried to 10% moisture content (Gunjal and Kadam, 1989). Dehulling of the seed is done in abrasive machine. Recovery in wet pretreatment method is reported to be 8–10% higher than that in dry processing method, but the quality of guar gum produced is inferior in terms of viscosity and colour (Gunjal and Kadam, 1989).

Wet pretreatment is usually given to pulses that involve soaking the seeds into water for 6–12 h followed by drying to about 10% moisture content and hull removal using abrasive machine (Kurien and Parpia, 1968). Wet dehulling is steeping the grains in water for certain time so that bond between hull and cotyledon is loosened followed by hull removal without breaking cotyledons. Hull does not separate from the cotyledons when seeds split prior to dehulling in wet condition. The process and machines for wet dehulling are scarce in literature.

This study was, therefore, taken up with objective to develop a new wet pretreatment process so that seeds may be dehulled in wet condition without splitting. Removal of hull from wet seeds requires application of compressive-, shear- and abrasive-forces simultaneously. Therefore a machine was developed for dehulling of pretreated guar seeds and pretreatment process and machine parameters were optimised.

2. Material and methods

2.1. *Materials*

Guar seeds (variety: HG-365) were procured from ICAR-Central Institute of Post Harvest Engineering and Technology, Abohar, Punjab (India) farm. The seeds were cleaned, graded, and sun dried. The dried seeds were packed in jute sacks and stored in air tight metallic containers. Desired amount of material was taken out from the container as and when required for experiments. Moisture content of the samples in triplicate was determined using standard hot air oven drying method (AOAC, 2000) and expressed in % dry matter basis (d.b.).

2.2. *Spatial dimensions and force-deformation behaviour of pre-treated seeds*

Spatial dimensions (length, width and thickness) of 100 pre-treated and randomly selected guar seeds were measured using a digital micrometre (Mitutoyo Corporation, Japan; accuracy ± 0.01 mm). Quasi-static (probe moving at very slow speed) compression test of 20 pretreated seeds (soaked in 0.2% ethanol solution for 40 min at 40 °C) was performed using texture analyser (Stable Micro Systems, England, model TA.HD.Plus; load cell 500 N; crosshead speed 3 mm min^{-1}; trigger force 0.05 N; Flat bottom cylindrical aluminium alloy probe of 25 mm diameter) to determine the force at bio-yield point in horizontal- and vertical-orientations (ASAE, 1998; Vishwakarma et al., 2012a). Horizontal loading tests were conducted with major axis of the seed and hilum being perpendicular to the direction of loading. For vertical loading, the major axis of the seed and hilum was positioned in the direction of loading. These properties were used to ascertain the experimental range of clearance between the two discs and minimum force required for splitting the conditioned seeds.

2.3. *Description of dehulling machine*

The guar seed dehulling machine was designed to remove the hull from pretreated seeds without splitting the cotyledons. Compressive force was expected to provide the necessary normal force to cause friction between the seed surface and wire mesh placed on rotating disc. Shear force was responsible for shearing the hull of pretreated guar seeds. Abrasion between seeds and wire mesh was expected to provide necessary force to separate the sheared hull from the cotyledons simultaneously. Therefore an under-runner, horizontal type machine was developed (Fig. 1). The upper disc of the machine was stationary to facilitate adjustment of clearance for compression whereas lower disc was rotating to generate shear and abrasion.

The dehulling machine comprised of feeding-, dehulling-, and hull separation-sections (Fig. 2). Feeding section of dehulling machine consisted of a hopper and feed rate regulator. The feed rate regulator was provided at the bottom of the feed hopper to control the feed rate (Fig. 2a). The feed hopper was attached to the upper disc of dehuller. Dehulling section consisted of two circular discs of 600 mm diameter. The upper disc was stationary, whereas the lower disc was rotating in horizontal plane. Both discs were made of mild steel plates on which steel wire mesh (3 mm × 3 mm openings) was fastened. In the upper disc, an opening of 130 mm diameter was provided at the centre (Fig. 2a). Upper disc was fixed on the main frame of the dehuller and mechanism was provided to move the upper disc up and down to adjust the clearance between discs (Fig. 2b). Lower disc of dehulling machine was mounted on a shaft of 30 mm diameter (Fig. 2c and d). A scraper of 200 mm × 100 mm was attached at the bottom of this disc to convey the dehulled lot towards outlet of the dehulling machine (Fig. 2c). Assembly of upper and lower discs was placed in a cylindrical casing of 680 mm diameter and 230 mm height. An outlet was provided at the bottom of the casing to discharge the material conveyed by the scraper to the inlet of hull separation section.