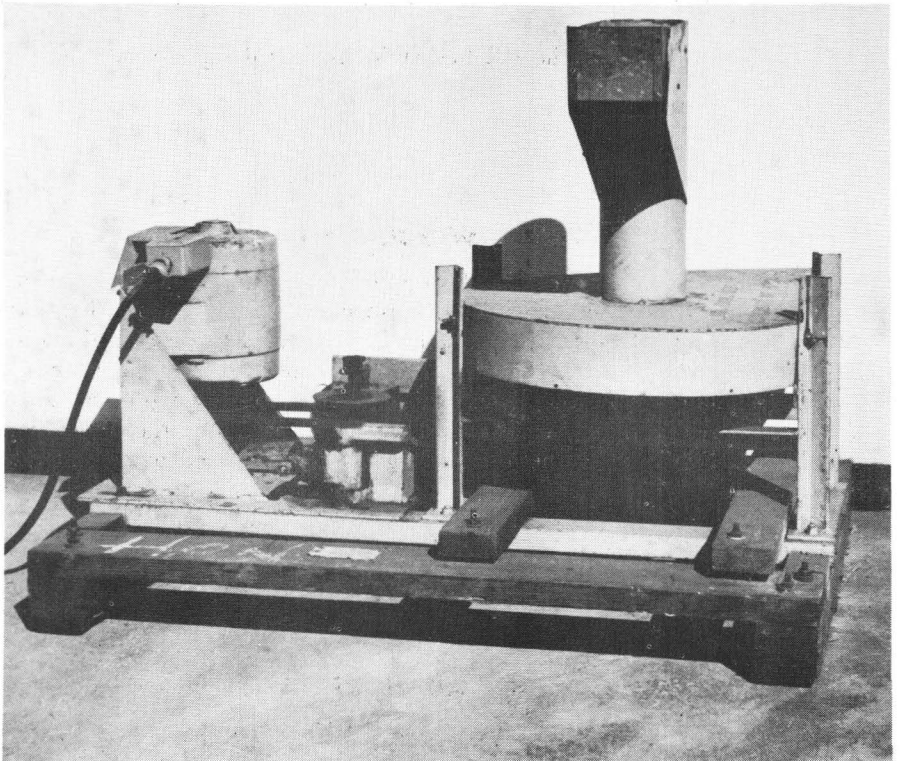


Equipment for Husking MACADAMIA NUTS

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COVER PHOTO: The P-2 husker in its final design form.

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EQUIPMENT FOR HUSKING MACADAMIA NUTS

D. M. Kinch, J. K. Wang, and R. E. Strohman

INTRODUCTION

One of the major problems of the growers of macadamia nuts has been the removal of the husks from the nuts (2). The green nut, that is, the nut fresh from the tree, has its husk tightly attached to it. When this green nut is allowed to dry, or as the farmers refer to it, "to cure," the husk changes from green to brown and quite often tends to loosen around the nut. However, the degree of loosening is variable and is to some extent influenced by the variety of the nut.

There are two basic mechanical principles that can be utilized in removing the husk from the nut. One method is to impart an impact to the husk of the nut so that the husk will fracture and piece by piece break away from the nut itself (4). Another method is to subject the husk to a frictional force by rubbing against a rough surface (3, 5, 6). By its very nature the friction method is less severe in its action. Huskers of this type using steel brushes have been tried by local industry. The performance of this machine was satisfactory but because the husk is rather strong and becomes quite tough when partially dried, the brushes are soon worn out and the cost of frequent replacement becomes uneconomic.

In the past, a popular method of husking nuts was to run the nuts between a low-pressure pneumatic automobile tire and a wooden chute (1). The rubbing action worked on certain varieties of nuts when the moisture content of the husks was high. However, on some varieties the green husks were tough. To husk these varieties greater force had to be applied to the tire, thus drastically increasing its wear. Rapid wear is characteristic of the friction-type huskers whether they use wire brushes or the surface of a rubber tire as the friction element. Also, the husking efficiency of the tire huskers was low.

Because of these facts, methods of removing the husk by impact were investigated by this department. The amount and the manner in which impact should be imparted to the husk were determined by experiment.

Based upon these results, two huskers serving two different sets of basic requirements were built. The design and operation of these two huskers are described in this bulletin.

After the introduction of the impact-type huskers a few years ago, another version of the rubber tire husker was built by a local machine shop. The main difference between the new and the old versions was that beads were welded across a metal chute in the new version. This made it in essence an impact-type husker.

DESIGN REQUIREMENTS

Size of Husker

It was found that because of the size of farms and the different operating conditions and economic considerations, the design requirements for an ideal husker were multi-valued. From the small farmer's point of view, the most important criteria of a husker was that it must be inexpensive. Furthermore, it should give a reasonably satisfactory performance with different varieties of nuts without necessary adjustments. The rate of husking was of secondary importance. On the other hand, for the manager of a large macadamia nut orchard the husking rate would be of great importance. Also his varietal strains would be few and he would have operators with more skill for adjusting the machine to the variety, the moisture content, etc.

The larger grower could well afford a more costly machine provided that this additional cost would give him large capacity in terms of pounds of clean nuts husked per hour, a high husking efficiency (measured as ratio of number of husked nuts per unit of time divided by total number of unhusked nuts fed to the machine), and trouble-free operation.

Principle of Design

It was determined that the best way of imparting an impact to the husk was in the form of a sharp blow tangential to the surface of the shell (see fig. 1). This would chip away the husk a piece at a time until it broke loose from the shell and at the same time would produce a minimum damage to the shell itself. If the blow is struck too high on the nut or if it is too severe, the nut will be cracked. If the blade is too low or not traveling fast enough when it strikes the nut, the husk will not be penetrated nor removed. In many cases the combination of blade height and velocity of impact required to remove the husks will crack the shell if the nuts are allowed to remain in the machine after they are husked.

The basic requirements for a successful nut husker of this type are that it must have some sort of holder or guide through which the nuts can pass in a continuous stream and which exposes the nuts to husking blades or teeth which are traveling at a high enough velocity to cut through the husks, and which strike the nuts at such an angle that the husks are removed without cracking the shells.

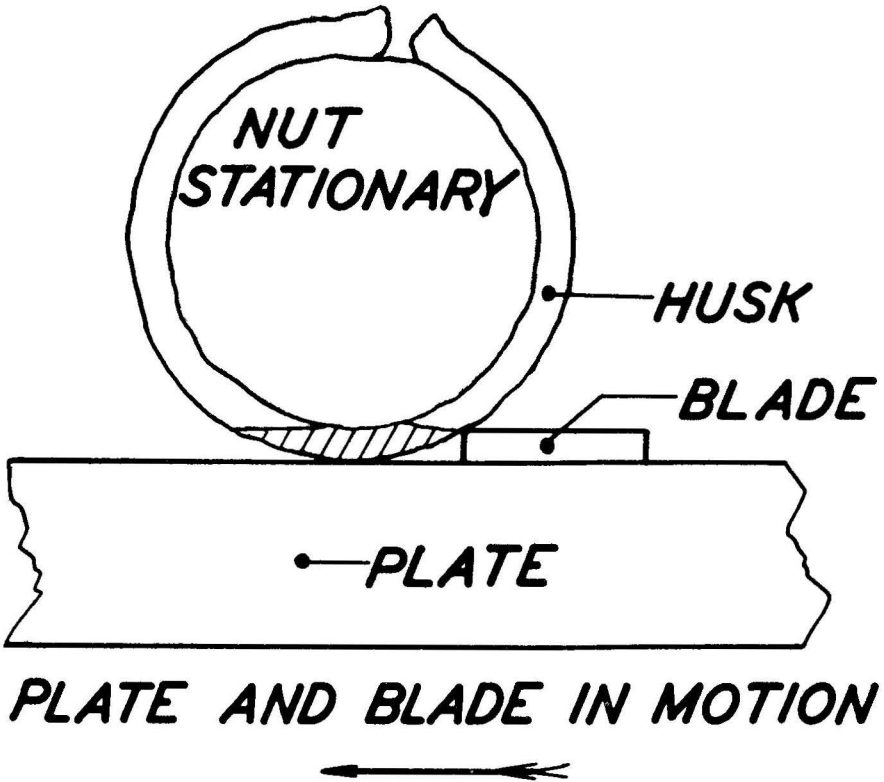


Fig. 1. Cross-sectional part of husk will be removed by impact of blade. If blade height is too high, it will also take a chip out of the shell, or possibly crack it.

PLATE HUSKER

First Design (P-1 Husker)

A high-capacity husker was first designed in an effort to meet the requirements of the larger grower. This husker became known as the plate husker. In its first design it took the form of a circular plate 18 inches in diameter and $\frac{1}{2}$ inch thick. This plate had cutting teeth machined into its surface. The plate was mounted on a vertical shaft so as to rotate in a horizontal plane. The nuts were guided over the surface of the plate in single file by means of a spiral so designed that the nuts entered the spiral at the center and left it at the outside. The direction of the spiral was in the direction of rotation of the plate so that as the blades struck the nuts they were pushed in the proper direction.

A series of rubber flaps located around the spiral retarded the nuts so that the teeth on the plate could knock the husks off (see fig. 2). Several versions of this model of husker were built, all with the same husking plate

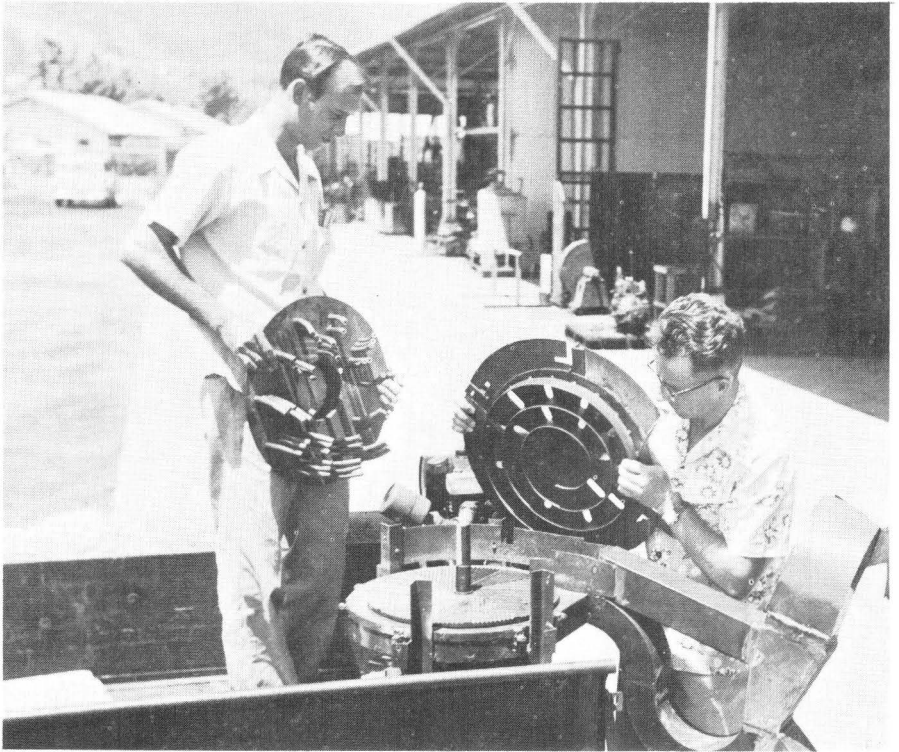


Fig. 2. The P-1 husker had milled teeth on the plate and rubber retarding flaps projecting down into the spiral nut guide.

but with different spirals and variations in the nut retarder flaps. Most of the difficulties which caused the changes to be made were caused by wet nuts with rotten husks clogging the spirals. It was found that when the spiral path was made 2 inches wide and when the retarders were made of three pieces of rubber hose inserted through holes in the spiral cover and mounted on a second plate in such a way that both depth and angle of the projection flaps were adjustable, there was not as much clogging as when solid flaps were used. If a particular batch of nuts gave trouble, the retarders were raised, or the angle changed. In extreme cases part of the retarding flaps could be removed. Of course, using these means to reduce clogging would also lower the husking efficiency.

While this version of the plate husker could be made to function satisfactorily under most conditions by a skilled operator, there were some objections to it on the part of the growers. These objections could be grouped under the following headings: First cost, maintenance expense, and operational difficulties.

One of the main reasons for the high cost of construction of the machine was the machining of the teeth on the plate. Another large-cost item was the adjustable retarder holder and the retarder flaps. Under the heading of maintenance cost came the need for frequent replacement of the rubber hose used for the retarder flaps and the difficulty of sharpening the teeth that were machined in the plate. As the result of repeated trials in the laboratory and on the farms of cooperating growers, it was found that to obtain best results the speed of the plate, the clearance between plate and spiral, the depth of the projecting flaps, and the angle of these flaps all have to be correctly adjusted. Since most of these adjustments were affected by changes in the others, this required a degree of mechanical skill on the part of the operator beyond what could normally be expected to be found among those who were likely to be using this machine.

Second Design (P-2 Husker)

As a result of this initial experience with the husker, experimental work was resumed in attempting to overcome these objections. On a new plate 28 bars, each 3/16-inch square, were welded radially on its surface to determine the correct blade thickness. These blades were cut down by small increments until the optimum thickness was reached. This thickness turned out to be 0.065 inch. When the blade height was greater than this, any speed great enough to remove 98 percent of the husks resulted in excessive cracking of the shell. At this thickness a speed could be found which resulted in at least 98 percent of the nuts being husked while less than 2 percent would be cracked. With blades thinner than the optimum, the highest practical speed would leave from 5 to 10 percent unhusked even though there were practically no nuts cracked.

Since this optimum thickness was very nearly that of 14-gage sheet steel, it was decided that for a low-cost plate with ease of tooth replacement, the blades would be cut from flat sheets and riveted to the plate.

The next problem was whether these teeth or blades should be hardened or not. Three groups of blades were made up. One group was made from plain hot-rolled stock, one group from annealed saw steel, and a third group from the same saw steel but which was hardened and tempered. All blades were of the same size and thickness—7 inches long, 1/4 inch wide inside, and 3/4 inch wide outside. A new plate was machined and drilled to receive the rivets. Twenty-eight blades randomly selected from the three groups were riveted on one side of the plate and 14 blades also randomly selected were riveted on the other side.

The blade spacing was then tested by running one-half of a batch of nuts through the machine and then reversing the plate and running the other half through. For all varieties tested when the machine was operating at the correct speed for the individual variety, a higher percentage of nuts were husked and a lower percentage cracked when using 14 blades than when using 28 blades.

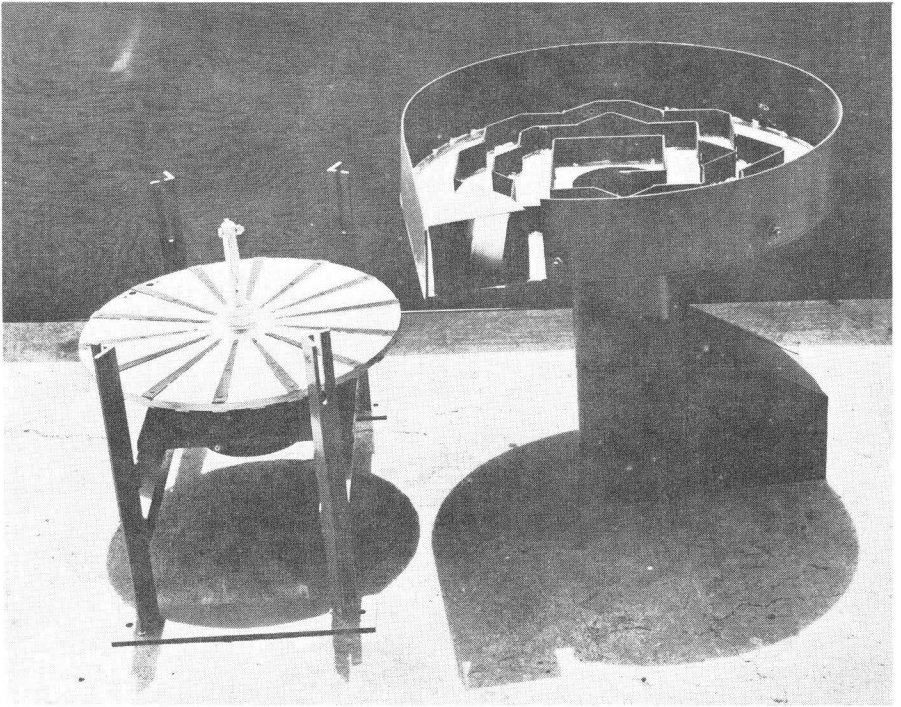


Fig. 3. On the right is the retarding spiral used on the P-2 husker. On the left is the husking plate with 14 blades riveted to it.

After the machine had been used for one year under factory conditions at Honokaa, no wear could be seen on any of the blades made of saw steel, whether they were hardened or not. This would indicate that the extra expense of hardening the blades could not be justified. Some of the blades made from plain hot-rolled steel showed sign of wear and some of those were broken by rocks which were accidentally mixed in with the nuts. Thus it could now be recommended that saw steel as purchased be used for blades wherever it is available.

To eliminate frequent clogging, the spiral was redesigned to act as a periodic retarder without the need for separate flexible retarder flaps. Several spiral shapes were tried. The one with the best over-all performance characteristics was in the shape of a "double square" or "cookie cutter" spiral (see fig. 3). This is in effect one "square" spiral superimposed on another so that the effect is somewhat like an expanding eight-point star. This spiral gave very good results although it did not quite match the smooth spiral with retarders in husking speed. But there were no retarders to adjust or wear out and there was no clogging.

TABLE 1. Recommended rpm of plate husker for green mature nuts

VARIETY	RECOMMENDED RPM	UNHUSKED %*	CRACKED %*
246	950	0	0.4
333	1150	0.7	0.2
336	850	0.4	4.5
425	825	2.9	2.0
475	850	1.2	0
508	1100	0.9	0.5

*Percent by weight.

During the winter of 1955-1956, this machine with its new spiral and riveted blades was tested in cooperation with the Horticulture Department of the Hawaii Agricultural Experiment Station, using macadamia nuts which were grafted varieties from Poamoho Experimental Farm. The varieties were harvested and husked separately and this permitted a good check on the performance of the machine on nuts which were reasonably homogenous. It was found that the optimum rotational speed of the plate varied not only with the physical condition of the nuts, that is, their moisture content and length of time after harvest, but also with the varieties.

The optimum speed in revolutions per minute and the percent of nuts left unhusked and the percent cracked at this speed are shown in table 1. These results show that the speed was quite critical. Changing the speed as much as 25 rpm on some varieties would result in a large increase in nuts cracked or nuts unhusked. Table 2 gives test results on two of these varieties. Thus it can be seen that if certain varieties are mixed and husked together, either the percent cracked or the percent unhusked, or both, will be higher than when they are kept separate and the machine adjusted accordingly.

TABLE 2. Relationship between rpm of plate husker and percentage of nuts cracked

VARIETY	PLATE RPM	CRACKED %
336	850	4.5
336	875	5.8
336	900	15.71
508	1050	0.45
508	1100	0.5
508	1150	1.9

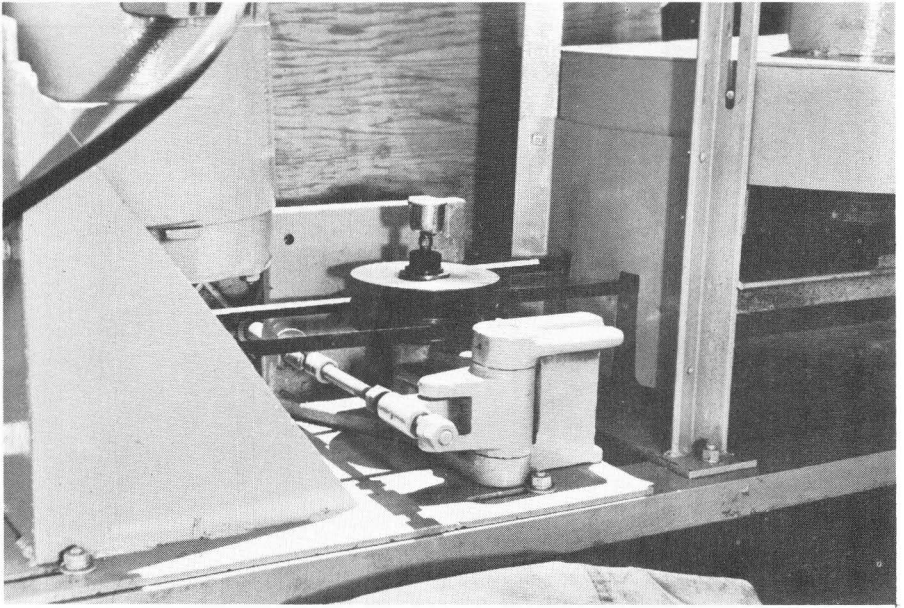


Fig. 4. The variable-speed drive for the plate husker is adjusted by the hand wheel at the rear. The double pulley countershaft causes the plate to increase in speed when moved to the right.

Since the speed of the machine is quite critical for optimum husking efficiency, it is necessary to use some form of variable-speed drive which can be set for any desired speed. It was found that commercial variable-speed drives in the proper horsepower and speed range for this application were too expensive to be practical. Commercial variable-speed drives have the further disadvantage that in order to get a wide range of speed they must use a dove-tail construction of the pulleys. This causes rapid belt wear. A low-cost and comparatively simple drive was designed and built to give the needed speed range on this machine (see fig. 4). This design also eliminates the dove-tail feature which causes rapid belt wear. The principle of operation, however, is the same.

This variable-speed drive is essentially a counter shaft between the motor and the husker. Mounted on a shaft are two pulleys that revolve at the same rpm. One of these is the driven pulley which receives power from the motor, the other is the driving pulley which transmits the power to the husker. When these pulleys are the same size, the velocity of the two belts will be equal and the drive has no effect on the ratio of motor speed to husker speed. When a driven pulley is larger than the driving pulley, then

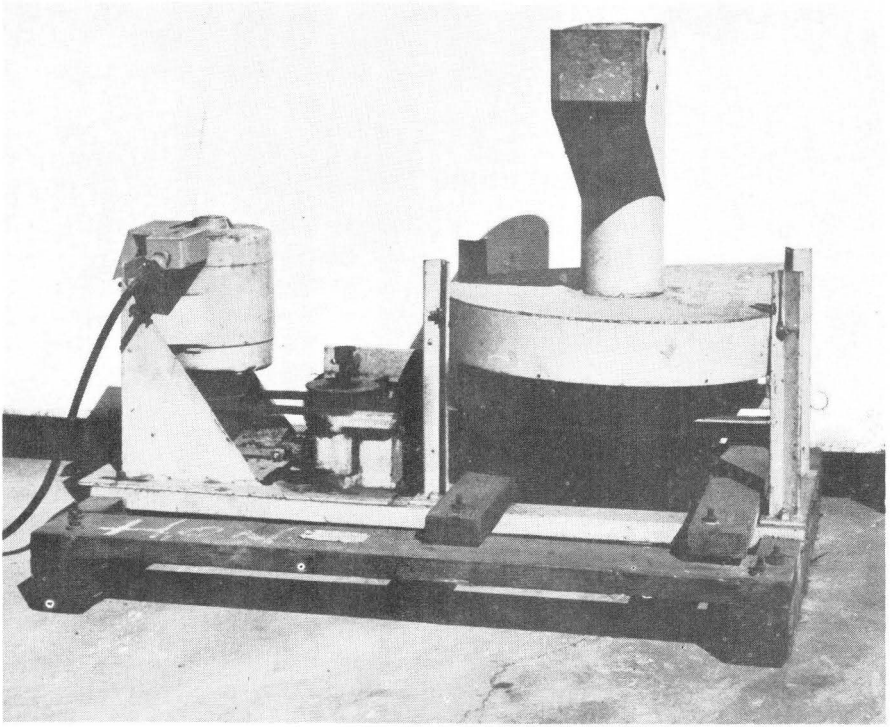


Fig. 5. The P-2 husker in its final design form. This husker uses saw-steel blades riveted to a 16-inch diameter plate. The plate rpm is adjustable.

the velocity of the belt to the husker is less than that of the belt from the motor, and the husker slows down. Conversely, if the driven pulley is smaller than the driving pulley, then the velocity of the belt to the husker is greater than that of the belt from the motor and the husker speeds up.

If the belt tension is to remain equal, then any change in the pitch diameter of the pulleys must be accompanied by a corresponding change in center distance. In this drive the position of the counter shaft is adjustable so that as one center distance is reduced, the other is increased by the same amount. The two inner sheave faces are free to slide on the hub of the counter shaft so that when tension on one belt is increased that on the other is decreased. The center section slides in the direction of the lesser tension until the tension is equalized. This action changes the pitch diameter of the two pulleys and gives the required change in the speed of the husker. This speed change is effected by a hand wheel through a threaded nut which positions the counter shaft.

Time trials run in conjunction with these tests indicated a capacity of 1400 pounds of clean nuts per hour when using a 1 HP motor to drive this husker. Figure 5 shows the P-2 plate husker in the final design form.

CYLINDER HUSKER

The design requirements of the plate husker were based upon the needs of the larger grower for a high-capacity machine. However a sizeable percentage of the macadamia nut production in the Islands is produced on small acreages by those who tend a few trees or a small grove as a cash crop. A husking machine suited to their needs should be as inexpensive as possible and have a small power requirement that could be supplied by a 115 volt single-phase line. Previous work with plate huskers had shown that the basic requirement for a successful nut husker was some form of holder or guide which causes the nuts to pass in a continuous stream and which exposes the nuts to the husking blades or teeth which must have a high enough velocity to remove the husks by chipping them away.

One of the design features of the plate husker which added considerably to its cost arose from a need for a complicated guide for the nuts. In order to reduce the size and weight of the machine as well as dispense with the complicated guide, it was decided to place the husking blades on the surface of a cylinder and utilize a simple straight guide that would keep the nuts on the cylinder as they moved by gravity down the guide. For the cylinder, a 4-inch extra strong pipe ($4\frac{1}{2}$ -inch O.D.) 24 inches long was used. After trying several types of husking teeth on the cylinder, it was found that $3/16$ -inch square steel bars welded on the cylinder parallel to the axis would do the job. Tests indicated that six bars gave the best spacing. If four bars were placed on a $4\frac{1}{2}$ -inch-diameter cylinder, the nuts did not have time to return to the surface of the cylinder after having been struck by one bar before the next bar arrived, and thus full bites were not taken by the husker bar, causing the capacity to be sharply reduced. Since the geometry of the action on a cylinder husker was considerably different from that on a plate husker, a new series of tests were made to determine the correct height of these bars above the surface of the cylinder. By starting with $3/16$ -inch-high bars and periodically turning them down by given increments on a lathe, it was found that a height of 0.070 inch seems to work best.

In the first design of the cylinder husker the nut guide was made of flat bars set radially around a 2-inch circle with the bottom sector missing. It was thought that the edges of the bar would have some husking action on the nuts as they spun on the guide. However it was found that the bars kept breaking and they were not adding to the husking action, so the guide was changed to a slotted 2-inch pipe which worked much better (see fig. 6).

In order for the nuts to be husked they must stay on the cylinder for a certain length of time but if they are kept on the cylinder too long, not

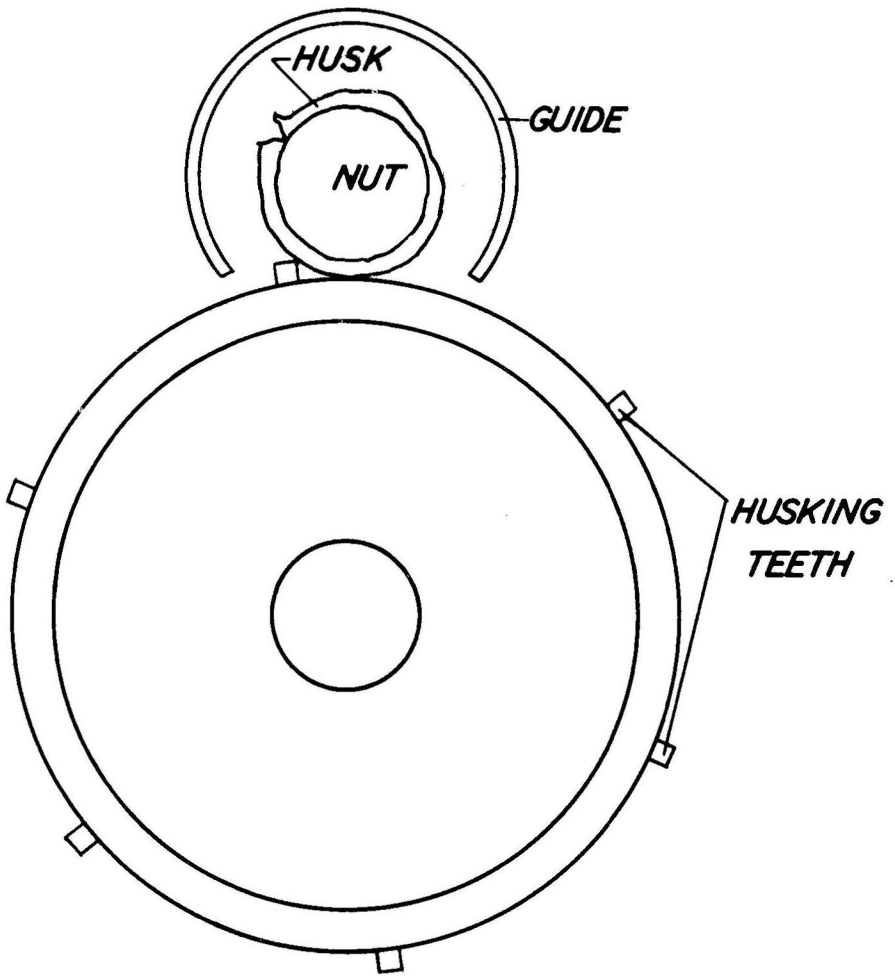


Fig. 6. In the cylinder husker, the husking teeth always act at right angles to the direction of travel of the nuts down the guide.

only is the capacity to the machine reduced, but also there would be a higher percentage of the nuts cracked. The length of time that the nuts stayed on the cylinder was adjusted by the angle of the incline of the cylinder and guide. Accordingly, the machine was built with an adjustable angle. By trying various angles it was found that about 15 degrees was best for dry nuts and 10 degrees for green nuts.

In order to change the speed of the cylinder the motor was used in conjunction with a variable-speed pulley so that changes could be made quickly and easily and any desired speed could be maintained.

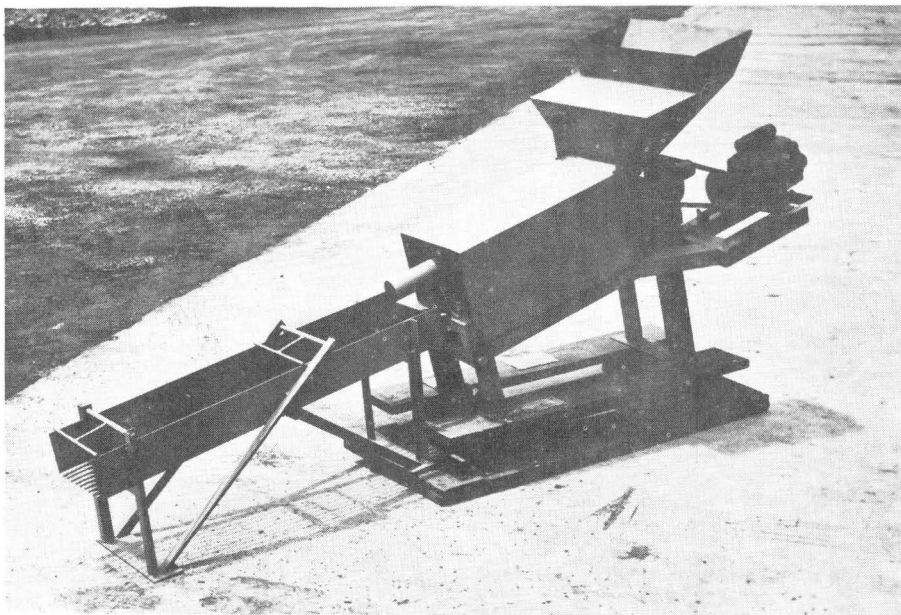


Fig. 7. The cylinder husker is a simple low-cost machine designed for the small grower with only a few trees in production for a cash crop.

A difficulty in the design of the machine was the problem of getting the nuts from the hopper and started down the nut guide. Several forms of mechanical feeding or vibrating hoppers were tried but within the cost limits imposed on this machine, they were not economically feasible. The simple method finally used was to place some spiral welds around the portion of the cylinder which extends under the hopper. These beads have a tendency to push the nuts into the guide. There is a tendency with this system for the nuts to bridge over the hopper outlet when the hopper is filled too full. This bridge can be easily broken by shaking the hopper or poking it with a stick. The system works well and adds very little to the initial cost of the husker. It is essential that the portion of the hopper over the spiral beads be covered to prevent the nuts from being thrown out when the hopper is nearly empty. This husker is shown in fig. 7.

The results of a number of tests indicate that this cylinder husker has a husking capacity of about 140 pounds of clean nuts per hour.

SORTING TABLE

A necessary adjunct of a husking machine is the sorting mechanism. Some means of separating the husk and unhusked nuts after they have passed through the husker must be provided. For the larger plate husker

there are commercially available sorting mechanisms used in other nut crops so that no research was done on this phase of the problem. For the cylinder husker the concept of low initial cost excluded such power-driven sorting devices. Therefore research was undertaken on the design of a simple sorting table that would aid the hand sorting and which could keep up with the capacity of the small machine. It was so designed that any piece of husk or any nut smaller than the smallest commercially acceptable nut would fall through the table and only the full-sized nuts and the larger pieces of husk remain on top. The person doing the sorting then discards the large pieces of husk and takes out any unhusked nuts to be returned to the hopper of the machine. When a batch of nuts has been sorted and inspected it is desirable if the operator can place them quickly and easily in a container and move the next batch into position on the table with a minimum amount of time and effort. After testing several ideas and designs, it was found that the above conditions could be met by making the bottom of the table out of $\frac{1}{4}$ -inch steel rod placed $\frac{7}{8}$ inch between centers. This gave a space of $\frac{5}{8}$ inch between adjacent rods. Any husked nuts smaller than $\frac{5}{8}$ inch in diameter were considered to have no commercial value. Two quick-acting gates divided the table into three sections. The nuts coming from the husker collected in the first section while the nuts in the second section were being hand sorted. The third section was a spillway leading to a container for the clean nuts. It was found that when the bottom was given a slope of 5 degrees with the horizontal, then the nuts rolled from one section to the other when a gate was raised (see fig. 8).

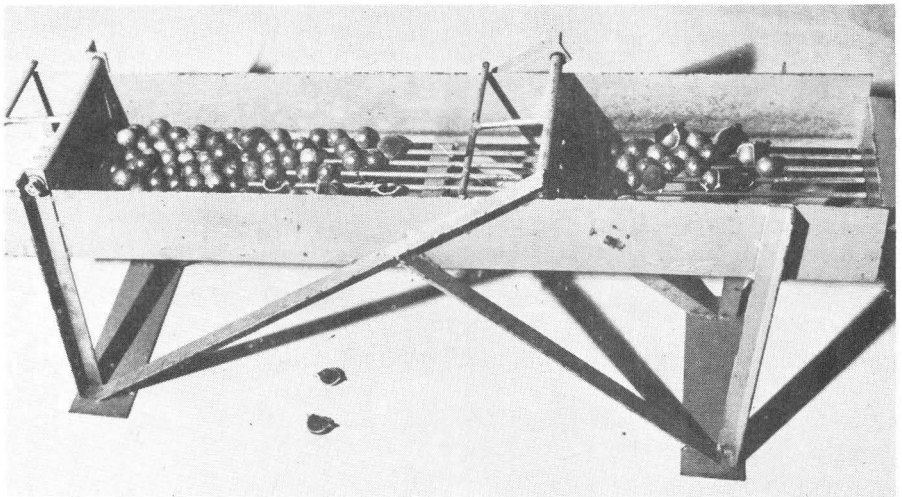


Fig. 8. A simple sorting table. The husker would be placed at the right and the clean nut container below the left end of the table. Most husks fall through. Inspection and final sorting are then done on the center section.

DISCUSSION

The plate husker and the cylinder husker as well as the newer version of the rubber tire husker all operated on the same basic mechanical principle; that is, an impact is given the husk tangential to the nut shell. This force either loosens and knocks off the entire husk or will at least loosen and knock off a small portion of it. In order for this impact to be great enough to remove husks and still not so great as to damage the shell or kernel inside the shell, correct operating procedures are required for the machine of whichever type it may be.

Mechanical damage usually inflicted by impact takes two forms. One is cracking of the shell. The relationship between cracking and impact received by the nut in terms of husker rpm has been found to be quite critical. The other mechanical damage which is of prime importance to the commercial value of nuts is the breakage of the kernels. When nuts are green the moisture content of the kernels is high and the kernels are tightly fitted inside the shell. Nut shells therefore act as an impact absorber to protect the kernels. When nuts have been freshly dried, kernels will shrink and there will be space between the kernel and shell. Impact will therefore be transferred to the kernel, possibly causing breakage. It is therefore recommended that nuts be husked as soon as possible after they have dropped from the tree.

Table 3 gives a summary of tests on kernel breakage. Different husking methods were compared on the basis of nut kernel breakage by impact inflicted upon nuts by different husking processes.

TABLE 3. Percentage by weight of various-sized broken pieces vs. different husking methods

HUSKING METHOD	HALF KERNEL OR LARGER	QUARTER KERNEL TO HALF KERNEL	LESS THAN QUARTER KERNEL
Hand	100	Trace	Trace
Plate	100	"	"
Tire	100	"	"
Cylinder	93	5.4	1.6

After the nuts were husked, samples of each batch were carefully sawed through the shells to remove the kernels so that a true picture of the internal damage to the kernel could be obtained. The table shows no significant differences between the husking methods as far as kernel breakage is concerned. There is an apparent increase, however, in the kernel breakage by the cylinder husker which could very well have been caused by an operating speed slightly too high.

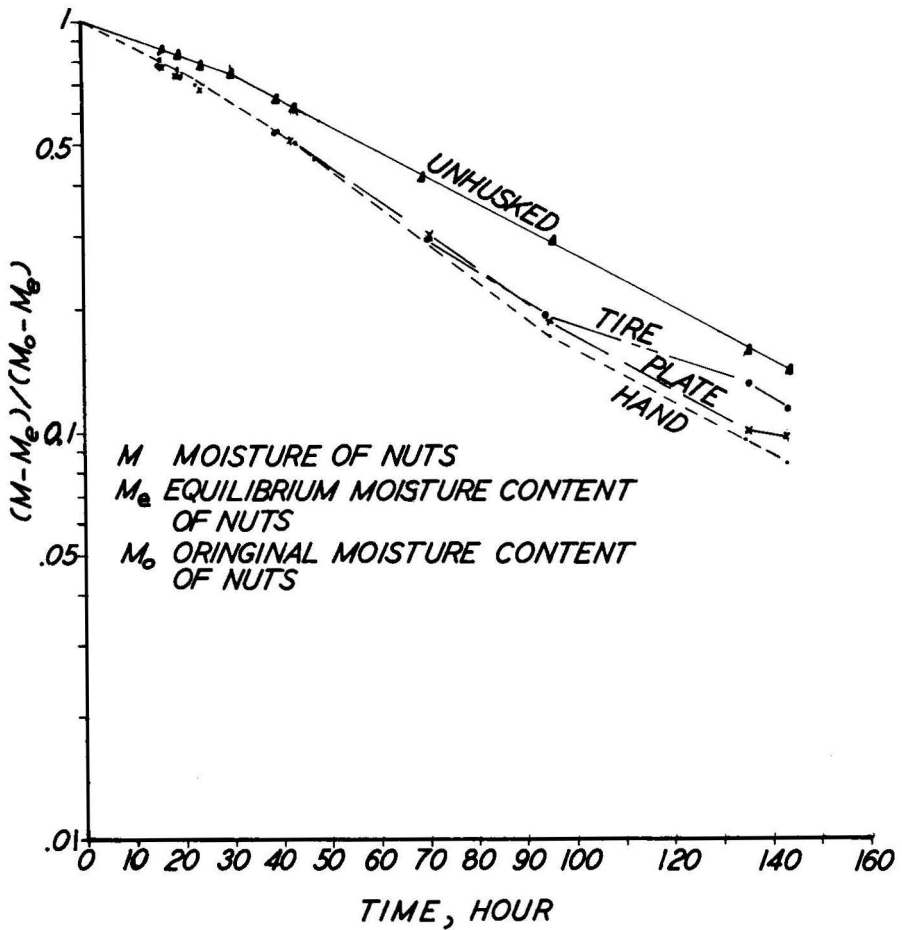


Fig. 9. Husking methods vs. drying rate. Tests showed that the husking methods have no detectable effect upon the drying characteristics of the nuts.

In addition to mechanical damage to the kernels due to husking, other quality variations, for instance rancidity, must also be considered. A sample of green nuts was divided into four parts. One part was hand husked; another part husked by the plate husker; the third part by the cylinder husker; and the fourth part was husked by a rubber tire husker. Samples from these four treatments were stored for 2 months and then given a taste test for rancidity. Because of the lack of standards in tasting and judgment of rancidity among both industries and researchers, only relative indication was sought. The result of the test indicated that nuts husked by different methods suffered about the same amount of spoilage. An analysis of variance performed upon the data showed that there was no reason to believe that random variations did not account for these slight differences.

Another problem related to husking is the drying of the nuts after husking and previous to the cracking operation. This is a research problem in itself and generally not related to the husking method. However the effect of type of husker upon drying rate was investigated and fig. 9 shows that the husking methods have no detectable effect upon the drying characteristics of the nuts.

THE FUTURE

Looking forward, it is obvious that the degree of mechanization in present-day macadamia nut farming practice needs to be greatly increased. To date there are two major on-the-farm operations, namely, harvesting and husking. From an engineering point of view, these two operations should and could be combined into one.

It was with this ultimate goal in mind that the decision was made to design a type of husker that could be later incorporated into the "nut combine." The inherited inability of the tire-type husker to give a high husking efficiency together with a high husking rate without jamming therefore disfavored itself in the eyes of the investigators. The plate husker with its high capacity and relatively small size could be easily integrated into the mechanism of a nut combine. Experimental data are lacking but general indication seems to be that nuts should be processed as soon as possible after husking. The authors feel that unnecessary storage or "curing" after husking should be eliminated and, if necessary, drying by a forced air dryer should be investigated so that this unavoidable operation could be made continuous or at least automatic.

SUMMARY

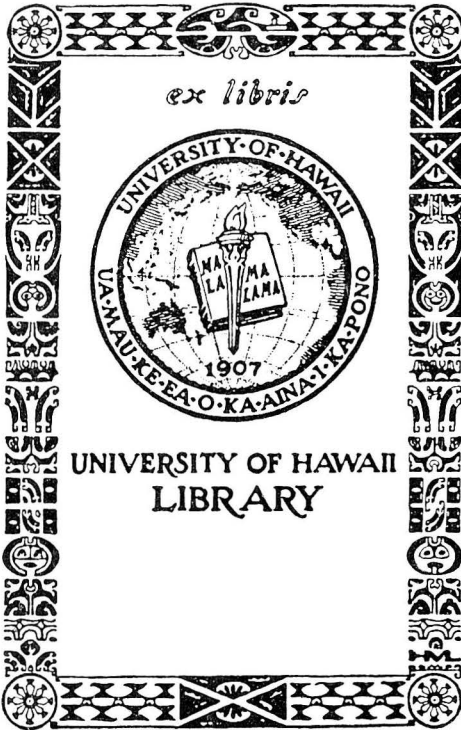
1. A high-capacity plate-type husker specially suited to the needs of the commercial grower has been designed and tested.
2. A smaller, simpler, and lower-cost cylinder-type husker has been designed and tested. It is slanted towards the needs of the small farmer.
3. The rubber tire husker used by farmers in certain sections was discussed and its performance compared in several aspects.
4. The husking efficiency of the three types of huskers was compared. The plate husker and tire husker can both husk 98 percent of nuts while at the same time cracking less than 1 percent of the nuts. For the same husking efficiency the cylinder husker will crack about 6 percent of the nuts husked.
5. The plate husker leads the three in husking rate of 1400 pounds per hour of clean nuts, which is about three times as high as the tire husker. Husking rate of the cylinder husker is about 140 pounds per hour. The plate husker is dependable and does not need continuous attention while

in operation. Frequent bridging of nuts over its feed hopper demands the constant attention of the operator of the cylinder husker. Frequent jamming of nuts between its metal chute and the rubber wheel makes supervision of the rubber tire husker necessary at all times.

6. The rpm of the plate husker is critical in its operation and must be carefully adjusted when the variety or condition of the nuts is changed. Its performance is very sensitive to nut variety, and when variety of nuts to be husked has been altered, several trial runs are needed to determine the appropriate rpm. The recommended rpm in table 1 are to be used as a guide only. Minor variations are needed to suit circumstances for best results. The performance of both plate and tire husker is affected by the speed. Excessive speed of either one causes excessive cracking. However the effects of speed are less critical for the tire husker than in the case of the plate husker.
7. Comparative tests of the three main husker types show them to be equivalent as far as keeping quality of the nuts after husking is concerned and as far as the rate of drying of the nuts after husking is concerned.
8. The actual cost of construction of the huskers will vary considerably, depending on local machine shop labor charges. In Honolulu, the cylinder husker could be built for about \$200.00 less motor, and the plate husker for around \$600.00 less the 1-HP motor.
9. Detailed construction drawings for both the P-2 plate husker and the cylinder husker can be obtained from the Agricultural Engineering Department, University of Hawaii, Honolulu 14, Hawaii. A nominal charge for printing and mailing will be made: \$1.00 for the cylinder husker and \$2.00 for the plate husker plans.

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