International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jet.htm
2014 Vol. 4 (2) April-June, pp.125-131/Kaankuka et al.
Research Article

EFFECT OF CYLINDER TYPE AND SPEED ON ACHA (*DIGITARIA EXILIS*) DEHULLING

***T.K. Kaankuka, I.N. Itodo and S.E. Obetta**
Department of Agricultural and Environmental Engineering,
University of Agriculture, Makurdi, Benue State, Nigeria
**Author for Correspondence*

ABSTRACT
This study was carried out to determine the effects of cylinder type and speed on acha dehulling. The performance of the dehulling unit for; rate of operation, percentage undehulled acha, dehulling efficiency, acha recovery efficiency and dehuller performance index against three different rasp bar cylinder types (open, closed and abrasive) using three different cylinder speeds of 1630 rpm (12.46 m/s), 2200 rpm (13.82 m/s) and 2800 rpm (14.66 m/s) were carried out. The cylinder-concave clearance of 10 mm was kept constant. The experimental design was a Completely Randomized Design (CRD) in a 3 x 3 factorial arrangement. The data obtained were analysed using ANOVA at a probability level of $p \leq 0.05$ for the test of significance. The study showed that the abrasive cylinder type gave a better performance at the speed of 2800 rpm.

Key Words: *Acha, Cylinder types, Dehulling unit, Fonio, Rasp bar*

INTRODUCTION

Acha also known as fonio is perhaps the World's fastest maturing cereal, producing grains just 6 or 8 weeks after they are sown (TNAP, 1996). The semi-late and late varieties take 100 to 120 days and 150 days to mature respectively. Each year West African farmers devote approximately 300,000 hectares of land to cultivating acha (TNAP, 1996 and Jideani, 1999). According to Cruz (2004), acha is grown on more than 380,000 hectares and produces 250,000 tonnes of grains annually. The crop supplies food to 3 – 4 million people (TNAP, 1996).

Dehulling acha is a difficult and time-consuming task because of the extremely small size of the grain. The average length of acha is 1.604 mm, with a one thousand grain mass of 0.529 g (Philip, 2011). This is in agreement with the nearly 2000 grains to one gram given by Cruz (2004). The threshed grain still surrounded by husks or hull is called "acha paddy" or "raw acha".

The enacted grains in protective hulls are released by pounding with mortar and pestle, which produce impact and rubbing action in a process called dehulling or dehusking (Gyang and Wuyep, 2005). According to Kwa (written communication, undated) when using cylinder and concave as a mechanical means of dehulling, the removal of the hulls is achieved as acha seeds are carried on the periphery of a cylinder and held there by centrifugal force due to the rotation of the cylinder. The differential movement between the cylinder and concave effects the dehulling process in the same way the pestle effects the dehulling process during the downwards stroke. Dehulling of the acha seeds consists mainly of impact and shearing by the external forces exerted on each seed between the cylinder and concave.

There are different cylinder types used for threshing and dehulling. The type of cylinder used is one of the major factors affecting dehulling. Tandon *et al.* (1988) considered five parameters that influenced threshing efficiency and kernel damage, namely, cylinder peripheral speed, cylinder type, concave type, concave clearance and grain moisture content. They reported that concave clearance and cylinder peripheral speed had significant effect on the threshing efficiency and grain damage for pulse threshers.

While cereal could accommodate smaller concave setting and higher cylinder speed, legume crops such as beans and peas need a wider concave setting and lower speed to avoid cracking. Generally, the smaller and finer the grain to be shelled or threshed is the smaller the required concave clearance and the higher the speed requirements (Klein and Harmond, 1986).

Efforts have been made in some West African countries to develop dehulling machines that will facilitate the processing of fonio. Marouzé *et al.* (2008) reported that using the Engelberg type principle is not suitable for acha dehulling. In Senegal fonio (acha) husk is removed by manually pounding the grains in sand for an hour. Once the husks are removed by friction with the sand, meticulous washing was needed to isolate the grains. A Senegalese, Sanoussi Diakité developed a acha dehulling machine known as the "Sanoussi". Rotating abrasive fibers exercise a rubbing action on the acha. However using "Sanoussi" principle, Marouzé *et al.* (2008), reported a low output of about 25 kg/hr with a high percentage of broken grains. Tokan *et al.* (2012) developed an acha husking machine that uses a pair of knurled rollers at a speed ratio of 1.5:1, this enabled frictional forces to be developed for husking. They reported that 5 kg of acha was dehusked in 15 minutes.

Acha dehulling is yet to be mechanized in Nigeria. In order to increase acha production, the development of acha dehuller has therefore become necessary. Traditional dehulling is very tedious and time consuming (Vietmeyer *et al*., 1996; Kwon-Ndung and Masari, 1999), with each woman hulling between 1 and 2 kg/h (CIRAD, 2004; Cruz, 2004), constituting a major bottleneck in its processing and utilization. Thus, mechanizing the processing of acha is essential, both to reduce the painstaking work for women and to improve the quality and availability of the product in the market. The dehulling unit plays a key role in determining the performance of a dehuller. Therefore, the study was conducted to evaluate the performance of different cylinder types (open, closed and abrasive) and cylinder speed (1630 rpm, 2200 rpm and 2800 rpm) on acha (*Digitaria exilis*) dehulling.

MATERIALS AND METHODS

The commonly grown acha variety (*Digitaria exilis*) was used for this study. The dehulling mechanism consisted of a dehulling cylinder which rotates inside a concave. Some acha properties and machine specifications used for the experiment are presented in Table 1.

Table 1: Some Acha Properties And Machine Specifications Used For The Experiment

S/N	Variables	Levels/Specifications
1	Acha variety	*Digitaria exilis*
2	Acha moisture content (%)	8.31
3	Concave diameter (mm)	190
4	Concave length (mm)	260
5	Cylinder concave clearance (mm)	10
6	Length of Shaft (mm)	460
7	Length of threshing cylinder (mm)	220
8	Cylinder diameter (mm)	170
9	Cylinder speed (rpm)	1630, 2200, and 2800
	(m/s)	12.46, 13.82, and 14.66
10	Cylinder (rasp bar types)	Abrasive, Closed and Open

The acha dehulling unit operates on the principle of axial flow movement of material, and dehulling takes place by impact and rubbing actions in the concave clearance. The values of the weighed dehulled and undehulled acha, the time taken to dehull, and the weighed chaff were used to determine the performance parameters of the cylinders at each combination variables. An electric motor with a rating of 1 hp and speed of 1400 rpm was used to run the machine. During the test period, the speed of the shaft was recorded using a tachometer. Dehulling time was recorded using a stop watch. Samples were taken from the grain and chaff outlets for evaluation. Some of the machine adjustments such as for the blower, orifice opening, cylinder concave clearance and output control were all kept constant throughout the experiment. They had proved satisfactory in the preliminary tests.

A closed, open and abrasive type of rasp bar cylinders (Fig. 1) were designed, constructed and fitted on the machine one after the other to evaluate their performance. Undehulled acha of 1 kg sample was used for each of the experiment. The evaluation for the cylinders were undertaken at the speeds of 1630 rpm (12.46 m/s), 2200 rpm (13.82 m/s) and 2800 rpm (14.66 m/s) in a 3 x 3 two-factor experiment that was replicated thrice in a Completely Randomized Design (CRD). The results were analyzed using ANOVA at $p \leq 0.05$ to determine if cylinder type and speed had any significant effect on the dehulling efficiency. The means were separated using Fisher-Least Significant Difference (FLSD) at $p \leq 0.05$.

Description of the concave and dehulling cylinders

The dehulling unit was made up of the cylinder and concave. The concave which enclosed the cylinder was constructed from closely welded mild steel rods of 5.6 mm. All the cylinder types (Fig. 1) were of 170 mm diameter and length of 220 mm. Shafts of 25 mm diameter having lengths of 460 mm were passed through the center of the cylinders and the end plates. To each end of the shaft was welded a circular mild steel (160 mm diameter x 3 mm thick) which was slightly twisted to form a spiral conveyor that aided the movement of acha in the dehulling chamber.

For the abrasive cylinder, an abrasive material of 1.25 mm thick was wrapped round the formed cylinder (Fig. 1). The closed cylinder type was constructed from mild steel rods of 5.6 mm which were welded together diagonally. The open cylinder type was constructed from mild steel rods of 5.6 mm diameter arranged diagonally and welded at gaps of 12 mm between each rod.

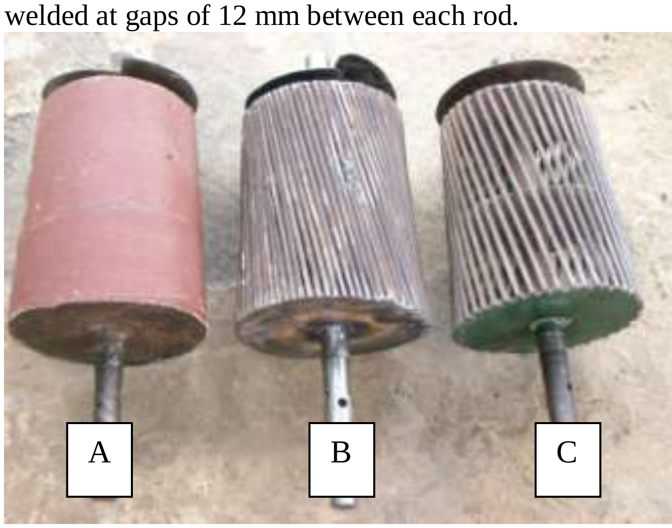

Figure 1: Dehulling cylinder types: Abrasive (A), Closed (B) and Open (C) cylinder

RESULTS AND DISCUSSION

Table 2 is a summary of the ANOVA of measured parameters for different cylinder types and speeds. The performance of the cylinder types with different cylinder speed levels for rate of operation, percentage undehulled acha, dehulling efficiency, acha recovery efficiency and dehuller performance index are presented in Table 3.

Table 2: Summary of the Anova of measured parameters for different cylinder types and speeds

Parameter	*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rate of Operation, kg/h	Cylinder Type (T)	1440.08	2	720.0401	121.0208*	3.65E-11	3.554557
	Cylinder Speed (S)	4148.883	2	2074.442	348.6619*	4.05E-15	3.554557
	Interaction (TxS)	628.6132	4	157.1533	26.41355*	2.55E-07	2.927744
	Error	107.095	18	5.949722			
	Total	6324.672	26				
Percentage Undehulled	Cylinder Type (T)	1053.734	2	526.867	51.88347*	3.37E-08	3.554557
	Cylinder Speed (S)	6926.794	2	3463.397	341.0596*	4.91E-15	3.554557
	Interaction (TxS)	485.4837	4	121.3709	11.95206*	6.46E-05	2.927744
	Error	182.7867	18	10.15481			
	Total	8648.799	26				
Dehulling Efficiency	Cylinder Type (T)	1074.176	2	537.0878	54.65409*	2.26E-08	3.554557
	Cylinder Speed (S)	6914.082	2	3457.041	351.7888*	3.74E-15	3.554557
	Interaction (TxS)	464.3022	4	116.0756	11.81186*	6.96E-05	2.927744
	Error	176.8867	18	9.827037			
	Total	8629.447	26				
Acha Recovery Efficiency	Cylinder Type (T)	757.2896	2	378.6448	44.27444*	1.12E-07	3.554557
	Cylinder Speed (S)	3395.014	2	1697.507	198.4872*	5.44E-13	3.554557
	Interaction (TxS)	234.9148	4	58.7287	6.867069*	0.001537	2.927744
	Error	153.94	18	8.552222			
	Total	4541.159	26				
Dehuller Performance index	Cylinder Type (T)	523.6184	2	261.8092	26.78424*	4.03E-06	3.554557
	Cylinder Speed (S)	3256.639	2	1628.319	166.5843*	2.44E-12	3.554557
	Interaction (TxS)	208.2158	4	52.05396	5.325351*	0.005212	2.927744
	Error	175.9455	18	9.774748			
	Total	4164.419	26				

** = significant at $p \leq 0.05$ level, ^{ns} = not significant at $p \leq 0.05$*

Table 3: Summary of mean effect of cylinder type and cylinder speed on acha dehulling

S/N	Parameter	Cylinder types								
		Open			Closed			Abrasive		
	Cylinder Speed (rpm)	1630	2200	2800	1630	2200	2800	1630	2200	2800
1	Rate of operation, F_r (kg/hr)	27.32[a]	59.23[b]	63.28[b]	20.47[a]	42.45[b]	48.18[c]	22.56[a]	27.07[b]	48.67[c]
2	Percentage undehulled acha, P	59[a]	36[b]	26[c]	55[a]	23[b]	27[b]	53[a]	18[b]	5[c]
3	Dehulling efficiency, η_D (%)	41[a]	64[b]	74[c]	45[a]	77[b]	74[b]	47[a]	82[b]	95[c]
4	Acha recovery efficiency, η_A (%)	30[a]	47[b]	55[c]	35[a]	60[b]	54[c]	38[a]	62[b]	70[b]
5	Dehuller performance index, E_{pi}	28[a]	45[b]	53[c]	34[a]	58[b]	53[c]	35[a]	57[b]	65[b]

Means having the same letter in the same row for each cylinder type are not statistically different from each other at $p \leq 0.05$ using FLSD

Effect of cylinder type and cylinder speed on rate of operation

Table 2 is a summary of the ANOVA of measured parameters for different cylinder types and speed. The rate of operation increased with increasing cylinder speeds of the three cylinder types investigated (Table 2). In the mean separation, the rate of operation was significantly different at all the speeds investigated for the closed and abrasive cylinder types. However, for the open cylinder type, there was no significant difference in the rate of operation at the speeds of 2800 rpm and 2200 rpm. This suggests that the speed of 2800 rpm or 2200 rpm could be used. However, a speed of 2200 rpm should be used to reduce power consumption, because according to Joshi (1981) increase in cylinder speed, increases the power requirement at the main shaft. The open cylinder type gave the highest rate of operation of 63.28 kg/hr at the speed of 2800 rpm of the three cylinder types investigated, while the closed cylinder gave the least of 48.18 kg/hr at the same speed. The least rate of operation of 20.47 kg/h was obtained with the closed cylinder at a speed of 1630 rpm.

Effect of cylinder type and cylinder speed on percentage undehulled acha

The percentage undehulled acha was significantly different at all the cylinder types, speeds and their interactions (Table 2). It was observed that with increasing cylinder speeds the percentage undehulled acha reduced. However, the closed cylinder had higher undehulled acha at the speed of 2800 rpm (27%) than 2200 rpm (23%), but there was no significant difference (Table 3) between them. This suggests that the speed of 2800 rpm or 2200 rpm could be used for the closed cylinder, but to reduce power consumption the speed of 2200 rpm should be used.

For all the speeds investigated the abrasive cylinder gave the least percentage undehulled acha (5%), followed by the closed cylinder (23%) then the open cylinder (26%). The cylinder speed of 1630 rpm gave the highest percentage undehulled acha for all the three cylinder types investigated. It can be seen that the higher the cylinder speed the lower the undehulled acha, this is in agreement with Klein and Harmond, (1986) who reported that, the smaller and finer the grain to be shelled or threshed the smaller the concave clearance required and the higher the speed requirements.

Effect of cylinder type and cylinder speed on dehulling efficiency of acha

Dehulling efficiency increased with increasing cylinder speed for the cylinder types (Table 3). The result is in the agreement with that obtained by Alonge and Adegbulugbe (2000) who evaluated a grain Thresher-II and observed increase shelling efficiency with increase in speed, Desta and Mishra (1990), while evaluating sorghum (grain) thresher observed same trend of increase in threshing efficiency with increased speed, Rizvi *et al.* (1993) observed increase in sunflower threshing with increased drum speed.

It was observed that the dehulling efficiency was significantly different for all the cylinder types, cylinder speeds and their interaction (Table 2). The dehulling efficiency increased with increasing cylinder speeds for the open and abrasive cylinder types. However, the trend was a bit different for the closed cylinder, the speed of 2200 rpm (77%) had a higher dehulling efficiency than the speed of 2800 rpm (74%), but there was no significant difference (Table 3). This suggests that for the closed cylinder, the speed of 2800 rpm or 2200 rpm could be used, but to reduce power consumption the speed of 2200 rpm should be used. For all the speeds investigated the abrasive cylinder gave the highest dehulling efficiency of 95% at a speed of 2800 rpm. The lowest dehulling efficiency of 41% was recorded with the open cylinder at a speed of 1630 rpm.

Effect of cylinder type and cylinder speed on acha recovery efficiency

It was observed that the acha recovery efficiency was significantly different at all the speeds investigated for the three cylinder types and their interaction (Table 2). Table 3 shows that the acha recovery efficiency increased with increasing cylinder speed for the open and abrasive cylinders investigated. In terms of significant difference for the abrasive cylinder for the speeds of 2800 rpm and 2200 rpm there was no difference. However, a different trend was observed for the closed cylinder, the speed of 2200 rpm gave higher acha recovery efficiency than the speed of 2800 rpm of 60% and 54% respectively. The abrasive cylinder gave the highest acha recovery efficiency of 70% at 2800 rpm while the least was from the open cylinder which was 30% at the speed of 1630 rpm.

Effect of cylinder type and cylinder speed on dehuller performance index

Dehuller performance index was significantly different for all the cylinder types, speeds and their interaction (Table 2). The higher the speed the higher the dehuller performance index, however, for the closed cylinder the speed of 2200 rpm gave a higher dehuller performance index than the speed of 2800 rpm (Table 3). There was no significant difference in the dehuller performance index between the speeds of 2800 rpm and 2200 rpm when the abrasive cylinder was used. However, the highest dehuller performance index of 65% was obtained from the abrasive cylinder at the speed of 2800 rpm while the lowest dehuller performance index of 28% was obtained from the open cylinder at a speed of 1630 rpm.

Conclusion

The efficiencies of the mean results from the parameters evaluated showed that the best result was obtained from the abrasive cylinder, followed by the closed and the open cylinder. For most of the parameters investigated, efficiencies increased with increasing speeds of 1630, 2200 and 2800 rpm. The abrasive cylinder gave the best result probably because of its rough surface which gave better rubbing and shear effect on the acha which is the best action for dehulling. From literature, smaller seeds require higher speeds for effective dehulling which could be the reason why the higher speed of 2800 rpm gave the best result. The mean best result recorded for percentage undehulled acha, dehulling efficiency, acha recovery efficiency and dehuller performance index were 5%, 95%, 70% and 65% respectively from the abrasive cylinder at the speed of 2800 rpm. The closed cylinder gave better results than the open cylinder but at the cylinder speed of 2200 rpm. The open cylinder gave the highest rate of operation of 63.28 kg/hr compared to the abrasive and closed cylinders which gave 48.67 kg/hr and 48.18 kg/hr respectively.

Considering the results from the performance parameters, the abrasive cylinder type gave a better result at an interactive speed of 2800 rpm (14.66 m/s).

REFERENCES

Alonge AF, and Adegbulugbe TA (2000). Performance evaluation of a locally developed grain thresher – II. *Journal of Agricultural Mechanization in Asia, Africa and Latin America*. **31**(2) 52 – 54.

CIRAD, French Agricultural Research Centre for International Development. (2004). Fonio: An African cereal crop. Accessed: April 2010, *Available:* http://fonio.cirad.fr/index.php/fonio_en

Cruz JF (2004). Fonio: a small grain with potential. *LEISA magazine on low external input and sustainable Agriculture.* LEISA INDIA, Vol. 6. Issue 1 – Valuing crop diversity. Pp. 16-17. *Available:*http://www.leisa.info/index.php

Desta K and Mishra TN (1990). Development and performance evaluation of a sorghum thresher. *Agricultural Mechanization in Asia, Africa and Latin America.* 21(3) 24-29

Gyang JD and Wuyep EO (2005). Acha: The grain of life. *Raw Materials Update. A Bi-annual publication of the Raw Materials Research and Development Council*. **6**(1) 39-41.

Jideani IA (1999). Traditional and possible technological uses of *Digitaria exilis* (acha) and *Digitaria iburua* (iburu): *A review. Plant Foods for Human Nutrition* 00:1-13. Kluwer Academic Publishers. Printed in the Netherlands.

Joshi HC (1981). Design and selection of thresher parameters and components. *Agricultural Mechanization in Asia, Africa and Latin America,* **12**:61-68

Klein LM and Harmond JE (1986). Effect of varying cylinder speed and clearance of threshing cylinder in combing crimson clover. *American Society of Agricultural Engineering Trans*. **9**(4) 499 - 500

Kwon-Ndung EH and Misara SM (1999). Overview of Research and Development of fonio (*Dagitaris exilis* Kippis Stapf) and Prospects of Genetic Improvement in Nigeria. In: *Genetics and food security in Nigeria.* GSN Publication, Nigeria. 71-76.

Marouzé C. Thaunay P, Fliedel G and Cruz JF (2008). Designing a fonio mill; screening and operating principle and Its validation. *Agricultural Mechanization in Asia, Africa and Latin America (AMA). Dec. 2008.* **39**(3) 9 – 15.

Philip TK (2011). Development of an acha (*Digitaria exilis*) dehulling machine. Unpublished PhD thesis, University of Agriculture, Makurdi, Benue State, Nigeria.

Rizvi SHA, Amjad N and Shaheren MD (1993). Comparative performance of different threshing drums for sunflower. *Journal of Agricultural Mechanization in Asia, Africa and Latin America,* **24**(1) 23-27

Tandon S, Kirirohi BS, and Sharma PRS (1988). Threshing efficiency of pulse using step-wise regression technique. *Agricultural Mechanization in Asia, Africa, and Latin America,* **19**(3) 55-57.

TNAP (The National Academy Press), (1996). Lost crops of Africa: Volume 1: Grains. Pp 59 – 76. *Available:* www.nap.edu/books

Tokan A, Danladi YB, Shekarau MBE and Datau SG (2012). Design, fabrication and testing of a fonio dehusking machine. *International Journal of Engineering innovation and Research.* 1(6) 489 – 399. *Available:*www.ijeir.org

Vietmeyer, NE, Borlaugh NE, Axte J, Burton JR, Harlan KO, and Rachie O (1996). Fonio (Acha). In: Lost Crop of Africa Vol. 1 Grains. BOSTID Publications National Academy Press, New York.