PEANUT SHELLER DESIGN PARAMETERS

by

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INTRODUCTION

Two techniques are presently employed to shell most of the peanuts produced in Nigeria. These are hand shelling and manually operated mechanical shellers. Even though the shelling process takes 2 to 5 percent of the total labor input in peanut production processes, shelling constitutes an important stage which determines the quality and quantity of shelled products obtained for the domestic trade or for export. Broken seeds are undesirable, because once the seed coat has been removed the exposed seeds are susceptible to contamination by dust and can absorb moisture easily. This leads to fungal growth that produces a toxic substance called aflatoxin. Aflatoxin is fatal to domestic animals and humans.

Hand shelling gives the maximum whole kernel count but it is a slow process with a maximum capacity per person of about 30 to 40 lb per hr. Mechanical shellers have a capacity of about 200 to 300 lb per hr. However, the minimum seed crackage that has ever been recorded by one of these machines under experimental conditions was 15 percent. The average percentage whole-kernel content obtained from the farmers using the "Kano Groundnut Decorticator" ranges from 60 to 80. Selling only unbroken seeds brings more money to the farmers and it is a law that the quality of the export peanuts meets the requirement of oversea markets. Therefore, peanuts shelled by these mechanical shellers must be hand sorted since there are no screening devices commonly available to separate the cracked seeds.

Even though some research was done as early as 1953 for evaluation and recommendation of the best peanut shellers, little attempt was made to improve the efficiency and the capacity of the Kano Groundnut Decorticator. The hand-powered design, upon which the sheller was first built in England, has remained nearly the same for the past 20 years.

In the peanut producing areas of United States, the shellers are but a small portion of a factory-like shelling plant. These shellers are not owned by individuals because of their size, capacity and complexity. Rather, they are owned by individual businessmen who do the shelling, grading and bagging for the farmers.

Considering the present trend of peanut production in Nigeria with respect to quantity per farmer and the availability of capital for machine investment, it would be ideal and profitable if some form of simple mechanical shellers could be designed to achieve a maximum whole-kernel yield and a greater capacity over the existing Kano Groundnut Decorticator. The author, having worked with this sheller, and knowing its operating conditions and shelling performance, feels strongly that the failure to improve the design of this sheller is long overdue.

At the pace of Nigerian economic and social development, increased social services will continue to change the lives of the educated ones. The concept to maintain cheap labor in place of mechanization has outlived its usefulness. The more the younger generations are educated, the more they desire to have the modern amenities, the more they hate drudgery, and mechanization will become a rule rather than exception. With increasing wage rates, the comparative economic situation will displace peanut production for other crops or mechanization will increase as a possibility to cut down production costs.

Peanut production in Nigeria attained commercial importance during and after the first World War when vegetable oils were needed for the manufacture of margarine, soaps, lubrication and for kitchen purposes in many European markets. In addition, the completion of the Lagos-to-Kano railroad in 1912 enhanced production because of the easy transport from the producing areas to the sea coast. For more than one decade, Nigeria ranked first as the largest exporter of peanuts in the world market. A yearly fluctuation in peanut production is due to weather stresses and price advantages for other crops. It has been estimated that Nigeria produces 2 to 3 million metric tons of peanuts, consumes about a third of this quantity, and sells the rest, worth about a hundred million Naira ($160m) annually. Exports are in the form of shelled seeds (nuts), peanut oil and peanut cake.

The peanut crop has many economic uses. Over 400 different products have been produced from peanuts. Among these products, a famous American scientist, George Washington Carver (1864-1943) discovered and synthesized 300 different products from peanuts so he was justifiably named, "The Peanut Man", (Albus, 1972). Some of the most important products produced from peanuts are peanut butter, ice cream, shaving lotion, shoe polish and artificial milk. As a legume, the plant has the ability to convert free atmospheric nitrogen to an available form of nitrate (NO_3), for use by other plants which do not have this unique ability. Thus agronomically, peanut production becomes very important to the people who practice an intercropping system and who use very little nitrogenous fertilizer on their farms.

The seeds are edible after shelling and more palatable when roasted. Helleiner (1964) estimated about 30 percent of the peanuts produced in Nigeria are consumed as confectionery peanuts. The haulms left over after peanut harvest make an excellent fodder for livestock.

Oyenuga (1967) found that peanut seeds contain about 25 to 48 percent oil so they are grown primarily for their oil content. Many peanut oil extraction plants have been constructed in Nigeria to extract oil. The oil together with peanut cake are shipped overseas or are consumed locally. In fact, many livestock-feed manufacturing companies have been built to make use of peanut cake for manufacturing livestock protein concentrates.

LITERATURE REVIEW

Types of Peanut Shellers in Nigeria

Simple shellers were introduced in Nigeria as early as 1900. All the models were hand operated. The basic components consisted of some form of a cylinder, a perforated shelling concave and a hand lever to be powered by man. The cylinder assumed a pendulum-like oscillation when the handle was moved back and forth in one plane. In other models, the shelling concave was made to oscillate about stationary shelling bars. Still later in a few models, the shelling bars and the concave were arranged so that the concave assumed a linear reciprocating movement against stationary shelling bars. Research was conducted by the Agricultural Engineering Department, Ministry of Agriculture, Northern Nigeria and by Haynes (1962) to evaluate the performance of these shellers in terms of capacity, shelling efficiency, and the quality of shelled peanuts. The summary made by Haynes mentioned four main models. The first two are the A.E.C., manufactured by the Amalgamated Engineering Co., Lagos; the Senafrica, manufactured by Senafrica Implement Factory, Kano, which like the A.E.C. has a slotted metal sheet for the concave (1 7/8" by 5/8" slots), six shelling bars and a side mounted handle. The third type is the Sarkin Casa (see Figure 1), distributed by United Africa Co. It has slotted holes (2" by 5/16" slots), and seven shelling bars with a centrally bolted double spade-grip handle. The fourth sheller is the Primier Sheller, manufactured by R. Hunt and Co., Essex, United Kingdom, which has a woven wire-mesh concave (3/8 sq. in.), four bars and two handles bolted on each side of the sheller. Haynes (1962) indicated that the Primier was identical to the Ransome Kano Decorticator (peanut sheller).

The Ransome Kano Decorticator, which has come to be the standard peanut sheller in Nigeria, does not completely fit the description and the claim made by Haynes to have been identical with the Primier sheller. From Figure 2, the present Kano sheller (the Kano Groundnut Decorticator) appears to be more like the Senafrica or A.E.C. shellers as it is manufactured in Kano by Ransomes Sims and Jefferies, Ltd. The Kano sheller has six bars mounted on a quarter-arc cylinder called a quadrant. The quadrant oscillates freely on a splindle which also carries a side mounted handle to distinguish it from Sarkin Casa sheller. The concave is made from slotted wire mesh. Figure 2 shows the sheller in operation. One or two people can hold the same handle and rock it back and forth.

The good aspects of the Kano sheller are its simplicity in construction, no technical skill requirement for operation, and minimum rotational parts. Wear and maintenance are reduced to a minimum, the machine is light for easy transportation, and the costs are reasonable for most farmers.

The weaknesses of the Kano sheller center around the change of concaves and the cylinder-concave clearance adjustment. The concaves are securely bolted so that the farmers rarely take them apart. The concave

Fig. 1: The Sarkin Kasa sheller. The handle is mounted in the middle of the quadrant spindle. From Haynes (1962).

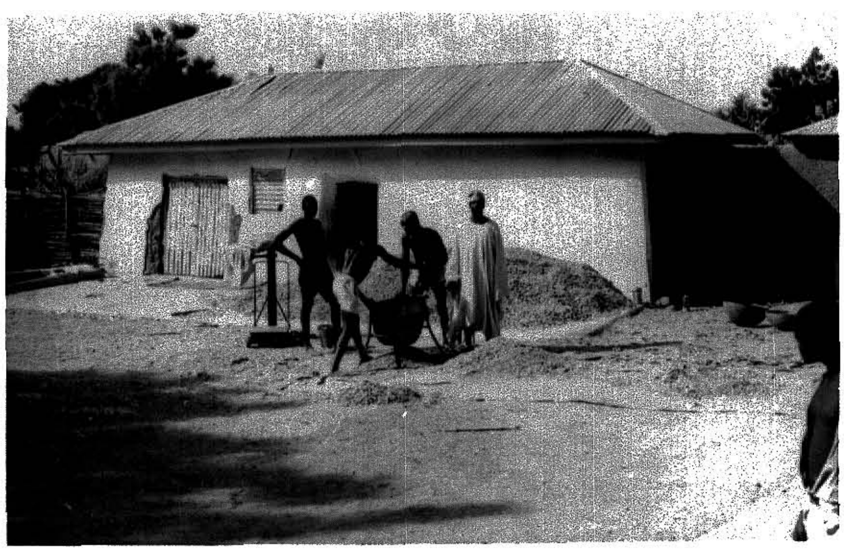


Fig. 2: The Kano peanut sheller with a side mounted handle and operated by two people.

and the machine are produced as a unit to shell a specific variety. To shell another variety of a different pod size, a separate unit has to be used. However, Schneider (1971) obtained a similar peanut sheller from Senegal which has facilities for changing concaves. The concave is inserted by sliding it between guides and it is held in position by a single pin; thus, one machine can be used with any concave size.

The clearance adjustment is effected by the use of elongated radial slots in the quadrant on which the shelling bars are bolted in position. The bolts are slackened, the bars are moved up or down the slots, and the bolts are tightened again. Before this is done, the sheller assembly is removed by withdrawing a spindle that holds the sheller assembly together. This process can take from 30 to 60 minutes.

Development of the Modern Peanut Sheller

The basic peanut shelling components used in the United States are similar to a grain combine. Both have a cylinder that carries specially designed bars, a specially designed concave or grid and a regulated space between the cylinder and concave for shelling or threshing operations. However, there are a lot of differences in the accessory design for specific functions. The peanut sheller is stationary in a plant that is more like a factory requiring many complex accessory machines. Construction for shelling operations include the receivers, conveyors, precleaners, vibratory screens which screen peanut pods into their average size to be shelled by a given stage, the actual shellers (numbering 3 to 5 stages according to pod size variations), aspirators for seed separation from the hulls, graders and bagging facilities. The complexities of the shelling plants according to Davidson (1962) require a large capital investment. The handling capacity is about two to five tons per hr. In the mechanized peanut producing areas in the United States, farmers rarely own shelling plants of this enormous size. Instead, they are owned by companies or private businessmen who do the shelling, grading and bagging of the farmer's stocks.

The presence of large scale commercial shellers does not mean there are no available small rotary shellers that can be compared to the Kano sheller in size and capacity. G. H. Larson (1974) reported on the introduction of a motor driven cylinder for peanut shelling in Nigeria from Japan. Braide (1974) reported on the development of peanut sheller using the wooden blocks that was introduced into Nigeria from Japan. This followed an attempt made by Musa (1971) to introduce a rotary peanut sheller for the first time in Nigeria.

There are also some modifications in size and design characteristics to meet certain shelling conditions. Davidson and McIntosh (1971) developed a laboratory quarter-sized shelling cylinder, which was a simulation of an ordinary commercial sheller, to investigate shelling properties and sheller characteristics using small samples of peanuts. Brown and Reed (1952) developed a small peanut sheller with a capacity of 200 to 400 lbs per hr. These small shellers were used by Reed and Coppock (1952) for studying shelling quality and sheller characteristics. Beattie (1952) reported on the use of a rubber covered surface on concave and cylinder bars in order to reduce abrasion so that a maximum whole-kernel yield could be obtained. However, the practical applications for rubber covered surfaces are still unknown because few studies have been made to test the effect(s) of rubber covered units for power requirement, wear and capacity. Dickens and Mason (1962) reported on the use of a translational reciprocating sheller in which the concave was to move against a stationary row of shelling bars. This sheller was to shell samples for grading where a maximum whole-kernel count was required.

Physical and Mechanical Factors Affecting Shelling Performance

Physical properties. Moisture content is one of the physical properties affecting shelling quality. Davidson, Blankenship and Hutchison (1970) found that split kernels increase with a decrease in moisture content. They determined the optimum moisture content for shelling and for safe storage, without deterioration in quality, to be 7 to 8 percent on a wet basis. Beattie (1947) studied the effect of moisture content on breakage, splitting, and skinning of peanut seeds during shelling. By increasing the moisture content in peanuts from 7 to 15 percent, the seed crackage was reduced by 500 percent over that found at the 7 percent moisture content. Reed and Coppock (1952) conducted extensive research on the effects of moisture content on shelling quality and machine performance. They independently demonstrated a similar effect of moisture content on shelling performance.

The rate of drying is another important factor that has drawn the attention of researchers in peanut shelling industries. Sometimes, weather stress at harvest time necessitates artificial drying (curing) in order to reduce moisture content to a safe-storage level. McIntosh and Davidson (1971) found that kernel crackage increases with an increase in the rate of peanut curing. Woodward and Hutchison (1972) cited a theory that high temperatures during drying bring about shrinkage or expansion of the seed coat as a result of internal stresses caused by moisture or temperature gradients. The shrinkage or expansion weakens the seed coat and the cotyledons are loosely held by the seed coat.

Pod size and pod uniformity are the determining factors with regard to the choice of concave design and clearance setting. Genetics of the peanut contribute to the size and uniformity during pod maturity (Yona, 1960).

Seed-coat tensile strength was another peanut characteristic found to affect seed crackage. Woodward (1973) demonstrated that the force for seed separation depends upon the seed coat and is independent of the kernel size. Weakened seed coats can account for a high rate of split kernels. Yona (1960) found out that the seed-coat strength is genetically influenced. This contributes to some inherent variation in shelling quality even though different varieties might be shelled by the same sheller and under the same conditions.

Ambient shelling temperatures are a less significant factor in shelling quality. However, McIntosh and Davidson (1971) found that peanuts shelled at cool temperatures were somewhat less subject to splitting.

Insect infested peanuts and mechanical damage, during harvesting and handling, affect the amount of split kernels during shelling. Panyne, et. al. (1970) found that kernel crackage during shelling was proportional to the number of insects present in the peanuts. Insects feed and lay their eggs in the seeds after they have pierced through the shell.

<u>Mechanical factors</u>. Cylinder characteristics are important to

achieve high performance in threshing, shelling and grinding mechanisms. The main components of a peanut-shelling cylinder are the number of shelling bars, cylinder size, cylinder bar surface configuration, cylinder bar support members (cylinder head), and whether the sections between bars are closed or open. Reed and Coppock (1952) investigated the shelling performance of three shellers with different design characteristics. One had a bar surface configuration of diamond-shaped studs in staggered rows. The second used a smooth bar, 5/8-in. square in cross-section, with open sections between the bars. The third sheller used angle-iron bars mounted on solid disc end plates and had either open or closed sections between bars. Short cylinders generally have support plates or discs at each end of the cylinder on which the bars are mounted, whereas long cylinders will have about three supports. The surface configuration of the cylinders used by Reed and Coppock in the first cylinder are similar to the Hendrick and Medley shellers used by Davidson (1962) while the smooth type is similar to the Appomattox and Pearman shellers also used by Davidson. See Figure 3.

The smooth shelling bars are designed so the distance between all points on the bar surface and the concave is constant or the distance may reduce from the front to rear of the bar to give a wedging action. In any event, the peanuts as fed fall into the sections between bars, are thrown out against the concave by centrifugal force, and are crushed between the bars and the concave.

The Kano sheller has six bars mounted on the semi-circular cylinder-like quadrant. Each bar carries rows of staggered cast-iron spikes. The semi-circular cylinder rubs peanuts against a stationary concave.

Reed and Coppock (1952) studied the influence of these cylinder

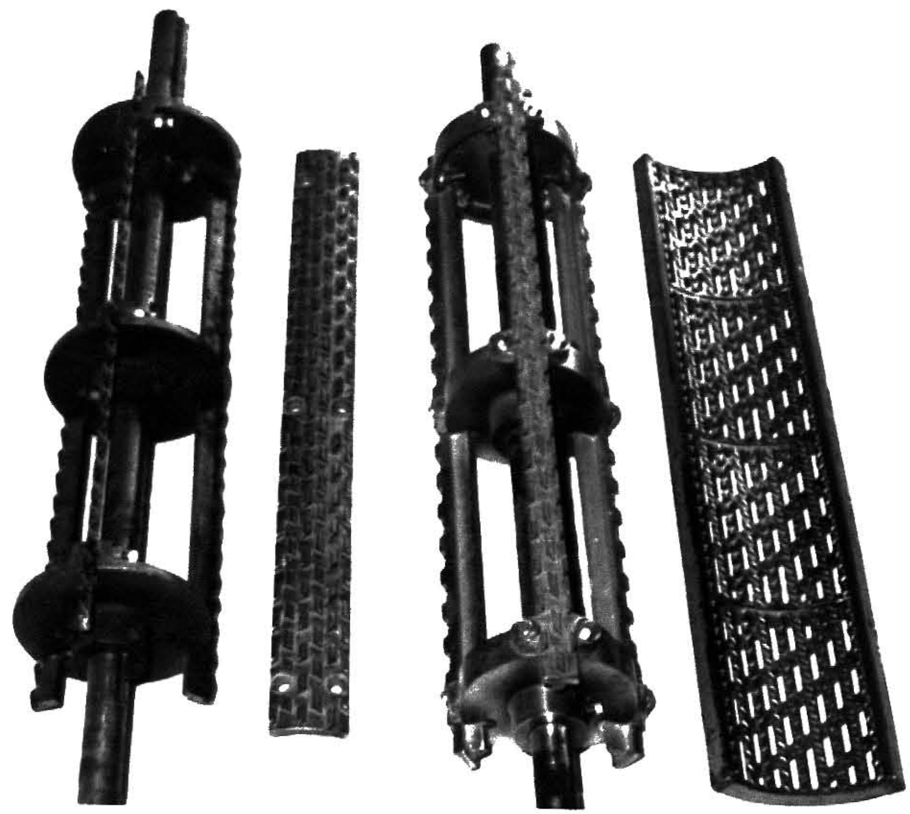


Fig. 3: One of the commercial cylinders and concaves in common use in the peanut producing areas of the United States. Davidson (1974).

design characteristics on sheller capacity, kernel crackage, shelling efficiency and seed germination performance. They found there was a 20 to 30 percent increase in shelling capacity using three bars instead of four bars and crackage was found to be lower with the three-bar cylinder. These results concerning kernel crackage were verified by Musa (1971) and Braide (1974) when the number of cylinder bars was reduced. The capacity of the angle-iron bar cylinder with closed sections between bars was higher by 50 to 80 percent as compared to the open-center configuration; but kernel crackage was also higher. A cylinder which caused the wedging action between the bars and the concave had twice the capacity over the uniform distance bar arrangement; however, it had higher kernel crackage but not as high as the angle-iron bar.

From these studies the optimum cylinder bar configuration appears to be the three-bar cylinder with cast iron bars.

Perforation shape is the most important characteristic of the sheet metal concave. Reed and Coppock (1952) found the long slotted perforations to give the highest capacity and lowest kernel crackage. Normally, the concave is identified by a number which represents the slot-width in 64ths of an in.; therefore, a size 28 means a 28/64-in. wide slot.

Other peanut concaves are made with steel bars or a cast-iron grate. In Nigeria, the Kano-sheller concave is made from wire mesh with openings identified in fractions of an in. It is difficult to compare the performance of the wire mesh concave with the perforated-sheet metal concave because it is the only available concave type.

Both Reed (1952) and Davidson (1971) independently found that the maximum shelling capacity and minimum kernel crackage occur at an optimum spacing between the cylinder and concave. Operating below this optimum spacing decreases capacity and increases crackage.

The capacity of shelling can be increased by increasing the feed-rate. A feed-gate is generally used to regulate the feed-rate. Reed and Coppock (1952) found that capacity can be increased by 15 to 25 percent, without affecting shelling quality, by increasing the feed-gate opening. They also demonstrated that reducing the number of concave sections from four to three increased the capacity by 76 to 106 percent.

The energy absorbed by peanuts is proportional to the cylinder inertia and peripheral speed. This is confirmed by Reed et. al. (1952) and Davidson (1971) that a given size of peanut sheller has an optimum speed and feed-gate opening for maximum capacity and minimum kernel crackage. When the speed and feed-gate opening are properly coordinated, capacity is found to increase appreciably without increasing kernel crackage. It is also evident that a maximum shelling quality can be obtained when both physical peanut properties and sheller characteristics are appropriately integrated into an operational sheller.

INVESTIGATION

Research Objectives

1. To determine experimentally the power required to shell peanuts at a given rate to provide a basis for the development of manually or motor driven peanut sheller.
2. To study the effects of cylinder-concave clearance, cylinder speed, feed-rate and their interactions upon the power requirement and shelling quality.
3. To provide a basic design for a peanut sheller using a

rotary cylinder, a mechanism for easy change of concaves and cylinder-concave clearance adjustment, and a manual or motor drive system. The sheller must have a capacity of about 500 to 1000 lbs per hr., be simple to operate, and be built at a minimum cost.

Equipment

The experimental threshing unit used by Zaidi (1974), was modified to simulate a peanut shelling mechanism which would help to predict torque as a function of certain factors. The basic changes included the replacement of the threshing rasp bars with peanut shelling bars, the replacement of the concave with a suitable peanut concave, and the placement of a hood and a hopper about the cylinder to permit recirculation of peanuts.

The shelling cylinder is 12 in. in diameter made with two aluminum discs as the end plates which according to Zaidi (1974) were used to provide minimum inertia. The cylinder has open sections between cylinder bars. The cylinder, together with the shelling bars, has an overall diameter of 13 3/8 in. and is 7 1/4 in. long. Four shelling bars are uniformly placed on the circumference of the cylinder. Each bar is 7 1/4 in. long, 1 3/4 in. wide and 1/2 in. thick and cut from ordinary mild-steel bars. Two rows of staggered studs, placed in the bars and protruding out on one side by 3/8 in. make up the shelling surface. Each stud was beveled to an angle of about 34° on the outer end. The other end of the studs was welded to the bar in order to fix them in position (Figure 8). The studs were made from 5/8 in. steel rod. These bars are not conventional ones, in commercial use, in the United States or

Nigeria. They are somewhat like the Kano sheller bars; however, the design was selected for easy construction and based principally on the author's experience (Musa, 1971). The cylinder shaft provided for torque measurement and is appropriately described under the section on the torque calibration. The choice of $\frac{1}{2}$ in.-thick steel bars was to increase the cylinder inertia with the aim of shelling effectively at a lower constant cylinder speed.

The concave was made from conventional peanut concave stock. It is a perforated, slotted metal sheet of the type described by Reed and Coppock (1952) and was obtained from the National Peanut Research Laboratory, Dawson, Georgia. The design features are shown in Figure 10a. Size 28 (28/64 in.) was used. The concave is 1 in. greater than the cylinder in radius with an arc length of 15 in. The concave is retained by a $\frac{1}{4}$ in. thick member placed below and at the ends of the concave. The concave slots are $1\frac{1}{2}$ in. long.

Other modifications involved the construction of a hood, a feed-gate and a hopper. The hopper has one side extended to form a deflector so the peanuts can be smoothly fed between the cylinder and the concave. The hood was placed approximately 3 in. from the cylinder. The arrangement of the hood, the hopper and the concave assures recirculation of material. Shelled material is therefore forced to pass through the concave perforation. The beater bar, which was used to prevent recirculation of material in small grains, was removed. The belt feeding unit was removed and the feed opening was sealed off by the side hood.

The cylinder was powered with a V-belt drive. Power was transmitted through a speed reduction unit (15 to 1 ratio) from a 1 hp. electric motor. The motor has a constant speed of about 1725 rpm and a variable

V-sheave was used on the speed reducer output shaft to vary the cylinder speed.

The shelled material was discharged only through the perforated concave. Seed separation was effected by placing a fan underneath the concave to blow away the hulls. The kernels fell on to a matted surface to reduce further seed crackage due to impact. No screening facilities were provided; the grading into unshelled pods, whole-kernels, cracked-kernels, trash and bald kernels was all done by hand.

Determination of Pod Size Distribution

Prior to the shelling experiment, some preliminary tests were conducted to determine the amount of impurities and pod size distribution in the peanut lot that was to be shelled. Table 3 gives the proportion and the percentage composition in terms of foreign material, damaged pods, immatured pods, visible diseased pods, visible cracked seeds and healthy pods. Four dimensions were taken on a peanut pod. These included the pod length, maximum and minimum pod diameter, and the diameter at the constriction. Among these dimensions, the most important dimension was the maximum pod diameter which determined the concave-perforation size that was to be used in the shelling process. Tables A1 to A4 in the Appendix show the values of these measurements made on 20 pods randomly taken from different varieties including the variety that was used in this experiment, while Table 1 shows the average measurement and their standard deviations. Table 2 gives the percentage of the number of pods going through each standard screen size from each variety.

Table 1. Comparison of Statistical Analysis of Pod Size Variation in Four Peanut Varieties.

		Varieties			
		Florunner	3566.72	3513.72	5-38
Length (in.)	Average	1.0526	1.1196	1.1741	1.143
	Longest	1.272	1.209	1.668	1.395
	Shortest	0.707	1.012	1.040	1.014
	S.D.	0.15555	0.06025	0.1513	0.0828
W_{max} (in.)	Average	0.5047	0.50865	0.4838	0.4732
	Largest	0.585	0.569	0.543	0.545
	Smallest	0.372	0.419	0.451	0.455
	S.D.	0.1136	0.04066	0.0224	0.0351
W_{min} (in.)	Average	0.4048	0.34525	0.4124	0.36985
	Largest	0.532	0.385	0.498	0.420
	Smallest	0.345	0.289	0.282	0.315
	S.D.	0.1467	0.0314	0.0549	0.0231
W_c (in.)	Average	0.3782	0.46745	0.45155	0.444
	Largest	0.531	0.532	0.497	0.487
	Smallest	0.281	0.409	0.400	0.416
	S.D.	0.1416	0.03339	0.02596	0.0174

S.D. - Standard Deviation; W_{max} - maximum pod diameter; W_{min} - minimum pod diameter; W_c - width at constriction.

Table 2. Percent Pod Size Distribution in Four Peanut Varieties.

	Varieties			
Screen size, 64ths-in.	US-Florunner %	N-3513.72 %	N-S-38 %	N-3566.72 %
35	35	0	0	15
33	30	15	20	25
31	5	30	50	40
29	5	40	30	5
27	15	10	0	2
25	10	5	0	0

Table 3. Determination of Peanut Quality for Shelling Experiment.

Replication	Total Weight gm	Foreign Material gm	Damaged Pods gm	Immature Pods gm	Visibly Diseased Pods gm	Visibly Cracked Seeds gm	Healthy Pods gm
1	500	5.5	33.8	63.8	-	2.4	394.5
2	500	5.5	20.0	72.9	0.6	6.1	394.9
3	500	4.0	31.0	101.0	1.1	2.0	360.9
Average	500	3.0	28.7	79.23	0.60	3.5	383.4
Percent		0.6	5.65	15.85	0.12	0.70	74.10

Torque Calibration

The torque calibration was made on the cylinder-shaft transducer which had been constructed for this function by Zaidi (1974). The detailed design features of the transducer and the mounting of the strain gages were adequately described by Zaidi. Figure 5 was reproduced from Zaidi and Figure 4 was modified to show the placement of the 45° rosette-type strain gages and the subsequent insertion of the $\frac{1}{4}$-in. square section to the main cylinder shaft.

Two equal lever arms, $18\frac{1}{2}$-in. long, were placed horizontally perpendicular to the cylinder and opposite each other in place of two shelling bars. The load-cell transducer and oscillograph chart recorder were balanced and a load was added to one of the arms in the direction of cylinder rotation in increments of 100 gm. This continued until no further deflection on the chart recorder was observed. At this point, the safety pin had deflected and was resting on the pipe member so any further applied load was transmitted through the pipe member and the $\frac{1}{4}$-in. member was protected from permanent deformation.

The procedure was repeated about 5 times. Data are shown in Appendix B.

When a single regression was fitted to the observed points, the scattered points showed two distinct curves similarly obtained by Zaidi (1974). A special statistical computer program was obtained from Statistics Department to characterize the two segmented straight-line curves, estimate the break-point and confidence limits. The true torque (y) is:

$$y = 1,8552 + 0.5758X \qquad X < 122.50 \qquad (1)$$

$$Y = 40.5787 + 0.2597X \qquad X > 122.50 \qquad (2)$$

EXPLANATION OF FIGURE 4

Fig. 4: Drawing shows the placement of strain gages on the ¼-inch square member and the insertion of this member into the main cylinder shaft. Modified from Zaidi (1974).

1. Strain gages
2. Safety pin to limit angular deflection
3. Main cylinder shaft
4. Bearing which allows angular deflection but prevents bending.
5. Pipe to keep the main shaft straight.
6. Torque-transducer shaft ¼-in. square cross-section.
7. Cap placed over the reduced-sized shaft (8) with a hole drilled in it to carry one end of the torque-transducer shaft.
8. Reduced-sized cylinder shaft.
9. Hole for strain gage wire.

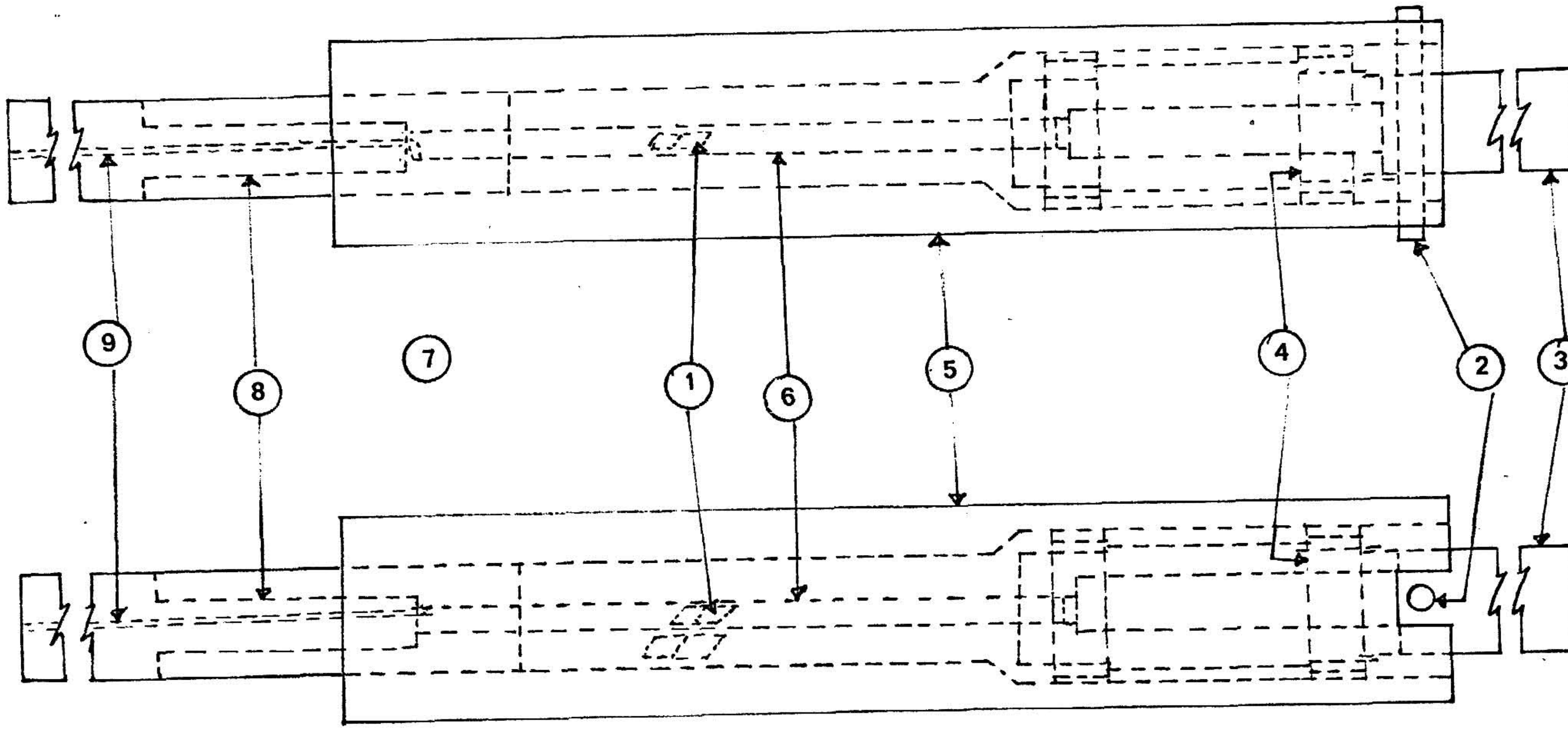


Fig. 4: Drawing shows the placement of strain gages on the 1/4-inch square member and the insertion of this member into the main cylinder shaft. Modified from Zaidi (1974).

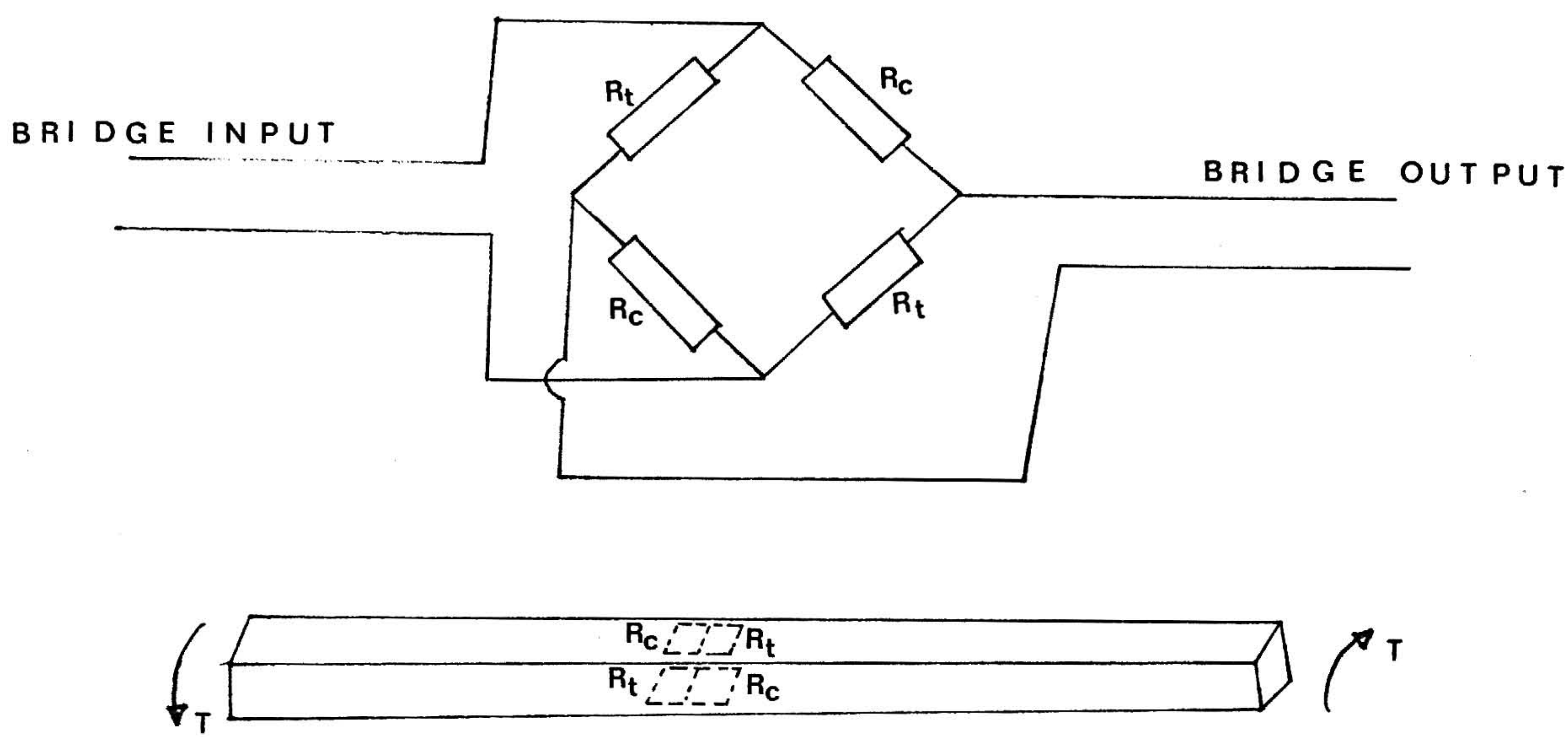


Fig. 5: Strain gage placement and bridge arrangement for sensing torque on the cylinder shaft. From Zaidi (1974).

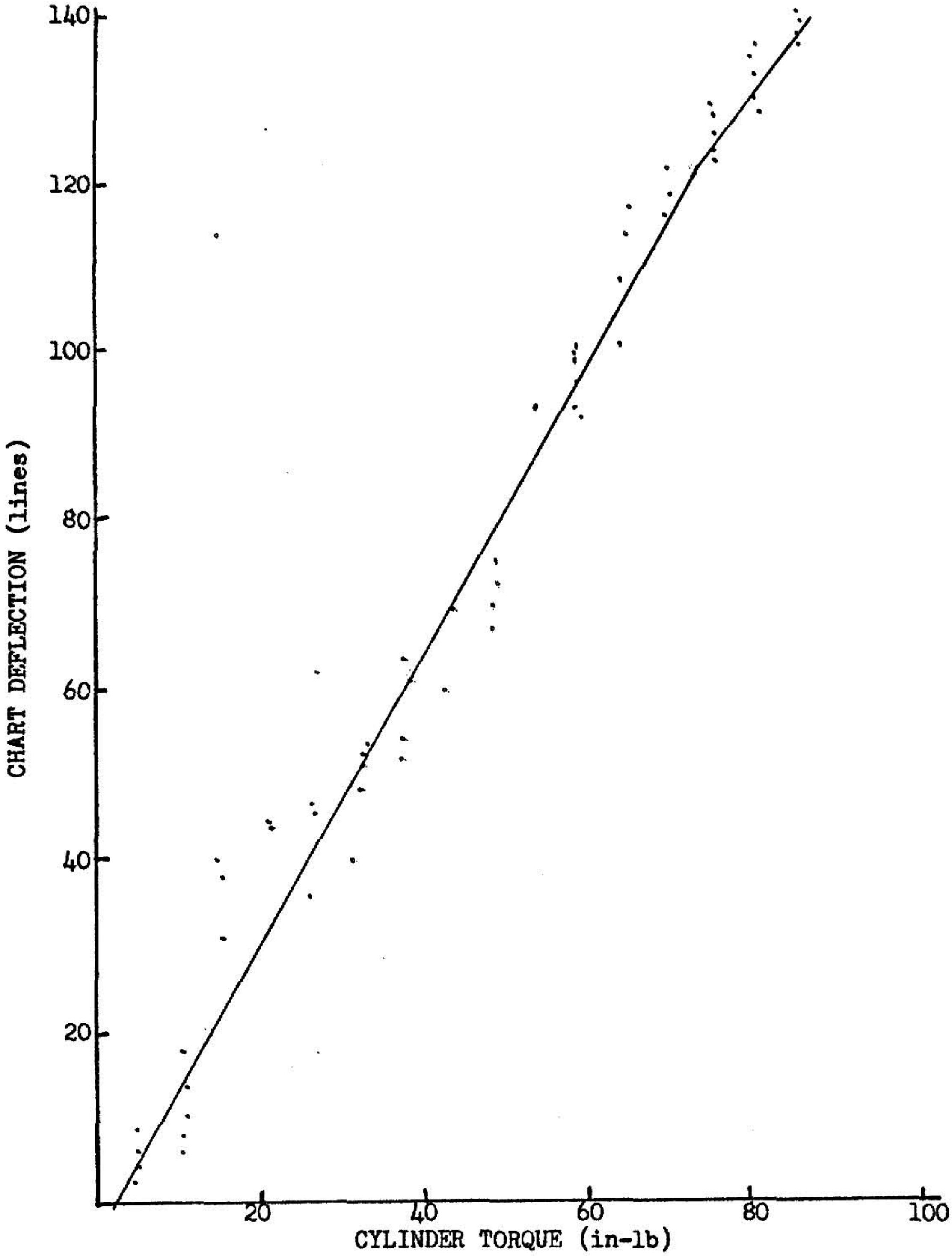


Fig. 6: Cylinder torque versus recorder chart defletion curve.

	Alpha 1	Alpha 2	Beta 1	Beta 2
Estimates	1.8552	40.5787	0.5758	0.2597
Std Error	1.156	16.125	0.0134	0.1164
L-con-Lt	-0.4575	8.328	0.541	0.0269
Up-con-Lt	4.16789	72.8291	0.6106	0.4925

Where alpha and beta are type one and two errors respectively, and L-con-Lt and Up-con-Lt are lower and upper confidence limits, respectively. X is lines deflection and y is the torque input. All the observed points in this experiment fell below 122.50; therefore, equation (1) was used to determine torque-input in the experiment.

Shelling Experiment

Peanut shelling was performed in laboratories of Agricultural Engineering Department. About 500 lb of peanuts were procured from the Coastal Plain Experiment Station, Tifton, Georgia, in December 1973. Shelling did not start until June, 1974. By this time some of the peanuts were infested by insects but the percentage damage was insignificant and of no major concern in the shelling experiment. The variety was later found to be Florunner which is one of the dominant varieties around Tifton. The shelling experiment started on June 10th and ended three weeks later.

Three variables at three levels each and replicated three times formed the main part of the experiment (3 treatments x 3 levels x 3 replications = 81 observations). The variables were cylinder speed, clearance and feed-rate. Later in the experiment, three samples each of clean pods and uniform pods were sorted from the peanut lot and shelled at one of the machine settings to evaluate the effect of foreign material on shelling quality and torque and to determine whether uniform pods could be shelled completely by one stage.

Three cylinder speeds were chosen and set at 150, 200 and 300 rpm. The low speeds were chosen to determine whether the effect of cylinder mass would contribute to better shelling characteristics. For hand operation, the cylinder speed should be low to reduce the number of pulleys required to step up the cylinder speed. With proper design of a hand cranking mechanism a suitable leverage could be designed to power the sheller. With a constant motor speed of 1725 rpm and a 15 to 1 speed reduction unit (s.r.u.), an output speed of 115 rpm was obtained. V-belts and pulleys, sizes 4, 5½ and 8 in. in diameter, were selected to transmit the respective power from the motor to the shelling cylinder. The pulleys on the motor input shaft of the s.r.u. and cylinder shaft were all 3 in. in diameter. Furthermore, a pickup was installed on the cylinder shaft and connected to a tachometer for true speed read out. The actual speeds registered were 160, 220 and 310 rpm.

Clearances between the cylinder and the concave were set at 1/2-, 3/4- and 1-in. spacings. The choice of spacings was purely the author's preference based upon his experience in running a similar experiment. On a conventional sheller, the recommended clearance is from 1 to 1½ in.

Feed-rate was regulated by a feed-gate set at 1, 2 and 3 in. The weight of peanuts maintained a constant flow into the shelling area but at the 1-in. opening, a light hand pressure was applied to accelerate the inflow of peanuts.

The number of shelling bars on the cylinder was fixed at 4, a single concave-perforation size of 28/64-in. slots was used for all the shelling experiments, moisture content was determined to be 3.0 percent and no attempt was made to preclean the samples before the shelling experiment. The field curing method was assumed to be by natural drying in the windrow.

Before the shelling experiment was started, a pod-size distribution was made on four varieties to determine the percentage of peanut pods passing through a set of screens. This was done to estimate the optimum screen size needed to shell the peanuts with minimum seed crackage and minimum whole pods passing through. In Table 2, the four variety sizes and the corresponding percentages are given. The 28/64-in. screen was chosen based upon the seed size.

Each sample was weighed at 1500 gm (3.304 lbs) and placed in the hopper with the feed-gate closed. The motor was started, the torque transducer amplifier was properly set at a constant gain of 200, the speed of the recorder chart paper was set at 0.1 unit per second, and a constant input voltage was set at 7 volts. The fan was switched on. The soft surface was placed underneath the concave to receive the shelled seeds. The air blast from the fan was directed underneath the concave to blow away the hulls and light foreign material. Figure 7 shows the experimental set up while Figure 9 shows a sample of shelled peanuts that were yet to be sorted for evaluation of shelling performance.

<u>Symbols Used in Recording Experimental Data</u>

The major variables to be investigated were given the following symbols for clarity and brevity.

1. Speed - K (3 treatments x 3 replications)

   K_1 = 160 rpm

   K_2 = 220 rpm

   K_3 = 310 rpm

2. Clearance - i (3 treatments x 3 replications)

   i_1 = 1/2-inch spacing

   i_2 = 3/4-inch spacing

   i_3 = 1-inch spacing

3. Feed rate - x (treatments x 3 replications

   X_1 = 1-inch opening

   X_2 = 2-inch opening

   X_3 = 3-inch opening

4. D - Lines deflection on the recorder

5. T - Torque (in-lb)

See Appendix Table C.

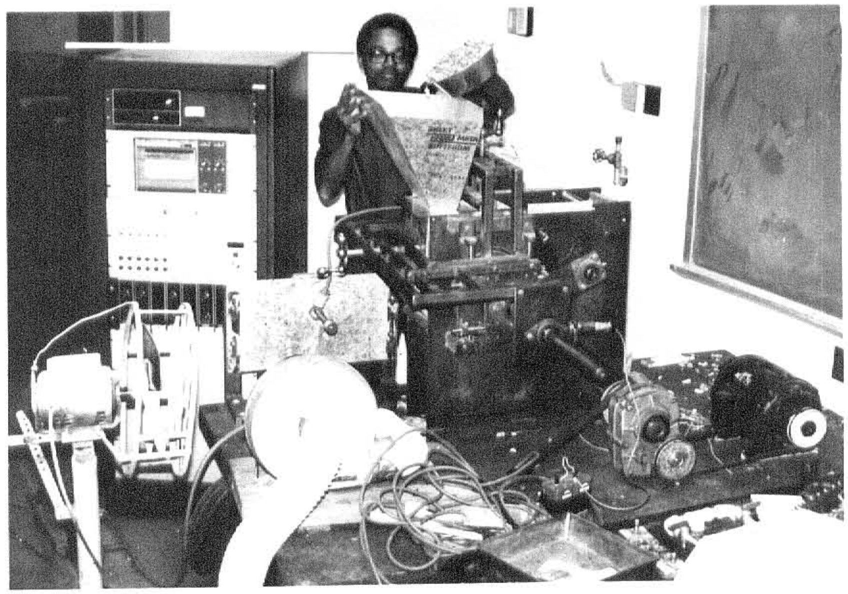


Fig. 7: Equipment for the shelling experiment. The load cell in the background (left) measures cylinder torque and speed.

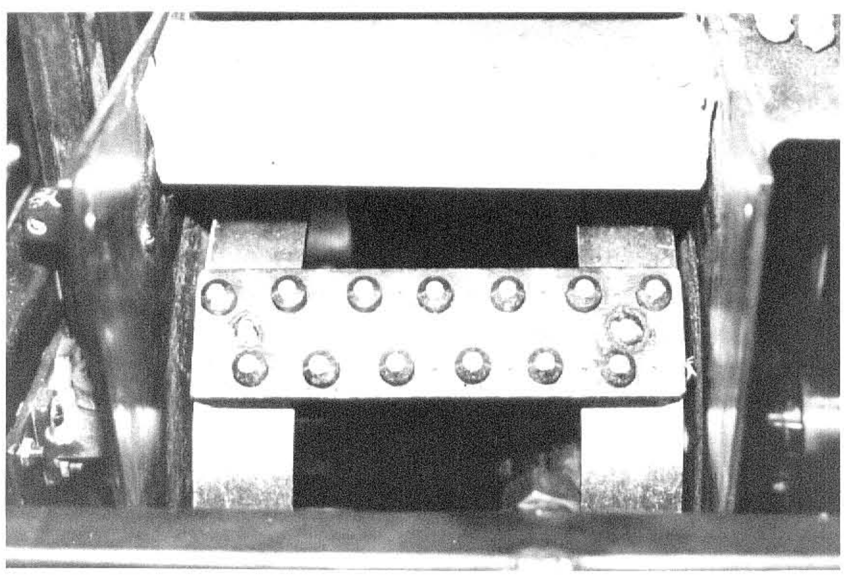


Fig. 8: Shelling cylinder showing the cylinder bar design features on the aluminum end plates.

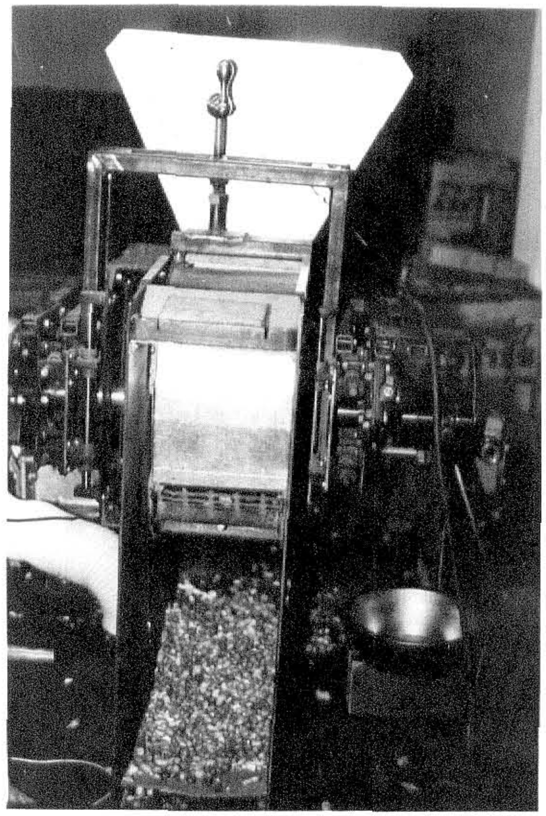
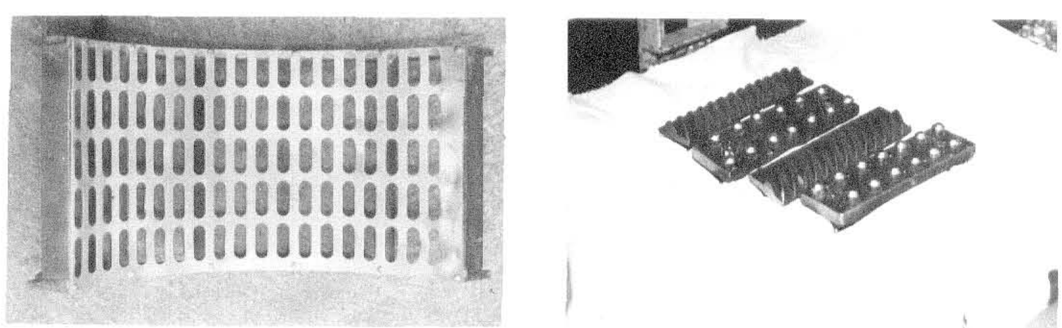


Fig. 9: Side view of the sheller showing a portion of concave and shelled peanuts.



a b

Fig. 10: (a) Detailed design of the concave and (b) a comparison of the laboratory cylinder bars with those of the wheat-combine rasp bars.

EXPERIMENTAL RESULTS AND DISCUSSION

The shelling experiment considered only three variables; namely, cylinder speed, clearance between the cylinder and concave, and feed-rate. Moisture content, number of shelling bars, type of feed opening into the shelling unit, and concave perforation configuration were known to affect capacity and shelling quality but no attempt was made to study these factors. The effect of shelling-bar design on shelling performance cannot be ascertained in the experiment because no attempt was made to compare the performance of shelling bars.

Kernel crackage is a most important factor in the peanut shelling process. Any factor affecting kernel crackage directly affects whole kernel yield. Machine components that perform the shelling process are to produce a minimum kernel crackage. Unlike other physical factors, such as the presence of foreign material (stones, plant debris, etc.) moisture content and curing methods which can be controlled, machine design factors must be accurately incorporated for optimum shelling performance. Therefore, the results obtained in this experiment place the most emphasis on factors affecting kernel crackage and energy input at those levels. Furthermore, peanut physical properties affecting single stage shelling were evaluated to determine the economic implications of the number of shelling stages.

Peanut Pod-Size Distribution

Table 2 summarizes the peanut pod-size distribution for four varieties. Florunner variety, a U.S. variety, shows a pod-size variation from the largest screen holes (35) to the smallest screen holes (25) while S-38, which is a popular Nigerian variety, shows a large percentage concentration of pod sizes in the 33 to 31 screen sizes. Thus, in the order of uniform pods, N-S-38 and N-3513.72 varieties are more uniform while Florunner and N-3566.72 varieties show non-uniformity. Table 3 presents the average pod dimensions and their standard deviations. From this table Florunner has an 11.36 percent standard deviation compared to 2.24 and 3.51 percent in N-3513.72 and S-38 varieties, respectively.

Shelling Quality, Torque and Power

Table 4 shows the average shelling performance in terms of percent unshelled pods, whole and cracked kernels, and torque input in in-lb. for each machine setting. Table 5 shows a rearrangement of Table 4 in order to show the effect(s) of each factor. Each row shows the effect of feed-rate (x) at constant cylinder speed (K) and cylinder-concave clearance (i) setting; at K_2 and i_1 the torque ranges from 39.28, 44.18 to 56.56 in -lb for feed-gate openings at X_1, X_2 and X_3 respectively. Likewise, the columns show the effect(s) of cylinder-concave clearance (i) from one cell to another while the speed effect is shown columnwise within each cell. Figures 11 to 16 are graphical representations at each of the three cylinder-concave clearance settings and at constant feed-rates. Tables 9 to 12 show the Least Significant Differences (LSD) at the percent level for each factor and their interactions. Trash and bald kernels were not considered. Their effects were considered to be of secondary importance. Any factor affecting kernel crackage directly affects whole-kernel yield; therefore, the statistical analysis given here for cracked kernels could equally represent whole-kernel yield.

The experimental data show an unequal number of observations due to cylinder plugging at certain machine settings. Therefore, Table 8 has

Table 4. Average Percent Shelling Performance in Terms of Unshelled Pods, Whole Kernels, Cracked Kernels and Torque-input.

Variable	Torque-input in-lb	Unshelled Pods %	Whole Kernels %	Cracked Kernels %
$k_1i_1x_1$	17.40	11.82	43.20	44.97
$k_1i_1x_2$	-	-	-	-
$k_1i_1x_3$	-	-	-	-
$k_1i_2x_1$	22.20	23.24	53.74	23.03
$k_1i_2x_2$	23.74	33.25	51.76	15.00
$k_1i_2x_3$	20.67	23.14	57.12	20.12
$k_1i_3x_1$	22.01	22.10	57.67	19.71
$k_1i_3x_2$	24.31	29.63	54.05	16.30
$k_1i_3x_3$	26.04	28.24	53.65	18.11
$k_2i_1x_1$	41.68	7.88	31.82	60.30
$k_2i_1x_2$	53.59	6.33	32.99	60.68
$k_2i_1x_3$	57.04	6.96	34.88	58.16
$k_2i_2x_1$	39.28	22.70	49.38	27.89
$k_2i_2x_2$	45.53	20.25	52.19	27.56
$k_2i_2x_3$	47.06	22.36	48.43	29.20
$k_2i_3x_1$	35.16	35.00	40.93	17.43
$k_2i_3x_2$	43.31	36.96	44.55	20.84
$k_2i_3x_3$	47.92	25.94	52.64	20.36
$k_3i_1x_1$	75.15	3.41	14.89	81.71
$k_3i_1x_2$	-	-	-	-
$k_3i_1x_3$	-	-	-	-
$k_3i_2x_1$	60.88	14.94	21.59	63.47
$k_3i_2x_2$	62.32	7.64	29.47	62.88
$k_3i_2x_3$	68.08	7.86	30.72	62.08
$k_3i_3x_1$	67.12	24.75	33.03	42.22
$k_3i_3x_2$	58.96	18.18	36.21	45.61
$k_3i_3x_3$	56.08	17.46	38.54	44.00

k - cylinder speed; i - cylinder-concave clearance; x - feed-rate.

Table 5. Analysis of Peanut Shelling to Determine the Effects of Sheller Characteristics on Shelling Quality and Power Requirement.

Speed	Torque in-lb	Unshelled Pods %	Cracked Kernels %	Torque in-lb	Unshelled Pods %	Cracked Kernels %	Torque in-lb	Unshelled Pods %	Cracked Kernels %
		i_1x_1			i_1x_2			i_1x_3	
K_1	16.83	9.61	47.76	-	-	-	-	-	-
K_2	39.28	7.80	63.05	44.18	7.10	61.18	56.56	7.29	61.39
K_3	77.87	3.55	80.55	-	-	-	-	-	-
		i_2x_1			i_2x_2			i_2x_3	
K_1	20.86	24.19	23.27	24.31	36.46	15.11	22.01	19.85	23.70
K_2	37.85	24.39	26.83	43.60	19.53	30.14	45.04	31.97	25.39
K_3	62.32	28.73	46.90	62.32	8.03	61.87	70.96	8.26	62.39
		i_3x_1			i_3x_2			i_3x_3	
K_1	23.74	22.06	17.85	24.89	23.93	18.83	26.62	29.20	17.21
K_2	26.33	52.98	13.79	40.72	41.57	16.52	42.45	23.31	23.57
K_3	65.20	30.56	42.22	65.20	20.33	46.52	53.68	19.37	44.44

K - cylinder speed; i - cylinder-concave clearance; x - feed-rate.

been devised to provide the appropriate n-observations to be used in the LSD computation. Furthermore, each pair of comparisons had to have their LSD computed separately unless other pair-means within each set have the same n-number of observations. Tables 10 and 12 show the computation of the LSD and those that are significant at the 5 percent level.

Cracked Kernels. In terms of maximum and minimum kernel crackage the minimum crackage of 15.00 percent was obtained at a cylinder speed of 160 rpm, 3/4-in. cylinder-concave clearance and a 2 in. feed-gate setting (see Table 4 and 5). The percentage unshelled was high at 33.25 and the ratio of whole kernel to cracked kernels was 0.7753. The torque input was 23.74 in-lb (0.0603 hp.), and at an estimated capacity of 317 lb. per hr. Maximum cracked kernels, 81.71 percent, occurred at 300 rpm, 1/2-in. cylinder-concave clearance and 1-in. feed-gate opening. The ratio of whole kernels to the cracked kernels was .1541. From Table 9, cylinder speed, cylinder-concave clearance and the interaction between cylinder speed and cylinder-concave clearance are highly significant. The LSD computations in Table 10 (a and b) show that they are all significant at the 5 percent level. But considering cylinder speed and cylinder-concave clearance, only $K_1 - i_2$; $K_1 - i_3$ and $K_2 - i_3$ are non-significant (Table 10d). Cracked-kernel yield was not affected by feed-rate (see Table 9 and 10c and the interactions in e and f of Table 10). Among the three factors, cylinder speed is the most important factor in kernel crackage, as can be seen in Figures 11 to 13.

Cylinder Torque. From Table 5, the cylinder torque input was found to vary both rowwise and columnwise. Therefore, the power input was found to be affected by cylinder speed, cylinder-concave clearance and feed-rate. With the 2 and 3-in. feed-gate openings for K_1 and K_3, the cylinder plugged. Torque increased for every increase in feed-rate except at $K_1i_2x_3$ where it went from 20.86 in -lb in $K_1i_2x_1$ and 24.31 in-lb in $K_1i_2x_2$ to 22.01 in -lb in $K_1i_2x_3$. Experimental error might account for this unusual behavior. Columnwise, the effect of cylinder-concave clearance is not very great as can be seen in Figures 14 to 16. However, from Table 11 the interaction of cylinder-concave clearance and feed-rate is the only non-significant factor. From the LSD computation, cylinder speed is significant at the 5 percent level, cylinder-concave clearance 2 and 3 are non-significant; therefore, they have the same effect. Also feed-rate x_2 and x_3 have the same mean. The interactions of the three factors are shown, as to which factors are significant, in d, e and f of Table 12.

Unshelled Pods. Although no detailed statistical analysis of unshelled pod was made, Table 5 shows the rate of the unshelled-pod with an increase in cylinder speed. The cylinder-concave clearance effect, at wider spacing and higher speeds, makes the percentage of unshelled pod higher. The presence of unshelled pods was likely a result of small pods which could pass through the concave slots. At higher speeds or narrow cylinder-concave clearances, the impact energy absorbed by the pod directly in contact with the shelling bars is enough to crush the pods whether they are small or large.

Performance of Uniform Pods, Clean Pods and Grain-Rasp Bars

Table 6 shows a comparison of shelling performance with unsorted, clean and uniform pods and the corresponding torque input. The torque requirement for unsorted peanuts was 43.60 in-lb, 39.0 in-lb for clean pods and 36.92 in-lb for uniform pods. The percent unshelled was

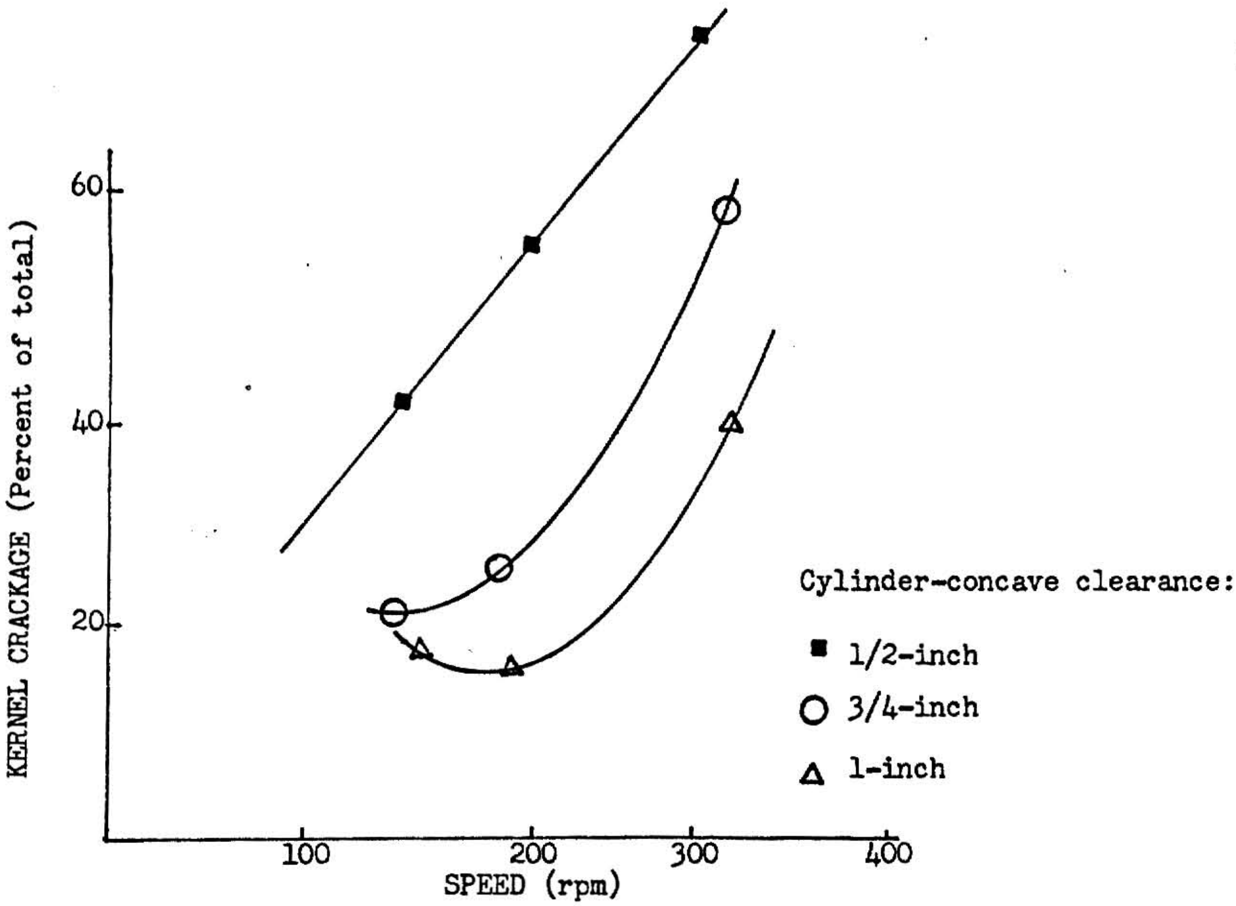


Fig. 11: Percent kernel crackage versus cylinder speed at the 1-inch feed-gate opening.

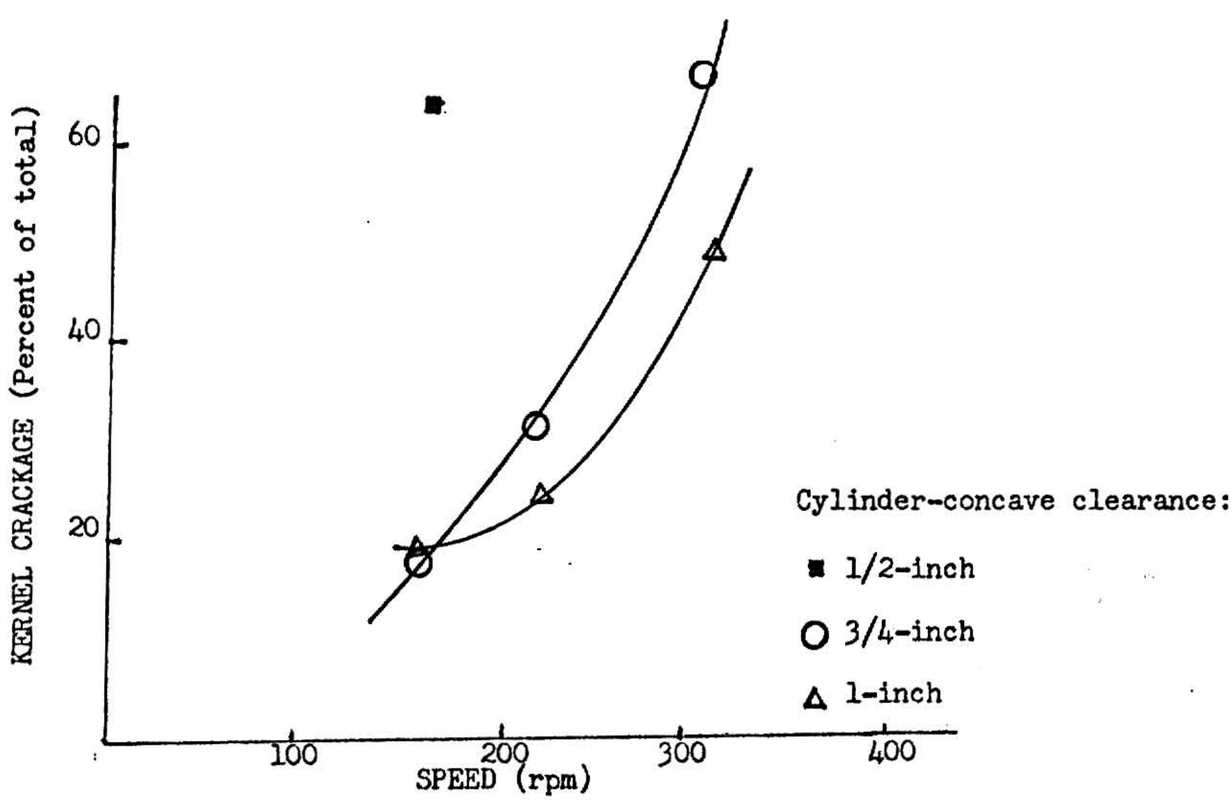


Fig. 12: Percent kernel crackage versus cylinder speed at the 2-inch feed-gate opening.

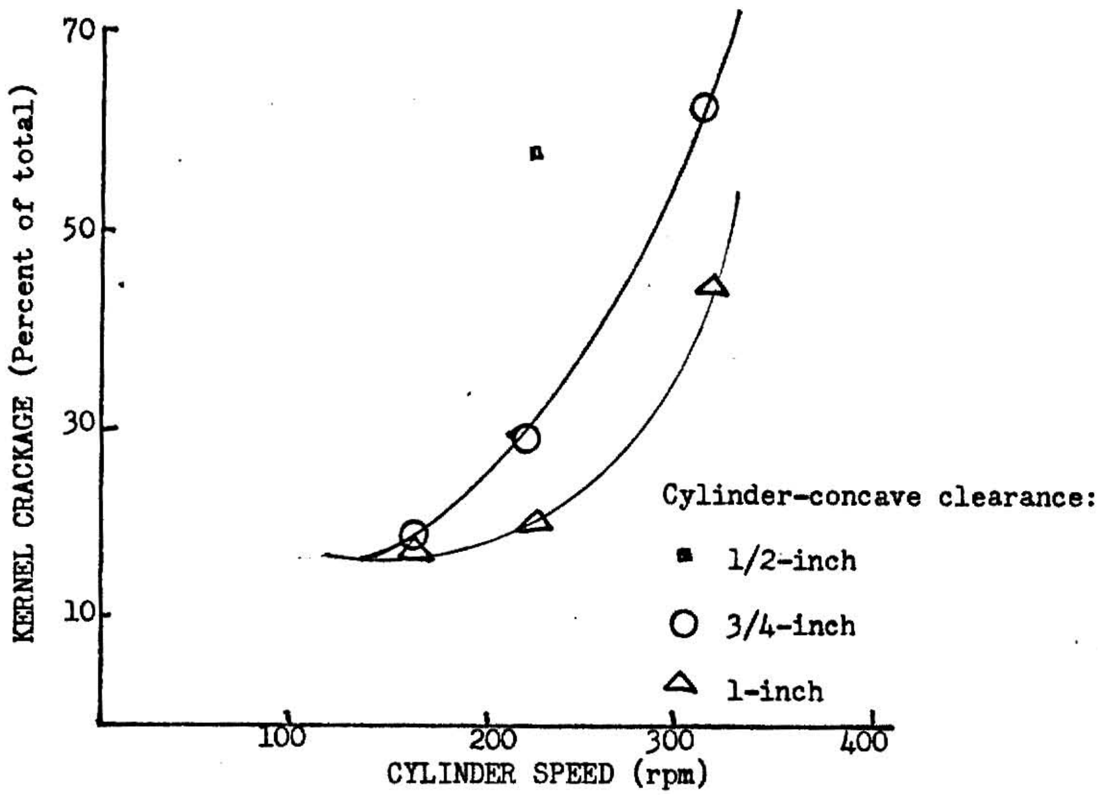


Fig. 13: Kernel crackage versus cylinder speed at the 3-inch feed gate-opening.

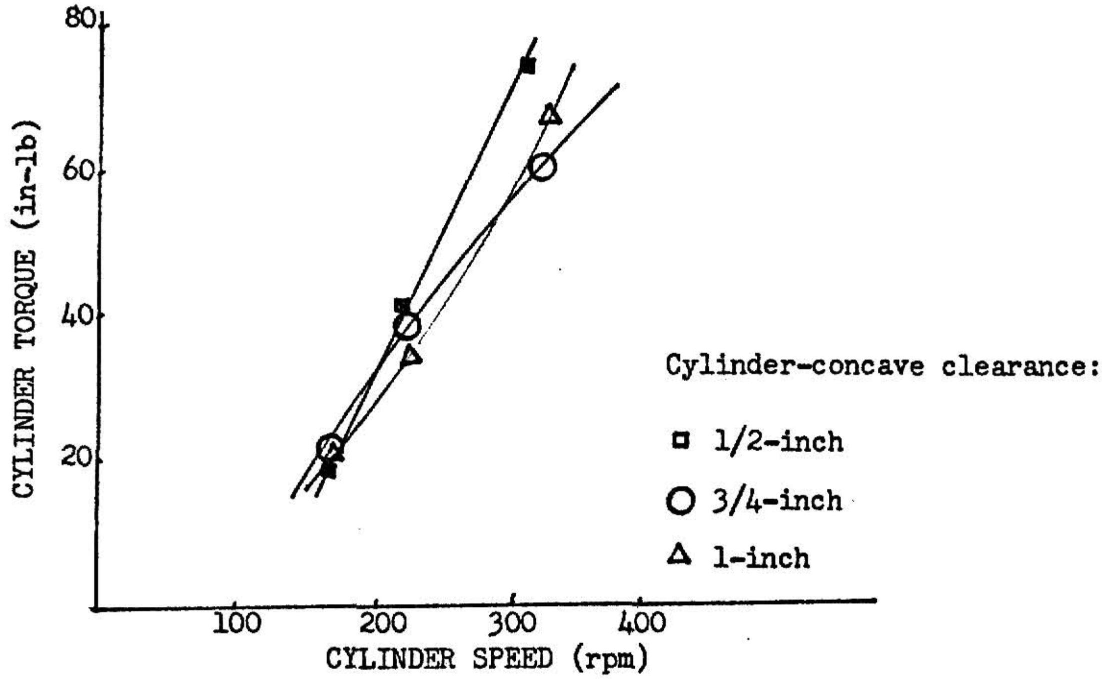


Fig. 14: Cylinder torque input versus cylinder speed at the 1-inch feed-gate opening.

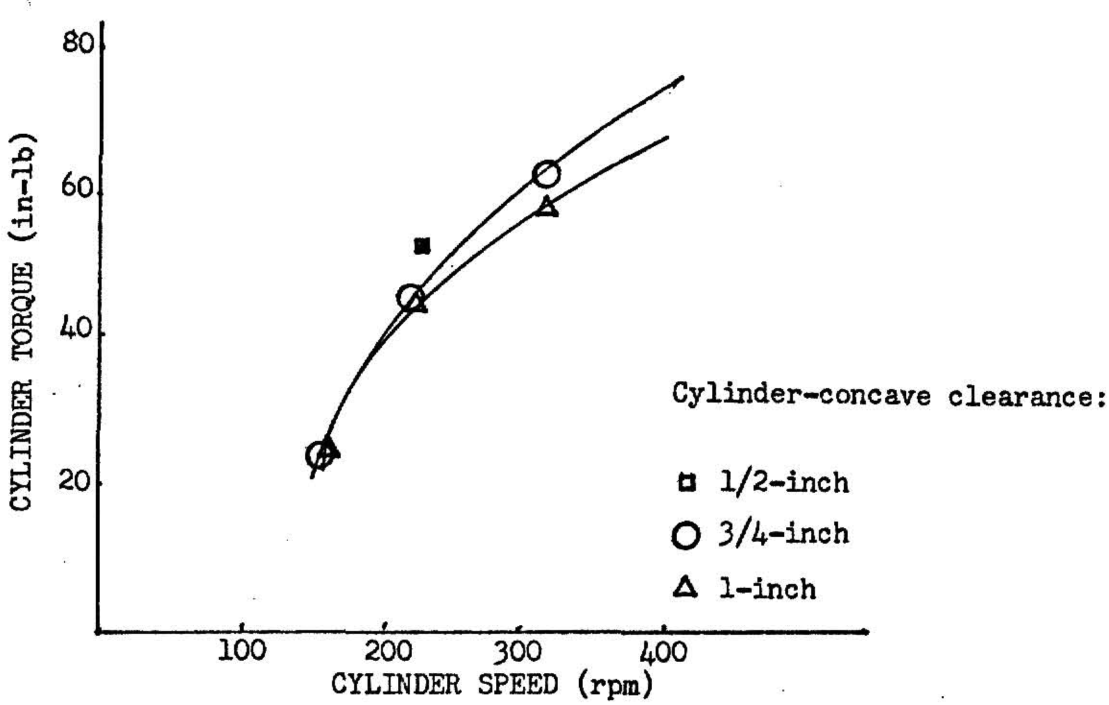


Fig. 15: Cylinder torque input versus cylinder speed at the 2-inch feed-gate opening.

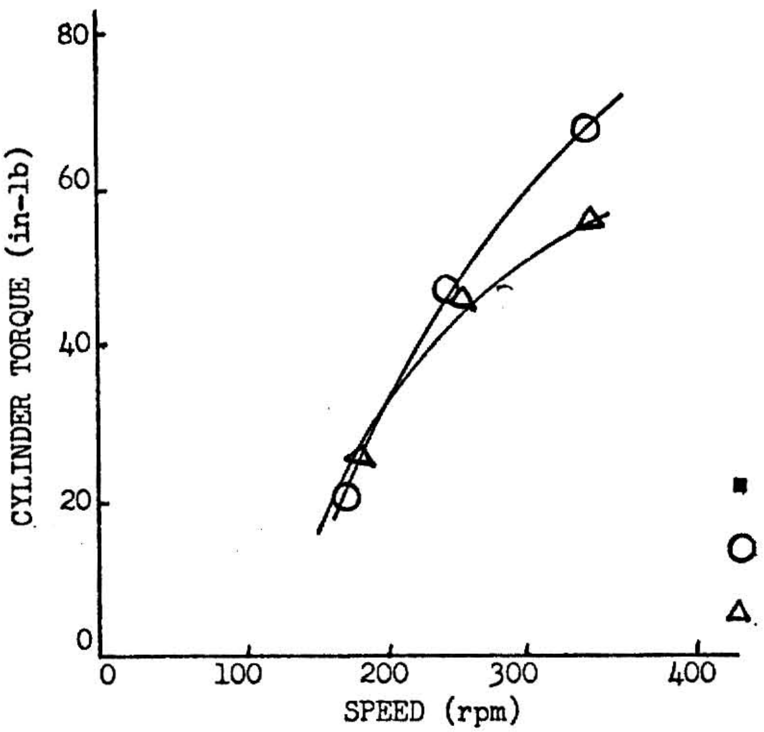


Fig. 16: Cylinder torque input versus cylinder speed at the 3-inch feed-gate opening.

Table 6. Comparison of Shelling Performance and Power Requirement to Shell Ordinary Peanut Lot, Clean and Uniform Pod Samples at the Shelling Conditions $K_2i_2x_2$*

Sample	Torque in-lb	Unshelled Pods %	Whole Kernels %	Cracked Kernels %
Unsorted peanut	43.60	19.68	50.33	30.14
Clean pods	39.00	12.10	57.17	32.30
Uniform pods	36.92	3.24	58.33	38.40

*K_2 - 220 rpm cylinder speed; i_2 - 3/4-in. cylinder-concave clearance; x_2 - 2-in. feed-gate opening.

Table 7. Performance Characteristics of Conventional Grain Rasp Bar in Peanut Shelling.

Variable	Torque in-lb	Unshelled Pods %	Whole Kernels %	Cracked Kernels %
$K_2i_2x_2$	-	-	-	-
$K_2i_2x_2$*	37.65	11.81	44.88	43.31
	38.97	11.79	44.43	43.78
	36.06	14.45	39.58	45.97

*The cylinder failed to turn at 200 rpm, 3/4-in. clearance and feed-gate opening setting at 2 and 3 in. X was set equal to 1½-in. opening.

Table 8. Number of N-Observations as Used in LSD Computations in the Analysis of Cracked Kernels and Torque Input.

Speed

21	27	21

Clearance

15	27	27

Feed-rate

27	21	21

Speed x clearance

3	9	9	9	9	9	3	9	9

Speed x feed-rate

9	6	6	9	9	9	9	6	6

Clearance x feed-rate

9	3	3	9	9	9	9	9	9

Table 9. Analysis of Variance for Cracked Kernels.

Source	D.F.	Mean Squares	F-Ratio	Prob.
Speed	2	589702.06	202.91	0.00
Clearance	2	196102.06	67.48	0.00
Feed-rate	2	1186.30	0.41	0.667
Spd-Clear	4	21519.55	7.41	0.0001
Spd-Fdrt	4	3124.64	1.08	0.379
Clear-fdrt	4	3457.65	1.19	0.327
Residuals	50	2906.21		
TOTAL	68			

Table 10. Comparison of Cylinder-Speed, Cylinder-Concave Clearance and Feed-Rate Affect on Cracked Kernel Yield.

a)

Speed	Mean
1	276.04
2	388.56
3	680.94

$LSD_{.05}$ (1,2 = 2,3)[1] = 31.53

$LSD_{.05}$ (1,3) = 33.44

Comparisons: all are significant.

b)

Cylinder-concave clearance	Mean
1	276.04
2	388.56
3	680.94

$LSD_{.05}$ (1,2 = 1,3)[1] = 34.89

$LSD_{.05}$ (2,3) = 29.49

Comparisons: all are significant

c)

Feed-rate	Mean
1	453.90
2	453.96
3	437.69

$LSD_{.05}$ (1,2)[1] = 31.53

$LSD_{.05}$ (1,3) = 31.53

$LSD_{.05}$ (2,3) = 33.44

Comparisons: all are non-significant

Table 10, continued.

d)

Speed	x clearance	Mean
K_1	i_1	404.07
K_1	i_2	218.42
K_1	i_3	205.63
K_2	i_1	625.84
K_2	i_2	317.69
K_2	i_3	222.14
K_3	i_1	865.16
K_3	i_2	676.33
K_3	i_3	501.33

$LSD_{.05}$ (1-1, 1-2 = 1-3, 2-1 = 2-2, 2-3 = 3-2, 3-3)[2] = 72.24

$LSD_{.05}$ (1-1, 3-1) = 88.47

$LSD_{.05}$ (1-2, 1-3 = 2-1, 2-2 = 2-3, 3-2 = 3-3) = 31.08

Comparisons: 1-2, 1-3, 2-3 are the same mean
2-1, 3-2 are the same mean while all other comparisons are significant

e)

Speed	x feed-rate	Mean
1	1	304.08
1	2	256.27
1	3	267.76
2	1	379.39
2	2	399.27
2	3	387.02
3	1	678.22
3	2	706.31
3	3	658.28

$LSD_{.05}$ (1-1, 1-2 = 3-2, 3-3)[2] = 57.11

$LSD_{.05}$ (1-1, 2-1 = 2-3, 3-1) = 51.08

$LSD_{.05}$ (1-2, 1-3 = 3-2, 3-3) = 62.56

Comparisons: 1-1, 1-2 and 1-3 are non-significant
2-1, 2-2 and 2-3, 3-1 and 3-3 are non-significant
all other comparisons are significant

Table 10, continued.

f)

Clearance x	feed-rate	Mean
1	1	641.63
1	2	663.91
1	3	589.52
2	1	421.98
2	2	386.29
2	3	404.18
3	1	298.08
3	2	311.66
3	3	319.36

$LSD_{.05}$ (1-1, 1-2 = 1,2)[2] = 72.24

$LSD_{.05}$ (1-2, 1-3) = 88.47

$LSD_{.05}$ (1-1, 2-1 = 2-2, 2-3 = 3-1, 3-2 = 3-3) = 51.08

Comparisons: 1-1, 1-2 and 1-3 are non-significant
2-1, 2-2 and 2-3 are non-significant
3-1, 3-2 and 3-3 are non-significant

1. Notations in brackets mean comparisons between individual variables which have the same number of observations (n) in Table 8.

2. Notations in brackets mean the combination effect(s) of two factors compared to the next combination(s).

Table 11. Analysis of Variance for Cylinder Torque Input.

Source of Variation	Degrees of Freedom	Mean Square	F-Ratio	Probability
Speed	2	18553.68	314.60	0.00
Clearance	2	164.66	2.80	0.07
Feed-rate	2	258.50	4.39	0.018
Speed x clearance	4	145.82	2.48	0.06
Speed x feed-rate	4	215.28	3.65	0.01
Clearance x feed-rate	4	37.67	0.64	0.64
Residuals	50	58.91		
TOTAL	68			

Probability values indicate that only cylinder-concave vs. feed-rate is non-significant on cylinder-torque input.

Table 12. Comparison of the Cylinder Speed, Cylinder-Concave Clearance and Feed-rate Effects on Cylinder Torque-Input.

a)

Speed	Mean
1	36.17
2	76.00
3	110.20

$LSD_{.05}$ (1,2 = 2,3) = 4.49

$LSD_{.05}$ (1,3) = 4.76

Comparisons: all are significant

b)

Clearance	Mean
1	80.11
2	71.98
3	70.28

$LSD_{.05}$ (1,2 = 1,3) = 4.97

$LSD_{.05}$ (2,3) = 4.20

Comparisons: clearance 2 and 2 are non-significant

c)

Feed-rate	Mean
1	69.27
2	75.33
3	77.17

$LSD_{.05}$ (1,2 = 1,3) = 4.49

$LSD_{.05}$ (2,3) = 4.76

Comparisons: feedrate 2 and 3 are non-significant

Table 12, continued.

d)

Speed x	clearance	Mean
1	1	34.50
1	2	35.33
1	3	38.67
2	1	84.94
2	2	73.11
2	3	69.94
3	1	120.88
3	2	107.50
3	3	102.21

$LSD_{.05}$ (-1-1, 1-2 = 1-3, 2-1 = 2-2, 2-3 = 3-2, 3-3)^2 = 10.28

$LSD_{.05}$ (1-1, 3-1) = 12.60

$LSD_{.05}$ (1-2, 1-3 = 2-1, 2-2 = 2-3, 3-2 = 3-3) = 7.27

Comparisons: 1-1, 1-2 and 1-3 are non-significant
2-1 and 2-2 are non-significant
2-2 and 2-3 are non-significant
3-2 and 3-3 are non-significant

e)

Speed vs	feedrate	Mean
1	1	32.44
1	2	38.50
1	3	37.56
2	1	64.00
2	2	79.22
2	3	84.78
3	1	111.37
3	2	108.25
3	3	110.98

$LSD_{.05}$ (1-1 = 1-2 = 3-2 = 3-3) = 8.13

$LSD_{.05}$ (1-1 = 2-1 = 2-3 = 2-3 = 3-1) = 7.27

$LSD_{.05}$ (1-2 = 1-3 = 3-2 = 3-3) = 8.91

Comparisons: 1-2, 1-2, 1-3 are non-significant
2-2, 2-3 are non-significant
3-1, 3-2, 3-3 are non-significant

Table 12, continued.

f)

Clearance	vs feedrate	Mean
1	1	71.48
1	2	82.98
1	3	85.87
2	1	67.61
2	2	72.94
2	3	75.39
3	1	68.72
3	2	70.06
3	3	

$LSD_{.05}$ $(1\text{-}1 = 1\text{-}2 = 1\text{-}3)^2 = 10.28$

$LSD_{.05}$ $(1\text{-}1 = 2\text{-}1 = 1\text{-}2 = 2\text{-}2 = 2\text{-}3 = 3\text{-}1 = 3\text{-}2 = 3\text{-}3) = 7.27$

$LSD_{.05}$ $(1\text{-}2 = 1\text{-}3) = 12.60$

Comparisons: Only 1-1, 1-2 and 1-3 are significant similar. The percent unshelled for unsorted peanuts was 19.68, 12.10 percent for clean pods and 3.24 percent for uniform pods. For unsorted peanuts the crackage was 30.14 percent, 32.30 percent for clean pods and 38.40 percent for uniform pods. Both samples were shelled at a cylinder speed of 200 rpm and 3/4-in. cylinder-concave clearance. The clean pods had the highest whole-kernel yield by 63.90 percent when only the whole and cracked kernels were taken into consideration.

The rasp bar sheller bars did not perform well at the optimum operating conditions as shown in Table 7. At a cylinder speed of 200 rpm, 3/4-in clearance, and 1½-in. feed-gate opening (which was the maximum feed-rate to prevent plugging), the maximum whole-kernel yield was 42.97 percent.

EXPERIMENTAL CONCLUSIONS

Peanut sizing is necessary to select concave opening sizes for maximum shelling efficiency. Some desirable peanut characteristics for one-stage shelling efficiency are:

1. Uniformity: From the pod-size distribution in the four varieties evaluated, Florunner would not be an ideal variety for one stage shelling for the following reasons:
   (a) A high percentage of crackage is expected for some kernels are too large to go through the concave opening.
   (b) A high tendency for small immature pods to pass through the concave unshelled, thus reducing shelling efficiency.
   (c) Multiple shelling stages or interchangeable concaves are necessary; therefore, there is a need for screening devices and a higher power input to run the additional mechanisms.

The N-S-38 and N-3566.72 varieties would give the maximum shelling efficiency because the pods are more uniform; thus there could be some saving in machines and energy. Fortunately, the S-38 and S-3566.72 varieties are the most popular varieties grown in Nigeria.

2. Trash: The presence of trash in the form of plant debris, insect damage and mechanical damage affect shelling performance both in energy requirement and whole-kernel yield.

From the data obtained in the experiment, the three factors studied showed the following effects upon cracked kernels and power input:

1. Kernel crackage was found to increase with an increase in cylinder speed, increase with a decrease in cylinder-concave clearance and be unaffected by changes in feed-rates.
2. Torque was found to be a function of cylinder speed. From a log-log plot, the functional relationship was established to be

$$T = aK^b$$

where:

T = torque in in-lb

K = cylinder speed in rpm

and a and b are constants.

Using a log-log paper, most of the data points fell on a linear curve. The following equation was used (Snedecor and Cochran, 1967)

$$lmT = lna + blnK$$

from which the constants a and b were obtained. They were obtained from the experimental data using a least-square method. When this method was applied to the data obtained at the 3/4-in. cylinder-concave clearance, the torque input versus cylinder speed relationship was

$$T = 5.235K^{.4294}$$

Torque was also found to increase with close cylinder-concave clearances and with higher feed-rates.

3. The cylinder was easily plugged at higher feed-rates due to an accumulation of peanuts in the sheller faster than the rate they were shelled.
4. The unshelled pods decreased significantly in amount at increased cylinder speeds and decreased cylinder-concave clearances. The feedrate was found to have no effect on the amount of unshelled pods.
5. Peanut shelling bars performed better than did grain rasp bars. The rasp bars required a higher torque when they shelled at the same feed-rate as did the peanut bars.
6. The range of power requirement was from 0.0603 hp at the optimum shelling condition to 0.3 hp at the most critical peanut shelling condition. The corresponding range in shelling rate was 317.76 to 750 lb per hr. Thus, the capacity was doubled but the kernel crackage increased four times. It is expedient to shell at lower speeds in order to obtain a high quality yield in whole kernels.
7. The power requirements indicated that a manually powered sheller could be designed to obtain the 500 lb per hr. rate of shelling.

THEORY RELATED TO PEANUT SHELLING

Peanut Pod Characteristics

The primary purpose of peanut shelling is to separate the kernels from the shells. The kernels are referred to as seeds or nuts and the shells as hulls. From pod and seed measurements, it was found that the seed occupies less than the total volume in the shell.

The pod morphology and the shell texture have evolved special techniques in freeing the seeds from the pod either by hand or by a mechanical device. The cereal grains when fully matured are generally dry and hard in texture. Seed separation is by threshing. Threshing is done by beating, animal tramping or by mechanical threshing employing the cylinder-concave technique. Grain crackage is usually insignificant when any of these techniques are used. Peanut plants are unusual members of the legume family that set fruit in the ground. Two operations are necessary to obtain the seeds. Firstly, the plants are uprooted, windrowed and threshed to obtain the pods. Secondly, the pods are shelled by hand or by the cylinder-concave technique.

A study of pod shape and certain physical properties helps to appreciate peanut shelling techniques. The shell and the seed are bilaterally symmetrical. The lateral line on the shell is gummed together by a weak and less fibrous tissue that can be torn apart with an application of force along this lateral line. The line is called a "suture". Hand shelling is accomplished by orientating the pod so that the force is applied by pressing the pod between the thumb and the second and third fingers. The shell and the seeds are hygroscopic. When they absorb sufficient moisture they expand. With sufficient moisture the shell and the seed expand and rupture the shell. Germination occurs when the seeds expand and rupture the shell in a natural environment.

Mechanical shelling fundamentally follows the same principle. However, just like grain threshers have been designed to attain a high capacity and still maintain quality, mechanical peanut shellers have been designed to shell at high capacity and still maintain quality. But unlike hard grains, peanut seeds are delicate cotyledons loosely held together by germ tissue called a plumule and enveloped by thin membrane called a seed coat or testa. Shelling surfaces and mechanisms must be designed to operate so that seeds are not bruised or cracked severely.

Energy Requirement in Peanut Shelling

Varieties affect shelling performance. By establishing a standard of comparison, the energy required to crush a pod can be regarded as one of the intrinsic properties distinguishing one variety from another. Intuition and experience have been used as a means of choosing some form of rough surface configuration for most shelling, threshing and grinding mechanisms. There are many different designs and configurations of peanut shelling cylinders in use; however, unique peanut physical properties can justify the use of these different shelling cylinders. Therefore, a standard of comparison can be used to shell peanuts of many varieties more economically in terms of power and equipment costs.

Several methods might be used to calculate energy input in peanut shelling. A pendulum method can be used to calculate energy required to shell peanuts. The impact energy, Ep, is the energy dissipated by a pendulum weight, W, suspended, g is the acceleration due to gravity and x is the vertical distance traveled by the weight as shown in Figure 17.

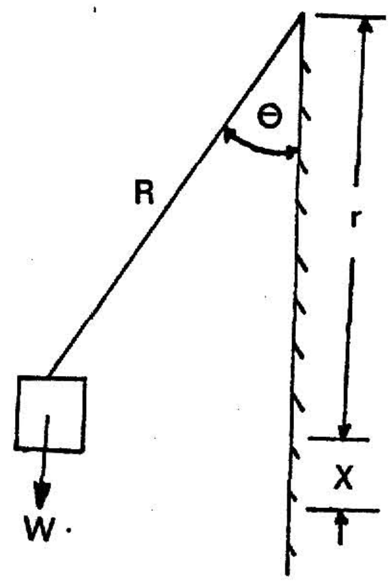


Figure 17. Pendulum method to determine the energy requirement to shell peanuts.

From the geometry of the pendulum, the resultant energy, Ep, is obtained from the following relationship:

$$Ep - WX = WR\ (1-\cos\theta) \qquad (3)$$

The pendulum method is limited to one or a few pods. The precision of the pendulum method will depend on the orientation of the impact surface and the path traced by the pendulum weight. The experimental performance of varieties using the pendulum can be compared by using equation (3).

A theoretical and experimental energy determination can be obtained directly from a shelling cylinder. In shelling a pod with shelling bars arranged on the periphery of a cylinder, the energy, Ep, must be supplied by the rotating cylinder. If Np is the rate pods are fed into the machine, the power, Pp, required to shell all the pods is given by

$$Pp = Ep\ Np = \frac{\text{in-lb}}{\text{peanut}}\ \frac{\text{peanuts}}{\text{sec.}} = \frac{\text{in-lb}}{\text{sec.}} = \frac{\text{m-Newton}}{\text{sec.}} \qquad (4)$$

The impact energy is supplied by the reduction in speed of the cylinder bars as they strike the peanuts. In Figure 18, the cylinder has inside and outside radii, r_1 and r_2, respectively, and the shelling bars, located on the periphery of the cylinder, have an effective radius, r_3. The kinetic energy, KE, of the cylinder - and-bar assemblage is given as

$$KE = \tfrac{1}{2}Iw^2 \qquad (5)$$

where:

I is the assemblage mass moment of inertia, in-lb $sec.^2$

w is the angular velocity, radians per sec.

Exclusive of losses, the power, Pp, required to shell the peanuts is the power necessary to maintain the kinetic energy of the assemblage. For a uniform cylinder with a uniform bar arrangement, I is given as

$$I = \tfrac{1}{2}m_c\ (r_2{}^2 - r_1{}^2) + \tfrac{1}{2}m_b\ (r_3)^3 \qquad (6)$$

where:

m_c and m_b are cylinder and bar masses, respectively.

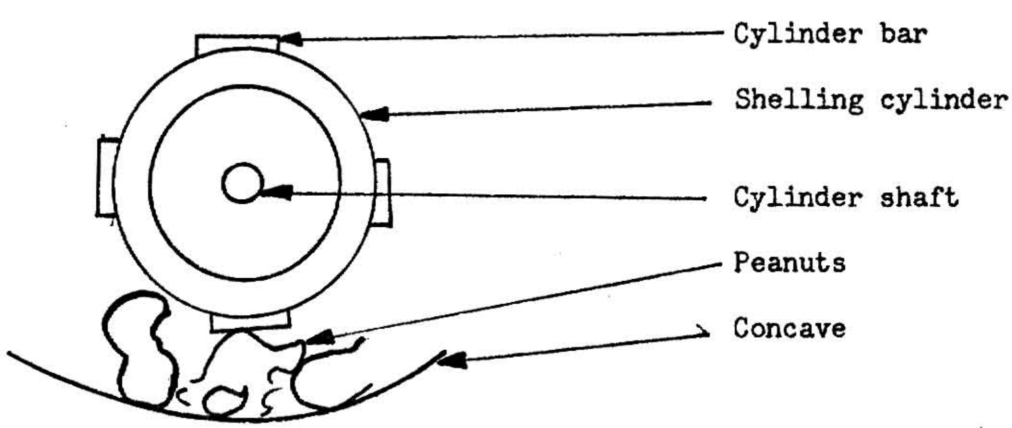


Fig. 18. Cylinder–concave mechanism in shelling peanuts.

By substituting (6) into (5)

$$KE = \frac{1}{2} \left[\bar{m}_c \left(r_2^2 - r_1^2\right) + m_b \left(r_3\right)^2 \right] w^2 \qquad (7)$$

When the feed-rate of peanuts is constant, the power requirement, Pp, will be constant too. The cylinder speed, cylinder weight, cylinder radii, and cylinder bar weights can be varied in seeking optimum shelling conditions.

Torque is applied to the cylinder shaft in order to maintain the kinetic energy of the system. This torque is easily determined by the use of strain gages mounted in the same manner as the experimental thresher unit. Power can be calculated easily by the use of the following equation:

$$P = \frac{TN}{9.55} \qquad (8)$$

where:

P is power, in-lb per sec.

T is torque, in-lb.

N is shaft speed, rpm.

Equation 8 is derived as follows:

$$P = T \text{ in-lb} \quad N \frac{\text{rev}}{\text{min}} \quad \frac{2 \quad \text{rad}}{\text{rev}} \quad \frac{1 \text{ min}}{60 \text{ sec}} = \frac{TN}{9.55}$$

If the efficiency in energy requirement of the shelling process is needed, the ratio of the energy required to shell peanuts, EpNp, over that of observed or calculated cylinder energy is given as

$$SE = \frac{EpNp}{\text{observed cylinder energy}} \qquad (9)$$

where:

SE is the shelling efficiency.

Cylinder Flywheel Effect

By increasing the cylinder moment of inertia, the peripheral speed can be reduced at constant power-input and at constant capacity. By increasing cylinder-bar mass and the cylinder diameter, a greater flywheel effect is introduced into the cylinder. This has an effect of temporary power storage to maintain a more uniform cylinder speed and damps out peak power requirements. For manual operation an additional flywheel might be installed.

Explanation of Figure 19.

Fig. 19. Cylinder-concave arrangement.

1. Cylinder drive-shaft
2. Cylinder end plate
3. Cylinder bar
4. Hopper
5. Top panel
6. Adjustment screw
7. Concave support plate
8. Feed-gate valve
9. Cylinder side hood
10. Concave groove
11. Hinge rod
12. Cylinder-concave clearance
13. Concave side strips

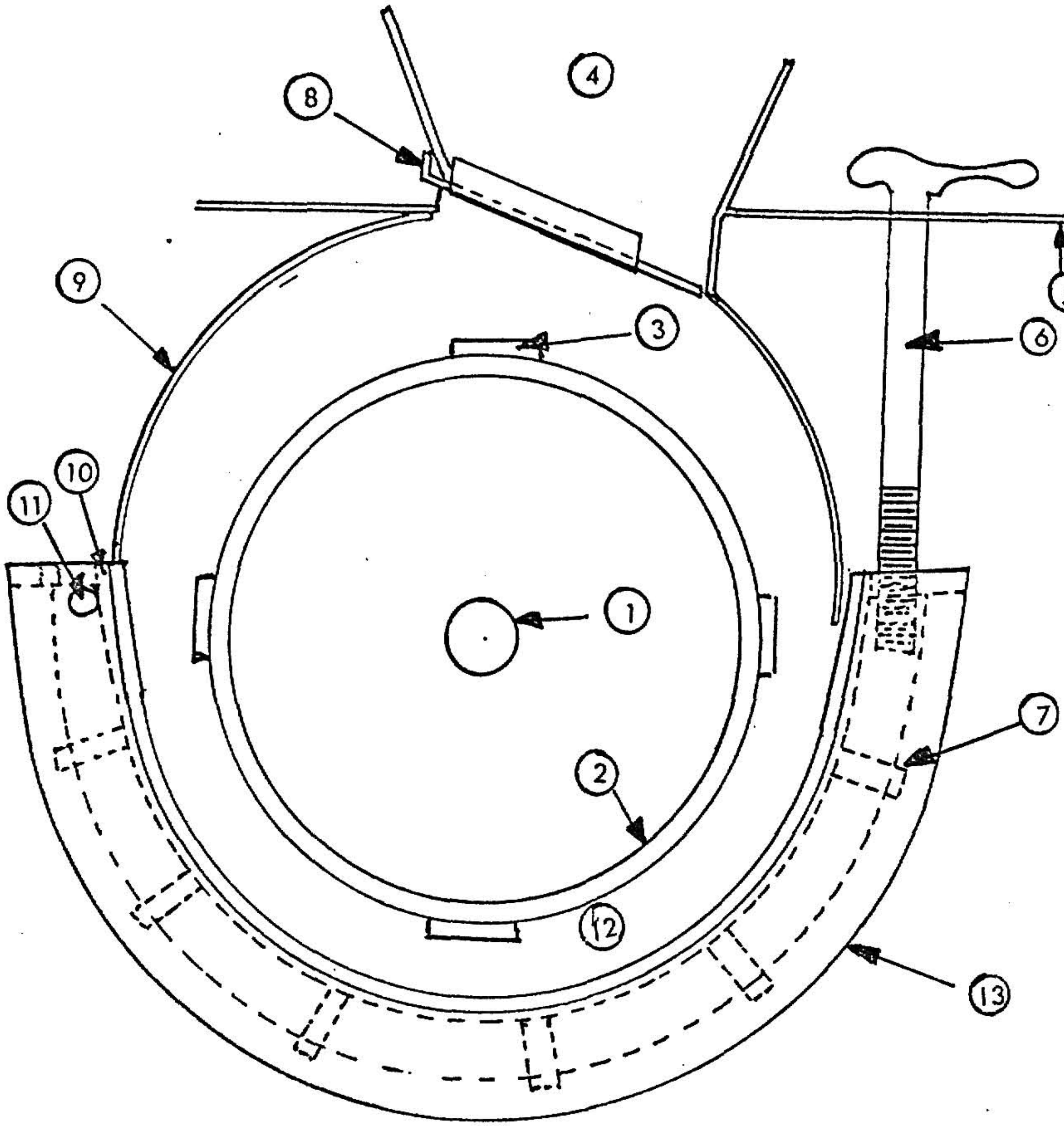


Fig. 19. Cylinder-concave arrangement. Design by Musa, 1974.

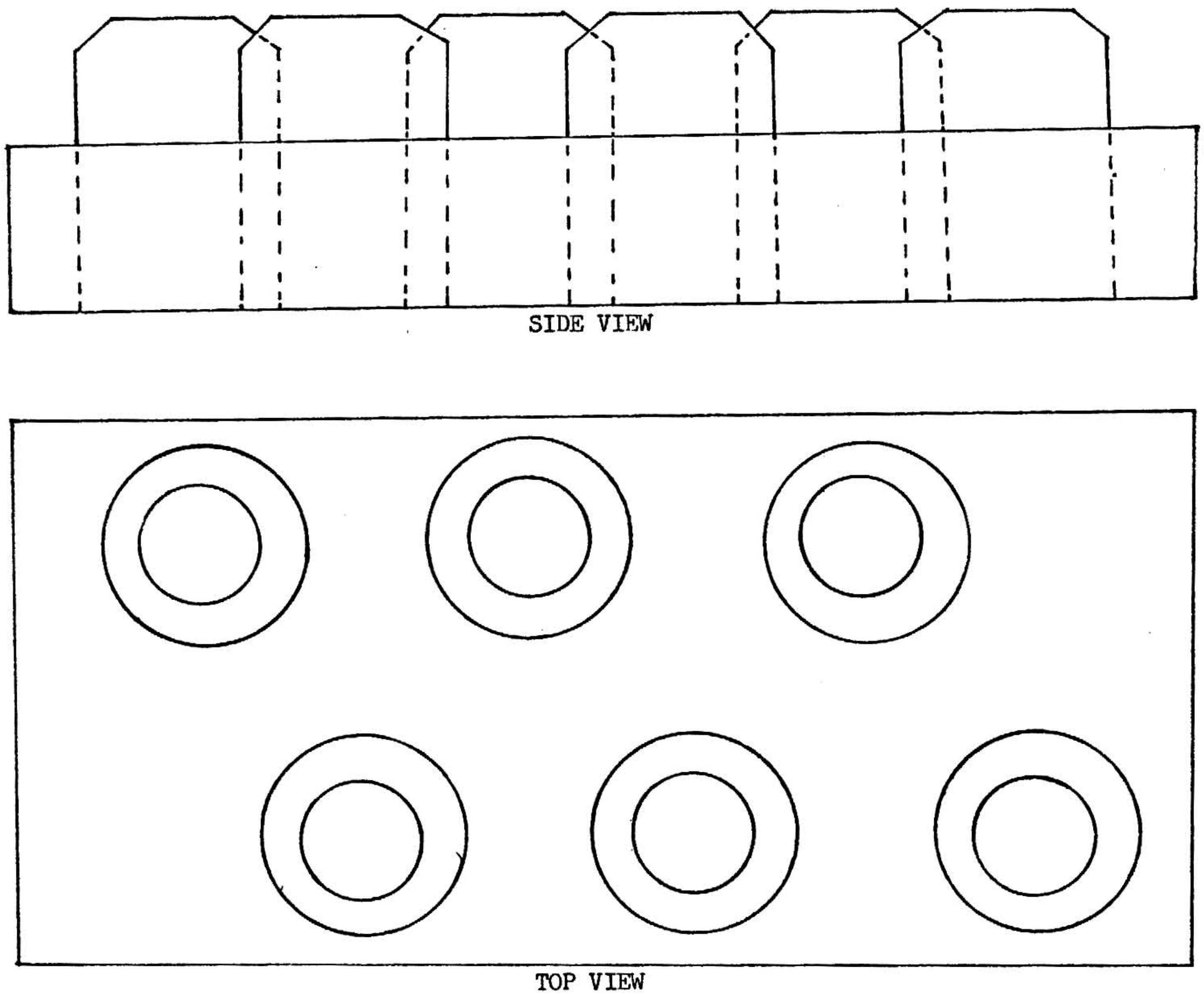


Fig. 20. Detailed design of a cylinder bar. Design by Musa, 1974.

The Concave Design

Supports for the concave are formed of semicircular strips of steel cut from a 1/8-in. stock. The sides contain grooves (Figure 21) into which the metal-sheet concave is slid and held in place by a pin.

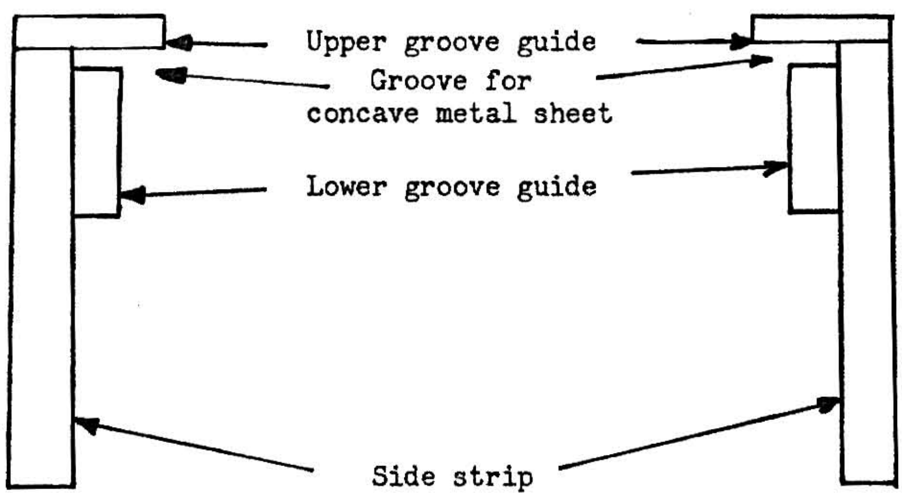


Fig. 21. A cross section from Figure 21 showing grooves for retaining the concave. Design by Musa, 1974.

The grooves are made by welding together strips of 1/8-in. and 1/4-in. steel to form the upper and the lower lips of the groove, respectively. The concave assembly is hinged at (7) in Figure 19, on a rod and held in position by the adjustable screw (3) of Figure 19, for cylinder-concave clearance adjustment.

Cylinder-Bar Design Characteristics

The shelling bar surface configuration used in the shelling experiment designed to be easily fabricated. Their shelling performance showed they have some potential. In this experiment an 18 percent minimum kernel crackage was obtained compared to 30 percent obtained at optimum shelling conditions by Braide (1974) who used casted tapered spiked shelling bars. By using wooden cylinders he obtained a 14 percent minimum kernel crackage. Reed and Coppock (1952) obtained 15.1 percent and Davidson (1962, 1971) obtained 8.0 percent from some commercial shellers at optimum shelling conditions.

The author foresees the future prospect of the present design when certain shelling factors affecting kernel crackage are taken into consideration. The peanuts used in the experiment had less than 5 percent moisture content and the shelling concave had short slotted holes ($1\frac{1}{2}$-in. long). Reed and Coppock (1952) found these to increase kernel damage when compared to the longer slotted concaves. See Figure 20 for detailed design. The bars are made from steel bars and iron rods (Figure 8).

Method of Feeding Peanuts into the Shelling Cylinder

The feed-gate opening is to be as wide as the cylinder width. The in-let opening is such that peanuts fall in the direction of cylinder rotation. The feed-rate is regulated by a feed-gate. This arrangement assures smooth and constant peanut flow into the cylinder. The hopper is large to serve as a temporary reservoir and the width of its lower section is equal to the cylinder width. The cylinder does not need an agitating device to assist flow into the cylinder.

Additional features such as a fan, vibrating screens and drive systems will be similar to the ones used by either Brown and Reed (1944) or those that are locally available.

SUMMARY

Power determination and kernel crackage are both very important. They act concurrently to determine the optimum shelling performance with respect to capacity. From the experiment, cylinder speed, cylinder-concave clearance and feed-rates were found to affect power-input. Kernel crackage was found to be affected by cylinder speed and cylinder-concave clearance. Other factors affecting shelling quality, capacity and power requirement are moisture content, number of shelling bars, cylinder design characteristics and concave slot sizes, but these were not studied in this experiment. Three factors; namely, cylinder speed, cylinder-concave clearance and feed-rate were studied. Three observations of each factor and three replications formed the main part of the experiment.

Torque was recorded for each test to provide a basis for power determination. Torque applied to the main cylinder shaft was measured by a torque transducer mounted on the cylinder-drive-shaft of an experimental threshing unit. The torque transducer consisted of a specially made cylinder shaft with strain gages mounted on a reduced section to measure the angular deflection of the cylinder shaft due to the torque applied. Cylinder speeds were 160, 220 and 310 rpm; cylinder-concave clearances were 1/2, 3/4 and 1-in. Feed-rates were established by 1, 2 and 3-in. feed-gate openings. Kernel crackage (splits, bald and broken seeds) ranged from 18 to 81 percent. Torque requirements ranged from 15 to 75 in-lb (0.0833 to 0.409 hp.). The power required to run the machine without load was 0.023 hp. at 160 rpm and 0.043 hp. at 300 rpm.

A design of a peanut sheller is proposed which is aimed at

improving existing shellers in Nigeria in terms of capacity, shelling quality and ease of operation. The basic design centers around the shelling bars, concave with a provision for changing perforated metal sheets to shell different peanut varieties, and easy cylinder-concave adjustment. The expected shelling rate is 500 lb per hr of shelled and cleaned seeds. The sheller can be powered manually.

SUGGESTIONS FOR FUTURE STUDIES

1. The shelling surface configuration will be studied more closely to determine the optimum size of stud dimension in relationship to power requirement, capacity and shelling quality. The number of shelling bars, the size and thickness of the shelling bars will also receive some attention.
2. The size and slot characteristics of the concave will be investigated concurrently with the cylinder characteristics on shelling performance.
3. The cylinder speed will be studied in small increments to obtain a more realistic curve profile for shelling quality.
4. Certain physical and biological properties of peanuts will be studied to establish a table of reference for most available peanut varieties and related mechanical shelling units.

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APPENDICES

Table Al. Florunner - US - Variety: Pod Size Measurement.

Serial No.	LP in.	Wmax in.	Wmin in.	Wc in.	Ds in.
1	0.76	0.375	0.345	0.375	0.314
2	1.105	0.50	0.429	0.437	0.340
3	1.084	0.51	0.472	0.375	0.330
4	1.209	0.530	0.500	0.470	0.415
5	1.132	0.532	0.513	0.500	0.399
6	1.141	0.540	0.430	0.437	0.430
7	1.272	0.546	0.466	0.437	0.451
8	1.100	0.540	0.455	0.470	0.443
9	1.180	0.552	0.433	0.437	0.405
10	1.103	0.534	0.478	0.437	0.407
11	1.150	0.585	0.517	0.531	0.452
12	1.150	0.543	0.532	0.470	0.330
13	1.091	0.515	0.385	0.375	0.337
14	1.147	0.543	0.505	0.375	0.457
15	0.707	0.443	0	0	0.347
16	0.861	0.543	0	0	0.411
17	0.954	0.503	0.445	0.375	0.405
18	0.964	0.455	0.435	0.407	0.264
19	0.962	0.442	0.386	0.357	0.320
20	0.980	0.372	0.368	0.281	0.259

LP - Pod Length; Wmax - maximum pod diameter; Wmin - minimum pod diameter; Wc - width at construction; Ds - seed diameter.

Table A2. 3513.72 Variety: Pod Size Measurement.

Serial No.	LP in.	WC in.	Wmax in.	Wmin in.
1	1.455	0.455	0.495	0.361
2	1.065	0.433	0.464	0.426
3	1.111	0.449	0.451	0.432
4	1.125	0.473	0.457	0.446
5	1.206	0.400	0.496	0.395
6	1.193	0.410	0.463	0.495
7	1.075	0.481	0.451	0.402
8	1.668	0.471	0.472	0.469
9	1.153	0.458	0.485	0.379
10	1.190	0.440	0.508	0.391
11	1.194	0.457	0.482	0.454
12	1.200	0.497	0.506	0.498
13	1.225	0.453	0.454	0.423
14	1.127	0.471	0.476	0.4444
15	1.094	0.415	0.494	0.346
16	1.117	0.444	0.480	0.433
17	1.098	0.423	0.479	0.282
18	1.095	0.483	0.543	0.449
19	1.040	0.473	0.524	0.401
20	1.055	0.445	0.496	0.322

LP - pod length; WC - width at constriction; Wmax - maximum pod diameter; Wmin - minimum pod diameter.

Table A3. 3566.72 Variety: Pod Size Measurement.

Serial No.	LP in.	WC in.	Wmax in.	Wmin in.
1	1.117	0.438	0.529	0.367
2	1.140	0.514	0.544	0.384
3	1.116	0.455	0.510	0.365
4	1.203	0.409	0.534	0.376
5	1.149	0.460	0.501	0.335
6	1.129	0.484	0.537	0.355
7	1.084	0.469	0.568	0.325
8	1.145	0.442	0.481	0.329
9	1.111	0.450	0.489	0.335
10	1.024	0.426	0.432	0.293
11	1.012	0.524	0.561	0.350
12	1.106	0.451	0.496	0.359
13	1.209	0.478	0.505	0.354
14	1.149	0.439	0.505	0.354
15	1.059	0.436	0.457	0.325
16	1.209	0.476	0.496	0.356
17	1.190	0.474	0.419	0.385
18	1.135	0.508	0.522	0.289
19	1.014	0.532	0.569	0.302
20	1.090	0.484	0.505	0.352

LP - pod length; WC - width at constriction; Wmax - maximum pod diameter; Wmin - minimum pod diameter.

Table A4. S-38 Variety: Pod Size Measurement.

Serial No.	LP in.	WC in.	Wmax in.	Wmin in.
1	1.395	0.448	0.500	0.384
2	1.090	0.467	0.469	0.387
3	1.112	0.431	0.505	0.359
4	1.150	0.437	0.480	0.375
5	1.123	0.435	0.465	0.370
6	1.188	0.469	0.490	0.420
7	1.063	0.455	0.500	0.354
8	1.116	0.487	0.512	0.362
9	1.144	0.439	0.455	0.365
10	1.117	0.416	0.483	0.357
11	1.255	0.441	0.527	0.399
12	1.124	0.429	0.510	0.350
13	1.050	0.445	0.459	0.390
14	1.246	0.455	0.544	0.397
15	1.164	0.460	0.472	0.357
16	1.014	0.460	0.514	0.341
17	1.128	0.423	0.545	0.315
18	1.121	0.436	0.486	0.363
19	1.098	0.428	0.488	0.365
20	1.165	0.435	0.519	0.387

LP - pod length; WC - width at constriction; Wmax - maximum pod diameter; Wmin - minimum pod diameter.

Table B. Static Calibration of Known Cylinder Torque-Input vs. Oscillograph Chart Deflection.

Weight gm	Torque in-lb	Deflection, Lines — Replications 1	2	3	4	5
100	5.3	2.3	5.0	9.0	4.5	6.5
200	10.6	5.0	10.0	13.1	8.2	18.0
300	15.9	30.0	39.0	38.0	40.0	23.0
400	21.2	32.0	46.0	44.0	46.0	32.2
500	26.4	35.6	48.0	47.0	49.0	48.4
600	31.7	40.0	50.0	52.0	53.0	54.0
700	37.0	51.6	62.0	54.8	60.0	65.0
800	42.3	59.6	66.0	68.0	67.0	70.0
900	47.6	68.0	70.0	73.0	73.0	76.0
1000	52.9	76.0	78.0	94.0	95.0	95.0
1100	58.2	92.0	92.5	100.0	100.5	102.5
1200	63.4	106.0	101.0	109.0	115.0	118.0
1300	68.7	114.5	115.0	115.0	120.0	122.5
1400	74.0	122.5	127.5	124.5	129.0	130.5
1500	79.3	130.0	135.0	135.0	137.5	135.0
1600	84.6	136.0	136.0	137.5	140.0	141.0

Table C. Comparison of Cylinder Speed, Cylinder–Concave Clearance and Feed-Rate Effects on Power Requirement and Shelling Quality.

Date	Variables	Reps.	Deflection Lines	Total Pod Weight gm	Unshelled Pods gm	Whole Kernels gm	Cracked Kernels gm	Trash gm	Bald Kernels gm
6/11/74	$K_1 i_1 x_1$	1	26.0	1115.5	104.0	461.5	517.0	10.0	23
		2	27.5	1066.7	100.6	449.1	482	3	32
		3	27.5	802.2	124	334	311	7.1	26.1
	$K_1 i_1 x_2$	1							
		2							
		3							
	$K_1 i_1 x_3$	1	easily plugged. - too little a clearance						
		2	for easy turning*						
		3							
	$K_1 i_2 x_1$	1	33	1165.5	265.5	576.5	255.4	18.1	50.0
		2	38	1187.8	258.8	609.9	259.9	12.0	47.2
		3	35	1221.9	260.5	630.2	262.7	26.5	42.0
6/12/74	$K_1 i_2 x_2$	1	29	1025.6	362	481	150	10	22.6
		2	37	1213.8	395.8	598.5	170	21	29
		3	38	1234.1	350.3	663	182.8	10	28

Table C, continued.

Date	Variables	Reps.	Deflection Lines	Total Pod Weight gm	Unshelled Pods gm	Whole Kernels gm	Cracked Kernels gm	Trash gm	Bald Kernels gm
	$K_1i_2x_3$	1	35	1193.5	227	645.5	271	20	30
		2	27	1193.1	345.7	634	176.0	15.5	22.9
		3	36	1219.7	231.6	708.6	239	13.5	27
6/15/74	$K_1i_3x_1$	1	38	1053	214	582.9	173.1	44	39
		2	35	1147.6	246	631.5	235.6	7.0	27.5
		3	32	1164.3	249	636	240	10.5	37.8
	$K_1i_3x_2$	1	40	1195.2	280.2	670	220.5	8	14.5
		2	38	1193.5	305	655	202.5	15	16
		3	39	1195	451.5	567	147.5	14	15
	$K_1i_3x_3$	1	42	1194.3	292	633	210	20.1	31.2
		2	43	1222.1	346	635.1	204	9.0	28
		3	41	1210.5	348	603	217.5	12	30
6/22/74	$K_2i_1x_1$	1	65	1111.2	84.2	314.6	680.4	9	23
		2	70	1077.5	83	350.1	614.8	5	24.6
		3	72.5	982.5	76	316	568.5	7	15

Table C, continued.

Date	Variables	Reps.	Deflection Lines	Total Pod Weight gm	Unshelled Pods gm	Whole Kernels gm	Cracked Kernels gm	Trash gm	Bald Kernels gm
	$K_2i_1x_2$	1	73.5	1095.2	75.2	336	648	14.0	22
		2	97.5	1124	28.0	358	700	8.5	19.5
		3	98.5	1162.8	95	389.6	642	14	22.2
	$K_2i_1x_3$	1	95.0	1103.4	78	335.2	657	16	17.2
		2	95.0	986.1	50	369.2	532.4	17.5	17.0
		3	97.5	1053.4	86.1	356.3	589.5	6.0	15.6
	$K_2i_2x_1$	1	62.5	1132.5	270	540	297	8	17.5
		2	65.0	1147.1	245.2	572.8	289.8	20.0	19.3
		3	62.5	1215.5	256	565	365	11.5	15
	$K_2i_2x_2$	1	76.5	1165.1	220.4	568.0	340.2	22.2	14.3
		2	77.5	1141.4	203.6	597	326.6	55	9.0
		3	77.5	1744.2	277.6	639	282.6	17.8	34.2
	$K_2i_2x_3$	1	75	1184.3	350.1	467.0	278	49.0	40.2
		2	80	1120.9	204.5	541.2	334	13.2	28.0
		3	80.5	1199.7	179.1	581	346	47.8	45.8

Table C, continued.

Date	Variables	Reps.	Deflection Lines	Total Pod Weight gm	Unshelled Pods gm	Whole Kernels gm	Cracked Kernels gm	Trash gm	Bald Kernels gm
6/21/74	$K_2i_3x_1$	1	42.5	1048	532.2	533.8	138.5	27	15.5
		2	65.0	1263.5	455.5	551	223	15	19
		3	66	1186.8	407	521.9	237.5	4.8	15.6
	$K_2i_3x_2$	1	67.5	1222.8	493.8	497.8	196.2	18.5	16.7
		2	71.0	213.7	470.6	510	217.8	5.1	10.2
		3	77.5	1194	347	568	240	7	32
6/21/74	$K_2i_3x_3$	1	70.5	1225.1	278.3	634	281.7	5.1	26
		2	80	1171.8	316.1	600	216.0	5.9	33.8
		3	89.5	1194.6	305.4	594.8	248.6	4.4	41.4
6/22/74	$K_3i_1x_1$	1	117.8	1134.5	36.5	158	890	15	35
		2	132	1083.5	37.5	168	851	12	15
		3	105	1063.1	34.5	148	860	4	16.6
	$K_3i_1x_2$	1							
		2							
		3	Impossible to run - was plugged.*						

Table C, continued.

Date	Variables	Reps.	Deflection Lines	Total Pod Weight gm	Unshelled Pods gm	Whole Kernels gm	Cracked Kernels gm	Trash gm	Bald Kernels gm
	$K_3i_1x_3$	1							
		2							
		3							
6/28/74	$K_3i_2x_1$	1	105	1063.6	299	253.6	488	13	10
		2	97.5	1161.5	101	268	770	10	12.5
		3	105	1096.5	77	180	810	15.5	14
	$K_3i_2x_2$	1	105	1164.7	88.8	333	684.4	32.5	26
		2	100	1066	88	297	650	11	20
		3	110	1143.7	69	319.5	690	28	37.2
6/28/74	$K_3i_2x_3$	1	120	1108.8	89.5	318	676	3	22.3
		2	110	1137	78	320.6	685.5	20.7	32.2
		3	115	1094.6	64	347.5	633.1	15	35
6/29/74	$K_3i_3x_1$	1	110	1079.5	320	285	442	16.5	16
		2	105	1153.1	270	296.1	558	13	16
		3	125	1070.4	246	569.5	425	5	15

Table C, continued.

Date	Variables	Reps.	Deflection Lines	Total Pod Weight gm	Unshelled Pods gm	Whole Kernels gm	Cracked Kernels gm	Trash gm	Bald Kernels gm
	$K_3i_3x_2$	1	110.0	1183.9	236	384.7	540	9	14.2
		2	90	1161.9	178.0	441.5	524	4.7	15.7
		3	97.5	1184.8	216.3	428	516.5	4	20
	$K_3i_3x_3$	1	95	1160	174	467	498	7	14
		2	90	1149.5	215.5	399	490	20	27
		3	97.5	1199.3	205.5	445.8	508.5	11	28.5
6/29/74	Uniform pods ($K_2i_2x_2$)	1	61.02	1097.2	54.0	614	413.2	-	16.0
		2	59.28	1115.2	29.1	639.1	421	-	26.0
		3	59.63	1040.4	22.0	612.	396.8	-	9.6
6/29/74	Clean pods ($K_2i_2x_2$)	1	64.5	1029.1	113.1	578.	337	-	11.0
		2	56.68	1163.9	102.1	685	359.5	-	17.5
		3	57.54	180.1	119.5	640.2	393.	-	27.4
			Trial with a conventional combine rasp bars						
	$K_2x_2i_2$	1							
		2	Easily plugged*						
		3							

Table C, continued.

Date	Variables	Reps.	Deflection Lines	Total Pod Weight gm	Unshelled Pods gm	Whole Kernels gm	Cracked Kernels gm	Trash gm	Bald Kernels gm
	$K_2i_2x_2$	1	62.14	1166	121.9	581.3	483.8	4.0	45.0
		2	64.44	1174.2	129	486.2	479.	20.0	60.0
		3	59.38	1072.3	150.2	411.5	478	14.6	18

*At the second and third feed rate, a cylinder speed of 160 and 300 rpm, the cylinder plugged and a clearance of ½ inch. The same situation occurred with combine rasp bars at a cylinder speed of 200 rpm and 3/4-inch clearance which was to be compared to the $K2i_2x_2$ setting. When the feed gate was set 1½-inches wide, the sheller functioned smoothly.

PEANUT SHELLER DESIGN PARAMETERS

by

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The main purpose of the investigation was to study the power requirements to shell peanuts in order to have a basis for designing a sheller that would use a rotary cylinder. Power requirements for shelling were determined by using a torque transducer mounted on the cylinder-drive shaft of an experimental threshing unit (Zaidi, 1974). The torque transducer consists of a specially made shaft with strain gages mounted on it to measure the twisting of the cylinder-shaft due to the torque applied. Three variables; namely, cylinder speed, cylinder-concave clearance and feed-rate each at three levels and replicated three times, formed the main part of the experiment. A comparison of the effects of clean and uniform pods on shelling quality was also made.

Some basic modifications were made on the threshing unit to simulate shelling parameters. The rasp bars were replaced by shelling bars, the grain concave was replaced with a peanut concave. The beater was removed and side hoods and a specially made hopper were installed to ensure recirculation of shelling material. Power was supplied by a 1-hp electric motor and transmitted to the cylinder-shaft through a speed-reduction unit which permitted the cylinder speed to be varied. Peanuts were sized in order to determine a suitable concave-slot size. Grain-cylinder rasp bars were also tried to compare their shelling performance with those of the peanut-cylinder bars. The torque transducer was calibrated to give an accurate torque-input read out.

The results from the experiment showed that an optimum shelling performance was obtained at 160 rpm cylinder speed, 1-in. cylinder-concave clearance, torque input was 23.74 in-lb (0.0603 hp) and the capacity was determined to be 317.76 lb per hr. The power required to run the machine without load was 0.023 hp at 160 rpm. The range of power input in the whole experiment was from 0.0833 to 0.409 hp.

The results showed that uniform pods required minimum power, allowed a maximum shelling efficiency and caused least kernel crackage. Clean pod-samples gave a better shelling performance than dirty pod-samples but not as good as the uniform pod-samples. Peanut shelling bars gave a better shelling performance than the grain-cylinder rasp bars. Rasp bars caused a high rate of kernel crackage and the cylinder was easily plugged at higher speeds and feed-rates.

Theoretically if all other factors are held constant, the length of the cylinder can be increased with a corresponding increase in capacity and power. Since the power requirement at the optimum shelling performance is below a rated human-power level (0.10 hp), the cylinder length can be increased to obtain a higher capacity or to use external sources of power for mechanized peanut shelling.

The proposed design features include exchangeable concaves by providing guides for the concave to slide in and out easily. The cylinder-concave adjustment facility is provided on the concave design mechanism. Heavier bars on the cylinder or heavier cylinder end-plates are to be used in order to provide a flywheel effect. The flywheel effect is necessary for manual operation in smoothing out torque peaks due to irregular surges and to maintain constant speed.