Evaluation of a Small-Scale Peanut Sheller

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ABSTRACT

Small-scale peanut shelling equipment has been designed and used to meet various needs and scales. A laboratory-scale sheller has been used by researchers to approximate the shelling outturns of a commercial shelling plant using 2 to 10 kg samples. A single commercial-sized sheller will have a shelling capacity up to 23 MT/hr. Commercial shelling operations utilize multiple shellers, each designed to shell a narrow range of peanut sizes. There are enterprises such as small seed processors or manufacturers in developing countries that need shelling equipment capable of processing 100 to 1000 kg of peanuts per hour with the capability of mechanically separating the hulls from the shelled material. A three-stage sheller was designed, fabricated, and tested to determine its throughput (kg/h), the efficiency of separating the hulls from the shelled peanut kernels, and sizing the shelled peanut kernels. The sheller had a maximum shelling rate in the first shelling stage of 1087 kg/h operating at 252 rpm. Approximately 93% of the peanuts were shelled in the first stage of shelling. An air velocity of 9.55 m/s was used to aspirate a mixed stream of peanuts and hulls and removed 97% of the hulls. The sheller was equipped with vibratory screens to separate the material into unshelled, edible sized peanut kernels, and oil stock.

Key Words: Aspiration, capacity, decortication, groundnut, shelling.

Peanut shelling is the process by which the outer hull or shell of a peanut is broken and the kernel or seed is removed and separated. The process is accomplished by hand and mechanically. Hand shelling is a slow process, but results in a very high percentage of whole kernels. Mechanical shelling usually involves forcing the in-shell peanut (peanut pod) between a fixed surface and one moving parallel to that surface imparting a combination of shear and compressive forces on the peanut hull causing it to fracture, open, and extract the kernel. In large commercial shelling equipment, the shelling compartment contains a semi-cylindrical fixed shelling grate and a series of bars that rotate within the shelling grate enclosure. The clearance between the shelling grate and the sheller bars ranges from 1.90 to 3.49 cm and the opening in the shelling grate ranges from 0.56 to 1.27 cm depending on the peanut pod size (Davidson, Whitaker, *et al.,* 1982). A single sheller will have a shelling capacity up to 23 MT/hr. Commercial shelling operations utilize multiple shellers, each designed to shell a narrow range of peanut sizes.

Smaller scale shelling equipment has been designed and used to meet various needs and scales. Davidson *et al.* (1981) designed a laboratory-scale sheller to approximate the shelling outturns of a commercial shelling plant using 2 to 10 kg samples. The shelling grates are sheet metal with punched slotted holes sized according to the peanuts being shelled. Peanut kernels, hulls, and unshelled peanuts fall through the slotted holes into a vertical airstream where the hulls are aspirated out the material stream into a cyclone collection system. The USDA, Agricultural Marketing Service uses a small sheller to shell 500 to 1000 g samples for official farmers stock grades. The shelling grate consists of three flat punched hole screens placed side by side in a frame that reciprocates back and forth in a horizontal motion beneath a series of spring loaded sheller bars. The material falls through the screen into a pan that carries the material beneath an aspiration fan to vacuum the hulls out of the material stream. The shelled and unshelled peanuts then fall into a pan where they are hand sorted (USDA, 2003). Approximately 3.5 minutes are required to shell a 500-g pre-sized sample (Lamb and Blankenship, 2005). Williams (2014) developed a hand-operated sheller that used a series of wooden rods spaced in a semi-circular pattern and a solid wooden wheel rotating within the rods. Brandis (2014) developed a Universal Nut Sheller for use in developing countries constructed from concrete and metal. In both instances, the hulls must be manually winnowed from the shelled peanuts. Both shellers can be powered by hand, bicycle, or small motor.

Meds and Foods for Kids (MFK) is an organization located in Cap Haitiens, Haiti that manufactures a ready-to-use therapeutic food (RUTF) for the treatment of severe childhood malnutrition from peanut paste. One of their objectives is to use locally grown peanuts in the production of the RUTF, thus helping improve the

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local economy. MFK and similar enterprises need shelling equipment capable of processing 100 to 1000 kg of peanuts per hour with the capability of mechanically separating the hulls from the shelled material.

The objective of this study was to evaluate the performance of a three-stage peanut sheller with aspiration and kernel sizing fabricated specifically for small scale peanut processing (Frank's Designs for Peanuts, Mexico Beach, FL)[1]. The sheller was a modified design of the Model 4 sheller described by Davidson *et al.* (1981) Specifically, the study was designed to evaluate the following aspects of the sheller:

1. The throughput (kg/h) of each stage of the sheller,
2. The efficiency of removing hulls and light trash from the shelled product, and
3. The efficiency of separating shelled from unshelled peanuts.

Materials and Methods

Sheller Description

A peanut sheller was designed and fabricated similar to the Model 4 sheller described by Davidson *et al.*, (1981). The sheller (Figure 1) consisted of four primary systems, the feed hopper, shelling chamber, hull aspiration system, and two shaker/sizers. The feed hopper was a gated box situated over top of the shelling chamber and was separated into three different sections so that each section of the sheller could be fed separately.

The shelling chamber was an open cylinder and concave design with three stages (Figure 2). The cylinder for each stage consisted of two metal bars made of 15.9 mm (0.625 in) square stock mounted 180° around a 152-mm (6-in) diameter disk on each end. The diameter of the shelling cylinders was the same for all three stages; the only difference in the shelling cylinders was their length. The lengths of the first, second, and third stage shelling cylinders was 267 (10.5 in), 181 mm (7.125 in), and 95 mm (3.75 in), respectively (Table 1). The shelling grate was a screen punched from 12-ga mild steel sheet metal then rolled to wrap 320° around the shelling cylinder. The diameter of the shelling grate and the screen openings depended on the sheller stage in which it was placed (Table 1). The screen openings decrease from first to the third stages of the sheller, because each stage is intended to shell progressively smaller peanuts.

[1]Mention of proprietary names or products does not imply endorsement of the product by USDA, ARS to the exclusion of similar products by other manufacturers.

The primary differences between the Model 4 sample sheller (Davidson *et al.*, 1981) and this sheller are as follows. The Model 4 sample sheller has a 95-mm diameter shelling cylinder compared to the 152-mm diameter cylinder of the prototype sheller. The prototype sheller has only two sheller bars on the cylinder, while the Model 4 sheller has 4 sheller bars on each cylinder. In addition, one of the sheller bars on the Model 4 sheller swings out as the shelling chamber empties to aid in cleaning the shelling grate. The shelling grates in the Model 4 sheller wrap 180° around the cylinder compared to 320° on the prototype sheller. The length of the shelling chambers for all three stages of the Model 4 sheller is a fixed146 mm, while the length of the shelling chambers of the prototype sheller decreases for each stage to account for the progressively smaller amount of peanuts that will be shelled in each stage.

As peanuts are shelled, the hulls, kernels, and small unshelled peanuts fall through the screen and into the aspiration chamber. The aspiration chamber is a rectangular section where air is flowing upward through a centrifugal fan and into a collection bin. The hulls and light material from the shelling chamber are lifted from the material stream and carried into the collection bin. The unshelled peanuts and the shelled kernels fall onto the top shaker screen equipped with 9.9 × 31 mm (22/64 × 1¼ in) slotted screen. The material larger than 9.9 mm should be mostly unshelled peanuts and is carried to the end of the screen and into a container. The material smaller than 9.9 mm falls through the screen onto a lower shaker/sizer screen equipped with 6.8 mm (17/64 in) round hole screen. The material falling through the 6.8 mm screen is predominantly small inedible peanut kernels and debris. The material riding to the end of the 6.8 mm screen is usually edible-sized whole and split peanut kernels.

The equipment was powered by three 0.75 kW electric motors, one each for the aspiration fan, the sheller cylinder, and the eccentric mechanism for the shaker/sizers. The sheller was driven by a V-belt on an adjustable speed sheave.

Evaluation Testing

Tests to evaluate the sheller were conducted in two phases. The purpose of the first phase was to determine the proper damper position in the hull aspiration system to remove the hulls from the shelled peanuts without removing excessive amounts of peanut kernels. The purpose of the second phase of testing was to determine the shelling rate of each stage of the sheller. Peanuts used in this study consisted of a mixture of runner cultivars made up of predominantly Georgia 06G (Branch, 2007) grown

Fig. 1. Prototype peanut sheller for small-scale peanut processing operations consisting of a feed hopper, shelling chamber, hull aspiration, and two shaker sizers.

under irrigated conditions at the National Peanut Research Laboratory's Bolton Research Farm located near Dawson, GA. A 1500-g subsample of the in-shell peanuts was obtained using a riffle divider. The sample was then sized over a series of slotted screens beginning at 15.9 mm (40/64 inch) down to a 4.8 mm (12/64 inch) wide slots. Approximately 200 grams of the largest pods from the pod sizing subsample were hand shelled and kernels sized to determine first stage shelling grate size. The first stage shelling grate size was selected as the size screen holding the largest kernel plus 0.8 mm

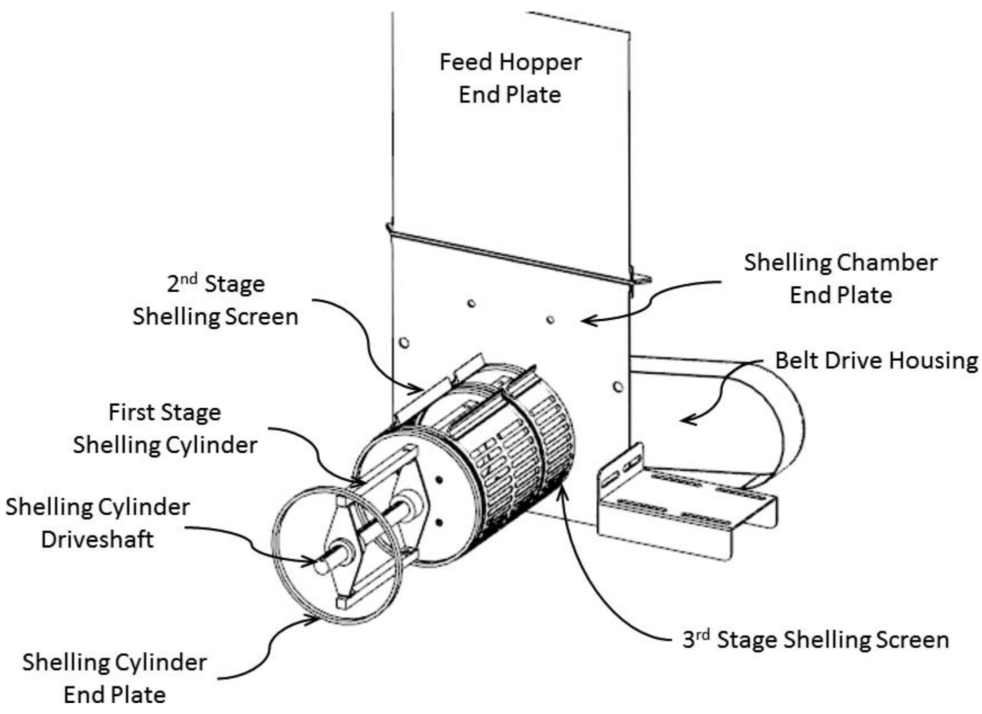

Fig. 2. Cutaway view of small scale peanut sheller.

Table 1. Physical dimensions of shelling cylinder and concave in small-scale prototype peanut sheller.

Sheller stage	Cylinder length	Concave diameter	Concave screen openings
	mm (in)		
1st	267 (10.500)	219 (8.625)	9.9 × 75 (26/64 × 3)
2nd	181 (7.125)	219 (8.625)	9.1 × 75 (23/64 × 3)
3rd	95 (3.750)	219 (8.625)	6.4 × 25 (16/64 × 1)

(2/64 inch). This is the same procedure outlined for processing the samples for the Uniform Peanut Performance Tests (USDA, 2013). The first and second stage shelling grate openings were 76 mm (3 inches) in length while the third stage grate openings were 25 mm (1 inch) in length. All sheller grate dimensions are shown in Table 1.

Aspiration System Tests. In the first phase, 16-kg samples of cleaned, unshelled runner type peanuts placed in the feed hopper of the sheller's first stage. Power was applied to the sheller and all motors allowed to reach full speed. The air velocity in the rectangular section of the aspiration chamber was measured using a hot wire anemometer (Model HHF42, Omega Engineering, INC., Stamford, CT). The hopper gate to the sheller was opened, allowing the peanuts to flow into the sheller's first stage. The equipment was run until all of the peanuts had passed through the 1st stage and the screens clear. The unshelled peanuts were then hand sorted and passed through the 2nd stage. After the 2nd stage was cleared, the remaining unshelled peanuts were passed through the 3rd stage. The weights of the sample, aspirated material, material riding the 9.9 mm slotted screen (+10 mm), material riding the 6.8 mm round screen (+7 mm), and the material fall through the 6.8 mm round screen (−7 mm) were recorded. A subsample of the aspirated material was collected from the collection bin and hand sorted into hulls, unshelled peanuts, and shelled peanut kernels and weighed. The screened material (+10 mm, +7 mm, and −7 mm) was subsampled and sorted into shelled, unshelled, and hulls and each component weighed. The aspiration airflow rate was changed by partially closing the in-line damper. Tests were replicated three times at five damper settings for a total of 15 aspiration tests.

Shelling Rate Tests. Using the results of the aspiration tests, the aspiration airflow rate was set to minimize peanut kernels aspirated into the hull system and minimize the hulls in the shelled material. A sample was placed in the 1st stage hopper, power applied to the equipment, and all motors allowed to reach full speed. The hopper gate was opened, a stopwatch timer started, and all of the material was allowed to flow through the 1st stage sheller. When material stopped falling from the sheller onto the top shaker/sizer, the stopwatch timer was stopped and elapsed time recorded. The rpm of the shelling cylinder was measured by placing the measuring tip of a handheld tachometer on the end of the sheller driveshaft while the sheller was operating under load. The screened and sized material was weighed. The +10 mm material was subsampled, and the subsample sorted into unshelled, shelled whole kernels, shelled split kernels, and hulls. Each component was weighed, and then added back to the original +10 mm material. The +10 mm material was then shelled through the 2nd stage, recording the time required to shell the material. Again, the screened material from shelling the 2nd stage was weighed. The resulting +10 mm material was subsampled, sorted, and component weights recorded, then shelled through the 3rd stage. The sheller rpm was changed by adjusting the variable speed sheave and the tests repeated. Three samples were shelled at each of four different speeds ranging from approximately 210 to 340 rpm.

Results and Discussion

Aspiration Tests

The air velocity in the hull aspiration section of the sheller ranged from 3.85 to 12.50 m/s depending on the position of the damper in the outlet of the aspiration system (Figure. 3). The air velocity in the aspiration system averaged 4.53 m/s when the damper was in the closed position. This is due to the damper having smaller dimensions than that of the duct so that the damper could fit and move freely inside the aspiration duct. This gap between the damper and the duct wall allowed the aspiration fan to maintain some airflow through the system even while the damper was in the closed position. Regression analysis was performed to determine the relationship between the damper position (DP, % open) and the observed air velocity (V, m/s). A first order expression had an $R^2 = 0.939$ (Eqn. 1).

$$V = 0.0778 * DP + 4.53 \tag{1}$$

Increasing the order of the regression equation to a quadratic resulted in a slightly improved $R^2 = 0.944$ (Eqn. 2).

$$V = -1.9619x10^{-4} * DP^2 + 0.0974 * \mathrm{DP} + 4.28 \tag{2}$$

The percent hulls (H) aspirated from the peanut stream increased exponentially from 60 and

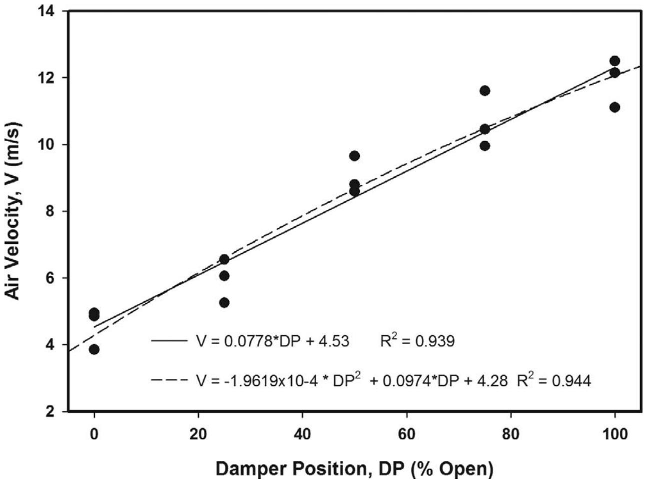

Fig. 3. Air velocity (m/s) as a function of the position of the damper installed in the hull aspiration duct (0 = closed, 100% = open).

asymptotically approached 100% as the air velocity increased from 4 to 12 m/s (Figure. 4).

$$H = 101.4\left(1 - e^{-0.3285*V}\right) \quad (3)$$

Similarly, the percent kernels aspirated (K) with the hulls increased exponentially from 0 to 0.7% and can be estimated as a function of air velocity (Eqn. 4).

$$K = 1.834 \times 10^{-4} e^{0.6519*V} \quad (4)$$

If a velocity, V, of zero is substituted in Eqn. 4, the percent kernels aspirated with the hulls calculated is 0.00018% and is a negligible amount and sufficiently close to zero.

Rearranging Eqn. 3 to determine the air velocity as a function of the percent hulls aspirated then shows that an aspiration air velocity of 9.55 m/s will remove 97% of the hulls. Substituting a value of 9.55 m/s in Eqn. 4 indicates that 0.1% of the kernels will be lost from the shelling system. Since this was an acceptable level of meats lost, Eqn. 1 was used to determine that the damper should be 65% open for the shelling rate tests.

Shelling Rate Tests

Selecting the appropriate shelling grate sizes is crucial to efficient peanut shelling. On average, 92.8% of the peanuts were shelled in the first stage using a 9.9 mm shelling grate and 6.5% were shelled in the second stage using a 9.1 mm shelling grate. More than 99% of the peanuts were shelled in the first two stages with only 0.7% of the peanuts being shelled in the third stage. These data confirmed that the procedure used to select the shelling grate sizes was appropriate and resulted in efficient peanut shelling.

Similarly, screen sizes for the vibratory sizing screens were selected to separate unshelled, whole edible sized kernels, edible sized split kernels, and small-sized peanuts normally used as oilstock (Table 2). After passing through the first stage sheller, 24.9% of the material was hulls that were aspirated and removed, 7.5% rode the 9.7 × 75 mm slotted screen, 67.2% fell through the 9.7mm slotted screen but rode the 6.7 mm round screen, and 1.2% fell through the 6.7 mm round screen. Of the 7.5% riding the 9.7 mm slotted screen, 81% were unshelled peanuts, 15.0 % were whole shelled peanut kernels,

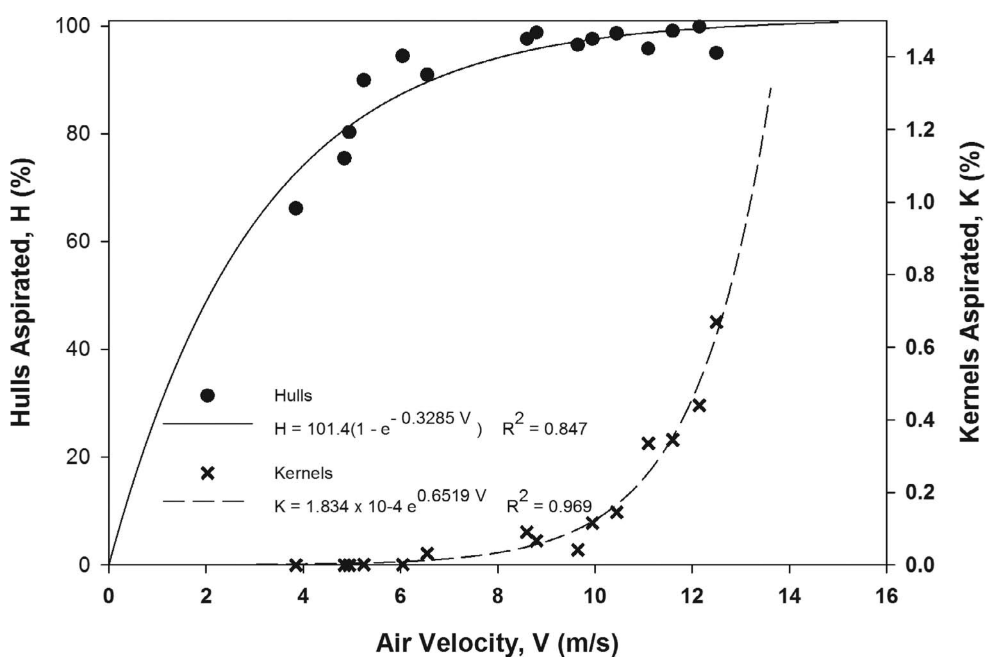

Fig. 4. The percent of hulls and peanut kernels aspirated as a function of air velocity in the hull aspiration chamber.

Table 2. Characterization of material riding and falling through screens to separate material after each stage of shelling.

Size description	1st Stage	2nd Stage	3rd Stage
	%		
Hulls Collected in Hull Bin[a]	24.6	18.0	45.6
Riding 9.7 × 75 mm slotted screen[a]	7.5	13.1	0.2
Unshelled[b]	81.4	72.4	0.0
Whole Peanut Kernels[b]	15.0	25.2	18.8
Split Peanuts Kernels[b]	1.0	6.4	68.9
Hulls[b]	0.9	0.9	0.0
Falling through 9.7 mm × 75 mm slotted screen but riding a 6.7 mm round screen[a]	67.2	66.1	52.0
Unshelled[b]	3.4	4.6	0.1
Whole Peanut Kernels[b]	75.3	69.5	44.0
Split Peanuts Kernels[b]	19.0	23.0	56.7
Hulls[b]	2.2	0.7	0.0
Falling through a 6.7 mm round screen[a]	1.2	2.8	2.2
Peanut Pieces[b]	45.5		
Foreign Material (dirt, rocks, etc)[b]	54.2		

[a]Percentages on the first line represent the percentage of total material after processing through the given sheller stage
[b]Percentages represent the fraction of material riding or falling through the prescribed screen

and 1.0% were split kernels. Approximately 93% of the material riding the 6.7 mm round screen were whole and split kernels, while 2.2 and 3.4% were hulls, and unshelled peanuts. More than half (54%) of the material falling through the 6.7 mm round screen was foreign material such as dirt. The other 46% was small whole and split kernels, and kernel pieces. The composition of the material riding each of the screens varied slightly depending on the stage of shelling. The material riding the 9.7 × 75 mm slotted screen was predominantly unshelled peanuts (81% and 72% for the first and second stages, respectively). Table 2 shows the composition of the material after passing through each stage of the sheller. As expected, more than 90% of the edible sized shelled peanuts fell through the 9.7 mm slotted screen but rode the 6.7 mm round screen. More than half of the material falling through the 6.7 mm round screen was foreign material with the remainder being broken pieces and halves.

Shelling capacity averaged 1087, 242, and 20 kg/h for the first, second, and third stage shellers respectively. The shelling capacity (kg/h) of the first two stages increased with increasing speed (rpm) until an optimum sheller speed (rpm_0) was reached, and then the throughput decreased as the speed increased (Figure 5). The shelling capacity (kg/h) of each stage was modelled as a function of sheller speed (rpm) using a lognormal function (Table 3). The regression parameter, rpm_0, represents the sheller speed where the maximum shelling capacity occurred. The optimum sheller speed for the first stage was 252 rpm and 276 rpm for the second stage. The third stage had a very low correlation to sheller speed as indicated by an $R^2 = 0.1680$. The very low sheller throughput was most likely caused by the shelling chamber never being filled. In a small scale commercial operation, unshelled peanuts from the first two stages would be accumulated until there was enough peanuts to fill the surge bin feeding the sheller. It is interesting to note that the optimum sheller speed was higher for the 2nd stage (smaller shelling grate size), indicating that more force was required to break the hull and force the material through the smaller shelling grate.

In a small production system, similar to that used by MFK in Haiti, a series of shelling grate sizes might be maintained on site so that the optimum sizes for each stage of the sheller could be used. The size of the shelling grate should be determined using a method similar to the method used evaluating the shelling characteristics for the Uniform Peanut Performance Tests (USDA, 2013). Once the grate size for the first stage is selected, the grate openings should be 1.2 mm (3/64 inch)

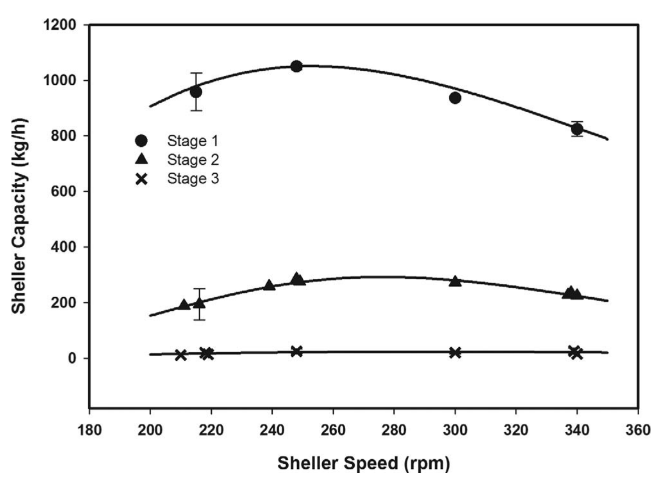

Fig. 5. Shelling capacity (kg/h) of each sheller stage as a function sheller speed (rpm).

Table 3. Regression parameters to estimate shelling capacity (kg/h) for each sheller stage as a function of sheller speed (rpm) using a three parameter lognormal function[a].

	Sheller stage		
Regression parameter	1st	2nd	3rd
a	1029	292	23
b	0.4394	0.2841	0.3605
rpm_0	252.1	276.2	289.9
R^2	0.8317	0.7775	0.1680

[a] $kg/h = a\exp\left\{-0.5\left[\left(\frac{\ln\left(\frac{rpm}{rpm_0}\right)}{b}\right)\right]^2\right\}$

smaller than the first, and the third stage 2 mm (5/64 inch) smaller than the second.

All peanuts are processed through the first stage, and the unshelled peanuts are separated by the vibratory screens and by hand. The unshelled from the first stage would then be accumulated and loaded into the second stage and shelled. In a similar fashion, the peanuts not shelled in the second stage would be sorted and fed back into the third stage.

This sheller is intended for use in developing countries and small capacity processors. In developing areas, capital for equipment is scarce, but labor is readily available. Therefore, this particular sheller was designed to maintain relatively low initial capital expenditure for equipment, and utilize the local population for hand labor to sort peanuts. To further reduce the cost of the equipment, a sheller could be fabricated with a single shelling chamber and peanuts processed through the single stage sheller with the first stage shelling grate installed. The unshelled could be sorted and accumulated until the batch has been processed. Then a smaller grate installed in the sheller, and the unshelled previously collected shelled. The process could be repeated until all the peanuts are shelled.

As demand for product increases, additional equipment can be purchased and upgraded to include improved sorting of shelled and unshelled, automatic recirculation of unshelled to the next stage, and size sorting of shelled kernels.

Summary and Conclusions

A three-stage peanut sheller based on designs originally developed for shelling and evaluating peanut samples for commercial shelling operations, was scaled up, fabricated and tested. The maximum shelling capacity through the first stage was 1087 kg/h with an average of 93% of the peanuts being shelled in the first stage. Regression equations were developed to estimate the sheller throughput as a function of sheller speed. Methods established and used the Uniform Peanut Performance Tests for selecting the appropriate grate sizes were used successfully in these studies. Tests also determined that the air velocity for aspirating and separating the peanut hulls from the shelled peanuts was 9.55 m/s. These tests showed that the sheller was suitable for small commercial shelling operations.

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