

Adaption of the Traditional Coffee Pulping Machine to Soybean Dehulling

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Abstract

Processing of soybean for human consumption requires wet heat treatment of the beans in order to inactivate anti-nutritional factors. After hot water treatment or steaming, dehulling of the bean has always been an uphill task for household processors in Tanzania. Dehulling is done by hand rubbing, which is tedious and time consuming. The traditional coffee pulping machine was adapted to dehull boiled soybean. Seven soybean varieties namely TGX-1876-2E, Bossier, Kaleya, TGX 1805-8E, Sable, Songea and Duicker were tried. This was a development process whereby three consecutively improved versions of dehulling machines were tested. The machines were branded M₁, M₂ and M₃, implying first, second and third generation, respectively. Bean recovery as a measure of performance was 74.3, 77.4 and 91.8% for M₁, M₂ and M₃, respectively compared with 89.7% for manual dehulling/rubbing. The respective throughput was 8, 10 and 28.2 kg/h compared with 0.43 kg/h for manual dehulling. The mean dehulling efficiency of the M₃ dehuller was 82.4% which was the highest. The M₃ dehuller's best performance was due to use of ball bearings to support the rasping roller axle instead of sleeves and its ergonomically suitable height. The M₃ dehuller could be adopted for soybean dehulling under rural livelihood conditions but the economics for owning and running it needs to be explored. Its improvement to make it motorised is recommended to increase throughput and increase chances for adoption in medium scale soybean processing.

Keywords: Varieties, dehullers, efficiency, recovery, throughput

Introduction

Soybean seed constitutes of 8-10% of hull by weight, the rest being the endosperm (Sessa and Wolf, 2001). The benefits of consuming soy foods include good nutrition profile, reduction in heart diseases through reducing blood cholesterol, reduced risk of cancer, control of menopausal symptoms, control of weight gain and longevity (Messina, 1999). The valuable nutrients leading to these benefits are in the endosperm. The soybean hull has the highest concentration of crude

fibre content (5%) compared with the rest of legumes (Makasa *et al.*, 2002). Also ground soybean hull increases protein emulsification effect at pH>4.5 (Martin and William, 1994), but has negative effects too.

Although consuming high fibre content foods such as soybean has several health advantages there are also some inherent disadvantages such as lowering efficiency of swallowed medicines, restriction of absorption of essential nutrients and minerals and gastrointestinal disorders including

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flatulence if consumed in large quantities (<http://www.dietary.fiber.info/>). In another communication, WHO/FAO (2003) recommends dietary intake of > 25 g per day of total dietary fibre but without specification of higher limits. Flatulence due to over consumption of fibres has been reported to be a common problem (Gray, 2002; Makasa *et al.*, 2002; http://www.oardc.ohio-state.edu/nesc/soybean_hulls_brief_o.htm). Soybean hulls in particular have the effect of urease activity in animal feeds which is a problem in ratios containing urea unless they are heat treated (<http://www.ingredients101.com/soybeanh.htm>). Due to uncertainties on maximum allowable consumption of fibres and the high fibre content of soybean hulls and the associated problems, dehulling of soybeans ensures that valuable soybean meal nutrients such as amino acids and carbohydrates are not diluted with undigestible fibre. Dehulling also removes the fibre that can bind unhealthy heavy metals such as copper (Cu^{++}) (Rowell, 2006). Therefore, it is important for the hull to be removed so as to remove indigestible oligosaccharides that may cause some health and nutrition problems.

Dehulling is classified into wet dehulling and dry dehulling. In wet dehulling the grain may be steamed or moistened with 10% water or soaked overnight in order to facilitate easy removal of the hull (<http://www.fao.org>). However, this process suffers from the risk of lipoxygenase activity unless in absence of oxygen or elevated temperature

storage (<http://www.soyfood.co.za/flexiweb>). In the presence of oxygen and this enzyme soybean lipid undergoes oxidative rancidity producing beany flavours. In some societies acceptance of soy foods has been low due to the beany flavour caused by the lipoxygenase enzyme (<http://www.australianoilseeds.com>). Dry dehulling is associated with high risk of developing beany flavour but also dry soybeans are more difficult to grind. This may lead to high tear and wear of mills unless wear resistant mills, which are expensive, are used. Due to these problems moist heat treatment (>80 °C for at least 30 minutes) before dehulling is recommended. This method eliminates lipoxygenase and other enzymes, improves taste, and enhances dehulling and milling (<http://www.soyfood.co.za/flexiweb>).

Currently in Tanzania, soybean processing is mainly done at the household level by few individuals for home consumption and small-scale vending. A few of these are using wet dehulling method. The process of removing the hulls is done by hand abrasion which is tedious and time consuming. This does not give opportunity for increased processing capacity that may be required as demand for soybean products may increase due to awareness campaign on nutritional qualities of soybean products. This problem can be solved by possessing improved dehulling methods. The objective of this study was therefore to research on mechanical means of dehulling as an

improvement to manual dehulling by hands to increase throughput.

Materials and methods

Prototype development

The study was conducted at Sokoine University of Agriculture in Morogoro, Tanzania. Dehulling was conceptualized as having a unit that will remove the hulls from wet heat-treated soybeans and collect both the endosperm and the hulls in two different streams. A rotation mechanism that will crack and shear the seeds against a stationery wall to remove the hull as stated in Omobuwajo *et al.* (1999) in dehulling African breadfruit was considered. Consideration for use of locally available materials to enhance affordability and possibility for group enterprises especially for women as emphasized in Gordon *et al.*, 2002 was a key factor. In searching for similar activities for other crops in Tanzania the existence of traditional coffee pulping machine was exploited for adaption studies for soybean dehulling.

The work started by contractual manufacturing of the traditional manually operated mechanical coffee dehuller from Kilimanjaro region (Rombo district), specifically for trials with wet soybean (Figure 1). The dehuller, M₁ (Figure 1) which is operated by a single person consisted of six principal parts. These include the grain hopper with the guiding base lying at 72° to the horizontal, the feed gate, the rasped aluminium metal sheet wound on a wooden rotating disc with a cranking handle extending outside the main body. Others are "chest" that

contains flow channels for guiding the dehulled seeds, the overflow outlet for the dehulled grains as the main product and outlet for hulls, all fitted on a wooden structure supported on wooden stands. M₁ operated principally like the coffee pulping machine, the only difference being reducing the clearance. However, the size was small and so was the height from the ground that made it a small capacity machine. The machine was tested in collaboration with the manufacturer.

The M₁ dehuller was improved to a second version, M₂ (Figure 2) and lastly to a third version, M₃ (Figure 3). M₂ had its hopper size and height from the ground increased for the purpose of increasing dehulling capacity. However, M₂ faced limitations, including difficulty in rotating the handle which led to more time consumption, escape of soybean with the hulls and difficulty to dismantle for repairing. The serrations on the drum were also too far apart (approximately 2 cm) and could contribute to poor dehulling. These limitations warranted fabrication of M₃, in which ball bearings were introduced to replace sleeves for easy cranking. Hulls' guard was introduced to collect any soybean that could escape with the hulls for further separation. Height was further increased to allow for a container to be put underneath for collecting the hulls. Also, parts forming the dehulling section were fixed with bolts and nuts instead of rivets, which made the earlier two versions difficult to dismantle. The serrations were made from blind holes that were 1 cm apart. Detailed sketches of the M₃ dehuller

are also shown (Figs. 4-11). The overall dimensions of the improved dehuller are 100cm x 78cm x 45cm (height: width: breadth). The dehulled seeds and hulls outlets are at 53 and 36cm, respectively from the floor. The weight is approximated to be 15 kg and the cost of manufacturing it is estimated at around TAS 400,000.

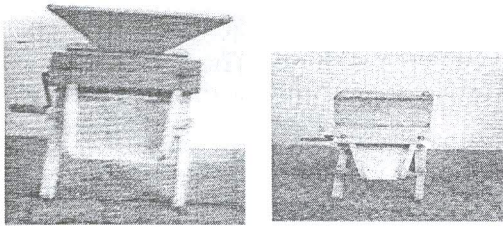


Figure 1. Generation 1 (M₁) dehuller Figure 2. Generation 2 (M₂) dehuller

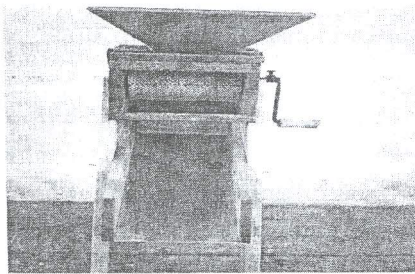
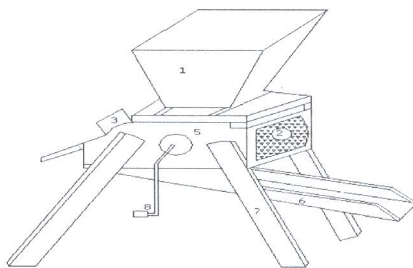


Figure 3. Generation 3 (M₃) dehuller



KEY

1-Hopper, 2-Drum, 3-Chest, 4 Front exit chute, 5-Wooden frame, 6- Rear exit chute, 7-Legs, 8-Handle

Fig. 4: Pictorial presentation of M₃ dehuller

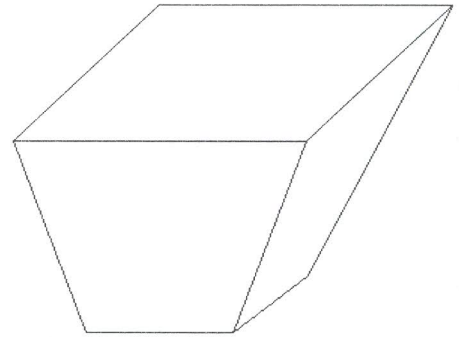


Fig. 5: The hopper

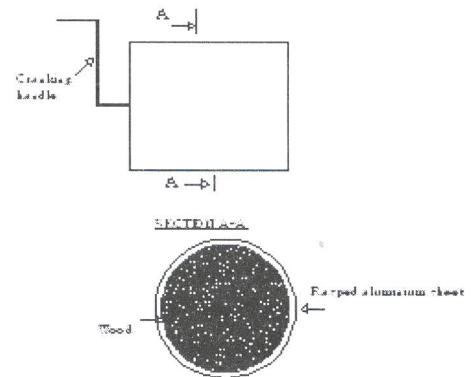


Figure 6: The Drum and the cranking handle

Figure 7: The chest

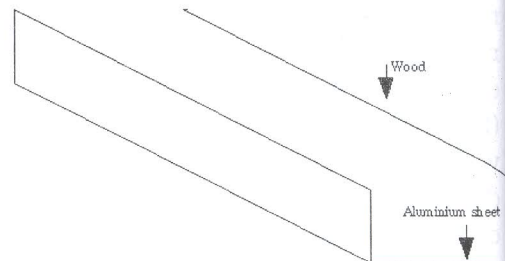


Figure 8: Front exit chute

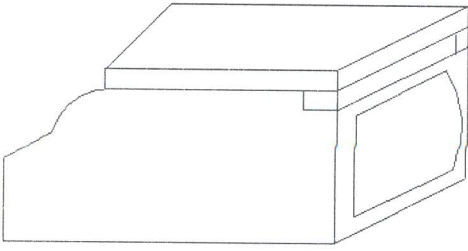


Figure 9: The wooden frame

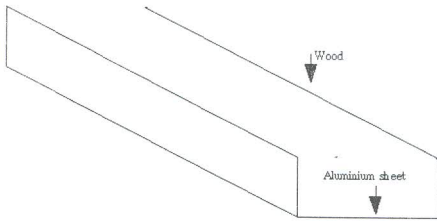


Figure 10: Rear exit chute

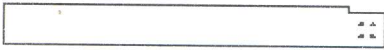


Figure 11: Leg

Testing of dehullers

Development of the mechanical dehullers was done in sequence (M_1 , M_2 and M_3) in a period of about two years in which on the spot testing and performance results and visual observations were used as bases for improvement of the successive versions.

The three dehullers (M_1 , M_2 and M_3) were tested using seven soybean varieties obtained from farmers in Mikumi (Kilosa district). These varieties were: TGX-1876-2E, Bossier, Kaley, TGX-1805-8E, Sable, Songea and Duicker. The process started by soaking 4 kg of each of the soybean in boiling water, and kept on hold for 30 minutes. The hot water was discarded and the beans were immediately cooled in cold

water. The dehulling experiments followed thereafter using the version in question (M_1 , M_2 or M_3) dehullers with parallel comparison with manual dehulling by hands.

The parameters measured were: bean recovery as a percentage of seeds passing through to the dehulled seeds container against those wasted in the hulls outlet; dehulling efficiency as a percentage of dehulled seeds measured in both outlets and throughput measured as the quantity of seeds passing through the machine per unit time. Dehulling efficiency was determined using three varieties namely *Duicker*, *Songea*, 49F and TGX-1805-8E.

Data analysis

Comparison between mechanical and manual dehulling by hands and between the three mechanical dehullers were analysed using MSTAT-C statistical package and the results obtained were subjected to Duncan's Multiple Range Test for mean separation.

Results and discussion

Visual assessment in the development stages

The first generation dehuller (M_1) had a small size hopper, which could contribute to low throughput (Table 2). In the next generations (M_2 and M_3) the size of the grain hopper was improved to have all the four sides converging to the feed gate at 72° to the horizontal and made bigger to accommodate more soybeans. In M_1 and M_2 the disc rotated on sleeve bearings which created some resistance to cranking

which was ergonomically not suitable. This was corrected in the M₃ dehulling machine by changing from sleeve bearings to standard ball bearings which facilitated easy cranking by the operators.

Dehulled soybean recovery

The percentage dehulled soybean recovery values for the three mechanical dehullers in comparison with manual dehulling by hand are presented in Table 1.

Table 1: Percentage recovery of dehulled soybean

Dehulling methods	Varieties of soybean							
	TGX-1876-2E	Bossier	Kaleya	TGX-1805-8E	Sable	Songea	Duicker	Mean
Manual by hands	88.4	88.2	86.6	87.2	87.0	95.1	95.3	89.7 ^a
M ₁	82.6	76.5	77.1	76.6	79.1	88.8	79.2	74.3 ^b
M ₂	67.2	74.9	78.7	79.2	74.2	80.2	87.6	77.4 ^b
M ₃	93.7	91.3	89.5	92.3	89.2	93.0	93.4	91.8 ^a

The mean recovery for the M₃ dehuller was significantly higher ($p<0.05$) than that for M₁ and M₂ dehullers and also for manual dehulling by hands. However, manual dehulling by hands led to significantly higher ($p<0.05$) recovery than that for M₁ and M₂ dehulling machines. The significantly higher ($p<0.05$) recovery displayed by manual dehulling by hands over M₁ and M₂ which were not significantly different ($p>0.05$) was a challenge that prompted further improvement to version 3 (M₃) of the mechanical dehuller. M₃ and manual dehulling were comparable in terms of recovery and in addition M₃ was less time consuming than manual dehulling. This means that the development work on the mechanical dehuller has reached a reasonable stage in terms of recovery and could be adopted.

Throughput

The throughput values for the three mechanical dehullers (M₁, M₂ and M₃)

were calculated for the seven varieties shown in Table 1 and are presented and compared with those for manual dehulling by hands (Table 2).

Table 2: Mean dehulling throughput

Dehulling method	Throughput (kg/h)
Manual by hands	0.43 ^a
M ₁	8.00 ^b
M ₂	10.00 ^b
M ₃	28.20 ^c

The mean throughput values from the developed mechanical dehullers were significantly higher ($p<0.05$) than from the value for manual dehulling by hands. Among the mechanical dehullers the mean throughput of generation 3 (M₃) of the dehuller was significantly higher ($p<0.05$) than that for generations 1 (M₁) and 2 (M₂), which were not significantly different ($p>0.05$). This implies that the development work from version 1 to

version 3 was done successfully. The higher throughput displayed by generation 3 (M_3) could have been attributed to use of standard ball bearings, which facilitated easy rotation of the disc as felt by operators. Throughput value for manual dehulling was low due to tediousness and the time consuming nature of manual dehulling by hands.

Dehulling efficiency

The mean dehulling efficiency for M_3 dehuller was 95.1, 70, 95.3 and 69.1% for *Duicker*, *Songea*, 49-F and *TGX-1805-8E*, respectively, with the mean value estimated at 82.4%. The reason for variation of values between varieties could not be explained but differences in size could have contributed. The sphericity (defined as mean values of seed intercepts) of these varieties are 0.861, 0.839, 0.869 and 0.810 mm, respectively (Zahir, 2008), implying that there may be a need to design the drum serrations and the chest depending on size of soybeans. However, this may add on to design and manufacturing costs, therefore it is important to design for the mean size of the possible varieties of soybeans available.

Conclusions

Adaptation studies were successfully done, out of which three versions of mechanical dehullers were developed from the traditional coffee pulping machine. Throughput, soybean recovery and dehulling efficiency of the last version of the dehuller were satisfactory but there is still room for further improvement. Another version of this machine that is motorised could

simplify the work further but should have a bigger hopper to match with the expected higher throughput.

Recommendations

The M_3 generation of the dehuller is recommended for use in the households intending to process soybean products commercially in places where electricity or diesel/petrol power is a limitation. However, economic analysis needs to be conducted to determine its worthiness under the conditions where they are intended to be used. Also, there is need to register and patent this development. Efforts should also be made to develop a motorized or powered dehuller for use at higher processing levels.

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References

- Gordon, A., Swetman, A. and Albright, K. (2002). Women in post-harvest operations: reducing the drudgery. Crop Post-harvest Programme, Issue Paper -6. June 2002.
- Gray, J. Dietary fibre: definition, analysis, physiology and health. In <http://europe.ilsis.org/NR/rdoulyres/0603B318-9329-4F54-9029->

- F7D27AEF327/0/Dietary Fibre (visited on 19/06/2008).
- <http://www.australianoilseeds.com> (visited on 19/09/2006). Advances in soybean processing and utilization
- <http://www.fao.org> (visited on 28/11/2005). Soybean processing
- <http://www.dietary.fiber.info/> (visited on 19/06/2008). What is fibre and its role in nutrition.
- http://www.oardc.ohio-state.edu/nesc/soybean_hulls_brief_o.htm, 18 September 2006. Soybean Hulls – a brief review.
- <http://www.soyfood.co.za/flexiweb> (visited on 28/11/2005). Soymilk production
- <http://www.ingredients101.com/soybeanh.htm> (visited on 18/06/2008). Soybean Hulls
- Makasa, F., Hachalema, R. and Kuvare, U. (2002). Unit 11. Cowpeas and soybeans in human nutrition. Distance learning for Agricultural Education. Cowpeas and Soybeans in Eastern and Southern Africa.
- Martin, S. T. and William M. B. (1994). Composition, functionality and some chemical and physical properties of eight commercial full-fat soy flours. *Journal of Food Processing and Preservation* 18:3, 229–252.
- Messina, M.J. (1999). Soy foods: their role in disease prevention and treatment. Chapter 10, in Lui, K. (1999), pp 442–448.
- Omobuwajo, T.O., Ikegwuoha, H.C., Koya, O.A and Ige, M.T. Design, construction and testing of a dehuller for African breadfruit. *Journal of Food Processing* 42, 3 November 1999, 173–176.
- Rowell, R.M. (2006). Removal of metal ions from contaminated water using agricultural residues. ECOWOOD 2006 – 2nd International Conference on Environmentally-Compatible Forest Products, Fernando Passoa University, Oporto. Portugal, 20–22 September 2006.
- Sessa, D.J. and Wolf, W.J. (2001). Bowman-Birk inhibitors in soybean seed coats. *Industrial crops and Products* 14: 73–83.
- World Health Organization (2003). Diet, nutrition and the prevention of chronic diseases. Report of a Joint WHO/FAO Expert Consultation. WHO Technical Report Series 916, Geneva, 2003.
- Zahir, A. (2008). Assessment of the effect of physical properties of different soybean varieties on the performance of locally fabricated soybean dehuller. BSc research project report, Department of Agricultural Engineering and land Planning, Sokoine University of Agriculture, 33p.