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PERFORMANCE OF ABRASIVE DISK DEHULLERS

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ABSTRACT

Traditional dehulling of cereal grains is a time cansuming, labour intensive, but important task performed by women in rural areas in developing countries. Dehulling separates the outer envelope, which contains both non-nutritional and organoleptically unacceptable factors, from the edible portion of the grain.

This paper discusses the performance of dehullers which use vertically rotating abrasive disks embedded in the grains being processed. Results of various studies are used to explain the effects of several parameters on the dehulling performance of the machines.

The performance of the dehullers depends on the speed of the rotation of the disks, the disk's surface characteristics, the quantity of grain in the dehuller, spacing between disks, the disk diameter, the physical characteristics of the grain, the duration of dehulling and the physical characteristics of the internal surface of the dehuller barrel. In the absence of detailed studies, in some cases, certain hypotheses are used to explain the operation of the dehuller.

It is concluded that even though the performance of abrasive disc dehullers are satisfactory, significant improvement may be obtained through studies aimed at understanding the mechanics of disk/grain, grain/grain and grain/wall interactions, during the dehulling process.

INTRODUCTION

Need for Dehulling

Semi-arid regions in developing countries such as Africa, for example, can only support the cultivation of cereals such as sorghum, millet and maize. As a result, a significant percentage of the population in many countries in Western, Central, Eastern and Southern Africa, depend on sorghum and millet for their daily meal. Other crops such as barley and quinoa contribute to the daily diets of populations in other parts of the world.

Rural women have traditionally improved the organoleptic quality of foods prepared from cereals buy processing the grains to remove the outer layers (the pericarp and testa). The pericarp (bran) contains mainly fibre whereas the testa contains anti-nutritional substances, such as polyphenols, which give a bitter taste to the grain and inhibit the digestion of protein from the grain [1]. Phytic acid, which is present in the bran and germ of sorghum and millet, combines with mineral elements such as calcium, iron, sodium, zinc, and magnesium, to form insoluble compounds (phytates) thus making them unavailable for human nutrition [2]. The presence of high concentratiens of C-glycosylflavones in undehulled millet has been linked to the incidence of goitre in Sudan [3,4]. All of these various anti-nutritional factors can be substantially reduced by dehulling.

Description of Traditional Dehulling

Traditional dehulling, which is done by women, involves pounding the wet grain in a mortar with a pestle. Wetting reduces damage to the grain and facilitates the removal of the bran. Once the required degree of dehulling has been achieved, the grain is washed to remove excess bran, dried to reduce its moisture content and then pounded into flour. This moist flour cannot be kept for more than 24 hours as it ferments.

Dehulling Equipment for Grains

Technologies that can be used for dehulling include roller milling equipment, rice dehulling equipment, attrition-type dehullers and abrasive-type dehullers [5]. Roller milling equipment does not appear to be very useful in dehulling sorghum or millet; the high degree of dehulling and colour of the flour obtained are unacceptable to the consumer. Rice milling equipment does not generally work well on these cereal grains. Abrasive-type dehullers use rotating abrasive surfaces to abrade the grain. Various types such as the Bavaria Record, the Wondergrain Jaybee, the FAO (fondateur de l'atelier de l'ouest) and Decomatic dehullers have been described [5].

Some of the disadvantages of various dehullers for village use are: their large capacities, often greater than 1000 kg/day; lack of spare parts; inability to dehull different grains without adjustment or mixtures of grains; and, the need to wet the grains.

Aim of Paper

The purpose of this paper is to discuss the performance of the abrasive-disk dehuller which has been developed at various research institutions in Canada and in Africa, for use on cereal grains and grain legumes. Both laboratory and field results and observations are used to explain the effect of various parameters on the performance of this dehuller. It is anticipated that the discussion will serve as a basis for further work aimed at improving the understanding of the operation of the dehuller, ultimately leading to an improvement of its performance.

DESCRIPTION OF ABRASIVE DISK DEHULLERS

General Features and Operating Principle

The basic features of the abrasive disk dehuller are shown in Fig. 1. It consists of several abrasive disks, rigidly mounted on a horizontal shaft rotating on bearings mounted on the ends of a trough-shaped barrel made of mild steel sheet. In operation, the disks are rotated in the grain at speeds ranging from 800 to 2500 rpm depending on the type of disk and abrasive surface being used.

Several models of this dehuller have been developed and have been fully described [6]. They have been developed to take into account specific dehulling needs and available technical skills in various countries. They are: PRL and Mini-PRL dehullers, developed at the Prairie Regional Laboratory of the National Research Council in Canada (now the Plant Biotechnology Institute); the RIIC dehuller manufactured by the Rural Industries Innovation Centre in Botswana and being used extensively in that country;

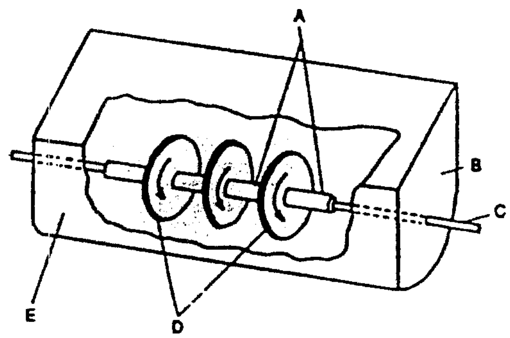

Figure 1. Basic features of the abrasive disk dehuller: A, spacers; B, end plate; C, shaft; D, abrasive disk; E, barrel.

Dehuller Type	Disc Type	Disc Speeds RPM	No. of Discs	Electric Motor Power HP
PRL	Stones	900-1300	,13	8
RIIC	Stones	2000	13	8
NUHULL	Stones	1500-2000	4	10
Mini-PRL	Resinoid	1500-2000	4	3
Mini-CRS	Resinoid	1500-2000	6	3
SISMAR/ ISRA 1	Resinoid	1500-2000	10	3
SISMAR/ ISRA II	Resinoid	1500-2000	8	3
Mini-ENDA	Stones	1500-2000	10	3

Table 1. Typical disc types, speeds and power for the abrasive disc dehullers.

the NUHULL dehuller manufactured by a Canadian manufacturer, Nutana Machine Ltd.; the Mini-CRS dehuller developed by the Catholic Relief Services in the Gambia and manufactured by local artisans; the Mini-SISMAR/ISRA 1 and II dehullers developed by the Centre Nationale de Recherches Agronomiques and a large manufacturing company SISMAR in Scnegal; and the Mini-ENDA dehuller developed by ENDA in Zimbabwe.

The PRL, RIIC and NUHULL dehullers are larger machines with aspiration systems for bran removal, whereas the Mini dehullers have lower capacities and operate in the batch mode. Typical features of these two sizes of machines are shown in Rgs. 2 and 3. Abrasive surfaces used in the dehullers arc in the form of carbonmdum stones or lightweight resinoid discs. Some of the main features and specifications of the dehullers are shown in Tables 1 and 2.

Some of the advantages of the abrasive disc dehuller over others mentioned earlier are: its operating principle is simple; it is potentially lower in price; it can be easily operated by persons with little technical skills; it can effectively dehull the grains in their dry state; it can dehull a wide variety of cereal grains and grain legumes without adjusting the geometry of the machine; it can dehull an assorted mixture of grains in the same batch.

ASPECTS OF DEHULLER'S PERFO:RMANCE

Laboratory and field studies [6] indicate that the performance of abrasive disk dehullers depend on:

- speed of rotation of the disks;
- physical characteristics of the disk surface such as roughness and hardness;
- number and diamcter of disks in the barrel, reflecting the total surface area available for dehulling;
- spacing betwcen disks and their angle of inclination to the shaft;
- distance between the end disks and the end plates of the barrel;
- clearance between the periphery and the barrel;
- presence or absence of aspiration during dehulling;
- roughness of the inner surface of the barrel;
- the rate at which grains are fed into the dehuller in the continuous mode, and the quantity of grain in the dehuller in the batch mode;

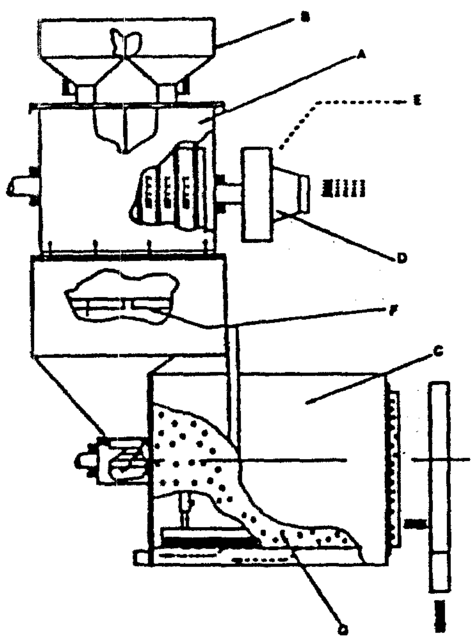

Figure 2. **Schematic showing specific features of the Mini-SISMAR/ISRA II dehuller:** A, dehullers; B, feed box; C, separator; D, aspirator; E, to cyclone; F, two trap doors; G, sieve. Solid arrows, movement of grains; broken arrows; bran (courtesy of SISMAR, Senegal).

- residence or retention time of the grain in the dehuller;
- physical characteristics of the grain being dehulled.

Available results are discussed in this section.

Effect of Speed of Rotation of Disks

Results of studies of three models of abrasive disk dehullers, using barley, sorghum and millet, have been reported [7]. The dehullers used were: a Graham Hill Thresher containing 13 Carborundum stones 30.5 cm in diameter and 3.2 cm thick; an experimental Resinoid Disk Dehuller containing 27 resinoid steel cut-off disks, 30.5 cm in diameter and 0.64 cm thick;

Dehuller Type	Through put kg/hr	Mode of Operation	Batch Size kg	Bran Aspiration
PRL	250-500	Cont.*		yes
RIIC	<800	Cont./Batch	5-15	yes
NUHULL	200-500	Cont./Batch	5-15	yes
Mini-PRL	80	Batch	7	no
Mini-CRS	80	Batch	7	no
SISMAR/ ISRA I	80	Batch	7	no
SISMAR/ ISRA II	80	Batch	2-8	no
Mini-ENDA	100	Batch	15	no

Table 2. Mode of operation and quantity of grains processed

* "Cont." means continuous mode.

an RIIC dehuller containing 13 carborundum stones 25.4 cm in diameter and 1.9 cm thick [7]. Typical results obtained are shown in Fig. 4 for disk speeds of 1300, 1700 and 2000 RPM. The degree of dehulling increases with the duration of dehulling (the retention time), for a given disk speed. Increasing this speed increases the degree of dehulling. For a given machine, therefore, optimum dehulling can be obtained using disk speed as a variable parameter. Similar results have been obtained with all the other dehuller models mentioned earlier using other cereals and grain legumes [6].

Configuration of Disks in Barrel

The gap between disk surfaces ranges from 1.5 to 3 cm [6] depending on the dehuller model. Obviously, the smaller the gap between disks, the larger the number of disks and the higher would be the degree of dehulling for a given operating condition. However, the quantity of grain dehulled would be reduced as the distance between the disks is decreased, and the energy consumption would increase. Thus for economical operation, the disk spacing should be maximized. Systematic studies to facilitate the choice of the optimum distance between disks have not been undertaken.

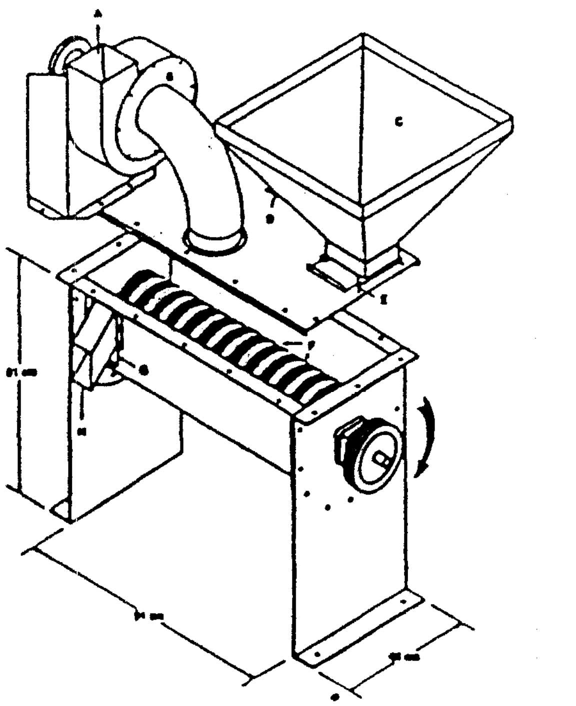

Figure 3. Exploded view of the PRL: A, bran to cyclone; B, fan; C, grain hopper; D, air inlet; E, feed gate; F, abrasive disks; G, adjustable gates; 1-l, overflow outlet for dehuller grains (from [6]).

Laboratory [7] and field [9] observations indicate that inclining the lightweight disks at the end of the dehuller to the vertical, improves the unifonnity of dehulling. The angle of inclination of the disks have ranged from 9 degrees [7], to 5 degrees which eliminated disk breakage [9], probably due to the reduction of the rotational stresses. Inclining all of the disks is expected to reduce dehulling time and improve the degree of dehulling but results arc not available to confirm the benefits of this arrangement. Improvement of the uniformity of dehulling has also been achieved by reducing the gap between the disks at the cnd of the shaft and the end plates of thc dehuller [10].

Effect of Grain Type

The performance of the dehuller depends on the type and variety of the grain being dehulled. Factors that influence dehulling have been discussed [6]. They are the pericarp thickness and hardness of thc grain.

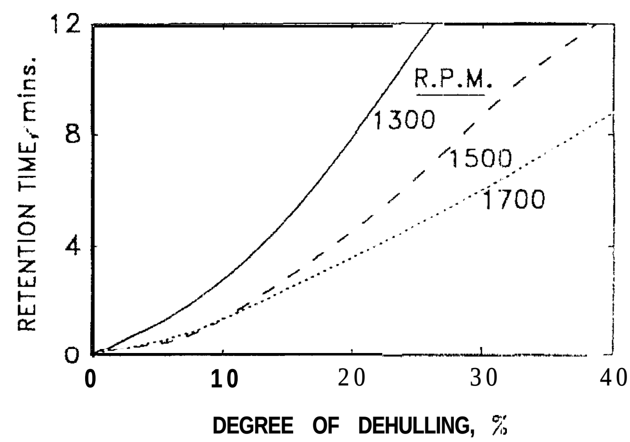

Figure 4. Effect of disk speed on Resinoid Disk Dehuller performance.

Effect of Mass of Grain in Dehuller

In practice the mass of grain dehulled in mills varies from 0.5 to over 20 kg. The speed of rotation of the disks, which is usualiy fixed for a given mill, depends on whether grinding stones or rcsinoid disks are used. The retention time is thus the parameter used to control the degree of dehulling of the grains.

Detailed studies on the effect of mass of grain used on dehuller performance arc availablc for several Mini dehullers [8, 10, 11]. Results for quantities of millet between 2 and 8 kg, which is similar for other grains, is shown in Fig. 5 for various disk speeds. Holding all other parameters constant. the degree of dehuiling increases as thc mass of the grain in the dehuller barrel is increascd.

Typical results for quantities ranging from 0.5 to 8 kg in the Mini-SISMAR/ISRA 1 machine using resinoid discs [10] is shown in Fig. 6. The degree of dehulling decreases with increasing mass of grain for loads less than 2 kg.

The following explanation can be givcn for the results in Fig. 6 using Fig. 7. At very low loads thc grain at level 1 in Fig. 7 is not in contact with thc disc; there

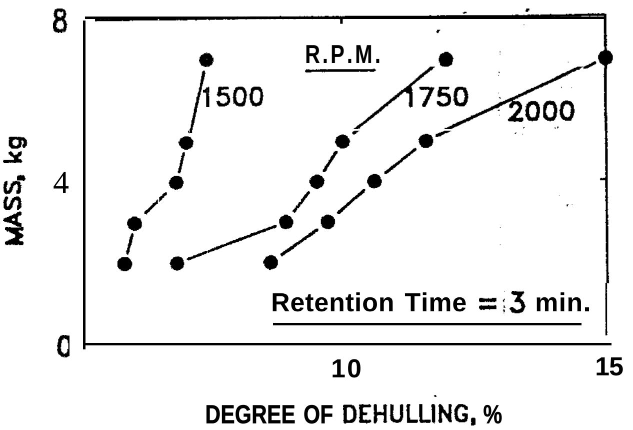

Figure 5. Effect of mass of grain on degree of dehulling for large quantities of grain in a Mini-PRL dehuller using carborundum stones.

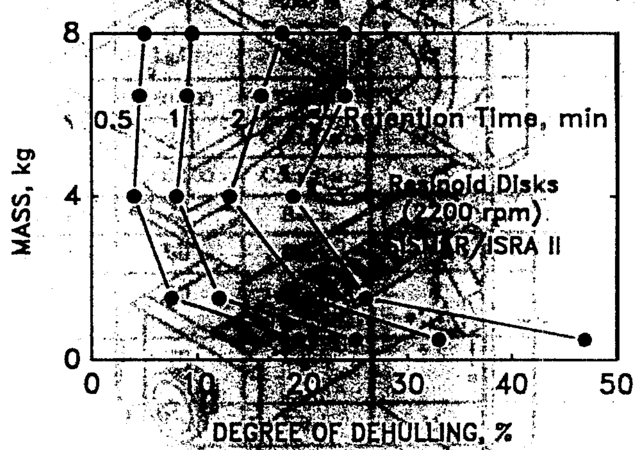

Figure 6. Effect of mass of grain on degree of dehulling of grain in a Mini-PRL dehuller using resinoid disks.

is no motion of grain, hence no dehulling. As the grain reaches level 2, the air motion caused by the rotating disks entrains grains which are then flung against the walls of the barrel. They break into fine particles, giving the impression that the grain is being dehulled. This effect increases significantly as the mass of grain increases between level 2 and 3, a maximum being attained at level 3 where the disk is now touching the grain imparts more kinetic energy to the grains. Between levels 3 and 4, the disks now embedded in the grain abrade the lighter envelope of the grains, giving an apparent decrease in the degree of dehulling. Above level 4, the degree of dehulling increases as the grains continue to be abraded.

It is hypothesized that the dehulling that occurs when the grain is between level 3 and 4 is predominantly due to friction between the rotating disks and the grains. As level 4 is surpassed, it is suggested that the dehulling is a contribution of the abrasion between disks and grain and between grains. (Bran in the barrel is considered to be part of the grain). The responsibility of the disk/grain and grain/grain interaction for the dehulling after level 4 may be supported by the fact that the degree of dehulling is decreased in practice if the bran is aspirated during dehulling. Observations of dehulling in the PRL dehuller indicates that this machine, which has aspiration, gives dehulled products with significant percentage of broken grains, whereas the Mini dehuller, which dehulls before separation of the grain and bran occurs, produces less broken grains.

The above discussion implies that in practice, the dehuller should operate [illegible] as possible, above level 4. This has been incorporated in the design of the Mini-SISMAR/ISRA II and in a Mini-CRS model so that the grain is above level 4 when about 0.5 kg is being dehulled.

Disk Wear

Disk wear is also related to the mass of grain being processed in the dehuller, although there are as yet no conclusive results on this aspect of dehuller performance. Results of field tests in Senegal [11] indicated that substantial disk wear occurred in machines installed in villages where batch dehulling of between 2 to 3 kg was done, compared to villages where batches were greater than 6 kg. Table 3 shows typical results of disk wear in two villages using similar grains and operating conditions, but using different batch sizes. The average wear as reflected in the diameter, thickness and mass of the disks is significantly greater in the village where 4 tonnes were

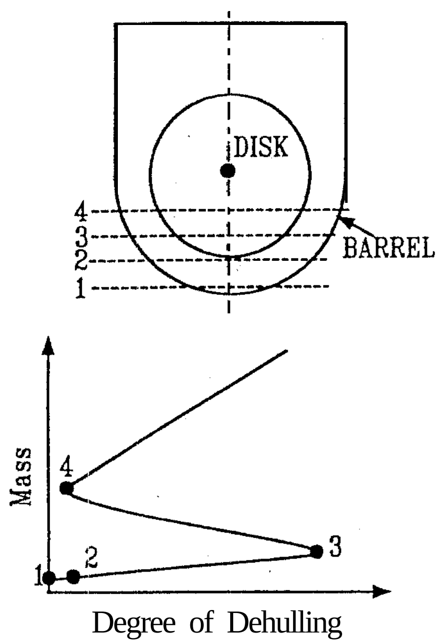

Figure 7. Diagram used to explain the effect of mass of grain on the degree of dehulling.

processed (in batch sizes less than 3 kg), compared to the village where 24 tonnes were being processed (in batch sizes greater than 6 kg).

Effect of Grinding Surface

Studies in Senegal [10] and in Canada [7] indicated that resinoid disks, which are smoother than carborundum stones, give better performance as indicated by degree of dehulling, uniformity of dehulling and power consumption. Mechanical aspects of the dehulling action between grinding stones and grain have been discussed [6]. Important characteristics of grinding stones for the dehullers appear to be grit size, the grade (proportion of bonding material) and the surface dressing. Examples of abrasive discs that have been used are:

- carborundum stones made of coarse grit silicon carbide abrasives (85% of the total composition) with vitrified clay bonds
- resinoid disks made of medium-grit aluminum oxitie abrasive (67%), cured phenol formaldehyde resin bond (14%), Fluorspar (10.6%) and reinforced with fibreglass (7%) to improve their strength.

The comparative performance of Iightweight disks and grinding stones can summarized as follows:

- Coarse grit stones abrade grains much faster than the smoother- faced resinoid disks but the colour of the resulting flour indicates that the resinoid disks produce more uniform dehulling as demonstrated by reflectance measurements.
- Grinding stones with coarse grit should be rotated at lower speeds in order to produce dehulling comparable to resinoid disks.
- Grinding stones consume more energy compared to lighter weight disks.

Results for the dehulling of maize using a Mini-PRL dehuller using 5 carborundum disks (3 kg each) and 8 resinoid disks (0.15 kg each) [10] are shown in Fig. 8. The carborundum stones consume more fuel to achieve a given degree of dehulling due to their weight and surface friction effect.

Effect of Internal Lining in Barrel

The interaction between disks and grain, grain and grain, and grain and the barrel wall is complex and not well understood. Observations made during the development of the RIIC dehuller, for example, indicated differences between results for a bare wall and one lined with rubber. The degree of dehulling was improved when the wall was lined with a rubber material; the dehulling was less uniform, and power consumption was increased [7] as shown in Table 4.

Power consumption is increased due to the restricted motion of the grains by the lining, and the resulting increased resistance to the rotation of the disks. This is because the lining restricts the motion of the grains near the wall, causing higher resistance to the rotation of the disks. In general the grains near the wall are less dehulled than thosc near the disks.

Areas for Further Studies

Although the mechanical performance of abrasive disc dehullers is satisfactory, the socio-economic

Disk No.	Bignona (24 t dehulled)†			Handallaye Tessan (4 t dehulled)‡		
	Dia. (mm)	Thick. (mm)	Mass (g)	Dia. (mm)	Thick. (mm)	Mass (g)
1	229	34	287.6	202	31	215.4
2	230	32	275.1	159	30	130.9
3	232	33	299.7	164	33	142.7
4	233	33	295.7	162	33	140.0
5	230	32	289.1	166	33	149.9
6	325	30	287.1	174	33	163.4
7	225	31	246.2	174	33	162.4
8	228	32	274.3	175	34	167.6
9	228	30	266.4	180	35	180.2
10	224	31	249.0	227	32	278.1
AV.**	229	32	277.0	178	33	173.1
% wear*	9.7	11.7	25.2	29.8	9.2	53.3

Table 3. Wear experienced by resinoid disks at village mills in Senegal.

** Average value for all 10 disks,
* Percentage wear with respect to new disks: diameter = 25.4 cm, thickness = 3.6 cm, mass = 370.3 g.
†Each batch dehulled greater than 6 kg.
‡Each batch dehulled between 2 and 3 kg.

viability of their operation is very often in question mainly due to the inability of rural women to pay for dehulling services, which is less than US$ 0.1/kilo of grain. Thus any changes in the design and/or operating conditions of the dehuller aimed at reducing its capital and operating costs would allow it to be more widely used. These technical changes can be obtained by improving the understanding of the performance of the dehuller.

There is a need to describe the mechanics of the interaction between the abrasive discs, the grain and the internal wall of the barrel. In such an investigation, it would be informative to determine the optimum spacing between discs and how to maximize the mixing of the grain so that uniform dehulling is obtained. Results of such a study should lead to the

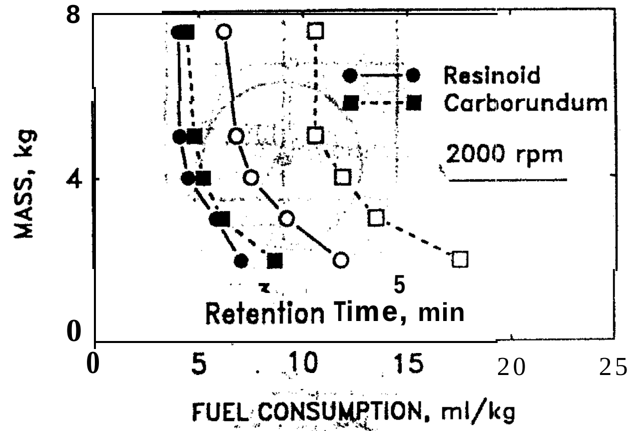

Figure 8. Comparison of the effect of abrasive disk types on power required by Mini-PRL dehuller.

proper sizing of dehullers for given loads, reduction of energy consumption and minimization of disk wear, with the ultimate reduction of capital and operating costs.

Since the major component of thé dehuller is the abrasive disks, it is of interest to investigate the effects of various types of discs on the dehulling of grains. Emphasis should be placed on longevity of disc surfaces and techniques for local manufacture.

Internal Surface	Disk Speed (rpm)	Through-put (kg/hr)	Power Input hp-hr/t	Degree of Dehulling (%)
Without liner	1300	518	7.26	14
	2000	1273	4.40	13
With liner	1300	636	8.58	14
	2000	1053	6.16	20

Table 4. Effect of liner in RIIC dehuller on power consumption, throughput and degree of dehulling for a given flour colour for sorghum

CONCLUSIONS

Abrasive; disk dehullers have several features which make them superior to other dehullers for use in developing countries. Their Performance is dependent on the types of grains, the physical arrangement and speed of rotation of the disks, the retention time, the internal surface of the. dehuller barrel, mass of grain being dehulled and the presence or absence of aspiration of the bran.

Their performance can be improved by studies aimed at understanding the mechanics of the dehulling process, i.e., the interaction between rotating disks, grains and the internal surface of the barrel. The development of appropriate abrasive surfaces that are durable and cheaper would encourage the wide spread use of the dehullers.

ACKNOWLEDGEMENTS

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REFERENCES

1. HULSE, J.H., LAING, E.M., and PEARSON, O.E., "Sorghum and the Millets, Their Composition and Nutritive Value", Academic Press, Toronto, Canada.
2. DOHERTY, C., ROONEY, L.W. and FAUBION, J.M., 1981, "Phytin Content of Sorghum and Sorghum Products", *Proceedings, International Symposium on Sorghum Grain Quality*, Oct. 28-31, ICRISAT, Patancheru, India. pp. 329-333.
3. OSMAN, A.K. 1981, "Bulrush Millet (Pennisetum typhoides) - a Contributory Factor to the Endemicity of Goitre in Western Sudan", *Ecology of Food and Nutrition*, Vol. 11, pp. 121-128.
4. GAITAN E. et al, 1986, "C-glycosyflavones: Goitrogens in Millet", *Frontiers in Throidology*, eds. Medeiros-Neto, G., and Gaitan, G., Vol. 2, Plenum Medical Book Company, N. Y.
5. REICHERT, R.D., 1981, "Sorghum Dry Milling", *Proceedings International Symposium on Sorghum*, Nov. 2-7, ICRISAT, Patancheru, A. P. India, pp. 547-563.
6. BASSEY, M.W. and SCHMIDT, Q.G., 1989, "Abrasive-Disk dehullers in Africa: from Research to Dissemination", *International Development Research Centre*, Ottawa, Canada.
7. OOMAH, B.D., REICHERT, R.D. and YOUNGS, C.G., 1981, "Quantitative Comparison Between Carborundum Stones and Resinoid Disks in Dehulling Cereal Grains", *Cereal Chemistry*, Vol. 58, No. 6, pp. 492-496.
8. MBENGUE, H.M., 1986, "Création d'un décortiquer au Sénégal, Premier Rapport Intérinaire", *Projet 3-P-84-0016-02*, Septembre. Centre Nationale de Recherches Agronomiques de Bambey, Sénégal.
9. NANCE, J.P., 1987, "Gambian Grain Dehuller, Final Report Phase One", Catholic Relief Services, The Gambia.
10. MBEMGUE, H.M., 1987, "Création d'un décortiqueur au Sénéegal, Deuxieme Rapport Intérinaire", *Projet 3-P-84-0016-02*, Centre Nationale de Recherches Agronomiques de Bambey, Sénégal.
11. MBENGUE, H.M., 1988, "Création d'un décortiqueur au Sénégal, Troisième Rapport Intérinaire", *Projet 3-P-84-0016-02*, Centre Nationale de Recherches Agronomiques de Bambey. Sénégal.