AN EVALUTION OF SOME MECHANICAL METHODS FOR SHELLING MELON SEEDS

BY

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ABSTRACT

A series of investigations were conducted on a number of mechanical devices which were designed for shelling melon seeds. The results of these investigations are reported in two parts in order to facilitate the presentation. Part I describe the results of using devices which subject the seeds to a combination of pressure and scrubbing simultaneously. Part II describes the performance of devices which bend and scrub the seeds simultaneously.

1. INTRODUCTION

The cotyledons of seeds from melon (Citrullus Valgaris) contain about 30 percent and 50 percent oil by weight. After the oil is extracted from the cotyledon, the residue contains mainly protein which can be incorporated into foods for babies and invalids. The cotyledons are enclosed in thin wall shells with a thick ring round the edges in one variety. In order to retain the high qualities of the protein and the oil, it is necessary to remove the shells from the seeds so that only the cotyledons are processed. The work reported in this paper describes the results on the tests carried out with some mechanical devices which were designed to remove the shells from the seeds.

While chemical methods seem possible and attractive, these studies have been limited to mechanical methods. At this stage of development, it is envisaged that the resulting processing machines will be used on the farm or in the villages. Chemical methods if handled carelessly by the farmer will render the products less valuable and unsuitable for human consumption. Furthermore, there is a great potential for using the shells as livestock feed and litter, it is therefore preferable to leave the shells or hulls free of chemicals. The mechanical methods studied can be classified into two kinds of devices which:

i. subject the seeds to some pressure and a scrubbing action simultaneously;
ii. subject the seeds to a combination of bending and scrubbing action simultaneously.

To facilitate the presentation, the results of these investigations are presented in two parts under the two healings given above.

2. PERFORMANCE TESTING OF THE DEVICES

Hunt [1] suggested that the performance of a shelling machine may be determined by the following measurements:

a) The amount of seeds shelled;
b) The amount of foreign materials in the seeds;
c) The amount of seeds not completely shelled.

The measurements suggested by Hunt have been modified to include readings on the amount of seeds which are shelled and damaged, partly shelled and damaged and those damaged (shelled and unshelled) because the broken ones may affect the processing qualities of the cotyledons. In addition if the cotyledons are to be marketed unprocessed, breakage will reduce the keeping qualities, shell life, and the price at which the product could be sold. The following measurements are therefore determined in the evaluation of the devices:

a) the number of seeds shelled and undamaged;
b) the number of seeds partly shelled and undamaged;
c) the number of seeds partly shelled and damaged;
d) the number of seeds unshelled and undamaged;
e) the number of seeds damaged(shelled and unshelled).

Readings on the amount of foreign matter are not included in the evaluation studies. The presence of foreign matter is considered a problem of cleaning after shelling rather that as part of the shelling process itself.

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Of the two common varieties grown, the one with the thicker ring round the shell, described as variety A in the previous paper [2] was used in testing the performance of the devices.

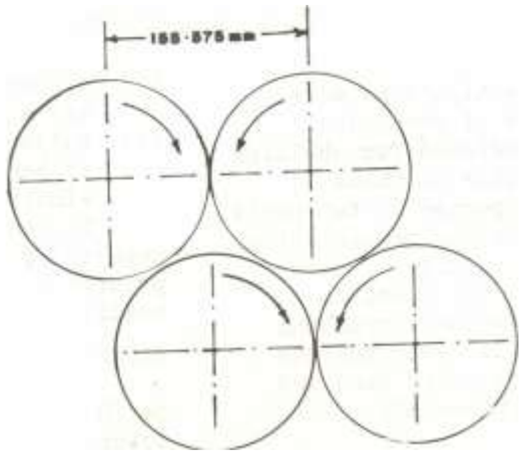

Fig.l. Schematic layout of the knurled roller machine

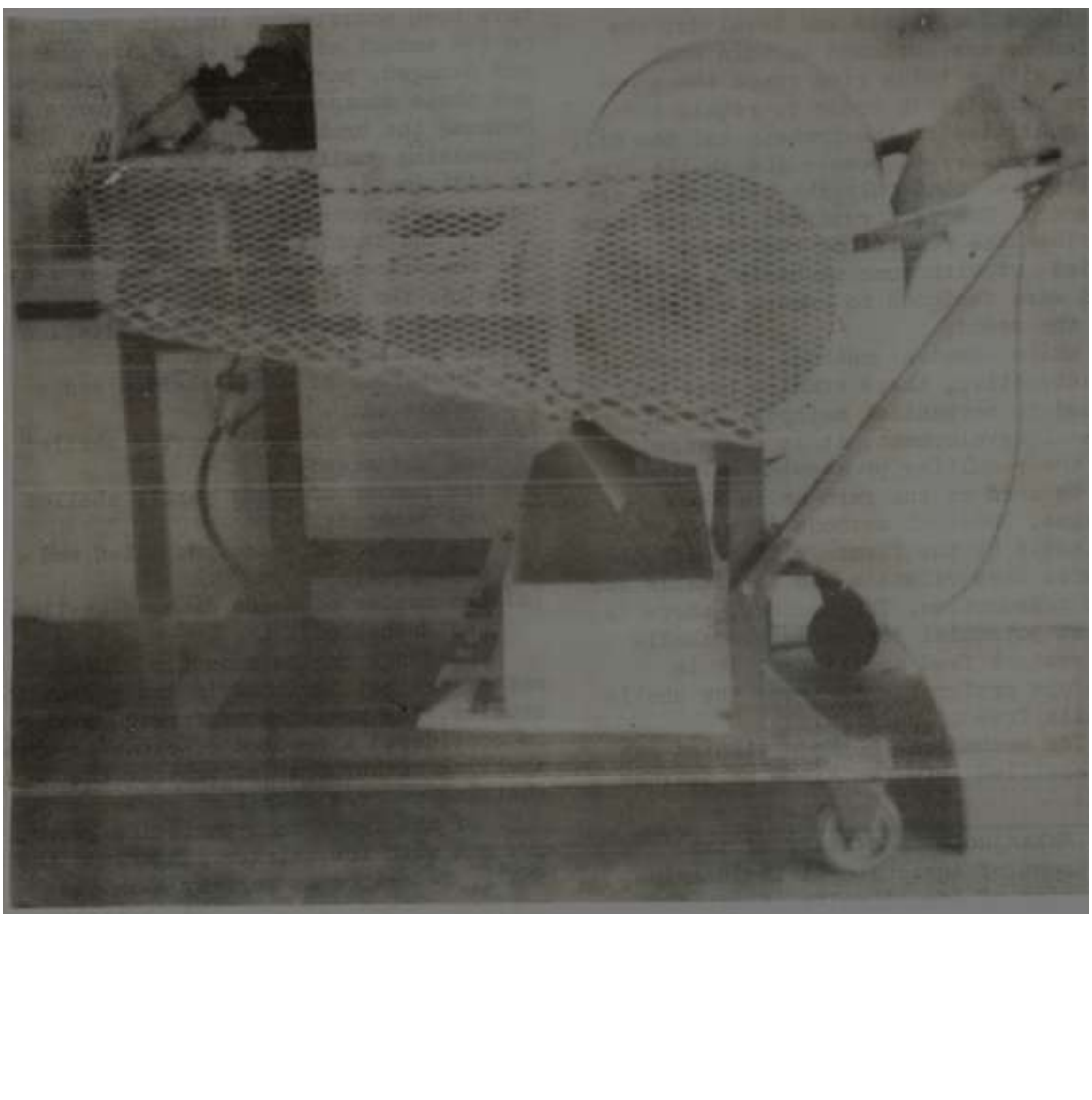

Fig. 2. The drum and the belt machine

3. DEVICES FOR SIMULTANEOUS PRESSURE AND SCRUBBING ACTION

3.1. KNURLED ROLLER MACHINE

Fig. 1 shows the schematic layout of the plain roller machine. The four cylindrical mild steel rollers were mounted on bearings such that the space between the rollers can be adjusted to obtain different degrees of pressure on the seeds. Preliminary tests show that rollers with knurled surfaces perform better than those with smooth surfaces. The rollers are driven in such a way that for any two mating surfaces, one is rotated at three times the speed of the other in the opposite direction. The rollers are 6 inches in diameter and 4 inches wide.

For each performance test, the machine was first operated for about five minutes after which 50 seeds randomly selected were fed into the machine. These were carefully collected and analyzed into the different classes described above. Each test was repeated 8 times for 8 different moisture contents. Preliminary tests showed that the speed for the fastest roller of 250 rev/min resulted in the least overall damage to the seeds. The speed of this roller was maintained constant at 250 rev/min throughout the test.

3.2 THE DRUM AND BELT MACHINE

Fig. 2 shows the machine which consists of a rubber drum 21 inches in diameter and 30 inches wide. A flat belt forms a segment of about 45 degrees round the outside of drum. There is a provision for tightening the belts to increase its pressure on the drum. The drum is driven by an electric motor through a combination of variable speed belt and chain drive.

The test was carried out in a manner similar to that described above at a seed moisture content of 8 percent. The test was replicated eight times for each of speeds 60, 50 and 38 revolutions per minute.

4. RESULTS AND DISCUSSION

4.1 KNURLED ROLLER MACHINE

Tables 1 and 2 present the summary of the performance of the machine. The overall performance of this device is poor. It is capable of shelling only about 2 percent of the seeds

On the average about 41 percent of the seeds are partly shelled and undamaged while another 18 percent are partly shelled and damaged. The number of seeds damaged (shelled and unshelled) at the lowest moisture content is high because the seeds is brittle and easily broken. The high number of seeds damaged at the high moisture content is due to the swelling of the seeds.

The most critical factors affecting the performance are the amount of gap between the surface of mating rollers and the pressure put on the seeds by the rollers. When the gap between the surfaces is reduced the seeds simple get crushed. When this gap is increased, the seed just slip past the roller. Another drawback of this device is due to the fact that the contact between the seeds and the roller surface is along a line. This concentrates the pressure and the time of contact between the seeds and the rollers is very small.

4.2. DRUM AND BELT MACHINE

The results of the tests on the drum and belt machine are shown in Tables 3 and 4. The overall performance although better than that of the knurled roller machine is not good enough. Only about 13 percent of the seeds were shelled, while about 26 percent went through the machine unshelled. The seeds accumulated between the belt and the drum when the pressure between the belt and the drum was low. When the pressure was increased, more seeds were broken and there was a lot of heat generated between the drum and the belt due to friction.

In general the results of the tests on the two devices indicate that the application of pressure coupled with a scrubbing action is not sufficient for shelling melon seeds. When these seeds are shelled by hand traditionally, each one is held between two fingers of each hand and then subjected to a combination of twisting and bending to break the shells. The parts of the broken shell are then pulled apart to release the cotyledon. The seeds are usually moistened in order to reduce the brittleness of the cotyledon. This reduces the number of cotyledons broken during the shelling process. The traditional method seems to suggest that a device which is designed to bend the seeds sufficiently until the shells break and then scrub the seed to remove the broken shells will be more successful. It is in attempt to collect the data on which to base the design of a device

Table 1: performance summary of the knurled roller machine

	Moisture Content	8	14	20	26	30	32	36	38
No. of seeds shelled and undamaged	Mean	2.00	0.88	0.88	1.25	1.25	1.38	1.38	1.38
	Std. Dev.	1.00	0.6	0.33	0.66	0.44	0.69	0.69	0.85
No. of seeds partly shelled and undamaged	Mean	13.38	24.38	23.50	24.50	23.38	20.63	18.75	17.00
	Std.Dev.	4.00	3.40	2.18	5.39	2.24	3.87	3.15	2.60
No. of seeds partly shelled and damaged	Mean	9.88	9.50	8.38	9.00	8.00	8.75	11.75	8.75
	Std.Dev.	2.45	1.50	2.58	2.29	2.00	1.79	1.92	1.86
No. of seeds unshelled and undamaged	Mean	11.75	10.88	9.25	8.00	8.13	6.00	5.75	4.50
	Std.Dev.	2.54	1.66	1.30	1.58	1.88	1.66	1.64	1.94
No. of seeds damaged (shelled and unshelled)	Mean	12.63	4.75	6.25	6.88	8.75	11.13	12.50	13.50
	Std. Dev.	3.29	2.28	*1.86*	2.88	3.52	3.90	2.50	1.23

Table 2: Variance ratios for the results of the performance tests of the knurled roller machine

No. of seeds Shelled and undamged	No.of seeds partly shelled and undamaged	No.of seeds partly shelled and damaged	No.of seeds unshelled and undamaged	No. of seeds damaged (shelled and unshelled)
2.12	8.13*	2.00	13.78*	9.82*

*Significant at 1% level

Table 3: Performance summary of the drum and belt machine

	Speed rev/min.	60	50	38
No. of seeds shelled and undamaged	Mean	7.63	6.75	5.63
	Std. Dev.	1. 78	1.09	.63
No. of seeds partly shelled and undamaged	Mean	11.88	23.38	18.38
	Std. Dev.	1.73	2.94	1.82
No. of seeds partly shelled and damaged	Mean	8.88	6.25	8.75
	Std. Dev.	1.33	2.00	1.86
No. of seeds unshelled and. undamaged	Mean	17.75	9.3t3	12.50
	Std. Dev.	2.49	3.59	2.50
No. of seeds damaged (shelled and unshelled)	Mean	3.63	5.25	5.5
	Std. Dev.	.97	1.64	1.58

Table 4: Variance ratios for the tests on the drum and belt machine.

No. of shelled and undamaged	No. of seeds partly shelled and undamaged	No. of seeds partly and damaged	No. of seeds unshelled and undamaged	No. of seeds damaged (shelled and un+ shelled)
4.30	45.94**	4.09*	14.94**	3.67*

*Significant at 5% level **Significant at 1% level.

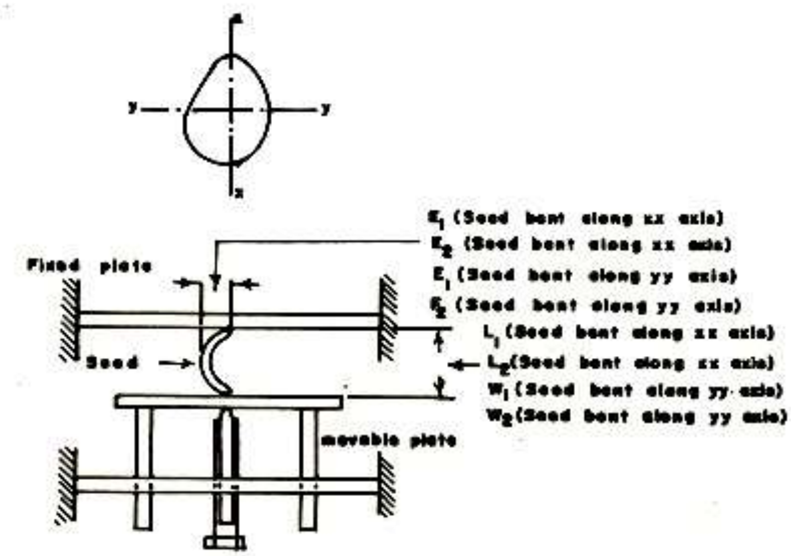

Fig.3. Schematic diagram of the rig built for bending the seeds.

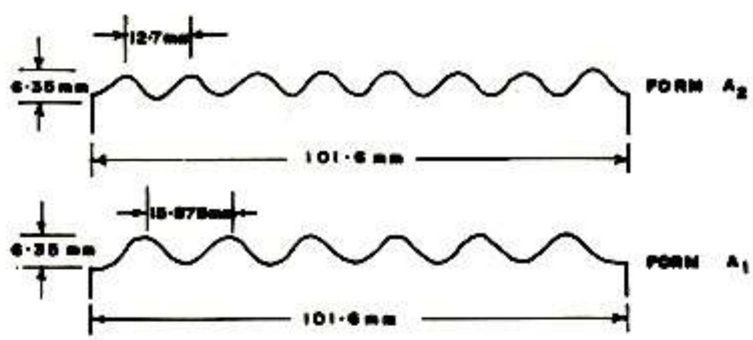

Fig.4. Dimensions of the ..utes

that may simulate the traditional method that the bending tests reported earlier [2] were undertaken. The results of the studies were used to determine the geometry of the bending components of the devices described in Part II of this series of papers.

PART II

DEVICES FOR SIMULTANEEOUS BENDING AND SCRUBBING ACTION

The static bending properties of melon seeds show that both the shells and the cotyledons are brittle at low moisture content. The cotyledons are less brittle compared with the shells at higher moisture contents. The bending tests were carried out in two stages. During the first stage bending continued until the shell broke while during the second stage the seed was bent further until the cotyledon broke (Fig.3). Generally after the first stage, the amount of subsequent bending (L_1-L_2) and the deflection (E_1-E_2) which the cotyledon can withstand before breaking increase significantly with increase in moisture content. These results seem to suggest that if when the seeds are bent along X-X axis. When the seeds are bent along the Y-Y axis, after the first stage the amount of subsequent bending (W1-W2) and deflection (F1−F2) which the cotyledons can withstand without breaking does not change appreciably with increase in moisture content a machine is built to bend seeds along the X-X axis while the deflection is maintained between E_1 and E_2, it will succeed in breaking the shells of a high proportion of the seeds without breaking the cotyledons. The design of flutes on the rollers and the size of the concave bars described below were based on these results.

5.1. THE FLUTED ROLLER MACHINE

Fig.4 shows the dimensions of the two types of flute forms that were generated on the rollers for this device. Fig.5 shows the schematic layout of the machine. It consists of 2 types of 3 rollers each. The first three rollers which have their flutes parallel to the axis (Fig.6 left roller) are mounted such that the ridges of one roller engage the furrows of the other and are driven at the same speed. The depth of engagement of the flutes is adjustable. The last three rollers, (Fig.6 right roller) which have the flutes in circular patterns along the surface, are driven at different speeds such that for any two mating rollers, one is driven at three times the speed of the other. The difference in the speeds of the last three rollers creates a rubbing action for loosening and separating the shells from the cotyledons. The set of the three rollers on the left rotate in the opposite direction of the other set on the right. Each roller has a mean diameter of 6 inches. The machine is equipped with a hopper (not shown in the diagram) which allows the seeds to be oriented properly before entering the machine.

The procedure adopted for testing is similar to that described earlier. After the machine had run continuously for about 10 minutes, 50 seeds randomly picked from the sample were fed through the machine. The seeds were carefully collected after going through the machine and analysed into the groups described above. Each test was replicated eight times, for each of the two forms of flutes and for eight different moisture contents.

5.2. THE CONCAVE AND CAGED CYLINDER MACHINE

Fig.7 shows the cross-section through the machine. The caged cylinder shown in Fig.8 consists of ¼ inch steel rods spaced at 3/8 inch intervals a 6 inches pitch circle diameter. The concave is made of six pairs of rubbered canvas which touch lightly the cylinder steel rods on the inside and outside. The procedure described above was also adopted for testing the effectiveness of the device. The test was replicated eight times at eight different moisture contents.

6. RESULTS AND DISCUSSIONS

6.1. FLUTTED ROLLER MACHINE

Tables 5 and 6 shows the summary of the performance of the two types of fluted rollers. Flute form does not have any significant effect on the number of seeds damaged (shelled and unshelled). However, the overall performance of the device is significantly affected by the flute form, seed moisture content and the interaction between the flute form and seed moisture content. Table 5 shows that the highest number of seeds shelled is at a moisture content of 8 percent for flute form A_1. At this moisture content, about 16 percent of the seeds were shelled. For the flute form A_2 the highest number is at 20 percent moisture content.

Fig.5. Schematic layout of machine showing the rollers with flutes parallel to the axis (top left) and rollers with flutes parallel to the circumference (bottom right)

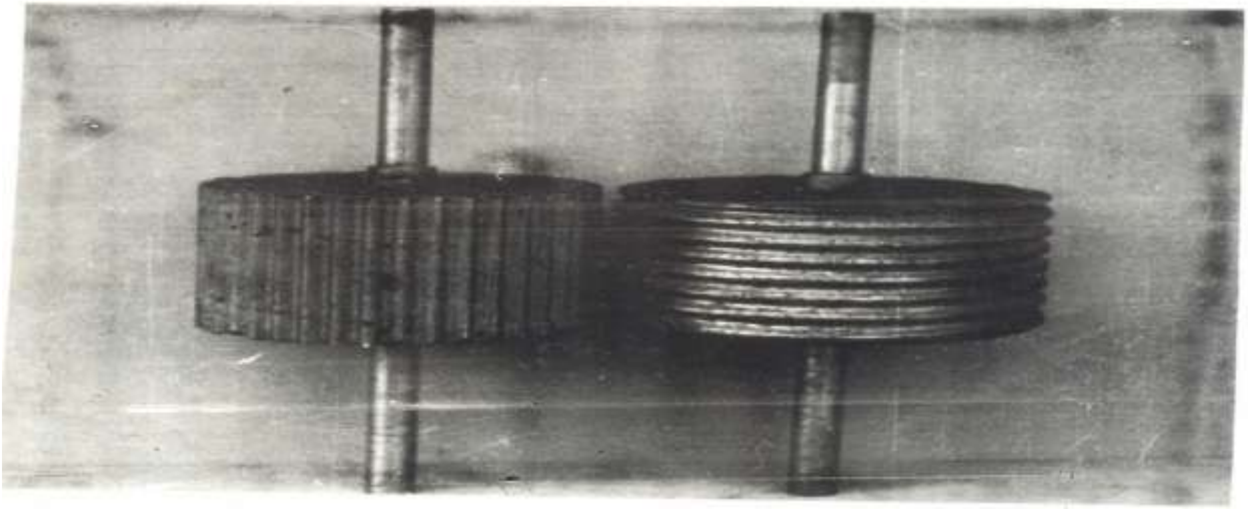

Fig.6. The Fluted Rollers

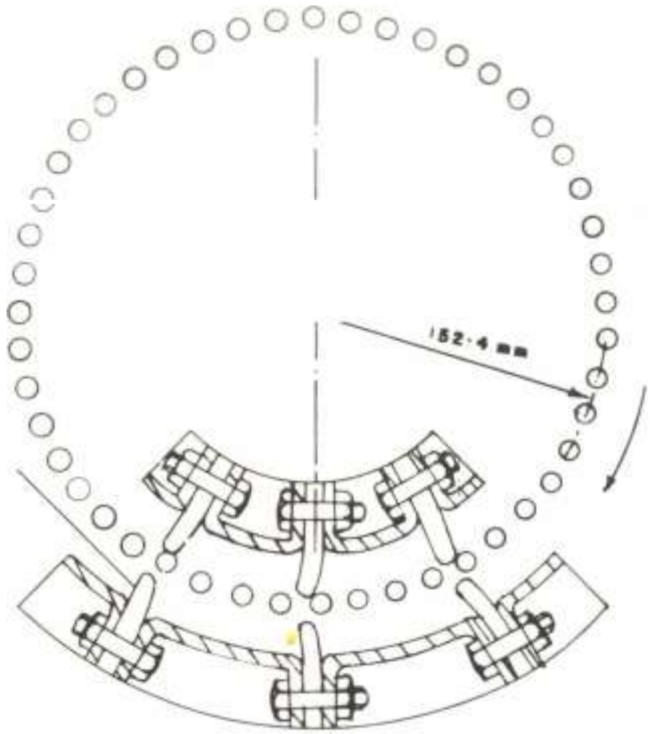

Fig.7. Section at the shelling unit showing the concave in two parts (cylinder rotates in the direction of the arrow).

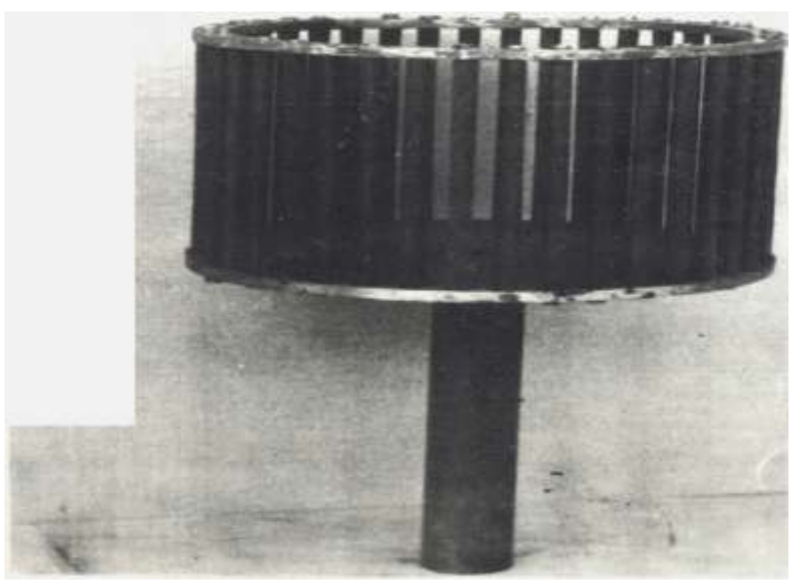

Fig.8. The caged cylinder

Table 5: Performance summary of the flutted roller machine

		Moisture content & wet basins	8	14	20	26	30	32	36	38
No. of seeds shelled and undamaged	Flute Form A_1	Mean	7.75	3.50	3.38	6.75	5.63	5.00	5.00	5.00
			1.98	1.50	0.86	1.20	0.99	0.87	0.87	1.32
	Flute Form A_2	Std.	3.25	6.63	8.38	5.98	7.63	5.25	6.75	6.25
		Dev.	1.30	0.86	1.32	1.05	2.34	0.83	1.09	0.75
No. of seeds partly shelled and undamaged	Flute Form A_1	Mean	11.88	20.25	20.13	21.50	21.13	18.75	14.75	13.13
			1.90	3.31	2.15	2.45	3.06	2.86	2.11	1.69
	Flute Form A_2	Std.	5.50	11.63	13.88	10.75	13.25	11.88	10.63	11.00
		Dev.	0.50	1.09	2.26	2.73	0.97	1.94	10.11	1.12
No of seeds partly shelled and damaged	Flute Form A_1	Mean	0.88	7.50	6.13	6.25	10.00	8.75	7.88	12.13
			0.78	2.06	2.20	1.48	2.45	1.48	1.17	2.15
	Flute Form A_2	Std.	4.88	6.88	5.25	5.50	4.50	5.50	5.88	6.25
		Dev.	1.27	0.93	1.39	1.50	0.87	1.22	1.17	1.56
No. of seeds unshelled and undamaged	Flute Form A_1	Mean	17.75	10.63	12.25	9.38	8.33	12.00	18.12	15.50
			2.17	1.49	2.74	2.78	2.67	2.17	1.85	3.50
	Flute Form A_2	Std.	30.00	20.50	18.25	21.63	19.38	21.75	20.88	21.75
		Dev.	1.73	2.50	2.83	2.39	1.80	2.33	1.69	0.97
No. of seeds damaged (shelled and unshelled)	Flute Form A_1	Mean	3.63	7.88	8.13	5.13	4.88	5.50	4.25	4.24
			0.86	1.96	1.05	1.27	1.36	0.87	0.97	1.00
	Flute Form A_2	Std.	5.50	4.38	5.25	6.13	5.25	6.38	5.88	4.75
		Dev.	1.00	0.70	1.20	1.17	1.93	1.32	1.00	0.66

Table 6: Variance ratios for the results of the performance tests of the fluted roller machine

Source of variation	No. of seeds shelled and undamaged	No. of seeds partly shelled and undamaged	No. of seeds partly shelled and damaged	No. of seeds unshelled and undamaged	No. of seeds damaged (shelled & unshelled)
Flute Form (A)	21.95**	293.69**	94.45**	376.08**	0.04
Moisture Content (B)	2.35*	30.23**	6.53**	31.00**	6.79**
Interaction	18.54	7.42**	6.52**	10.10**	9.52**

*Significant at 5% level **Significant at 1% level highest number is at 20 percent moisture content. This was about 17 percent of seeds fed through the machine. The number of seeds partly shelled and undamaged was very high. For flute form A_1, the proportion of seeds partly shelled and undamaged varied between 23.76 percent at 8 percent moisture content and 43 percent at 26 percent moisture content with an overall mean average of 35.3 percent. In the case of flute form A_2 the equivalent figures were between 11 percent at 8 percent moisture content and 26.5 percent moisture content with an overall mean of 22.14 percent. The number of seeds unshelled and undamaged was very high with an overall mean of 26 percent for flute form A_1 and 43.76 percent for flute form A_2.

Some of the seeds usually got stuck within the furrows of the flutes thus resulting in great damage to subsequent seeds fed through the machine. The figures reported for these series of tests were observed with the engagement of the flutes set such that the clearance between the crest of the flute and the engaging furrow was $\frac{1}{8}$ inch. When the engagement was reduced, many seeds escaped unshelled. On the other hand, when the engagement was increased more seeds were damaged. The overall performance that might be expected from the device is not as good as would be suggested by the results of static bending tests probably because the seeds behave differently under impact bending to which they are subjected by the device.

6.2. CYLINDER AND CONCAVE MACHINE

Tables 7 and 8 show the effect of moisture content on the performance of the machine. These results show that moisture content has a significant effect on the machine performance. However, like the fluted roller machine, the overall effectiveness of the device is very low. The percentage of the seeds shelled and undamaged was 20.5 percent on the average while about 51 percent of seeds were unshelled.

Some of the set-backs of the device include the generation of heat due to the friction between the rubber of the concave and the ¼ inch bars of the cylinder, accumulation of seeds in the concave between one bank of the rubber and the other and the difficulty of maintaining positive entry of the seeds into the space between the bars on the cylinder. Compared with the fluted roller machine, the proportion of the seeds unshelled and undamaged is higher and the proportion of seeds damaged (shelled and unshelled) is lower in the concave and roller machine. This is partly due to the fact that it was difficult to have the melon seeds placed on the concave rubbers centrally with respect to the concave rubbers and the rods in the cylinder. When it is not properly placed, the cylinder just pulls the seed along without subjecting it to full bending moment and in some cases, the seed just slips to one side in the concave without experiencing any bending moment at all. Similarly like the fluted roller machine, the number of seeds shelled is low compared with what might be expected.

CONCLUSION

Although the results of the static bending tests on melon seeds seemed to suggest that a machine designed to subject the seeds to a combination of bending and rubbing actions will shell melon seeds effectively, this hope had not materialized partly because the seeds seemed to behave fairly differently when subjected to impact bending moments compared with static bending moments and partly because of the difficulties inherent in the methods which, have been used to apply the bending and rubbing actions. Another concept based on the use of centrifugal devices for projecting individual melon seeds at high speeds against a guard is now under investigations. This method is more promising than those described in this paper.

REFERENCES

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2. MAKANJUOLA, G.A. A study of some of the Physical Properties of Melon Seeds, J. Agric. Engng. Res. 1972, 17 (1), 128 - 137.

Table 7: Performance summary of the concave and caged cylinder machine

	Moisture content & wet basins	8	14	20	26	30	32	36	38
No. of seeds shelled and undamaged	Mean	14.63	14.25	13.88	13.63	18.00	17.00	16.75	14.00
	Std. Dev.	1.36	2.77	2.64	1.06	1.41	1.23		2.12
No. of seeds partly shelled and undamaged	Mean	3.75	3.38	3.00	3.38	3.00	1.38	1.13	0.75
	Std. Dev.	1.87	0.85	0.71	1.22	1.00	0.85	0.77	0.83
No of seeds partly shelled and damaged	Mean	2.75	0.85	0.71	1.22	1.00	0.85	0.77	0.83
	Std. Dev.	0.44	1.50	5.00	4.75	4.88	2.38	2.75	2.58
No. of seeds unshelled and undamaged	Mean	24.63	27.50	26.63	21.38	19.25	27.38	25.75	30.00
	Std. Dev.	4.06	2.96	0.99	8.03	2.73	1.41	1.64	1.87
No. of seeds damaged (shelled and unshelled)	Mean	2.50	3.38	2.23	6.50	4.88	1.88	4.63	2.88
	Std. Dev.	1.12	1.04	0.69	0.97	0.47	0.59	0.97	1.36

Table 8: Variance ratios for the results of the Performance tests of the flutted roller machines

No. of seeds shelled and undamaged	No. of seeds partly shelled and undamaged	No. of seeds partly shelled and damaged	No. of seeds unshelled and undamaged	No. of seeds damaged (shelled and unshelled)
5.88*	15.25*	4.75*	14.63*	8.16*

*Significant at 1% level