# Effects of the Operating Parameters of the Rubber Roller Sheller

Mofazzal H. Chowdhury, Wesley F. Buchele
MEMBER
ASAE

SINCE the introduction of field shelling of corn by combines, many farmers have changed from ear corn harvesting to the harvesting of high moisture shelled corn. When the field shelling system for corn was first developed and introduced, kernel damage was relatively low because the ears were harvested and shelled at low moisture contents. But the introduction of grain driers has made harvesting of high moisture shelled corn feasible.

In the early 1900's, corn harvesting was a hand operation with minimal machine assistance. Even with the whole family husking corn, the job lasted into the winter. Since the introduction of field shelling of corn by combines, corn harvesting has become easier, earlier, and faster than ever before, and it is now a one man operation.

Unfortunately, field shelling of corn has created a number of problems, one of them being kernel damage. The kernel damage caused by the harvesting machine is called mechanical damage. Current estimates indicate that the mechanical damage of combined corn ranges between 16.4 to 19.4 percent in typical field harvesting systems (Ayres et al. 1972).

Mechanical damage affects short and long-term corn storage. Saul and Steele (1966) reported that high moisture field shelled corn could not be stored more than a few hours without deterioration in quality. They also reported that faster drying rates were required for damaged corn to prevent spoilage between harvesting and drying. Mechanically damaged corn has a lower market value (Eistner, ref. 5), and a lower export appeal. Bailey (1968) estimates that American farmers lose up to four cents per bushel on corn they sell because broken kernels alone reduces grade. Mechanical damage also decreases seed corn viability. Gomez and Andrews (1971) reported that root growth rate and germinations were drastically reduced because of the injured corn seeds. Research has been done both to improve the conventional shelling mechanism and to develop new shelling mechanisms in an attempt to reduce this mechanical damage.

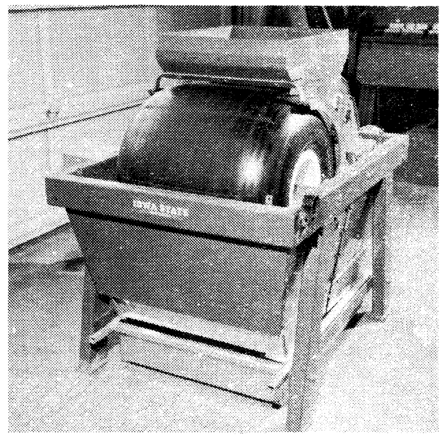

FIG. 1 The pneumatic primary roller.

In the conventional combine, the corn kernel is subjected to mechanical damage while passing through the shelling crescent (between the steel cylinder and the steel concave). Pickard (1955), USDA engineers (ref. 11), Fox (1969), and Brass (1970) studied the use of a relatively soft material, like rubber, instead of steel for the rasp bar and for the cylinder. Although their attempts were not fully successful, some of them show promise.

## OBJECTIVES

Rubber roller shellers built by Fox (1969) and Brass (1970) appeared to reduce mechanical damage. Although they presented data, additional information concerning the performance under a wide range of conditions was needed to establish base points for development work and to establish design parameters. The objective of this research was to determine the effect of operating parameters of the rubber roller sheller on kernel damage, shelling efficiency, and feed rate at a wide range of moisture contents of corn harvested directly from the field in a replicated experiment.

## EQUIPMENT AND PROCEDURE

A rubber roller sheller was developed as a laboratory test model by Brass (1970). This sheller was utilized for evaluation of the shelling principle and the effect of the shelling process on kernel damage. The basic functional components of this rubber roller sheller are the pneumatic primary roller (a terra tire, Fig. 1), the pneumatic orientation roller (Fig. 2), and the uni-directional bar concave.

Power for the shelling unit was transmitted from an agricultural tractor (Oliver 77) through a power takeoff shaft. This arrangement controls the primary roller rpm directly by positioning the throttle of the tractor. A double V-belt drive with a spring-tensioned idler was used to power the orientation roller. The spring-tensioned idler allowed for adjustment of the orientation roller position without retightening the belts.

The primary and orientation rollers rotate counterclockwise, allowing for motion in the opposite sense at their nearest point. The orientation roller

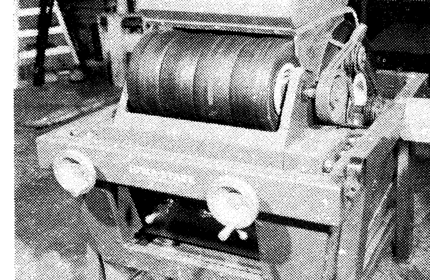

FIG. 2 The pneumatic orientation roller.

Article was submitted for publication in April 1974; reviewed and approved for publication by the Power and Machinery Division of ASAE in November 1974.

Journal Paper No. J-7564 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 1673.

The authors are: MOFAZZAL H. CHOWDHURY, Graduate Assistant, and WESLEY F. BUCHELE, Professor, Agricultural Engineering Dept., Iowa State University, Ames.

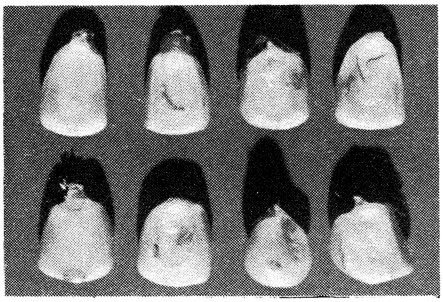

FIG. 3 Minor damage.

positions the ears of corn and feeds them from the hopper into the shelling crescent when they are parallel to the axis of the two rollers. The two rollers are adjusted so that one or both are deformed when an ear of corn passes between them. The rolling action of the ear of corn between the two cylinders subjects it to several cycles of compressive loading before its entrance into the concave area.

After passing the orientation roller, the ears roll between the concave and the primary roller. The inflation pressure of the pneumatic primary roller and the clearance between the concave and the rubber roller determines the magnitude of the load applied to the kernels of the ear. Shelling is induced in the concave area by the combination of rolling action and repeated compressive loading imparted to the rows of kernels as the ear passes over the uni-directional bar concave. The open area between the concave rods and the end of the concave allows discharge of the grain after it has been detached from the cob. The cob continues to roll toward the rear of the concave and drops into a collection pan.

The sheller was operated at four cylinder speeds (175, 250, 350, and 450 rpm) and at four levels of roller inflation pressure (6, 10, 14, and 18 psi). Three replications of each treatment resulted in forty-eight samples at each moisture level. The total number of samples for the five levels of moisture content (18, 20, 22, 24, and 29) resulted in two hundred and forty samples.

The ears of corn in the lots were weighed and dropped into the feed hopper. Immediately after every run, all the unshelled kernels were removed from the cob and weighed. The weight of the shelled kernels from each sample was obtained by subtracting the weight of the cobs and unshelled kernels from the total weight of the ears. The weight of the shelled kernels was used in conjunction with the weight of the unshelled kernels to determine the shelling efficiency of each run. Shelling efficiency is defined as the ratio of the weight of the shelled kernels to the weight of both the shelled and unshelled kernels. The shelled kernels were then mixed thoroughly, and two 200-gram samples were obtained by using a Boerner divider for moisture content determination and damage evaluation.

The moisture content was determined on wet basis, which is defined as the ratio of the pounds of water per unit to the toal weight of the unit (Hunt 1968). For moisture determination, one 200-g sample was dried in an oven at 200 F for 72 hr. The other sub-sample of 200 g was dried to 15 percent moisture content at slightly above room temperature for damage evaluation at a later stage.

## DAMAGE ANALYSIS

There is no standard method for describing the quality of grain from the standpoint of physical or mechanical damage. Hence, an attempt was made to develop a numerical damage index for quantitative, as well as qualitative, evaluation of kernel damage. By using a Boerner grain divider, a 100-g sub-sample was divided from the dried sample, which had been previously collected while running the rubber roller sheller, for damage evaluation. The 100-g sample was then passed through a 12/64-in. round hole sieve, and the material passed through the sieve was then weighed on a Mettler scale. The rest of the kernels from the 100-g sample were soaked in a Fast Green FCF dye (0.1 percent) for 4 min and were placed on a strainer. Excess dye was washed away with running tap water. Dyed samples were than spread on paper mats to dry for 24 hr before they were visually assessed for damage. For damage assessment, the kernels were inspected under a magnifying glass. A kernel was considered damaged if it was broken, cracked, chipped, had bruised pericarp, or any hairline crack on the pericarp. the Fast Green FCF dye stained these damaged parts and eased the inspection task.

A numerical damage index was developed in which the damaged kernels were divided into five categories according to the severity of damage and an approximate multiplying factor was decided for the different categories. The categories are:

$D_1$ = Broken kernels and the fine material that passed through 12/64-in. round hold sieve.

$D_2$ = Severe damage — broken, chipped, and crushed kernels (more than 1/3 of the whole kernel missing) (Fig. 5)

$D_3$ = Major damage — open cracks, chipped, and severe pericarp damage (Fig. 4)

$D_4$ = Minor damage — hairline cracks and spots of pericarp missing (Fig. 3)

$D_5$ = Whole kernels — did not absorb dye on any part except root tip

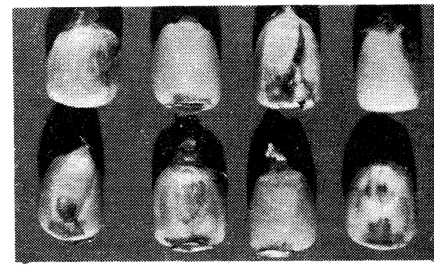

FIG. 4 Major damage.

Each kernel was checked separately by visual inspection under a magnifying glass and was placed in one of the five categories. The damaged kernels in each category were weighed, and the percentage of damage in each category was calculated on weight basis as follows:

$$d = \frac{w}{W} \times 100$$

where d = percentage of total damage

w = weight of the damaged fraction, gram

W = sample weight, gram

The multiplying factors for the different categories are (Chowdhury and Buchele 1974):

$D_1$ (Broken kernels & fine material) = 10

$D_2$ (Severe damage) = 10

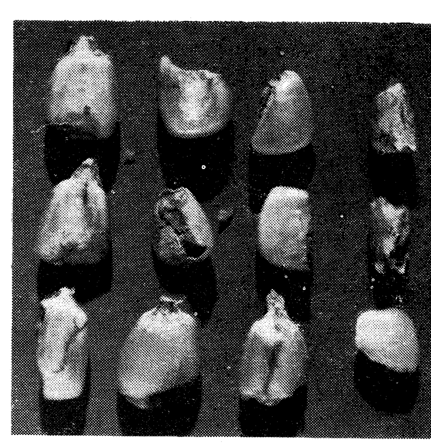

FIG. 5 Severe damage.

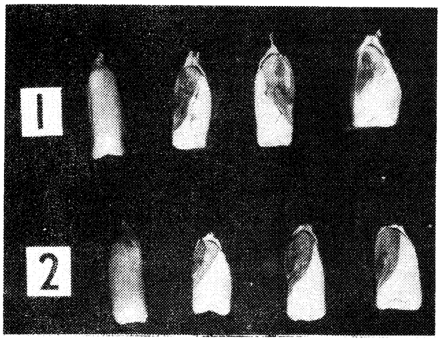

**FIG. 6 Sectioned externally sound kernels: 1. From rubber roller sheller - with crack; 2. From combine cylinder - crack free.**

$D_3$ (Major damage) = 6
$D_4$ (Minor damage) = 2
$D_5$ (Sound kernels) = 1

The damage index is then calculated by making a visual inspection of a 100-g sample and dividing the sample into five groups. The percentage weight of the different damage categories is then used to evaluate the damage index. The damage index is calculated as:

$$\text{Damage Index, D.I.} = \frac{(d_1 + d_2)(10) + (d_3)(6) + d_4(2) + d_5}{10}$$

where $d_1$ = percentage weight of $D_1$ class
$d_2$ = percentage weight of $D_2$ class
$d_3$ = percentage weight of $d_3$ class
$d_4$ = percentage weight of $d_4$ class
$d_5$ = percentage weight of $d_5$ class

and D.I. = 10, when the whole lot of damaged sample consists of sound kernels (i.e., $d_1 = 0$, $d_2 = 0$, $d_3 = 0$, $d_4 = 0$, and $d_5 = 100\%$)
D.I. = 100, when the whole lot of the damaged sample consists of broken corn, fine material, chipped, and crushed kernels. (i.e., $d_1 + d_2 = 100\%$, $d_3 = 0$, $d_4 = 0$, and $d_5 = 0$)

## STUDY OF INTERNAL GRAIN DAMAGE

The viability of corn kernels shelled by the combine rasp bar cylinder and the rubber roller sheller was determined by dividing the shelled corn into five different classes of kernels:

(a) Sound kernels
(b) Minor damaged kernels
(c) Major damaged kernels
(d) Severely damaged kernels
(e) Broken kernels (discarded)

The viability was determined by conducting a standard germination test in four replications on 50 kernels from each group. The results are shown in Table 1. The sound kernels from the rubber roller sheller had only 64.5 percent germination, even less than the minor damaged kernels, which had 76 percent germination. It was expected that the hand shelled sound kernels would have around 90 to 95 percent germination.

To compare this confusing result, germination tests were conducted on seeds from the same field of the same variety shelled by the rasp bar cylinder of a conventional combine. The germination of corn harvested by conventional combine was 92.5 percent for sound kernels and 79.5 percent for minor damaged kernels compared to the already mentioned germination of corn harvested by rubber roller sheller of 64.5 percent for sound kernels and 76 percent for minor damaged kernels. Hence, there was a distinct difference in germination of sound corn kernels harvested by conventional combine and the rubber roller sheller.

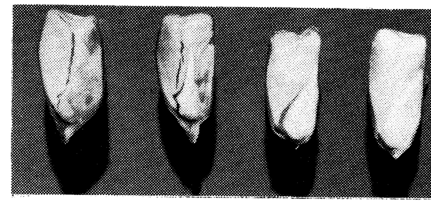

**FIG. 7 The different types of internal cracks observed in sectioned sound kernel from rubber roller sheller.**

To determine why germination of the sound kernels shelled by the rubber roller sheller was low, sound kernels from both shellers were studied using the tetrazolium test. Treating sectioned seeds with tetrazolium caused the live embryos to turn red, while dead embryos remained undyed. Examinations were made of the condition of the embryo and the internal structure of the kernels. Many of the sound kernels from the rubber roller sheller were found to have failed in shear; this produced an internal crack located between the embryo and the endosperm. The sound kernels from the conventional combine were almost crack free. (Fig. 6). The different types of internal cracks found in sound kernels are shown in Fig. 7. Some of the cracks started at the top, and some went all along the cross section, but were not visible on the outside. It is hypothesized that the internal cracks are one of the reasons for the death of the embryo and, consequently, no germination.

## RESULTS AND DISCUSSIONS

The analysis of variance (Table 2)

TABLE 1. STANDARD GERMINATION TEST FOR SEEDS FROM RUBBER ROLLER SHELLER AND CONVENTIONAL COMBINE.

| Shelling operation | Percentage of germination in | | | |
|---|---|---|---|---|
| | Sound kernels | Minor damage | Major damage | Severe damage |
| | 72 | 72 | 44 | 10 |
| | 78 | 86 | 40 | 6 |
| Rubber roller sheller | 52 | 72 | 48 | 6 |
| | 56 | 74 | 62 | 6 |
| Average | 64.5 | 76 | 48.5 | 7 |
| | 94 | 86 | 50 | 8 |
| | 84 | 78 | 50 | 8 |
| Conventional combine | 100 | 80 | 46 | 6 |
| | 92 | 74 | 40 | 6 |
| Average | 92.5 | 79.5 | 46.5 | 7 |

TABLE 2. ANALYSIS OF VARIANCE FOR SHELLING EFFICIENCY

| Source | Sum of squares | Degrees of freedom | Mean square | F value |
|---|---|---|---|---|
| Moisture content, A | 5836.29 | 4 | 1459.07 | 12.37** |
| Inflation pressure, B | 25343.04 | 3 | 8447.68 | 71.66** |
| Cylinder rpm, C | 17489.86 | 3 | 5829.95 | 49.46** |
| AB | 2487.18 | 12 | 207.26 | 1.75 |
| AC | 2410.50 | 12 | 200.87 | 1.70 |
| BC | 3253.18 | 9 | 361.46 | 3.06** |
| Residual | 4243.30 | 36 | 117.86 | |
| Corrected total | 61063.38 | 79 | 772.95 | |

**Significant at 1 percent level

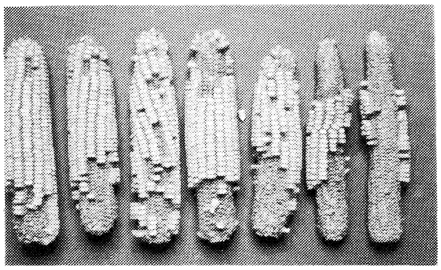

FIG. 8 Unshelled kernels following run through rubber roller sheller at different cylinder inflation pressure.

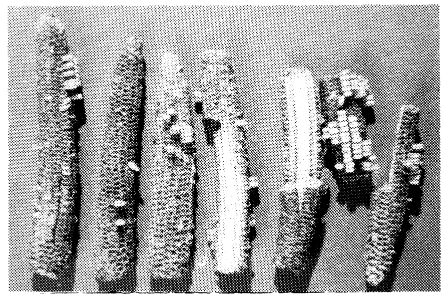

FIG. 9 Unshelled kernels following run through combine cylinder.

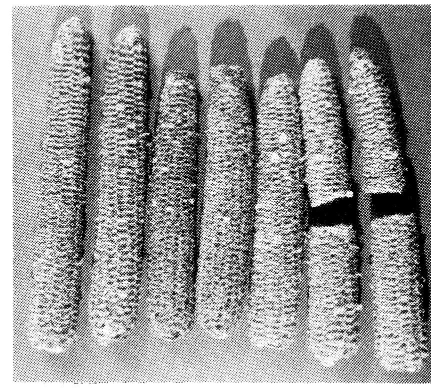

FIG. 10 Cobs following run through rubber roller sheller.

indicates that moisture content, cylinder inflation pressure, and cylinder rpm have a highly significant effect (at the 1 percent level) on shelling efficiency. The interaction between cylinder rpm and inflation pressure also was significant at the 1 percent level. The effect of moisture content on shelling efficiency and damage index is illustrated in Fig. 12. The increase in moisture content decreased shelling efficiency. The relationships between shelling efficiency at various cylinder rpm and inflation pressure are illustrated in Fig. 13. Shelling efficiency increased as the cylinder rpm increased. Shelling efficiency also increased with an increase in inflation pressure. The shelling efficiency sharply increased for all rpm as the cylinder inflation pressure was raised from 6 to 10 psi. The increase in shelling efficiency at various cylinder rpm for the cylinder inflation pressure of 14 and 18 psi, however, was not that sharp as they became asymptotic with 100 percent shelling efficiency.

Brass (1970) did not study the effect of cylinder inflation pressure and cylinder rpm on shelling efficiency. He did study the effect of kernel moisture content on shelling efficiency and reported, as we found, that shelling efficiency decreased with increase in moisture content of the corn.

Fig. 8 demonstrates how the shelling of corn kernels from the cobs increased with increase in cylinder inflation pressure. Fig. 9 shows the kernels left unshelled with typical combine harvesting (Figs. 10 and 11 show the cobs).

The analysis of variance for damage index (Table 3) indicates that the moisture content, cylinder inflation pressure, and cylinder rpm have a highly significant effect on damage index. They were all significant at the 1 percent level. The effect of the moisture content on the damage index is illustrated in Fig. 12. The damage index increased as the moisture content increased. The damage index increased most sharply with 18-20 percent and 26-29 percent moisture content. Brass (1970) also reported that moisture content had a highly significant effect at the 1 percent level on total kernel damage. He reported that minimum kernel damage occurred at 19 percent moisture content; we found minimum kernel damage at our lowest test moisture content of 18 percent.

The effect of the cylinder speed on damage index is illustrated in Fig. 13. The damage index increased as the cylinder rpm increased. Brass (1970) also reported that roller speed was significant at the 1 percent level for total damage.

The effect of the cylinder inflation pressure on damage index is illustrated in Fig. 14. It shows that damage index increased as cylinder inflation pressure increased. This result was in contradiction to Brass's result; he reported that roller inflation pressure was not significant at the 5 percent level.

The analysis of variance for feed rate (Table 4) indicates that moisture content, cylinder inflation pressure, and cylinder rpm were not significant at the 1 percent level. The only significant factor at 5 percent level was the kernel moisture content. It was expected that the feed rate would increase with increase in cylinder rpm. The smooth cylinder surface and lack of a positive feeding mechanism, however, might be the reasons for inconsistent feed rates.

There was less cob breakage in the rubber roller sheller compared with the conventional combine. Figs. 10 and 11 show the typical cobs from the rubber roller sheller and the combine, respectively.

The shelling in the rubber roller shellers is induced in the concave area by the combination of rolling action and repeated compressive loading imparted to the rows of kernels as the ear passes over the uni-directional bar concave. Because of this repeated compressive loading, the kernels

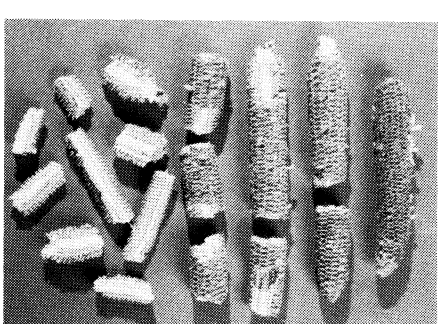

FIG. 11 Cobs following run through combine cylinder.

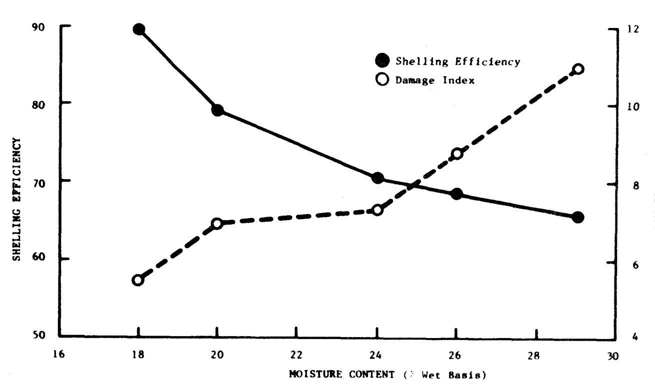


FIG. 12 Effect of kernel moisture content on shelling efficiency and damage index.

TABLE 3. ANALYSIS OF VARIANCE FOR DAMAGE INDEX

| Source | Sum of squares | Degrees of freedom | Mean square | F value |
|---|---|---|---|---|
| MC | 27647.75 | 4 | 6911.93 | 18.97** |
| PSI | 14061.24 | 3 | 4687.08 | 12.86** |
| RPM | 14269.40 | 3 | 4756.46 | 13.05** |
| MC*PSI | 2381.22 | 12 | 198.43 | 0.54 |
| MC*RPM | 5835.49 | 12 | 486.29 | 1.33 |
| PSI*RPM | 5180.18 | 9 | 575.57 | 1.57 |
| Residual | 13114.52 | 36 | 364.29 | |
| Corrected total | 82489.83 | 79 | 1044.17 | |

**Significant at 1 percent level

TABLE 4. ANALYSIS OF VARIANCE FOR FEED RATE

| Source | Sum of squares | Degrees of freedom | Mean square | F value |
|---|---|---|---|---|
| MC | 4599.16 | 4 | 1149.79 | 2.97* |
| PSI | 1946.19 | 3 | 648.73 | 1.67 |
| RPM | 1276.41 | 3 | 425.47 | 1.10 |
| MC*PSI | 5797.43 | 12 | 483.11 | 1.24 |
| MC*RPM | 3648.64 | 12 | 304.05 | 0.78 |
| PSI*RPM | 1503.57 | 9 | 167.06 | 0.43 |
| Residual | 13921.78 | 36 | 386.71 | |
| Corrected total | 32693.20 | 79 | 413.83 | |

*Significant at 5 percent level

undergo repeated compression until they are shelled.

The mechanical properties of the different parts of the kernel are not the same. The embryo is the softest part compared with the endosperm and horny endosperm. Hence, when the kernels are compressively loaded at the crown by the rubber tire or the crown is forced against the concave by the tire, a compressive shear failure takes place between the embryo and the endosperm. Some of the shear failures (internal cracks) were also found between the embryo and the endosperm and the embryo is killed. Others were between the embryo and the horny endosperm passing through the endosperm. All these types of internal cracks were found in sectioned, sound, and damaged kernels shelled by the rubber roller sheller (Figs. 6 and 7).

On the other hand, in the conventional combine, kernels are shelled by the impact of the rasp bars. Those kernels shelled by the direct impact are usually severely damaged, but those shelled by indirect impact are slightly damaged. Hence, most of them are shelled internally crack free (Fig. 6).

Since the phenomenon of the crack development was observed during the analysis of data, it is difficult to draw a definite conclusion concerning the formation of the internal crack and its effect on germination. This must be considered a preliminary study. The effect of this internal crack on the loss of quality during drying, handling, and storage operation has yet to be evaluated.

## SUMMARY AND CONCLUSION

A rubber roller sheller constructed by Brass (1970) in the form of a laboratory test stand was further evaluated. The objectives of this research were to determine the effect of moisture content, cylinder inflation pressure, and cylinder rpm of the rubber roller sheller on kernel damage, shelling efficiency, and feed rate.

The analysis of variance for shelling efficiency indicated that the moisture content, cylinder inflation pressure, and cylinder rpm are all significant at the 1 percent level. The shelling efficiency increased with increase in cylinder rpm and cylinder inflation pressure. The shelling efficiency decreased with increase in moisture content.

The analysis of variance for damage index indicated that moisture content, cylinder inflation pressure, and cylinder rpm are all significant at the 1 percent level. In this case, the damage index increased with increase in moisture content, cylinder inflation pressure, and cylinder rpm.

The analysis of variance for feed rate indicated that only moisture content is significant at the 5 percent level. Lack of positive feeding mechanism and proper orientation of ears is mainly responsible for this situation.

The formation of the internal cracks in the sound and damaged kernels shows a definite need for further study before any development is made on the rubber roller sheller. The effect of these internal cracks on germination is a primary concern if the rubber roller sheller is to be used for shelling seed corn.

A damage index was developed for quantitative, as well as qualitative, evaluation of kernel damage. This helps to evaluate damage in terms of fine materials, broken, chipped, and crushed kernels.

### References

1 Ayres, George E., Clarence E. Bobcock and Dale O. Hull. 1972. Corn combine field performance in Iowa. ASAE Grain Damage Symposium, Ohio State University, Columbia, Ohio. April 5-7.

2 Bailey, Joseph. 1968. Problems in marketing damaged grain and corn. Grain Damage

(Continued on page 490)

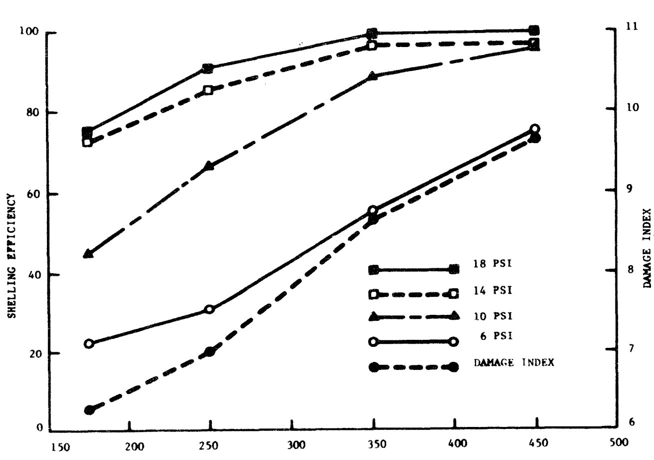


**FIG. 13 Effect of cylinder speed on damage index and shelling efficiency [at different cylinder inflation pressure].**

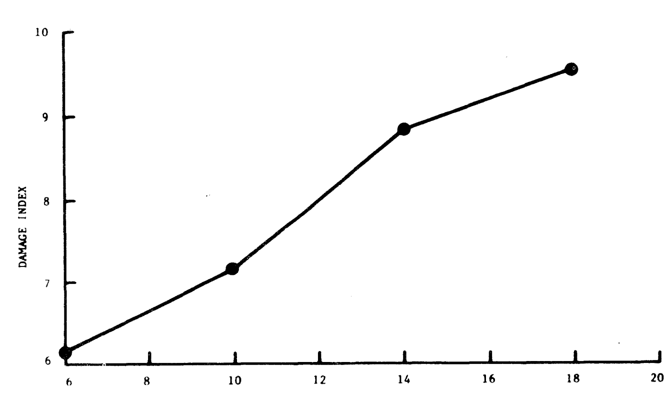


**FIG. 14 Effect of cylinder inflation pressure on damage index.**

for each channel and there exists very little overlap between channels.

The Berrymatic has been used to sort blueberries, black grapes, and bronze grapes. Both blueberries and black grapes were sorted with 740 and 800 nm filters. Comparator reference settings were set higher to compensate for the higher anthocyanin content of the black grapes. The anthocyanin content of bronze grapes is much lower than black grapes; hench, it was necessary to change the sorting filters to 510 and 630 nm in order to increase the sensitivity to compensate for the lower anthocyanin content.

The Berrymatic has the potential for many applications. Its high rate of sorting (up to 64 fruit/min compared to 10/min on the LTDM) permits rapid accumulation of sorted fruit in sufficient quantities to satisfy the requirements of many studies. For example, our Food Science Department has studied the possibility of mixing channel 1 fruit with channel 5 fruit to achieve an acceptable end product, thus, making use of the currently unacceptable green and overripe fruit. The machine has been used to check settings on mechanical harvesters by determining the maturity distribution of harvested fruit. Studies could be undertaken to measure the effects of cultural practices on fruit maturation and quality. Varieties and breeding lines could be characterized according to measurement with the machine.

Although tests have not been made, work is under way to adapt the Berrymatic for sorting cranberries, cherries, and larger fruit such as apples and oranges. In the latter case the cup will have to be modified to accomodate the larger fruit.

A high capacity production-type machine which sorts blueberries at a rate of nine berries per second has been developed and is reported in another paper (Rohrbach et al. 1973). It is a belt-type machine with three rows of cups and sorts berries into three catagories (underripe, ripe, and overripe). Results have indicated that a commercial prototype machine with 20 rows of cups could be built giving a nominal sorting rate of 18 pints per minute.

## References


1 Ben-Gera, I. and K. H. Norris. 1968. Direct spectrophotometric determination of fat and moisture in meat products. J. of Food Science 33(1):64-67.

2 Birth, G. S. and K. H. Norris. 1965. The difference meter for measuring interior quality of foods and pigments in biological tissue. Technical Bulletin No. 1341. United States Department of Agriculture, Agricultural Research Service, Washington, D. C.

3 Bittner, D. R. and K. H. Norris. 1968. Optical properties of selected fruits vs. maturity. TRANSACTIONS of the ASAE 11(4)534-536.

4 Butler, W. L. and K. H. Norris, 1960. The spectrophotometry of dense light scattering material. Archives of Biochem. and Biophys. 87:31-40.

5 Chance, Britton. 1951. Rapid and sensitive spectrophotometry: III. A double beam apparatus. Rev. Sc. Inst. 22:634.

6 Norris, K. H. and W. L. Butler. 1961. IRE Transactions on Biomedical electronics. BME-8(3):153-157.

7 Norris, K. H. and J. D. Rowan. 1962. Automatic detection of blood in eggs. AGRICULTURAL ENGINEERING 43(3):154-159.

8 Kushman, L. J. and W. E. Ballinger. 1973a. Relation of quality indecies of individual blueberries to photoelectric measurement of authocyanine content. To be published in J. Am. Soc. Hort. Sc.

9 Kushman, L. J. and W. E. Ballinger. 1973b. Effect of season, location, cultivar, and fruit size upon quality of blueberries sorted according to authocyanine content with transmitted light. To be published in J. Am. Soc. Hort. Sc.

10 Rohrbach, R. P., W. F. McClure, L. J. Kushman and W. E. Ballinger. 1973. Developments in automatic light transmission difference sorting of blueberries. ASAE Paper No. 73-6528, ASAE, St. Joseph, Mich. 49085.

11 Yeatman, John N. and K. H. Norris. 1965. Evaluating interval quality of apples with new automatic fruit sorter. Food Technology 19(3):123-125.