Factors affecting forage chopper performance

E. A. Ajav*, B. Yinusa

(Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan, Ibadan, Nigeria)

Abstract: The performance of a forage chopper is greatly dependent on some factors such as cutting knife angle, knife edge thickness etc. Therefore, in this work the effect of some factors (operating time and moisture) on forage chopper performance were determined. Moisture contents of the samples forage (Guinea grass-24.4%, 23.3%, 20.0% (wb), Siam weed-21.4%, 16.6%, 13.3% (wb) and Maize Stover-42%, 30%, 23% (wb)) were determined by oven-drying method. The machine was tested using Philippine Agricultural Engineering Standard at Department of Agricultural an Environmental Engineering in September, 2014. Effects of moisture content and operating time (Independent variables) on chopping efficiency, chopping capacity and length of cut of the machine were analysed using response surface design expert of 6.0.6 model. Responses were chopping capacity, chopping efficiency and length of cut. The results of the statistical analysis showed that, moisture content and operating time had significant effects ($p<0.05$) on the chopping capacities at 5% significant level while their effects on efficiencies were not significant at 5% significant level due to the cutting knife parameters of the machine. Moreover, the length of cut increased with the increase in moisture content but the effect was not significant. The chopping capacity, efficiency and length of cut are functions of the mechanical, physical properties of the material chopped and the cutting knife parameters of the machine.

Keywords: forage chopper, cutting knife parameters, moisture content, operating time

Citation: E. A. Ajav, and B. Yinusa. 2015. Factors affecting forage chopper performance. Agric Eng Int: CIGR Journal, 17(3): 112-116.

1 Introduction

Cutting is a size reduction process which can be done by pushing or forcing a thin sharp knife through the material to be chopped. When forage crops are used as feeds for animals, size of the fodder (forage) must be reduced as much as possible to aid proper feeding and palatability.

The grinding performance and physical properties of wheat, barley straws, corn stover and switch grass were studied by (Mani et al., 2004). They showed that switch grass had the highest specific energy consumption (27.6kWh/t) and corn stover had the least specific energy consumption (11.0kWh/t) at 3.2mm screen size. But they did not report their effects on the efficiency and capacity of the machine.

Adgidzi (2007) reported that, the average chopping rate for the dry materials was 24kg/h and the average chopping rate for the wet materials was 15.6kg/h. These values indicate that the machine performed better with dry materials than the wet materials. But he did not examine the factors affecting forage chopper performance.

Therefore, the output capacity, chopping efficiency and length of cut of a forage chopper may be affected by the mechanical properties, physical properties of the material, and the cutting knife parameters (Adgidzi, 2007). Hence the objective of this research was to determine the effect of operating time and moisture content on chopper performance.

2 Materials and methods

2.1 Forage crops

The data analyzed was obtained at Department of Agricultural an Environmental Engineering in September, 2014 from the trials carried out with the sample forages

Received date: 2015-03-20 **Accepted date:** 2015-07-02

***Corresponding author: E. A. Ajav,** Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan, Ibadan, Nigeria.

Email: yinusa_babatunde@yahoo.com, ea.ajav@mail.ui.edu.ng.

(guinea grass, Siam weed and maize Stover) tested on the machine. Each sample materials were in three replicates as shown in Tables 1and 2.

Table 1 Performance test data of the machine for forages with moisture content of 13.3% to 42%

Samples trials	Weight of output, kg	Output capacity, kg/h	Weight of material in chamber, kg	Operating time, s	Weight of uncut material, kg	Total weight input, kg	Moisture content, %	Chopping efficiency, %
Guinea Grass								
1st	2.200	132.0	0.020	60	0.030	2.245	24.4	98.7
2nd	1.476	88.56	0.060	60	0.028	1.564	23.3	98.2
3rd	1.474	88.44	0.096	60	0.056	1.626	20.0	96.6
Siam weed								
1st	1.606	96.36	0.023	60	0.000	1.629	21.4	100
2nd	1.767	106.0	0.025	60	0.000	1.792	16.6	100
3rd	1.777	106.6	0.027	60	0.027	1.824	13.3	98.9
Maize Stover's								
1st	1.619	97.14	0.249	60	0.118	1.986	42.0	94.1
2nd	0.438	29.20	0.010	54	0.000	0.448	30.0	100
3rd	0.674	50.55	0.079	48	0.110	0.863	23.0	87.3
Mean	1.448	88.32	0.065	58	0.041	1.553	22.8	97.09

Table 2 Performance test data of the machine for forages with moisture content of 26% to 62%

Samples trials	Weight of output, kg	Output capacity, kg/h	Weight of material in chamber, kg	Operating time, s	Weight of uncut material, kg	Total weight input, kg	Moisture content, %	Chopping efficiency, %
Guinea Grass								
1st	2.272	90.88	0.448	90	0.018	2.738	62	99.3
2nd	2.430	97.20	0.113	90	0.020	2.563	57	99.2
3rd	1.600	64.00	0.040	90	0.000	1.640	36	100
Maize Stover's								
1st	1.399	55.96	0.274	90	0.179	1.852	54	90.3
2nd	1.875	75.00	0.212	90	0.176	2.263	59	92.2
3rd	1.189	47.56	0.069	90	0.064	1.322	46	95.2
Siam weed								
1st	1.285	51.40	0.148	90	0.050	1.483	58	96.6
2nd	1.704	68.16	0.049	90	0.000	1.754	53	100
3rd	1.403	56.12	0.002	90	0.003	1.408	26	99.8
Mean	1.684	67.37	0.152	90	0.057	1.891	50	96.95

i) Moisture content

The moisture content of each samples were determined as given by PAES 219, (2004) as:

$$MC_{wb}=\frac{W_1-W_2}{W_1}\times 100,\%\ldots (1)$$

Where, MC_{wb} = Moisture content, %; W_1 = Initial mass of the sample, g; W_2 = Final mass of the sample, g.

ii) Chopper field capacity

The chopper field capacity for each material was determined as:

$$C_{fc} = \frac{W_P}{T_O} \quad \ldots (2)$$

Where, C_{fc} = chopper field capacity, kg/h; W_P = Weight of product, kg; T_O = Time of operation, h.

iii) Chopping Efficiency

The chopping efficiency for each material was determined as:

$$C_e =\frac{Wi-Wuc}{Wi}\times 100, \%\ldots (3)$$

Where, C_e = Chopping efficiency, %; W_{uc} = Weight of uncut materials, kg; W_i = Weight of input materials, kg.

2.2. Experimental design

Central composite rotatable design of response surface methodology was employed as reported by Montgomery (2005). The independent variables used for the study were moisture contents and operating time while the responses (dependents variables) were chopping capacity, chopping efficiency and length of cut as shown in Table 1 and 2.

3 Results and discussion

3.1The effects of moisture content and operating time on chopping capacity

The average chopping capacity obtained varies from 67.37 to 88.32kg/h from different sample trials as showed in Tables 1and 2, which were higher than the values (24 and 15.6kg/h) obtained by Adgidzi (2007).The effects of operating time and moisture content were significant on chopping capacity of the machine ($p<0.05$) as shown in Table 3 because the paddles helped to shred further the dry samples at high speed, which made them easier to be blown out of the chamber and the model that gave the best fit was a quadratic relationship as shown in Equation (4). The response surface plot of the relationship was shown in Figure 1. The goodness of fit for the model was expressed by the coefficient of determination (R^2) of 0.5798, which suggest that, the model could explain 57.98% of the variability in the response and the model satisfies lack of fit test.

Table 3 Analysis of variance on chopping capacity

Source	Sum of squares	DF	Mean square	F-value	Prob >F	
model	6940.37	5	1388.07	3.31	0.0414	Significant
A	38.761	38.76	0.092	0.7662		
B	211.24	1	211.24	0.50	0.4913	
A^2	172.29	1	172.29	0.41	0.5335	
B^2	2982.52	1	2982.52	7.12	0.0205	
AB	0.26	1	0.266	E.004	0.9807	
Residual	5029.13	12	419.09			
Lack of fit	5029.12	10	502.91	3.600E-003	1.397E+005	<0.0001 Significant
Pure error	7.200E-003	2	3.600E-003			
Cor total	11969.50	17				

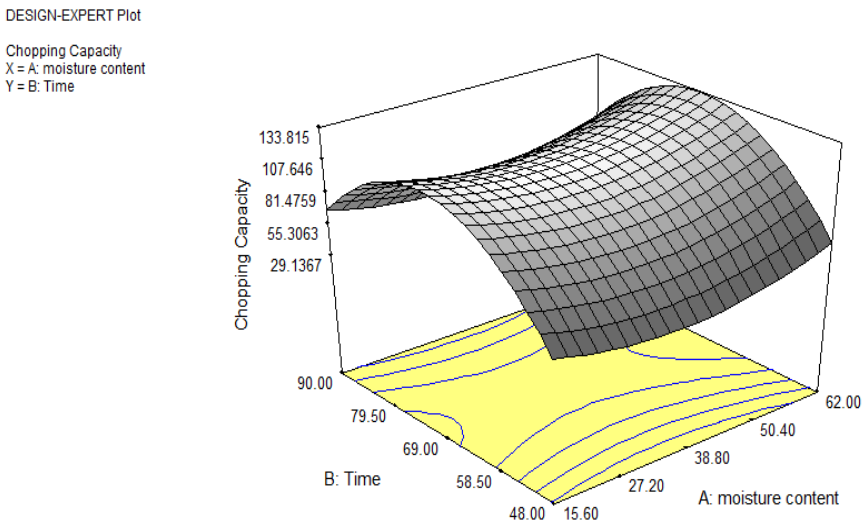

Figure 1 Effects of moisture content and operating time on chopping capacity

$$\text{Chopping Capacity} = 107.17 + 6.26A + 12.58B + 19.70A^2 - 65.11B^2 + 0.83AB \quad \ldots(4)$$

Where, A = moisture content (%), B = operating time(second).

3.2 The effects of moisture and operating time on length of cut

The average length of cut obtained was 2.99cm which is within the standard length of cut of 2 to 4cm for forage choppers and is close to the length of cut of 2 to

2.5cm obtained by Khope and Modak (2013). Result shows that, length of cut decreases with the decrease in moisture content and operating time as is shown in Figure 2, but the decrease was not significant ($p>0.05$) as is shown in Table 4 and the model that gives the best fit is a 2FI relationship.The goodness of fit for the model was expressed by the coefficient of determination R^2 (0.3294).While Equation (5) shows the interraction between moisture content and operating time on length of cut.

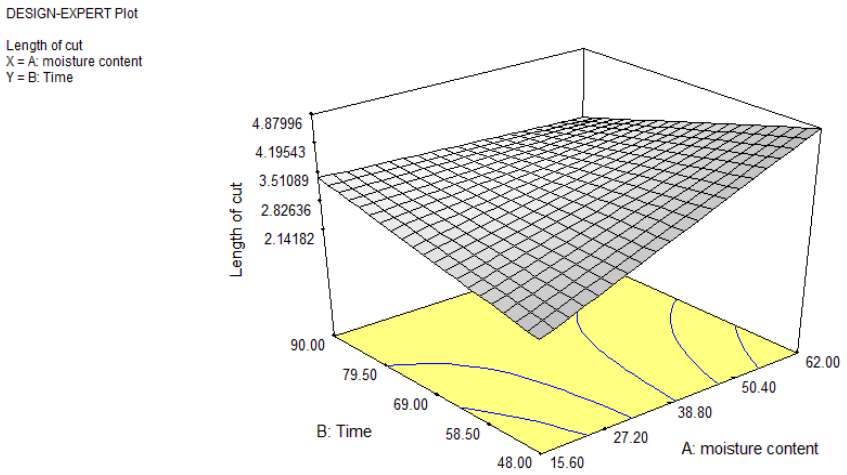

Figure 2 The effects of moisture and operating time on length of cut

Table 4 Analysis of variance on chopping capacity

Source	Sum of squares	DF	Mean square	F-value	Prob>F	
	2.01		0.67			
model	0.86	3	0.86	2.30	0.1224	Not significant
A	0.040	1	0.040	2.95	0.1078	
B	0.84	1	0.84	0.14	0.7171	
AB	4.09	1	0.29	2.89	0.1110	
Residual	3.91	14	0.33			Not significant
Lack of fit	0.18	12	0.090	3.61	0.2373	
Pure error	6.10	2				
Cor total		17				

Length of cut = 3.40+0.62A-0.11B -0.74 AB…(5)

Where A = moisture content (%), B = operating time(second).

3.3 The effects of moisture content and operating time on chopping efficiency

The mean chopping efficiency of the machine ranges from 96.95% to 97.09%. Adgidzi (2007) reported a chopping efficiency of 86% and 92% for wet and dry samples, which was close to the range obtained. The little variation could be due to adequate cutting parameters considered for this design, which could be related to the mechanical and physical properties of the design materials, as well as the cutting knife parameters. However, the cutting resistance of younger plants may be significantly lower than that of older plants. The mathematical expression in Equation (6) shows that a relationship occurs between the operating time, moisture content and the chopping efficiency. However, the effects of these variables are not significant on chopping efficiency of the machine ($p > 0.05$) and the model that gives the best fit is a quaderatic relationship.The coefficient of determination R^2 was found to be 0.3826, indicating that the relationship between the two independent varaibles as is shown in Figure 3 has a weak effect on the chopping efficiency of the machine.That is R^2 = 0.3677.

Chopping Efficiency = $100.53 - 1.60A + 4.40B+0.57A^2 -6.89B^2 - 1.22AB$ …(6)

where, A = moisture content (%), B = operating time(second).

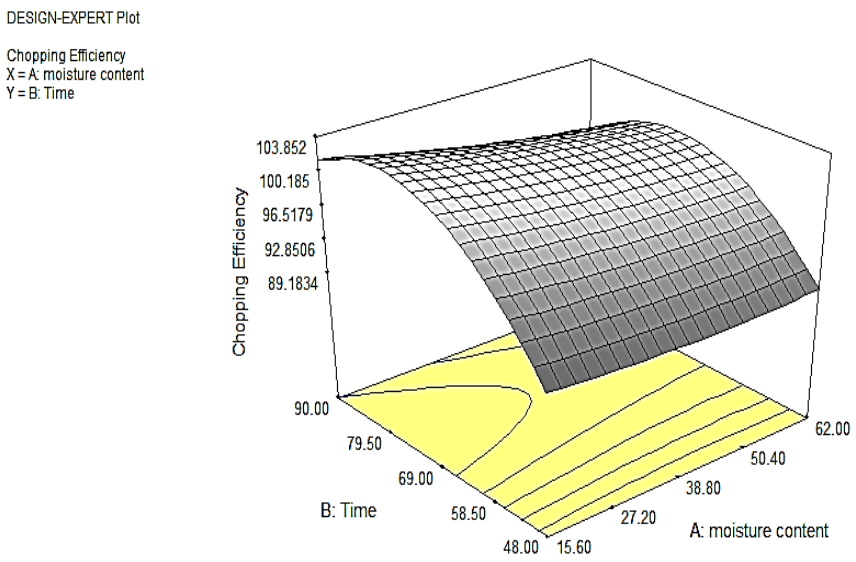

Figure 3 Effects of moisture content and operating time on chopping efficiency

4 Conclusions

The test results obtained show that, moisture content and operating time had a significant effects ($p<0.05$) on the average chopping capacities (67.37 to 88.32kg/h) of the forage chopper at 5% significant level while their effects on the average chopping efficiencies (96.97% to 97.09%) and length of cut (2.99cm) were not significant at 5% significant level.

References

Adgidzi, D.2007. Development and performance evaluation of a forage chopper..*Journal of Agricultural Engineering and Technology*, 15:12-24.

Khope, P.B, and J.P. Modak. 2013. Development and evaluation of a human powered flywheel motor operated forage cutter. *International Journal of Scienticfic and Technology Research*,2(3): 146-149.

Mani,S., L. G.Tabil, and S.Sokhansanj. 2004. Grinding performance and physical properties of

wheat and barley straws, corn stover and switch grass .*Biomass and Bio-energy*, 27(4):339-352.

Montgomery, D.C. 2005. Design and analysis of experiments: response surface method and designs. New Jersey: John Wiley and Sons, Inc.

Philippine Agricultural Engineering Standards (PAES 219).2005.For Agricultural Machinery -Forage Chopper, published by Philippine National Standard by the Bureau of Product Standards.