Computer applications for selecting operating parameters of stationary grain crop thresher

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Abstract: In this study, various operating parameters influencing performance of stationary grain crop threshers were established. These parameters were deduced from the established analytical models describing the underlying principles for the crop characteristics and machine variables as factors influencing the overall machine performance of a stationary multi-crop thresher. A computer programme written in Visual Basic was used to select optimum operating performance of the threshing process in a stationary tooth–peg grain crop thresher. An IITA-popularized stationary multi-crop thresher was used to test the practical feasibility of the computer based output of the threshing process. A split – split – unit statistical design was used for data collection. The data collected were analyzed using the GENSTAT 5 statistical package with its computer programme. The results showed that graphs of data from measured thresher performance indices against the predicted data for all the established models indicated high correlation between the models and the measured data at $p \leq 5\%$ significance level. The minimum energy requirements for detachment of sorghum and rice were observed at the threshing cylinder speed of 500 r/min (10.5 m/s) and 615 r/min (13.0 m/s), respectively. The combination of the threshing cylinder speed of 500 r/min (10.5 m/s) and 615 r/min (13.0 m/s) at crop moisture content of 12.8 % and 16.2 % indicated optimum threshing conditions for sorghum and rice, respectively.

Keywords: computer applications, grain, models, thresher, performance, simulation
DOI: 10.3965/j.issn.1934-6344.2010.03.008-018

Citation: Joshua Olanrewaju Olaoye, Kayode C Oni, Mary M Olaoye. Computer applications for selecting operating parameters of stationary grain crop thresher. Int J Agric & Biol Eng, 2010; 3(3): 8－18.

1 Introduction

Threshing of grain crop is a unit operation that requires attainment of sets of processing condition that must be attained for effective threshing action to be accomplished through manual or mechanical operation. Stationary grain crop threshers refer mainly to mechanical thresher that uses threshing cylinders in a localized position. This type of thresher is classified into two distinct methods based on feeding the crop into the thresher. The two methods are hold-on and throughput types.

Inappropriate threshing conditions in a manual threshing process reduces the grain output with respect to excessive and high energy input. In a mechanical threshing process the effect of the inappropriate operating conditions does not only affect the effective recovery of the grains from the other plant materials but it also leads to high grain loss. Grains losses are measured in terms of the damage to the grain kernel, loss to the mechanical elements and non germinability of the seeds. Threshing operation is the removal of grains from the plant residues. It could be done through the process of repeated

Received date: 2009-04-03 **Accepted date:** 2010-08-11

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pounding and dragging of the plant over a surface or through an aperture. Threshing operation is considered as one of the foremost important post harvest operation in grain production[1,2]

Proper adjustment of the operating conditions in a mechanical thresher has been determined by various researchers as the most critical success factors in grain threshing. The key variables of interest are generally classified as the machine parameters, crop characteristics and influencing environmental or processing conditions[2]. Olaoye and Oni[3] investigated crops characteristics of some common grain crops within the middle belt of Nigeria. The results of the investigation revealed that specific presentation of the grain size, geometrical dimensions of the grains and grain mechanical properties are the key parameters that can enhance successful separation of the grains free of plant residues. Many researchers had concluded that the variation of cylinder peripheral speed, effective concave clearance, and fan speed are the major machine variables that can influence threshing performance[4-8]. The fundamental and influencing environmental processing conditions with direct bearing on the effective performance of threshing systems are moisture content and feed rate[2,8]. These are extrinsic factors and they are established on the plant or machine variable through the interactions of the effect of the environment, crop characteristics and machine variables.

According to Olaoye[9] some crop parameters and machine variables are known to influence the performance of threshers. Each or combination of these parameters has influenced effects on the threshing ability and grain damage. He noted that the influences of both threshing ability and grain damage translate to measurable grain losses if not properly managed. Desta and Mishra[10] developed and conducted performance evaluation of a sorghum thresher. A combination of feed rate at three levels (6, 8, 10 kg/min), cylinder-concave clearance at two levels (7 and 11 mm) and cylinder speed at three levels (300 r/min (17.5 m/s), 400 r/min (10.1 m/s), 500 r/min (12.6 m/s)) were investigated. The results of the performance analysis showed that threshing efficiency increased with an increase in cylinder speed for all feed rates and cylinder concave clearances. The threshing efficiency was found in the range of 98.3% to 99.9%. At the recommended speed of 400 r/min (10.1 m/s) the power required for operating the thresher was 4.95 kW and the maximum output of the thresher was 162.7 kg/h.

Saeed et al.[11] tested and evaluated a hold-on paddy thresher. The field performance and economics of the machine were evaluated. A hold-on type Korea thresher (model NJ 810) was used for the study. The field performance of the machine was then measured by varying thresher cylinder speeds and crop feed rates at three levels of threshing cylinder speed ((450 r/min (15.5 m/s), 500 r/min (17.3 m/s), 550 r/min (19.0 m/s)) and crop feed rate at three levels (low (44 kg/h), medium (720 kg/h), high (1,163 kg/h)). The results obtained from the investigation showed that the grain damage in term of breakage was in the range of 0.4% to 1.2%. The percentage of the grain damage increased with the increase in cylinder speed for all feed rates. Grain damage was 0.4% for optimum operating condition. The threshing efficiency increased with increasing feed rate. The results of the comparison of mechanical threshing with manual threshing in term of grain losses clearly indicated 2.64% total loss from mechanical thresher as compared to 7.95% for manual threshing.

To minimize losses in a mechanical thresher, performance of the threshing machine must be evaluated using machine, crop and processing variables. The crop and machine variables are relevant to the performance evaluation of mechanical threshers. Olaoye[2] observed that mechanical threshing of crops become most advantageous at the instance of improved farming practices, use of high yielding varieties, multiple cropping system and expanded use of irrigation water. He noted that with such systems of cultural practices large quantities of crop will mature and must be harvested with relative benefits of mechanical processing equipment.

The requirement for modeling the performance of grain crop thresher is to establish known and expected machines and crop characteristics that may have direct influence on the processing technique of the crop and the final quality and state of the crop product. The computer modeling technique will assist to simulate the thresher performance at different levels of threshing machines variable and crop conditions. The computer models could be a decision making tool to allow repeated testing of different machine parameters and crop variables. The main objective of this study was to use computer models describing threshing actions to establish the appropriate operating parameters and performance of a stationary grain crop thresher.

2 Programme structure and development

The general principle of operation and evaluation of a stationary crop thresher using analytical models as developed by Olaoye[2] was adopted in the programme structure development. The crop and machine variables that are relevant to the performance evaluation of mechanical threshers were identified as cylinder speed, concave clearance, type of threshing mechanism, cylinder diameter, moisture content of crop, type of crop material and feed rate. The specific models for the programme design include the general threshing model, crop dwell time, power required for threshing operation, threshing efficiency, grain damage and separation efficiency.

2.1 Programme design and implementation

The general threshing model for stationary thresher is presented as Equation (1).

$$T = 1 - e - \left[\frac{t_c}{k_m \left(\dfrac{\sigma}{G + \dfrac{2\ddot{v}_s^2}{D}} \right)^{\frac{1}{2}}} \right] \quad (1)$$

Where: T is threshing model denoting the number of kernel threshed in the threshing cylinder in relation to the total number of kernels in the mixture of both grain and crop residue; e is exponential; t_c is dwell time, s; k_m is constant =2.448; σ is mass thickness of unwanted plant material; G is acceleration due to gravity; $\overline{V}_s$ is speed of the grain crop, m/s; D is cylinder diameter, mm.

The crop dwell time measures the time the crop spent in the threshing zone before finally discharged at the outlet[2].

$$t_c = \frac{L_c}{V_c} \text{, but } V_c = K_b V$$

$$t_c = \frac{1}{K_b} \cdot \frac{L_c}{V_t} \quad (2)$$

Where: t_c is dwell time of grain crop in the threshing zone, s; L_c is concave length of the threshing cylinder, mm; V_c is maximum velocity of crop after impact, m/s; V_t is peripheral velocity of the threshing mechanism; K_b is slippage factor.

Olaoye[2] also deduced that the Mean rate of threshing kernels is given as

$$\lambda = k_c \frac{C^3 (1 - M_{cwb})}{\sigma_{\max} V_t W} \quad (3)$$

Where: λ is mean rate of threshing kernels; V_t is peripheral speed of the cylinder, m/s; $M_{\rm cwb}$ is moisture content (wet basis) of the crop, %; W is width of the threshing cylinder=D (mm); $\sigma_{\max}$ is maximum distance between the threshing drum and the concave; C is concave clearance; K_c is constant associated with duration of grain crop within the overall length of the concave.

According to Olaoye[2], the energy required to detach grain from the panicle is presented as follows:

$$E_d = \frac{k_e V_s^{\frac{1}{2}} fr^{\frac{3}{2}}}{\rho W^2} \quad (4)$$

Where: K_e is a constant (grain size characteristics); Fr is feed rate, kg/h; ρ is free density of mass of grain crop, kg/m^3.

All other parameters as previously defined. The power required to detach the grain from the panicle is obtained as

$$P_d = k_s \left[\frac{k_e V_s^{\frac{1}{2}} fr^{\frac{3}{2}}}{\rho W^2} \right] \frac{V_T}{L_c} \quad (5)$$

Where: $k_r = k_s k_e$; k_r is a constant that is influenced by the resistance of the crop material to the machine component; L_c is concave length, mm.

Relating the power output from the cylinder in terms of the detached grain and the power input through the impact from the beater bars, the power required to detach grain crop is

$$P_d = \frac{3k_e}{2} \left[\frac{V_s^{\frac{3}{2}} fr^{\frac{3}{2}}}{\rho w^2 L_c} \right] \quad (6)$$

The power required to overcome frictional force during threshing operation is

$$p_f = \frac{2}{3} Nf \left[\frac{\sigma_{\max}}{C} \right]^n . \pi D L_c \quad (7)$$

The power required to turn the unloaded cylinder is

$$p_u = \frac{2\pi NrMc}{60\times 75}\left[g + \frac{V_T^{\,2}}{r}\right] \qquad (8)$$

Total power required from threshing operation is evaluated as:

$$P = \frac{3k_e}{2}\left[\frac{V_s^{\frac{3}{2}}\, fr^{\frac{3}{2}}}{\rho w^2 L_c}\right] + \frac{2}{3}uF\left[\frac{\sigma_{\max}}{C}\right]^n \pi DL_c + \frac{2\pi NrMC}{60\times 75}\left[g + \frac{V_T^{\,2}}{r}\right] \qquad (9)$$

Where: N is speed of the threshing cylinder, r/min; n is power factor; uF is factor depending on power to overcome friction; Mc is mass threshing cylinder; r is effective radius.

The damage incurred during threshing is related to the dwell time, separating process, factors related to the grains crop conditions and the characteristics of the crop[2]. Energy absorbed by the grain can be evaluated, thus giving an indication of the (maximum) energy that will cause the damage of the crop.

$$E = \frac{1}{2}\frac{\rho_{db} V V_T^{\,2}}{g(1-M_{cwb})}(1-k_s)^2(1-e^2) \qquad (10)$$

Where: e is coefficient of restitution by crop material; V is volume occupied by the grain crop in the threshing zone.

All other notations remain as previously defined. Details of the analysis of the threshing models are presented in Olaoye[2].

Figure 1 shows the major components and arrangement of a specific type of threshing unit that was used for the simulation of threshing process. The machine characteristics, crop parameters and performance indices for operating peg tooth thresher at optimum operating conditions are presented in Table 1. These parameters were used during the computer evaluation of the performance of the thresher.

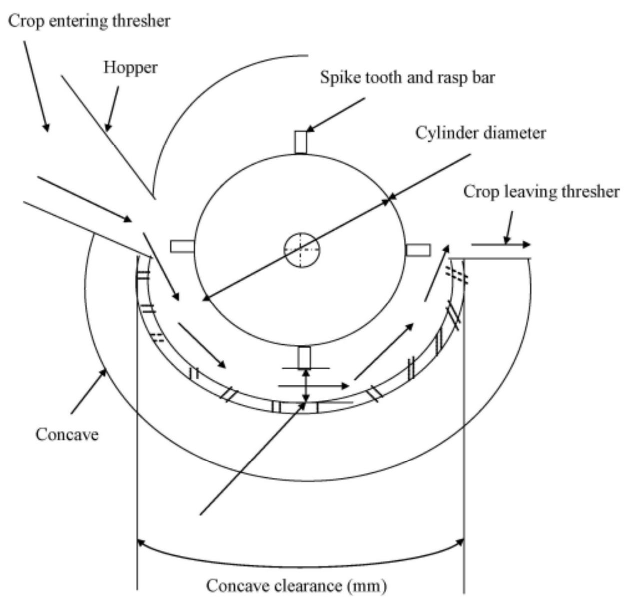

Figure 1 Cylinder concave arrangement of a combined spike tooth and rasp bar thresher mechanism

Table 1 Performance of different threshers for threshing grain crop under optimum operating conditions

S/n	Type of cylinder	Crop	Cylinder speed	Concave clearance /mm	Crop parameter	Cylinder dimension /mm	Performance index	Threshing capacity	Feed rate /kg · h^{-1}	Power source	Source
1	Rasp bar	Sorghum	400 r/min (10.5 m/s)	7.0	Gs = 4.33 mm G:S = 1:3 d = 0.22 g/cc ar = 33 ^{o} ai = 32 ^{o} Mc = 16.2 %	D = 480 L = 640	T_e = 98.3% C_e = 97.2% Gd = 1.12% Sl = 3.8% G = 85.3%	33.2 q/h	360	4.95 kW Electric motor	Desta and Mishra[10]
2	Tooth Peg	Chick pea	580 r/min (14.6 m/s)	30	Yd = 517 kg/ha Mc = 14.2%	D = 480 L = 640	T_e = 93.0% Gd = 2.2% Ml = 9.1%	190 kg/h	430	5.7 L/h Gasoline engine	Anwar and Gupta[12]
3	Tooth Peg	Multi crop Wheat, Sorghum, & Paddy Maize	(12.8 m/s) (10.5 m/s) (16.5 m/s) (15.0 m/s)	25 35-45 20	Mc = 20.2% Mc = 16.2% Mc = 15.5% Mc = 14.6%	D = 480 L = 640 D = 235 L = 830	T_e = 99.0% Gd = 2.0% 4.0%	276 kg/h Wheat 200 kg/h Sorghum 392 kg/h Paddy	500 450 550 500	3.7285 kW Electric motor	Majundar[13] Joshi[5]
4	Tooth Peg	G.nut	400 r/min (6.3 m/s)	25	Mc = 12.0%	D = 300 L = 1220 61 pegs	C_e = 95% Gd = 3% Sl = 6%	264 – 367 kg/h		Tractor PTO	Zafar, et al.[14]
5	Tooth beater	Millet	800 r/min (9.8 m/s)	6	Mc = 12.0% ar = 13.95^o d = 798 g/cc Gs = 3.9 mm	D = 235 L = 830	T_e = 96.8% Gd = 1.3% Sl = 4.5%		385	2.24 kW Electric motor	Ndirika[15]

Note: Gs = Grain Size; G:S = Grain to Straw Ratio; d = Bulk Density; ar = Angle of Repose; ai = Angle of Internal Friction; D = Cylinder Diameter; L = Cylinder Length; T_e = Threshing Efficiency; C_e = Cleaning Efficiency; Gd = Damaged Grain; Sl = Sieve Loss; G = Germination Rate; G.nut= Groundnut; Mc = Moisture Content (wet basis); Bl = Blower Loss; Yd = Yield; Ml = Machine loss; wb = wet basis.

2.2 Computer programming

A computer programme was developed and written in VISUAL BASIC to generate predicted values for the threshing performance models of a thresher handling sorghum and rice. The established mathematical models describing the relationship among the parameters and variables affecting threshing process were presented in section 2.1. These equations were used in the development of the computer programme. The machine set up during computer evaluation of the performance of the thresher was presented in Figures 2 and 3.

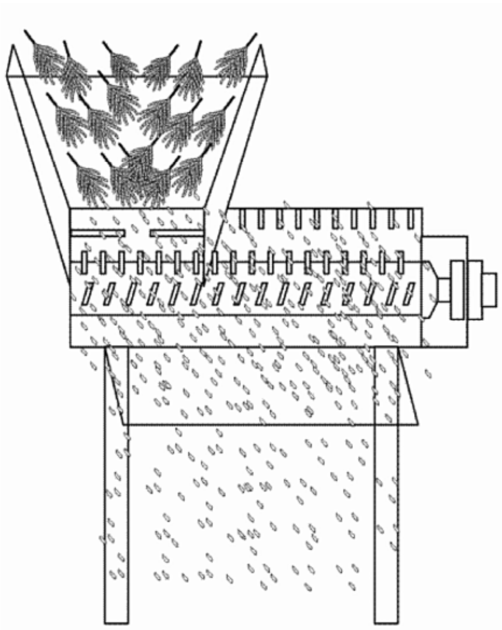

Figure 2 Machine setup showing damages due to inappropriate threshing conditions

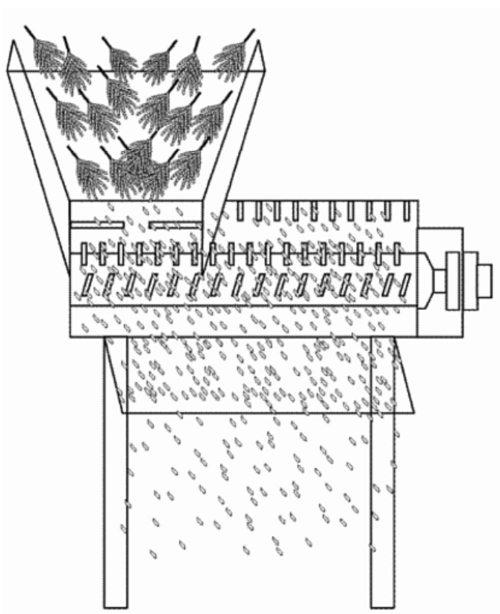

Figure 3 Machine setup showing grain discharge during threshing at appropriate conditions

The performance modeling equations and the modeling thresher shown in Figures 2 and 3 are the representative version of the threshing process. During the process of the simulation, the display of Figure 2 at the run of the programme indicates the presence of white grain particles at the discharge outlet together with the other grain particles showed that the sets of either chosen crop conditions or the machine parameters adversely affect the machine performance. The display of Figure 3 indicates the sets of chosen crops and machine parameters that represented thresher performance generated at or near optimum conditions. The simulation process follows the steps highlighted in the flow chart in Figure 4. The source code is with the authors.

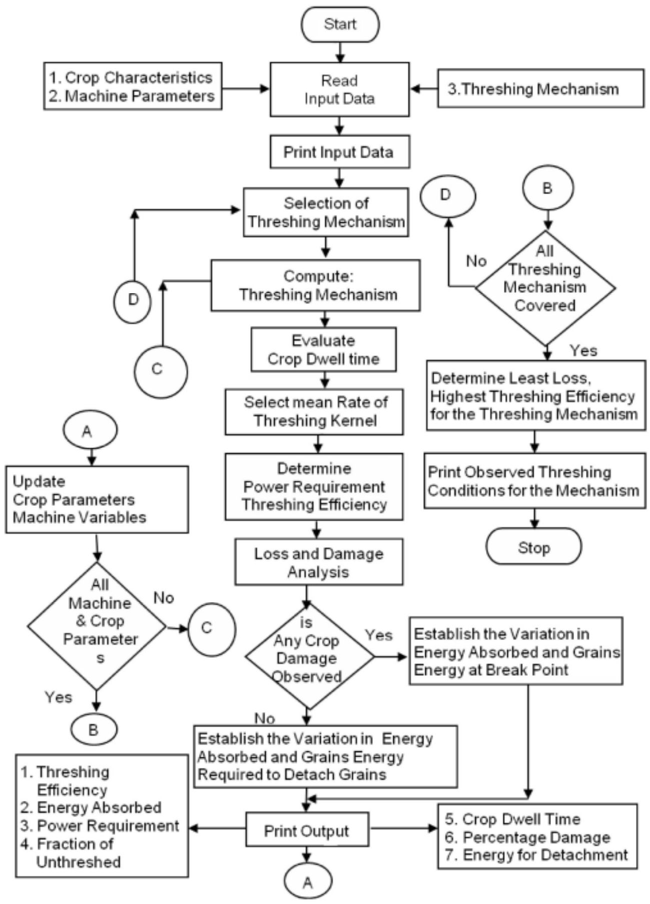

Figure 4 Flow chart for the programme for the simulation of threshing process

The validation of the simulation process and the predicted values of the models developed were determined to obtain how the results obtained from the simulated thresher compare with the observed performance.

3 Computer applications, testing and model validation

The programme was designed to assess the effects of machine variables and crop parameters on the performance of a stationary grain crops thresher. The major indices that were used in the programme include energy required to detach grain, grain operation, threshing operation and threshing efficiency. The values presented in Table 1 were used to evaluate the machine operation. The variables associated with the computations were displayed and the results are stored in the database provided. The results from the performance evaluation of the thresher can be used to establish ranges for computations and to classify the performance indices so as to be able to know the optimum operating conditions for various crops.

To test and validate the data generated from the computer simulation, data were also generated from the IITA popularized multi crop thresher for the validation of the performance models. Four levels of moisture content and threshing speeds were considered for the validation exercise for rice and sorghum. The moisture content ranges for rice were 12.8%, 16.2%, 22.8% (wb) and 32.2% while 10.6%, 12.8%, 20.2% and 26.7% (wb) were chosen for sorghum. These data were selected based on the physical characteristics and the type of the variety of the crop selected. The ranges of the threshing speed for rice and sorghum are 450, 580, 680 and 800 (r/min), and 510, 615, 760 and 890 (r/min), respectively. Rice and sorghum crops were collected and specific weights were measured using a meter balance with 0.01 g calibrations. The dwell time measurement was taken using the method described by Olaoye[2]. An automatic controlled stop watch was used for the measurement of time taken for the threshing of grain crop inside the threshing drum. The clock was an integral part of an optical sensor using (photo diode). A PND Gelger Tachometer was used to determine the speed of the rotating cylinder of the thresher. Grain loss was evaluated in term of fraction of damaged grains and fraction of unthreshed head in percentages following the definition in NSAE/NCAM/ SON[16] as presented in Equations (11) and (12).

3.1 Grain loss evaluation

Grain loss was evaluated in term of fraction of damaged grains (%) and fraction of unthreshed head (%). Fraction of damaged grains and fraction of unthreshed head was evaluated using the definition in[16] as presented in Equations (11) and (12).

$$F_{dg} = \frac{Q_b}{Q_T} \times 100\% \tag{11}$$

$$F_{ug} = \frac{U_T}{Q_T} \times 100\% \tag{12}$$

Where: F_{dg} is fraction of damaged grain; F_{ug} is fraction of unthreshed grain; Q_b is quantity of broken grain in sample, g; Q_T is total grains in sample, g; U_T is total unthreshed heads in sample, g.

3.2 Evaluation of threshing efficiency

Equation (13) was used for the evaluation of threshing efficiency[16].

$$\eta_T = 100 - \frac{Q_u}{Q_T} \times 100\% \tag{13}$$

Where: η_T is threshing efficiency; Q_u is quantity of unthreshed grain in sample.

The results generated by the predicting models were compared with the measured data. The comparison was to determine how well the predicting models fit and statistical significance test were used following the procedure described by Obi[17] and Snedecor and Cochran[18] respectively. Measured data from the IITA grain crop thresher using sorghum and rice were used to validate the performance models. The values of the associated constants and coefficients were presented in Table 2. These values were used in the simulation of the threshing processes as presented in the computer programming. The obtained results from the computer simulation were compared with the experimental investigation using IITA multicrop thresher. The computed values of the machine performance indices were represented by the results that were generated from the computer programming version of the threshing process. The graphs of measured values against predicted data for all the models were presented. The line of best fit and the coefficient of determination R^2 were used to measure how well the regression equation fits the data. The simulated results of each performance models obtained at variable cylinder speed V_F were used to compare values of each of the performance parameters obtained from experimental results.

Table 2 Estimated values of K_e and K_s (Constants and Coefficients) for different grain crops and threshing mechanisms

Types of grain crop	Values K_e, K_s and $K_r = K_s K_e$ for various threshing mechanisms							
	Rasp nars $K_s = 0.7$		Spike tooth $K_s = 0.35$		Beater bars $K_s = 0.5$		Wire loop $K_s = 0.25$	
	K_e	$K_s K_e$	K_e	$K_s K_e$	K_e	$K_s K_e$	K_e	$K_s K_e$
Rice	0.90	0.630	0.90	0.315	0.90	0.450	0.90	0.225
Sorghum	0.26	0.182	0.26	0.091	0.26	0.130	0.26	0.065
Millet	1.42	0.994	1.42	0.497	1.42	0.710	1.42	0.355

4 Results and discussion

The results of the comparison of the value of grain dwell time, threshing efficiency and total grain loss due to unthreshed fraction and damaged crop were made between the predicted data from computer simulation and the data that were obtained using the multicrop thresher for threshing sorghum and rice. The detailed results were presented in Tables 3 to 7. The graphical illustration of the relationship between the predicted and the measured results were presented as Figures 5 to 8. The R^2 value of goodness fit and its significance level respectively for each of the compared performance parameters were evaluated. The calculated R^2 and "t" value for each of the compared performance parameters at P<0.01 and P<0.05 level of significances were presented.

Table 3 Threshing efficiency of an IITA Multi-crop thresher

Moisture content /% wb	Threshing efficiency/%							
	S1		S2		S3		S4	
	Rep I	Rep II	Rep I	Rep II	Rep I	Rep II	Rep I	Rep II
Crop types (C1, Sorghum)								
M1	74.2	75.0	76.2	77.4	78.8	80.0	84.0	86.2
M2	76.4	78.6	80.2	82.6	84.0	84.4	88.4	90.1
M3	90.2	91.3	93.4	94.5	95.6	96.5	97.6	98.1
M4	94.5	94.6	96.4	96.3	98.0	98.0	98.6	98.7
Crop types (C2, Rice)								
M1	80.5	80.2	85.6	82.4	84.1	86.2	84.0	88.6
M2	81.3	82.2	84.7	83.3	86.4	85.0	87.2	86.2
M3	86.2	84.4	87.4	87.6	88.8	88.4	90.3	90.4
M4	86.6	84.8	88.1	88.2	88.6	90.4	90.4	90.8

Table 4 Unseparated fraction of grain crops

Moisture content /% wb	Fraction of unseparated grains from discharged grains/%							
	S1		S2		S3		S4	
	Rep I	Rep II	Rep I	Rep II	Rep I	Rep II	Rep I	Rep II
Crop types (C1, Sorghum)								
M1	28.78	29.86	30.39	31.67	34.18	34.59	42.86	43.12
M2	21.45	21.57	22.15	23.89	24.10	27.27	36.41	38.79
M3	7.69	9.70	11.49	12.16	17.51	17.55	19.83	28.76
M4	31.40	35.87	37.35	38.92	41.75	44.30	53.66	46.42
Crop types (C2, Rice)								
M1	40.76	41.50	42.35	49.39	77.43	77.48	81.82	88.48
M2	28.30	32.75	32.95	45.24	55.16	59.88	70.59	84.21
M3	12.53	16.81	25.25	33.33	41.38	53.47	57.41	63.71
M4	43.64	48.27	54.76	52.26	78.48	78.94	82.80	98.68

Table 5 Observed visible damage during threshing of grain crops

Moisture content /% wb	Visible damage/%							
	S1		S2		S3		S4	
	Rep I	Rep II	Rep I	Rep II	Rep I	Rep II	Rep I	Rep II
Crop types (C1, Sorghum)								
M1	1.85	1.39	1.84	1.93	2.20	2.10	2.41	2.95
M2	2.00	2.01	1.92	2.37	2.50	2.44	2.72	2.67
M3	2.09	2.11	2.82	3.74	5.13	4.05	7.57	6.70
M4	2.18	2.21	3.98	3.92	5.23	4.80	8.08	8.46
Crop types (C2, Rice)								
M1	1.11	1.12	1.38	1.46	1.51	1.56	1.69	1.62
M2	1.45	1.48	1.63	1.72	1.76	1.73	1.80	1.84
M3	2.10	1.79	2.24	2.28	2.94	2.93	4.64	4.77
M4	2.35	2.25	2.63	2.67	3.57	3.91	5.36	5.26

Table 6 Measured crop dwell time within threshing mechanism

Moisture content /% wb	Crop dwell time per kilogram of grain/s							
	S1		S2		S3		S4	
	Rep I	Rep II	Rep I	Rep II	Rep I	Rep II	Rep I	Rep II
Crop types (C1, Sorghum)								
M1	6.80	6.40	5.60	5.40	5.00	4.80	4.40	4.00
M2	6.00	6.00	5.00	4.80	4.40	4.00	3.80	3.80
M3	3.80	3.60	3.20	3.00	2.60	2.40	1.60	1.50
M4	4.20	4.80	4.10	3.80	3.20	3.20	2.20	2.10
Crop types (C2, Rice)								
M1	10.00	10.20	8.40	8.20	6.40	6.80	5.40	5.20
M2	8.20	9.00	7.40	7.20	5.50	5.40	4.80	4.80
M3	6.40	6.40	4.80	4.30	3.00	3.20	2.40	2.60
M4	7.00	7.20	5.30	5.10	3.40	3.60	3.00	3.20

The validity and effectiveness of modeling equations in computer simulation is related to the appropriateness of the values of the undetermined constant that were presented in the modeling equations[19,20]. The results generally revealed that the regression coefficient obtained from regression lines of various models are between 0.90 and 0.99 at 0.05 level of significance. The coefficients of determination of the modeling equations are all statistically significant at 5% level of probability, the high values of the coefficients of the determination show that the regression lines adequately fit the data points.

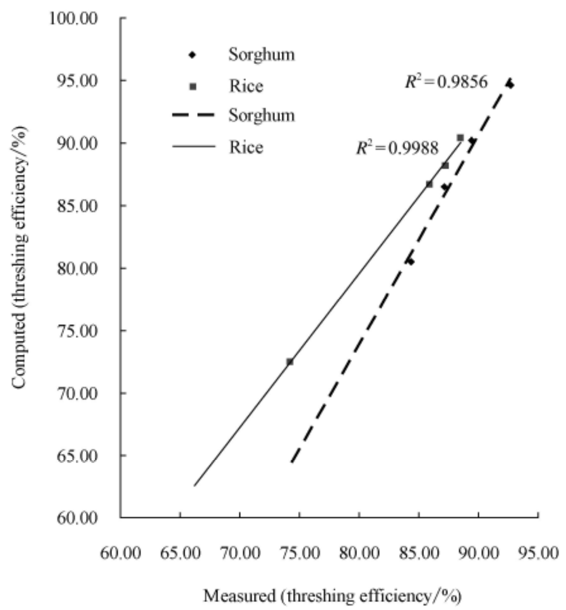

Figure 5 Computed versus measured threshing efficiency during threshing of Sorghum and Rice

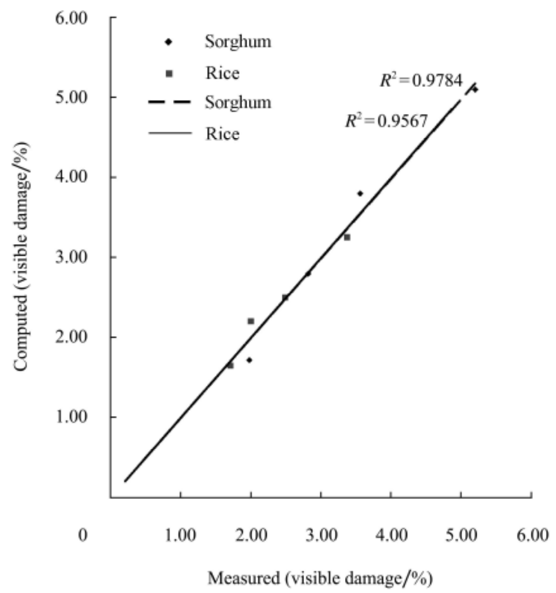

Figure 6 Computed versus measured visible damage for threshing of Sorghum and Rice

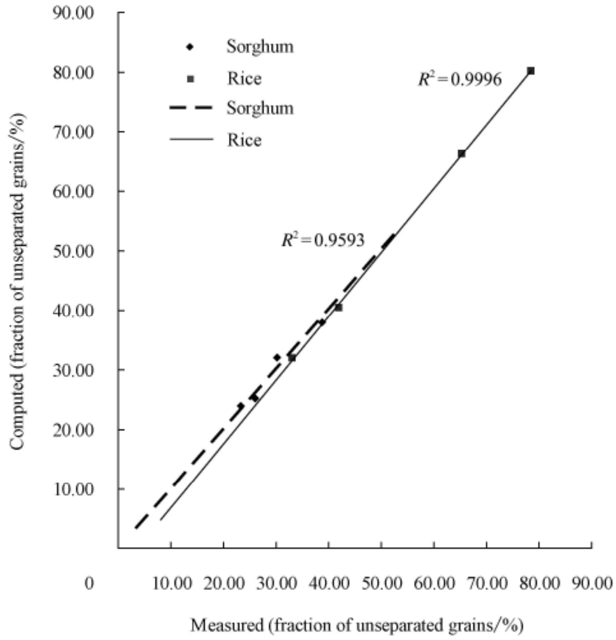

Figure 7 Computed versus measured fraction of unseparated grains from discharged outlet for threshing of Sorghum and Rice

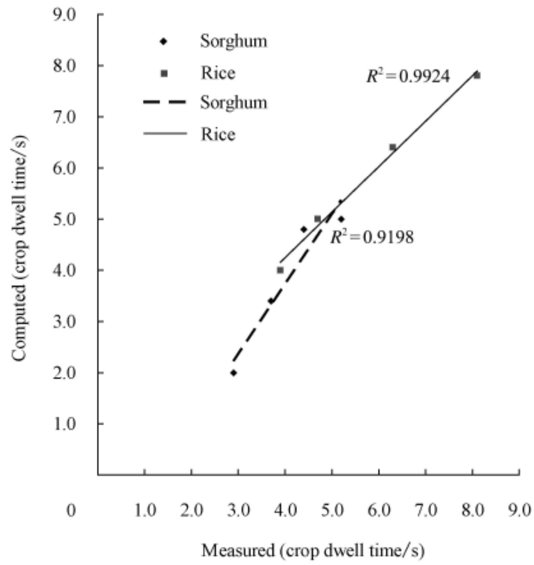

Figure 8 Computed versus measured crop dwell time during threshing of Sorghum and Rice

The validity and effectiveness of modeling equations in computer simulation is related to the appropriateness of the values of the undetermined constant that were presented in the modeling equations[19,20]. The results generally revealed that the regression coefficient obtained from regression lines of various models are between 0.90 and 0.99 at 0.05 level of significance. The coefficients of determination of the modeling equations are all statistically significant at 5% level of probability, the high values of the coefficients of the determination show that

the regression lines adequately fit the data points.

4.1 Results of the computer simulation of the threshing process

The operating parameters for threshing of sorghum and rice were generated from the computer programme developed and the results of the programme output were presented in Table 7. The records of the operating parameters as observed between the displays of Figures 2 and 3 clearly indicate optimum operating condition for the threshing process for the crop in reference. It was observed that the threshing efficiency mostly varied within the range from 78.9% to 96.8 % and 74.8% to 88.4% for sorghum and rice, respectively. Maximum threshing efficiency of 96.8% and 88.4% were obtained at cylinder speed of 500 r/min (10.5 m/s) and 615 r/min (13.0 m/s) and at the moisture content of 12.8 % wb and 16.2 % wb during the threshing of sorghum and rice, respectively. The least power requirement during threshing process occurring at moisture of 12.8 % wb and 16.2 % wb for sorghum and rice, respectively and at the threshing cylinder speeds of 500 r/min (10.5 m/s) for sorghum and 615 r/min (13.0 m/s) for rice. The highest power requirement occurred at 26.7% wb for sorghum and 32.2% wb for rice at threshing cylinder speed of 620 r/min (13.5 m/s) and 760 r/min (16.5 m/s) for sorghum and rice, respectively. The cause of the peculiar behaviour as indicated at moisture content 12.8% wb and 16.2% wb for sorghum and rice, respectively confirmed the significance of these parameters as also displayed by Figures 2 and 3. The least visible damage percentage was 1.6 and 1.1, found at 12.8% wb and 16.2% wb for sorghum and rice, respectively and at threshing cylinder speed of 500 r/min (10.5 m/s) and 615 r/min (13.0 m/s), respectively.

Table 7 Operating parameters for threshing Sorghum and Rice in a stationary grain crop thresher

Operating parameters	Types of grain crop	
	Sorghum	Rice
Moisture content/% wb	12.8	16.2
Cylinder speed/r·min^{-1} (m·s^{-1})	500 (10.5)	615 (13.0)
Energy for grain detachment/kJ	0.0730	0.0104
Power for grain detachment/kW	0.0098	0.00048
Visible damage/%	1.6	1.1
Threshing efficiency/%	96.8	88.4

In general, the percentage visible damage increased with increasing threshing cylinder speed for all moisture content and type of grain crops examined. The reason for this may be attributed to the increase in the inertia of the revolving threshing mechanism and its corresponding impact on the charged crop materials, especially at the detachment of grains from the panicle. At low moisture content of 10.6% to 12.8% wb for sorghum and 12.8% to 16.2% wb for rice, visible damage as high as 8.2% and 5.3% were observed, respectively, and correspondingly at high moisture content of 20.2% – 26.7% wb for sorghum and 22.8%–32.2% wb for rice low visible damage of 1.6% and 1.1% were observed for sorghum and rice, respectively. The energy requirement for the detachment of grain was the lowest for sorghum and rice at moisture content 12.8% wb and 16.2% wb, respectively corresponding to 0.073 kJ and 0.0104 kJ for sorghum and rice, respectively. The trend in the variation in the energy requirement for detachment of grains with reference to changes in moisture content is clearly indicated by shifting in the displays of Figures 3 and 4. This result has indicated that the detachment of grain crop is directly related to the nature of spikelet attachment strength of the grain to the portion of the panicle and grain ear to the stem[21]. The stem and spikelet attachment characteristics are influenced by the maturity of the crop and the quantity of the moisture within the plant material at this stage of development. The effects of the variation of the threshing cylinder speed on the energy requirement for the detachment of grains has shown that for all the values of moisture content examined a threshing cylinder speed is attained where corresponding least value of energy requirement for grain detachment is observed. Any decrease or increase in the threshing cylinder speed after this level would lead to subsequent increase in the energy requirement for grain detachment[22]. The observed results had shown that the amount of energy expended on the threshing of grain crops was not correctly channeled towards only detachment of grains at these other threshing conditions. This result has indicated that an appropriate threshing cylinder speed must be established and reconciled with the desirable threshing conditions and conditioning of plant material that will lead to high threshing yield and minimum loss.

5 Conclusions

The modeling equations were adopted to describe the threshing processes. The output of the computer simulation using the modeling equations had shown high level of correlation with the observed results of the thresher performance with an IITA popularize thresher that was used for the validation of the simulated results.

The compared results generally revealed that the regression coefficient obtained from regression lines of various models were between 0.09 and 0.99 at 0.05 level of significance. The results showed the R^2 values for the computed against predicted threshing efficiency for sorghum and rice as 0.985 and 0.998, respectively.

The performance modeling equations and the modeled thresher were used dynamically to observe machine performance by following changes in the machine parameter and crop characteristics.

The application of the simulated computer programme has indicated that the models can be used as a guide for the design of multicrop thresher for optimum operating performance. The simulated programme can be used to analyse the various input combinations of crop and machine variables for optimum thresher performance. Maximum threshing efficiency of 96.8% and 88.4% were obtained at cylinder speed of 500 r/min (10.5 m/s) and 615 r/min (13.0 m/s) and at the moisture content of 12.8% wb and 16.2% wb during the threshing of sorghum and rice, respectively.

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