© MAR 2026 | IRE Journals | Volume 9 Issue 9 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I9-1715284

Performance Evaluation of an Acha Cleaning and Destoning Machine

BOMAN JAMES BATURE[1], SAMUEL ENYI OBETTA[2], THERESA KANGYANG KAANKUKA[3], OSIGBHEMHE GEORGE OSI.[4]
[1, 2, 3, 4] *Department of Agricultural and Biosystems Engineering, University of Agriculture, Makurdi, Nigeria*

Abstract- The main objective of the study was to carry out an intensive performance evaluation of an acha cleaning and destoning machine in order to determine the parameters that affect cleaning and destoning of acha grain. The parameters investigated were de-stoning efficiency and cleaning efficiency. The effect of speed variations (350, 425 and 500 rpm) and deck tilt angle variations (4, 8 and 12 degrees) were verified at 5 % level of significance using Analysis of Variance (ANOVA) and means separation using F-LSD.The performance indicators investigated were Throughput capacity (TP), De-stoning Efficiency (DE), Acha Separation Efficiency (ASE), Impurity Level post-Separation (IML), Cleaning efficiency (CE), Chaff Separation Efficiency (CSE) and Tray Losses (TL).The result showed that the means of throughput capacity, de-stoning efficiency, impurity level after separation, acha separation efficiency, cleaning efficiency and tray loss of the machine were in the range of 36.96 to 49.82 kg/hr, 1.91 to 11.06 %, 11.60 to 37.73 %, 84.31 to 25.09 %, 88.40 to 62.27 % and 86.15 to 69.55 % respectively. The best results for de-stoning efficiency, acha separation efficiency and cleaning efficiency were obtained at machine speed of 350 rpm and tilt angle of 4 degrees to be 84.31 %, 88 % and 86.15 % respectively. Minimum impurity level after separation and tray loss of the machine were obtained at machine speed of 350 rpm and tilt angle of 4 degrees to be 1.91 % and 11.60 %. Maximum throughput capacity was obtained at machine speed of 500 rpm and tilt angle of 12 degrees as 49.82 kg/hr.

Index Terms- Performance, Cleaning, De-stoning, Acha,

I. INTRODUCTION

Acha (*Digitaria exilis*), also known as fonio, is a highly nutritious cereal grain indigenous to West Africa. It has been a staple crop for centuries among communities in countries such as Nigeria, Mali, Burkina Faso, and Guinea due to its drought resistance, short growth cycle, and adaptability to poor soils (Adoukonou-Sagbadja et al., 2006; Temple et al., 1991). Despite its agronomic and nutritional advantages, being rich in methionine, cysteine, and dietary fiber, acha remains underutilized largely due to postharvest processing challenges (Vodouhè et al., 2003).

After threshing, grains contaminated material other than grains (MOG) such as earth, small pebbles, plant and insect wastes and seed cases. Removal of the MOG is therefore essential to upgrade the quality of food material. These impurities or MOG lower the quality of the product and are also a focal point for potential infestation during storage. "Cleaning" means the phase or phases of the post-harvest system during which the impurities mixed with the grain mass are eliminated (Bashiri *et al*., 2010).

Traditionally, processing acha involves labor-intensive and time-consuming operations such as threshing, winnowing, washing, drying, cleaning, and destoning. These methods, often conducted manually, are not only inefficient but also result in significant grain loss and poor product quality (Adebiyi et al., 2014). One of the most critical postharvest constraints is the cleaning and destoning stage, which directly affects the purity, safety, and market acceptability of the final product. Stones, sand, and chaff are difficult to remove from the tiny grains due to their small size and light weight, which closely resemble impurities (Adedokun et al., 2022).

In response to these limitations, an acha cleaning and destoning machine has been developed. However, the success of such machines extends beyond design and machine production, it requires strong user acceptance. Key factors influencing the adoption of processing technologies include ease of operation, machine capacity, maintenance demands, and affordability (Odey et al., 2017).A comprehensive evaluation of preference of the machine can provide critical insights into the design suitability and potential adoption of these machines.

This study focuses on the performance evaluation of an acha cleaning and destoning machine. The evaluation involves assessing parameters such as Throughput capacity, De-stoning Efficiency, Acha Separation Efficiency, Impurity Level post-Separation, Cleaning efficiency, Chaff Separation Efficiency and Tray Losses. Analyzing these parameters aims at providing useful information into the machine effectiveness in reducing labour demand, improving grain quality and minimizing post-harvest losses.

1.1 Importance of Cleaning to Agriculture

Cleaning and destoning are essential to remove foreign materials such as stones, sand, chaff, and dust, which often contaminate acha during harvesting and drying. Due to its small grain size and similarity to impurities, traditional methods such as hand-picking, washing, and winnowing are labor-intensive and often ineffective (Adedokun et al., 2022). If these impurities are not adequately removed, they pose serious health risks to consumers and reduce the quality and acceptability of the grain in local and international markets (Vodouhè et al., 2003).

Inefficient cleaning and destoning lead to substantial postharvest losses. Manual methods often result in grain being discarded along with impurities, or damaged during washing and drying. Mechanizing these processes can significantly reduce losses and improve yield recovery rates, thereby supporting food security and farmer income (Adebiyi et al., 2014; Odey et al., 2017).

Properly cleaned and destoned acha commands a higher market price, both locally and internationally, due to its appearance, cooking quality, and safety standards. As consumer awareness of food quality increases, the demand for well-processed acha has risen. Cleaning and destoning are therefore critical steps for value addition, branding, and export readiness (Obilana & Manyasa, 2002).

II. MATERIALS AND METHODS

2.1 Description of the Machine

The acha cleaning and destining machine (Plate 1) comprises an inlet or hopper through which the acha-impurity mixture is fed into the machine. The hopper is situated at the top of the machine just above the separating deck. This hopper is slightly offset from the deck thus material fed in is conveyed into the deck under gravity. The machine also comprises a blower or (axial-flow fan). The fan is driven such that it supplies air mass at a velocity somewhere between the terminal velocities of light-weight chaff and the heavier acha grains plus stones. The fan is positioned under the deck to supply air towards the deck to lift lighter materials up for proper separation. There is also an outlet or chute through which the stone and chaff material is let out of the machine. This is made of mild steel plate welded to form an opening at one end of the deck. At the other end of the deck also is a collector for clean acha grains. The machine is also composed of the supporting frame and the drive units-including the power source (mechanical engine).

Plate 1: Acha Cleaning and Destoning Machine

2.2 Instrumentation and test materials

A quartz stopwatch was used for measurement of time during the performance evaluation of the machine. An electronic balance of sensitivity of 0.01 kg was used in weight measurements (Plate 2a) and a

© MAR 2026 | IRE Journals | Volume 9 Issue 9 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I9-1715284

digital anemometer was used to measure the air velocity of the blower (Plate 2b). A digital tachometer (DT 2235B) which has a sensitivity of one revolution per second was used to determine the speed of the machine (Plate 2c). The commonest available variety of acha (*Digitariaspp*) in Nigerian market was used for the evaluation.

(a)

(b)

(c)

Plate 1: Instruments for Measuring Experimental Parameters
(a) Digital Balance (b) Digital Anemometer (c) Digital Tachometer

2.2.1 Determination of the air velocity
The blower speed was attained with help of set of driver and driven pulleys of different sizes. The air velocity of the blower was measured using a digital anemometer (Plate 2b).

2.2.2 Determination of the machine speed
The machine speed of 350, 425 and 500 rpm were considered for the experiment and were attained with help of set of driver (30 mm) and driven pulleys of different sizes (210, 250 and 300 mm). The machine speeds during its evaluation were determined using a digital tachometer (DT 2235B) which has a sensitivity of one revolution per second (Plate 2c). Plate 3 shows the sets of driven pulleys used to vary the machine speed.

2.2.3 Determination of the deck tilt angle
The deck tilt angle of the machine was attained using a screw adjustment system with pointer device having a standard protractor. The deck angle is adjustable from 0 to 60 degrees.

A = 300mm B = 250mm C = 210mm

Plate 3: Pulleys Used to Vary the Machine Speed

2.3 Machine Evaluation Procedure

The performance of the machine was evaluated by calculating the Throughput capacity destoning efficiency, acha separation efficiency, tray loss, chaff separation efficiency and the impurity level after separation.

2.3.1 Determination of throughput capacity

The output capacity is the quantity of grain cleaned by the machine per time. The output capacity was calculated using equation 1 (Ndirika, 1994).

$$T_c = \frac{Q_s}{T} \quad (1)$$

Where;

$T_c = Throughput\ capacity, kg/hr$

$Q_s = Quantity\ of\ grains\ collected\ at\ the\ grain\ outlet, kg$

$T = Time\ taken\ to\ complet\ the\ cleaning, hr$

2.3.2 Determination of the destoning efficiency (DE)
The efficiency of the destoner was calculated using equation 2 as suggested by (Gbabo *et al*., 2015).

© MAR 2026 | IRE Journals | Volume 9 Issue 9 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I9-1715284

$$DE = \left(1 - \frac{M_{sca}}{M_{sm}}\right) \times 100\ \% \qquad (2)$$

Where, DE = Destoning efficiency, %, M_{sca}= Mass of sand in cleaned acha after separation, g and M_{sm}= Mass of sand in admixture, g.

2.3.3 Determination of acha separation efficiency (ASE)

This is the percentage ratio of the mass of clean acha to the acha in the mixture before separation, which was calculated using equation 3 (Gbabo*et al*., 2015).

$$ASE = \frac{M_{ca}}{M_{am}} \times 100\% \qquad (3)$$

Where, ASE = Acha separation efficiency, %, M_{ca}= Mass of acha collected at acha outlet, g and M_{am} = Mass of acha in admixture before separation, g.

2.3.4 Determination of impurity level after separation (IML)

This is the percentage ratio of mass of sand in the clean acha to the sum of the mass of clean acha and the mass of sand in the acha, which was calculated using equation 4 (Gbabo*et al*., 2015).

$$IML = \frac{M_{sca}}{(M_{ca}+M_{sca})} \times 100\% \qquad (4)$$

Where, IML = Impurity level after separation, %, M_{sca}= Mass of sand and chaff in cleaned acha after separation, g and M_{ca}= Mass of acha collected at acha outlet, g

2.3.5 Determination of cleaning efficiency (CE)

Cleaning efficiency is the ratio by mass of clean grains collected at the grain outlet to the total mass of clean grains and contaminants collected expressed in percentage. The cleaning efficiency was obtained using equation 5 as reported by Simonyan *et al.* (2006).

$$CE = \frac{G_o}{G_o+C_{cg}} \times 100\ \% \qquad (5)$$

Where;

$$CE = Cleaning\ efficency, \%$$

$$G_o = Mass\ of\ acha\ at\ the\ outlet, g$$

$$C_{cg} = Mass\ of\ contaminants, g$$

2.3.6 Determination of tray loss (TL)

This is the quantity of acha which was not recovered in the process. The tray loss was computed using equation 6 (Gbabo *et al.*, 2015).

$$TL = \left(1 - \frac{M_{ca}}{M_{am}}\right) \times 100\ \% \qquad (6)$$

Where, TL = Tray loss, %, M_{ca}= Mass of acha collected at acha outlet, g and M_{am} = Mass of acha in admixture before separation, g

2.3.7 Determination of chaff separation efficiency (CSE)

Chaff separation efficiency is the ratio by mass of chaff collected after separation and cleaning to the total mass of chaff before separation and cleaning expressed in percentage. The chaff separation efficiency was obtained using equation 7 as reported by Nadew, (2015).

$$CSE = \frac{M_{cf1}}{M_{cf2}} \times 100\ \% \qquad (7)$$

Where;

$$CSE = Chaff\ separation\ efficency, \%$$

$$M_{cf1} = Mass\ of\ chaff\ collected\ after\ separation\ and\ cleaning, g$$

$$M_{cf2} = Mass\ of\ chaff\ before\ separation\ and\ cleaning, g$$

2.4 Experimental Design

The experimental design for the statistical analysis follows a 2-treatment effects (machine speed and tilt angle) in a Completely Randomized Design (CRD) involving a 2-way classification of three observations (replications) per experimental unit. The experimental unit comprises 2 factors (three speeds 350, 425 and 500 rpm) at three tilt angles 4, 8 and 12°

each. The effect of variation among the means of these variables was analysed using Analysis of Variance (ANOVA) at 95% probability level of significance. Significant results were analyzed using the Least Significant Difference (LSD) to separate the means.

III. RESULTS AND DISCUSSION

Mean results of the efficiencies of the acha cleaning and destoning machine are shown in Table 1. The analysis of variance (ANOVA) at $p \leq 0.05$ for the effect of machine speed and tilt angle on the throughput capacity (Kg/hr) is presented in Table 2 and the Means using F-LSD is presented in Table 3.The analysis of variance (ANOVA) at $p \leq 0.05$ for the effect of machine speed and tilt angle on destoning efficiency (%) is presented in Table 4 while the Means using F-LSD is presented in Table 5.Analysis of variance (ANOVA) at $p \leq 0.05$ for the effect of machine speed and tilt angle on acha separation efficiency (%) is presented in Table 6 while the Means using F-LSD is presented in Table 7.

Analysis of variance (ANOVA) at $p \leq 0.05$ for the effect of machine speed and tilt angle on impurity level after separation (%) is presented in Table 8 while the Means using F-LSD is presented in Table 9.The analysis of variance (ANOVA) at $p \leq 0.05$ for the effect of machine speed and tilt angle on cleaning efficiency (%) is presented in Table 10 while the Means using F-LSD is presented in Table 11.Analysis of variance (ANOVA) at $p \leq 0.05$ for the effect of machine speed and tilt angle on chaff separation efficiency (%) is presented in Table 12.The analysis of variance (ANOVA) at $p \leq 0.05$ for the effect of machine speed and tilt angle on tray loss (%) is presented in Table 13 while the Means using F-LSD is presented in Table 14.

Table 1: Mean Results of the Efficiencies of the Acha Cleaning and Destoning Machine

Machine Speed (rpm)	Tilt Angle (°)	Throughput Capacity (kg/hr)	Destoning Efficiency (%)	Acha Separation Effciency (%)	Impurity Level after Separation (%)	Cleaning Efficiency (%)	Chaff Separation efficiency(%)	Tray Loss (%)
	4	36.96	84.31	88.40	1.91	86.15	53.80	11.60
350	8	38.02	79.59	87.68	2.44	85.47	56.07	12.32
	12	40.00	72.47	85.79	3.31	84.56	49.00	14.21
	4	41.61	66.48	80.06	4.18	82.30	56.20	19.94
425	8	42.07	56.03	74.44	5.72	79.40	51.40	25.56
	12	43.19	50.02	65.82	7.35	74.80	41.87	34.19
	4	44.96	45.65	71.15	7.36	75.61	49.73	28.85
500	8	46.66	34.75	63.14	9.64	71.06	44.93	36.86
	12	49.83	25.09	62.27	11.06	69.55	33.80	37.73

Table 2: Analysis of Variance (ANOVA) of the Effect of Machine Speeds and Tilt Angle on Throughput Capacity (kg/hr)

Sources of Variation	DF	SS	MS	F-cal	F-tab
Machine speed, N (rpm)	2	351.810	175.905	125.526*	3.55
Tilt angle, A (°)	2	46.602	23.301	16.628*	3.55
Interaction (N × A)	4	8.343	2.086	1.488^{ns}	2.93
Error	18	25.224	1.401		
Total	26	431.979			

* - Significant at $P \leq 0.05$ ^{ns} – Not Significant at $P \leq 0.05$

Table 3: Mean Values of the Effect of Machine Speed and Tilt Angle on Throughput Capacity (kg/hr) Using F-LSD

TIlt angle (°)	Machine Speed (rpm)		
	350	425	500
4	36.96[a]	41.61[b]	44.96[c]
8	38.02[d]	42.07[e]	46.66[f]
12	40.00[g]	43.19[h]	49.83[i]

F-LSD 0.05 = 2.03

Means having different letters in the same row are statistically different from each other at P ≤0.05 using F-LSD

Table 4: Analysis of Variance (ANOVA) of the Effect of Machine Speed and Tilt Angle on Destoning Efficiency (%)

Sources of Variation	DF	SS	MS	F-cal	F-tab
Machine speed, N (rpm)	2	8566.9	4283.47	183.65*	3.55
Tilt angle, A (°)	2	1195.3	597.64	25.62*	3.55
Interaction (N × A)	4	68.9	17.23	0.74 [ns]	2.93
Error	18	419.8	23.32		
Total	26	10251.0			

* - Significant at P ≤ 0.05 [ns] - Not Significant at P ≤ 0.05

Table 5: Mean Values of the Effect of Machine Speed and Tilt Angle on Destoning Efficiency (%) Using F-LSD

Tilt angle (°)	Machine Speed (rpm)		
	350	425	500
4	84.31[a]	66.48[b]	45.65[c]
8	79.59[d]	56.03[e]	34.75[f]
12	72.47[g]	50.02[h]	25.09[i]

= 8.28

Means having different letters in the same row are statistically different from each other at P ≤ 0.05 using F-LSD

Table 6: Analysis of Variance of the Effect of Machine Speed and Tilt Angle on Acha Separation Efficiency (%)

Sources of Variation	DF	SS	MS	F-cal	F-tab
Machine speed, N (rpm)	2	2185.88	1092.94	197.43*	3.55
Tilt angle, A (°)	2	332.64	166.32	30.04*	3.55
Interaction (N × A)	4	131.00	32.75	5.92*	2.93
Error	18	99.64	5.54		
Total	26	2749.16			

* - Significant at P ≤ 0.05

Table 7: Mean Values of the Effect of Machine Speed and Tilt Angle on Acha Separation Efficiency (%) Using F-LSD

Tilt angle (°)	Machine Speed (rpm)		
	350	425	500
4	88.40[a]	80.06[b]	71.15[c]
8	87.68[d]	74.44[e]	63.14[f]
12	85.79[g]	65.82[h]	62.27[h]

= 4.04

Means having different letters in the same row are statistically different from each other at P ≤ 0.05 using F-LSD

Table 8: Analysis of Variance of the Effect of Machine Speed and Tilt Angle on Impurity Level after Separation (%)

Sources of Variation	DF	SS	MS	F-cal	F-tab
Machine speed, N (rpm)	2	208.389	104.195	225.88*	3.55
Tilt angle, A (°)	2	34.283	17.142	37.16*	3.55
Interaction (N × A)	4	4.751	1.188	2.57 [ns]	2.93
Error	18	8.303	0.461		
Total	26	255.727			

* - Significant at P ≤ 0.05 [ns] - Not Significant at P ≤

0.05

Table 9: Mean Values of the Effect of Machine Speed and Tilt Angle on Impurity Level after Separation (%) Using F-LSD

Tilt angle (°)	Machine Speed (rpm)		
	350	425	500
4	1.91[a]	4.18[b]	7.36[c]
8	2.44[d]	5.72[e]	9.64[f]
12	3.31[g]	7.35[h]	11.06[i]

= 1.16

Means having different letters in the same row are statistically different from each other at P ≤ 0.05 using F-LSD

Table 10: Analysis of Variance (ANOVA) of the Effect of Machine Speed and Tilt Angle on Cleaning Efficiency (%)

Sources of Variation	DF	SS	MS	F-cal	F-tab
Machine speed, N (rpm)	2	798.459	399.230	194.73*	3.55
Tilt angle, A (°)	2	115.117	57.558	28.08*	3.55
Interaction (N × A)	4	34.397	8.599	4.19*	2.93
Error	18	36.903	2.050		
Total	26	984.876			

* - Significant at P ≤ 0.05

Table 11: Mean Values of the Effect of Machine Speed and Tilt Angle on Cleaning Efficiency (%) Using F-LSD

TIlt angle (°)	Machine Speed (rpm)		
	350	425	500
4	86.15[a]	82.30[b]	75.61[c]
8	85.47[d]	79.40[e]	71.06[f]
12	84.56[g]	74.80[h]	69.55[i]

F-LSD $_{0.05}$ = 2.46

Means having different letters in the same row are statistically different from each other at P ≤ 0.05 using F-LSD

Table 12: Analysis of Variance (ANOVA) of the Effect of Machine Speed and Tilt Angle on Chaff Separation Efficiency (%)

Sources of Variation	DF	SS	MS	F-cal	F-tab
Machine speed, N (rpm)	2	484.507	242.253	2.265[ns]	3.55
Tilt angle, A (°)	2	684.196	342.098	3.199 [ns]	3.55
Interaction (N × A)	4	114.151	28.538	0.267 [ns]	2.93
Error	18	1924.907	106.939		
Total	26	3207.760			

[ns] – Not Significant at P ≤ 0.05

Table 13: Analysis of Variance of the Effect of Machine Speed and Tilt Angle on Tray Loss (%)

Sources of Variation	DF	SS	MS	F-cal	F-tab
Machine speed, N (rpm)	2	2185.41	1092.70	197.35*	3.55
Tilt angle, A (°)	2	332.63	166.32	30.04*	3.55
Interaction (N × A)	4	131.05	32.76	5.92*	2.93
Error	18	99.66	5.54		
Total	26	2748.75			

* - Significant at P ≤ 0.05

Table 14: Mean Values of the Effect of Machine Speed and Tilt Angle on Tray Loss (%) Using F-LSD

TIlt angle (°)	Machine Speed (rpm)		
	350	425	500
4	11.60[a]	19.94[b]	28.85[c]
8	12.32[d]	25.56[e]	36.86[f]
12	14.21[g]	34.19[h]	37.73[h]

F-LSD $_{0.05}$ = 4.04

Means having different letters in the same row are statistically different from each other at P ≤ 0.05 using F-LSD

3.1.1 Effect of machine speed and tilt angle on throughput capacity (kg/hr)

Table 1 shows the effects of machine speed and tilt angle on throughput capacity (kg/hr) of the acha cleaning and destoning machine. It was observed that the throughput capacity increased with increasing machine speeds and tilt angle. The machine speed of 500 rpm had the highest throughput capacity of 49.83 kg/hr at the tilt angle of 12°. The least throughput capacity of 36.96 kg/hr was obtained at the machine speed of 350 rpm and tilt angle of 4° rpm. The low throughput capacity may be due to more resident time of materials on the machine. The Analysis of variance (ANOVA) at $p \leq 0.05$ of the effects of machine speed and tilt angle on throughput capacity (kg/hr) of the acha cleaning and destoning machine is presented in Table 2. It was observed that the throughput capacity was significantly different at all the machine speed and tilt angle investigated. There was no significant difference when the machine speeds and tilt angle interacted.This implies that the effect of machine speed is not the same as the effect of tilt angle.A 2-tailed F-LSD test at $P \leq 0.05$ shows that the differences between machine speeds and tilt angles treatment combinations means are stastically different for most of the treatment combinations (Table 3). This implies that these parameters must be controlled to effectively destone and clean acha

3.1.2 Effect of machine speed and tilt angle on destoning efficiency (%)

The study of the effects of machine speed and tilt angle on destoning efficiency (%) of the acha cleaning and destoning machine (Table 1) shows that destoning efficiency decreased with increasing machine speed and tilt angle. The best destoning efficiency of 84.31 % was obtained at 350 rpm machine speed and 4° tilt angle. The lowest destoning efficiency of 25.09 % was obtained at 500 rpm machine speed and 12° tilt angle. This implies that maximum ach adestoning efficiency is achieved when the machine is operated at low speed and low tilt angle. This study agrees with the work of Gbabo *et al*. (2015) who reported that destoning efficiency of machine increased with decreasing angle of inclination. The low destoning efficiency at increased tilt angle may be attributed to the high momentum and bouncing of the grains over the destoning surface without being properly destoned. The low destoning efficiency may also be due to high vibration of the machine as a result of high machine speed and high tilt angle which lead to less resident time of acha, sand and chaff to be destoned on the deck.The Analysis of variance (ANOVA) at $p \leq 0.05$ of the effect of machine speed and tilt angle on destoning efficiency (%) of the acha cleaning and destoning machine is presented in Table 4. There was a significant difference in the machine speed and tilt angle but no significant difference in the interaction of machine speed and tilt angle on the destoning efficiency. This implies that the effect of machine speed is the same as the effect of tilt angle. The means values of the effect of machine speed and tilt angle on destoning efficiency using F-LSD is presented in (Table 5). The means separation at $p \leq 0.05$ level of significance shows that the destoning efficiency was significantly different at all the machine speeds for all the tilt angles investigated. This implies that the factors should be carefully chosen.

3.1.3 Effect of machine speed and tilt angle on acha separation efficiency (%)

Table 1 shows the effects of machine speed and tilt angle on acha separation efficiency (%) of the acha cleaning and destoning machine. For the studied range, acha separation efficiency increased with decreasing machine speeds and decreasing tilt angles. A maximum acha separation efficiency of 88.40 % was obtained at 350 rpm machine speed and 4° tilt angle. A minimum acha separation efficiency of 62.27 % was obtained at 500 rpm machine speed and 12° tilt angle. This is in line with Okunola *et al.* (2015) that reported a decrease in separation efficiency as tilt angle increases. The decrease in separation efficiency may be due to sliding rather than tossing and of grains as a result of high machine speed and tilt angle. The low acha separation efficiency at high machine speed and high tilt angle may be due to high vibration of the machine which leads to less resident time of acha, sand and chaff on the deck. Table 6 is the analysis of variance (ANOVA) at $p \leq 0.05$ of the effects of machine speed and tilt angle on acha separation efficiency (%) of the acha cleaning and destoning machine. It was observed that there was a significant difference in the machine speeds, tilt angles and their interactions on the acha separation efficiency. This means that, the main effect of machine speed is different from the main effect of tilt angle and vice versa. The possible reason for the high significance for all the factors could be from the selected independent variables and their range. The machine speeds and tilt angles were selected based on past research.A 2-tailed F-LSD test at 95% level of significance shows that the acha separation efficiency was significantly different at all the machine speeds for all the tilt angles investigated except the 12^o tilt angle at machine speed of 425 rpm and 500 rpm that are not significantly different (Table 7). This implies that these parameters must be controlled effectively in oder to destone and clean acha.

3.1.4 Effect of machine speed and tilt angle on impurity level after separation (%)

Table 1 is the effects of machine speed and tilt angle on impurity level after separation (%) of the acha cleaning and destoning machine. For the studied range, impurity level after separation increased with increasing machine speed and tilt angle. The lowest impurity level after separation of 1.91 % was obtained at a speed of 350 rpm machine speed and 4^o tilt angle. The highest impurity level after separation of 11.06 % was obtained at of 500 rpm machine speed and 12^o tilt angle. This is in line with Gbabo *et al*. (2015) who reported that, the impurity level after separation increased with increasing angles of inclination of the reciprocating screen.Analysis of variance (ANOVA) at p≤ 0.05 significant level was conducted for the study of effects of machine speed and tilt angle on impurity level after separation (%) as presented in Table 8. There were significant differences for the machine speed and tilt angle but no significant difference in their interactions on the impurity level after separation. A 2-tailed F-LSD test at $p \leq 0.05$ level of significance shows that the impurity level after separation was significantly different at all the machine speeds for all the tilt angles investigated (Table 9). This implies that these parameters must be controlled effectively in order to destone and clean acha.

3.1.5 Effect of machine speed and tilt angle on cleaning efficiency (%)

Table 1 shows the effects of machine speed and tilt angle on cleaning efficiency (%) of the acha cleaning and destoning machine. For the studied range, cleaning efficiency increased with decreasing machine speed and tilt angle. The highest cleaning efficiency of 86.15 % was obtained at 350 rpm machine speed and 4^o tilt angle. The lowest cleaning efficiency of 69.55 % was obtained at 500 rpm machine speed and 12^o tilt angle. The decreased in cleaning efficiency may be due to less resident time of material to be separated over the deck. Okunola *et al.* (2015) reported an optimum machine performance on cleaning efficiency which occurred at lower tilt angle. Nadew, 2015 also reported a similar trend. Analysis of variance (ANOVA) at p≤ 0.05 significant level was conducted for the study of effects of machine speed and tilt angle on cleaning efficiency (%) as presented in Table 10. There was significant difference in the machine speed, tilt angle and their interactions on the cleaning efficiency. This means that the main effect of machine speed to be different from the main effect of tilt angle and vice versa. The possible reason for the high significance for all the factors could be the selected independent variables and their range. The machine speeds and tilt angles were selected based on past research. A 2-tailed F-LSD test at $p \leq 0.05$ level of significance shows that the cleaning efficiency was significantly different at all the machine speeds for all the tilt angles investigated (Table 11).

3.1.6 Effect of machine speed and tilt angle on chaff separation efficiency (%)

Table 1 is the effects of machine speed and tilt angle on chaff efficiency (%) of the acha cleaning and destoning machine. For the studied range, chaff separation efficiency generally increased with decreasing machine speed and tilt angle. The highest chaff separating efficiency of 56.2 % was obtained at 425 rpm machine speed and 8^o tilt angle. The lowest chaff separation efficiency of 33.8% was obtained at 500 rpm machine speed and 12^{o} tilt angle. Analysis of variance (ANOVA) at p≤ 0.05 significant level was conducted for the study of effects of machine speed and tilt angle on chaff separation efficiency (%) as presented in Table 12. There was no significant difference in the machine speed, tilt angle and their interactions on the chaff efficiency. This may be due to non uniformity in densities between paddy acha, sand and chaff. A similar train was reported by Nadew (2015).

3.1.7 Effect of machine speed and tilt angle on tray loss (%)

Table 1 is the effects of machine speed and tilt angle on tray loss (%) of the acha cleaning and destoning machine. For the studied range, tray loss increased with increasing machine speed and tilt angle. The lowest tray loss of 11.60 % was obtained at 350 rpm machine speed and 4^{o} tilt angle. The highest tray loss of 37.73 % was obtained at 500 rpm machine speed and 12^{o} tilt angle. This may be due to high inertia force acting on acha, sand and chaff as a result of the high machine speed. Nadew (2015) also reported a trend of increasing cleaning loss with increase in machine tilt angle and sieve oscillation.Analysis of variance (ANOVA) at p≤ 0.05 significant level was conducted for the study of effects of machine speed and tilt angle on tray loss (%) as presented in Table 13. There was significant difference in the machine speed, tilt angle and their interactions on the tray loss. This means that the main effect of machine speed to be different from the main effect of tilt angle and vice versa. The possible reason for the high significance for all the factors could be the selected independent variables and their range. The machine speeds and tilt angles were selected based on past research. A 2-tailed F-LSD test at $p \leq 0.05$ level of significance shows that the tray loss was significantly different at all the machine speeds for all the tilt angles investigated except the 12^{o} tilt angle at machine speed of 425 rpm and 500 rpm that are statistically different (Table 14).

IV. CONCLUSION

The performance of the machine was evaluated based on machine speeds (350, 425 and 500 rpm) and three levels of tilt angles (4, 8 and 12^{o}) to identify the optimum combination of the machine variables. The results of the performance evaluation showed that the means of throughput capacity, de-stoning efficiency, acha separation efficiency, impurity level after separation, cleaning efficiency, chaff separation efficiency and tray loss of the machine were in the range of 49.83 to 36.96 kg/hr, 84.31 to 25.09%, 88.40 to 62.27 %, 1.91 to 11.06 %, 86.15 to 69.55 %, 56.2 % to 33.8 % and 37.3 to 11.60 % respectively. The best results for de-stoning efficiency acha separation efficiency and cleaning efficiency were obtained at machine speed of 350 rpm and tilt angle of 4 degrees to be 84.31 %, 88 % and 86.15 % respectively. Minimum impurity level after separation and tray loss of the machine were obtained at machine speed of 350 rpm and tilt angle of 4 degrees to be 1.91 % and 11.60 %. Maximum throughput capacity was obtained at machine speed of 500 rpm and tilt angle of 12 degrees as 49.82 kg/hr.

REFERENCES

[1] Adebiyi, J. A., Obilana, A. B., Adepoju, A. O., & Olayiwola, I. O. (2014). Processing and utilization of fonio (*Digitaria spp.*) in Nigeria: Review. *Journal of Food Processing and Technology*, 5(7), 1–7. https://doi.org/10.4172/2157-7110.1000348

[2] Adedokun, S. A., Bamgboye, A. I., & Adedokun, K. A. (2022). Development and performance evaluation of a fonio destoner. *Agricultural Engineering International: CIGR Journal*, 24(1), 57–64.

[3] Adoukonou-Sagbadja, H., Wagner, C., Dansi, A., Ahlemeyer, J., Daïnou, O., Akpagana, K., & Ordon, F. (2006). Genetic diversity and population structure of fonio (*Digitaria exilis*) landraces in West Africa. *Theoretical and Applied Genetics*, 115(7), 917–928. https://doi.org/10.1007/s00122-006-0186-9

[4] Bashiri I.M., Zubairu M. andGambo A. (2010). Development of an acha hulling machine.

Journal of research in national development, 8 (1).

[5] Dachi, S.N. and Gana, A.S. (2008). Adaptability and evaluation of some acha (*Digitariaexilis*and *DigitariaiburuaKippisStapf*) accessions at Kusogi-Bida, Niger State, Nigeria. *African Journal of General Agriculture*, 4 (2): 73-77.

[6] Gbabo, A., Baba, N., Mohammed, A.K., and Lukman, A. (2015) Development and testing of a rice destoning machine. *International Journal of Engineering Research and Science and Technology (IJERST,)* 4(3):134-141.

[7] Nadew A. A. (2015). *Design and Development of Tef Grain and Chaff Separating and Cleaning Machine*. Unpublished MSc. Thesis Haramaya University, Dire Dawa, Ethiopia.

[8] Ndirika, V. I. (1994). Development and performance evaluation of a millet thresher. *Journal of agricultural engineering and technology1*(2): 80 – 89.

[9] Obilana, A. B., & Manyasa, E. (2002). Millets. In P. S. Belton & J. R. N. Taylor (Eds.), *Pseudocereals and Less Common Cereals* (pp. 177–217). Springer.

[10] Odey, E. A., Lawal, A. A., Yusuf, M. A., & Daudu, M. (2017). Farmers' perception and adoption of improved postharvest technologies of rice in Benue State, Nigeria. *Journal of Agricultural Extension*, 21(1), 125–136. https://doi.org/10.4314/jae.v21i1.10

[11] Okunola, A.A., Igbeka, C.J., Arisoyin, A. G. (2015). Development and evaluation of a cereal cleaner. *Journal of Multidisciplinary Engineering Science and Technology*, 2 (6):14-19.

[12] Philip T. K. and I. N. Itodo (2006). Acha (*Digitalia spp.*) a "Rediscovered" Indigenous Crop of West Africa. *Agricultural Engineering International*: *the CIGR Ejournal.* Invited Overview No 23. Vol. VIII. December, 2006.

[13] Simonyan, K.J., Yiljep, Y and Mudiare, O (2006). Modeling the Cleaning Process of a Stationary Sorghum Thresher. Agricultural Engineering International: *The CIGR Journal of Scientific Research and Development, 8*(2):14-20.

[14] Temple, V. J., Ojobe, T. O., & Kapu, M. M. (1991). Chemical composition of acha (*Digitaria exilis* and *Digitaria iburua*) grains. *Journal of the Science of Food and Agriculture*, 56(4), 561–564. https://doi.org/10.1002/jsfa.2740560413

[15] Vodouhè, R., Achigan-Dako, E. G., & N'Danikou, S. (2003). Fonio: An African cereal with potential. *Proceedings of the Workshop on African Crops*, IPGRI.