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EFFECT OF MOISTURE CONTENT, FEED RATE AND SPEED ON THE PERPORMANCE INDICATORS OF A SOYBEAN THRESHER

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ABSTRACT

A modified soybean thresher was evaluated for its performance indicators as influenced by moisture content, feed rate and speed. The performance evaluation was done at 3 levels each of moisture contents and feed rate and 5 levels of speed. Results show that, threshing and cleaning efficiency of 99%and 95%, respectively,scatter loss of 2.7%, mechanical grain damage of 1.01% and grain throughput capacity of 25.5kg/hr were obtained. Moisture content, feed rate and speed had significant effects on threshing and cleaning efficiency, scatter loss, mechanical grain damage and throughput capacity of the soybean thresher. It is recommended that in order to obtain good performance of the soybean thresher, the optimum moisture content of the material to be threshed is 14%.

Keywords: Moisture content; Feed rate; Soybean; Thresher

INTRODUCTION

Soybean (*Glycine max* L.Men) is a herbaceous annual legume that is usually erect, bushy and rather leafy. Cultivars range from 45-120 cm in height with growth period of 75-150 days and mostly have a main stem that branches from the lower nodes (Smith and Huyser, 1987).The extent of branching depends on environmental conditions (light and available moisture). The stems, leaves and pods are covered with fine tony or grey pubescence. The pods are small, straight or slightly curved and range in colour from light straw to nearly black. Soybean is one of the world's most important food crops having superior amino acid profile compared to other sources of plant protein. It provides about 64% of the world's oil seed meal supply and is a major source of oil, accounting for about 29% of total world production (Smith and Huyser, 1987). It contains about 40-41% protein and 20.5-21.5 % oil. Soybean is processed to separate the oil from the protein meal which is incorporated into the animal and poultry feeds. It is known to have been grown in China and Japan for thousands of years. It is referred to the "meat of the world" because it is the cheapest source of protein and oil. Soybean combines in one corm both the dominant world supply of edible vegetable oil, and the dominant supply of high-protein feed supplements for livestock. Soybean seeds have a wider range of economic importance. It ranges from industrial, food, pharmaceutical and agricultural products (Smith and Huyser, 1987). Worldwide soybean production amounts to around 130 million metric tonnes per year utilizing around 60 million hectares (FAO, 1980). If processed and used domestically soybean could become as economically attractive in Nigeria as in other parts of the world. Soybean can be the most practical means of relief from kwashiorkor (protein-calorie malnutrition) which is on the increasing prevalence among young African children. Other means of protein like wild animals and fish have disappeared due to indiscriminate hunting and fishing and has become very expensive for an average African family, hence the introduction of soybean crop in west and central African countries being encouraging (Ayagi, 1994). It can also be processed into a wide range of products for human consumption and utilization, which include oil for making margarine cooking oil, salad oils, synthetic gums, soaps and paints. It is also used in making soy flour used for bread, biscuits etc. Whole seeds can be soaked overnight and cooked as bean or for “dawadawa” (a northern Nigerian food sweating spice). Other products are soybean milk, soy-source, soybean curd and bean spouts (Marina, 1991).

Soybean is a warm season crop and its climatic requirements are about the same as those of maize. For germination and early plant development there is the need for a moderate moisture supply. The period of germination is the most critical stage and an excess or deficiency of soil moisture at this time could be harmful. Soil temperature of 15°C or more favour rapid germination and vigorous seedling growth which is essential for successful competition with weeds. Growing temperature of 20°C to 25°C appear to be optimum. Soybean produced in higher temperatures (about 32°C) tend to be low in oil quantity and quality (Marina, 1991). In Nigeria, improvement in production of soybean can only be possible when relevant machinery and equipments are developed for post harvest processing to encourage small-scale farmers (Ayagi, 1994).Hyetson (2003) observed that the moisture content at which threshing is carried out, concave drum clearance and pitch of screw are all factors that affects threshing. Oforka (2004) modified the existing institute (IAR) soybean thresher and obtained the best performance combination at a cylinder speed of 850 revolutions per minute(rpm), feed rate of 30 kg/h with samsoy-2 variety at 10 % moisture content of the grain. Also 96 % threshing efficiency, 2.86 % mechanical grain damage, 97 % cleaning efficiency, 2.86 % scatter loss and 33 kg/hr throughput capacity were obtained.

Anuson and Vilas (2006) developed and evaluated an axial flow soybean thresher. Machine crop parameters affecting the performance of the soybean thresher were evaluated. During the tests, four drum speeds 400, 500, 600 and 700 rpm and three feed rates 360, 540 and 720 kg/hr were used. The average moisture contents of grain used in the test were 32.88 (29.09%), 22.77 (18.72%) and 14.34 (16.78%). The most commonly grown soybean variety KKU-35 grown in Thailand was used for the test. The performance evaluation of the developed thresher was assessed in terms of output capacity, threshing efficiency, grain damage, grain losses and power requirement. The performance evaluation shows that at grain moisture content of 14.34% (w.b), feed rate of 720 kg/hr and a drum speed of 700 rpm with an average power of 1.85 kW, the output capacity, threshing efficiency, grain damage and grain loss were found to be 214 kg/hr, 99.49, 0.22 and 0.80 %, respectively.

Amir (1990) stated that one major improvement in threshing mechanism was the axial flow cylinder threshing system which when compared to the conventional transverse cylinder had higher capacity and lower seed damage.Transverse threshing cylinders usually have high peripheral speeds. To maintain that speed when threshing entire soybean plants requires a considerable amount of energy. Kanafojski and Karwowski (1976) reported that soybean threshing cylinder required about 40 % of the engine’s power. This is due to the fact that the threshing cylinder requires high power to thresh the whole soybean plant instead of only the pods. Mesquite and Hoag (1989) found out that soybean pods require only a small amount of energy to shatter them. To reduce mechanical damage while increasing the threshing capacity, efforts have been made to develop rotary threshing equipments. Amir (1990) reported higher capacity and lower damage to seeds with a twin rotor system than with a conventional transverse threshing cylinder. Mesquite and Hanna (1993) studied the mechanics of soybean threshing by developing a test stand to analyse the mechanical actions of frictional rubbing and impact on soybean plants by stimulating the movement of experimental units over a row of soybean plants, thereby obtaining 93 and 92% threshing efficiencies, respectively. Reliability is achieved by simplification and improvement. Machines built with fewer parts have higher reliability and that improvement can be attained during the design phase or during the test phase by simplifying the design first and then improving it as required (Joshi, 1981).According to Paulsen (1978), the goal of the threshing device must be to eliminate losses in the threshing process in terms of both macro and micro breaking, at the same time carrying out separation of the grains from the chaff.

This research was carried out with the view of evaluating the effects of moisture content and speed on the performance parameters of soybean thresher at different feed rates.

MATERIALS AND METHODS

Study Area and Machine Design

The study was conducted at the Agricultural Engineering Department, Ahmadu Bello University, Zaria. A soybean thresher was designed and constructed with modifications in the threshing unit, the fan blades of the blower and the size of the feed hopper (Nomau, 2012). The thresher consist mainly of a commercially available main frame made up of angle iron, the threshing unit, concave, the blower unit, the shaker mechanism, the sieve and the hopper.

The threshing unit was made up of cylinder, beaters and a perforated concave plate. The threshing cylinder also houses a threshing drum that consist of a long triangular shaped member on which a series of rasp bars are attached along the three edges. This cylinder drum is mounted on the bearing and is rotated in a perforated trough-like chamber, called the “Concave”. An auger is located below the threshing drum to convey the material into a collecting tray in the shaker unit. The clearance between the free ends of the beaters and the concave is 6mm. The size of the threshing unit was increased to a larger size than the existing threshing unit of the IAR soybean thresher by increasing the diameter and the depth of the threshing drum. Additional rasp bars in form of cutting knives were also added around the hopper section that covers the threshing drum. This was to enable the vegetative material of the soybean to be cut into pieces for easy threshing.

The shaker unit was located directly below the threshing cylinder and consists of a collecting tray and a sieve. This unit is to collect the threshed material and separate the grains from the chaff through a reciprocating motion provided by the main source of power of the thresher.

The blower unit consists of a four-blade fan that provides air current that assists in separating the grain from the chaff. The fan is located at a distance below the perforated concave.

The sieve plate was constructed using gauge 16 mid steel metal sheet and is positioned inside the shaker tray. It covers the entire dimension of the tray and also extend outwards in such a way that it is just below the fan.

The grain collector is located just below the sieve plate to collect the cleaned threshed grains.The transmission unit consisted of a thresher pulley, a fan pulley and a shaker pulley whose various diameters were determined. It also consists of a series of bearings, shafts and V-belts of variable lengths. The thresher is powered by a 4.5kW diesel engine.The thresher has a structural frame unto which all other components were mounted.

Various factors were considered in the design and construction of the improved soybean thresher.The thresher is operated using a 4.5 kW diesel engine. This was chosen due to irregular electricity supply and it is also cheaper than the petrol engine (Nomau, 2012). The diesel engine can also be operated at desirable speeds. The speed of 700 rpm was chosen as the optimum speed for the operation of the machine. This was chosen considering the optimum speed of 850 rpm used by Oforka (2004) which results to higher grain damage and higher scatter loss due to the high speed. Vertical flow was chosen for the direction of flow of the threshed material for simplicity in design. The size of the sieve openings (oblong openings of 8 mm wide and 10 mm long) was used taking into consideration the average size of the soybean grain that was determined by Huji (2002) to be 5.28 mm wide, 6.39 mm long and 4.69 mm thick. The angle of repose of 17.50^0 as determined by Huji (2002)

Experimental Design and Procedure

A layout of 5 levels of cylinder speed (S) (300, 400, 500, 600 and 700 rpm) by 3 levels of feed rates (F) (1.0, 1.5 and 2.0kgmin^{-1}) and 3 levels of moisture contents (M) (10, 13 and 14%) in a completely randomized block design (RCBD) form was used in three replications.

Using the three experimental factors above i.e F, S and M, a total of 45 treatments with three replications were conducted in order to determine the range of feeding rate, cylinder speed and moisture content that gives the best performance of the machine. At each combination, the threshed materials were collected at the outlets, cleaned and weighed. After threshing, the portion of the material containing unthreshed grains (grain and stalk) were collected, separated and weighed.

At the end of the experiment the following results were obtained.

Q_o = Quantity of clean grains collected at the grain outlet after threshing (kg)
Q_u = Quantity of unthreshed grains in sample (kg)
Q_b = Quantity of broken grains in sample (kg)
Q_L = Quantity of grains scattered around the thresher after threshing operation (kg)
Q_s = Quantity of threshed grains collected after a threshing operation (kg). $Q_s = Q_o + Q_L$
Q_t = Total quantity of grain in sample (kg). $Q_t = Q_u + Q_s$
W_t = Weight of chaff and grains at outlet of thresher (kg)
W_c= Weight of chaff at outlet of thresher (kg)
T = Time taken for complete threshing operation (min)

Performance Indicators

After construction, the thresher was evaluated on the following parameters:

Threshing Efficiency, Te (%)

This parameter was used to determine the threshing ability of the improved soybean thresher. It is the ratio of the quantity of unthreshed grain in sample to the total quantity of grain in sample

$$T_e = 100 - \frac{Q_u}{Q_t} \times 100$$ (Ndirika, 1994)

Where

Q_u = quantity of unthreshed grains in sample (kg)

Q_t= Total quantity of grain in sample (kg)

Mechanical (visible) Grain Damage M_D (%)

This parameter was used to determine the quantity of grains damaged during threshing. It is the ratio of the quantity of broken grains collected in sample to the total quantity of grains in sample (Ndirika, 1994) and it is given as

$$M_D = \frac{Q_b}{Q_t} \times 100$$

Where

Q_b = quantity of broken grains in sample (kg)

Q_t= Total quantity of grain in sample (kg)

Cleaning Efficiency C_e (%)

This is the ratio of the weight of the grain collected at the grain outlet to the weight of the total mixture of grain and chaff received at the grain outlet (Ndirika, 1994) and it is given as

$$C_e = \frac{W_t - W_c}{W_t} \times 100$$

Where

W_t = Weight of total mixture of grain and chaff received at the grain outlet (kg)

W_c = Weight of chaff at the main outlet of the thresher (kg)

Scatter Loss, S_L (%)

During the threshing operation some grains were lost due to scattering. Such grains were determined using the formula below:

$$S_L = \frac{Q_L}{Q_t} \times 100$$

Where

Q_L = Quantity of grains scattered around the thresher after threshing operation (kg)
Q_t= Total quantity of grain in sample (kg)

Grain throughput capacity, Tc (kg/hr)

This is the capacity of the thresher in terms of the total quantity of threshed materials in sample per unit time. Grain throughput capacity was calculated as done by Ndirika (1994) as:

$$T_C = \frac{Q_s}{T}$$

Where

Q_s = Quantity of threshed grain collected after a threshing operation (kg)
T = Time taken for a complete threshing operation (min)

Moisture Content (%)

The moisture content of the threshed grains was determined on wet basis using the oven drying method. The moisture content was calculated using the formula:

$$M_{wb} = \frac{W_w - W_d}{W_w} \times 100$$

Where

W_w= Weight of wet sample before drying (kg)
W_d= Weight of sample after drying (kg)
M_{wb} = Moisture content on wet basis (%)

Instrumentation

i. The moisture content (%) was determined using an oven dryer and a weighing balance.
ii. The shaft speed (m/sec) was determined using a tachometer.
iii. The feed rate (kg/min) was determined using a weighing balance and a stop watch.
iv. The time (min) for threshing was measured with a digital stop watch.

Data Analysis

The results obtained from the experiment were subjected to analysis of variance and where there is a significant difference, the Duncan Multiple Range Tests was used to separate the means (P<0.05). Graphical plots were generated using the MS Excel software.

RESULTS AND DISCUSSION

The soybean thresher constructed was used to carry out the performance evaluation. The results of the mean performance parameter for the soybean thresher at three moisture contents for different feed rates are presented below. The result of the analysis of variance carried out is also presented below.

Effect of Moisture Content on Threshing Efficiency at Different Feed Rate

The result of the performance evaluation of the soybean thresher carried out shows the mean threshing efficiency at different combination of moisture content and feed rate. A high threshing efficiency of 99% was obtained at the lowest moisture content of 10% and at the lowest feed rate of 1 kg min^{-1}. This result is higher than that obtained by Oforka (2004) which was 96%. There is lower efficiency at higher feed rate and higher moisture content. This indicates that threshing efficiency increases with decrease in moisture content and feed rate (Nomau,2012).

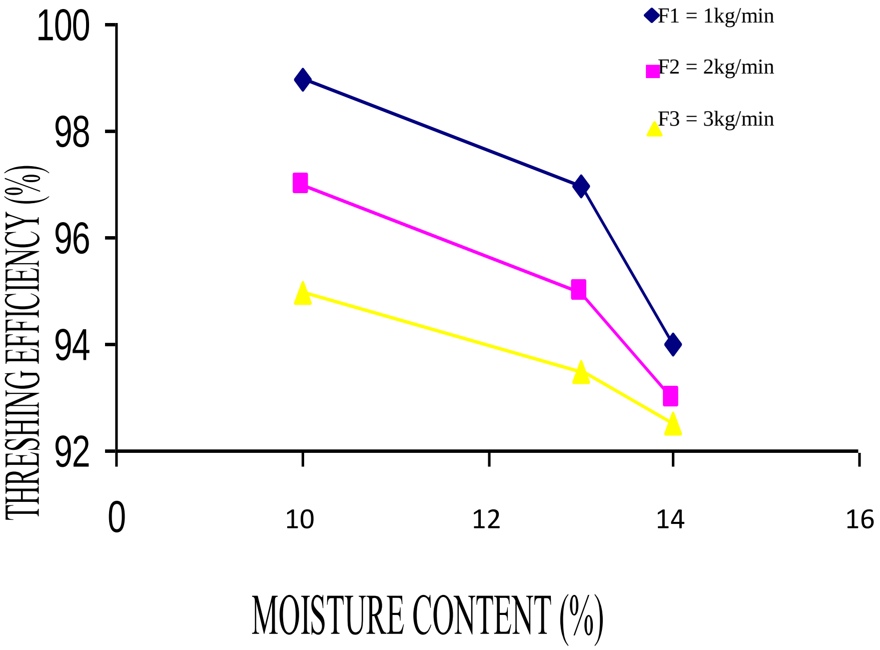

Fig1: Effect of Moisture Content on Threshing Efficiency at Various Feed Rate

Effect of Moisture Content on Cleaning Efficiency at Various Feed Rate

Fig.2 Shows that the drier the material to be threshed, the higher the cleaning efficiency. Cleaning efficiency of 95% was achieved at the lowest moisture level of 10% and at the lowest feed rate of 1 kg min^{-1}. This is as compared to Hyetson (2003) who reported a lower cleaning efficiency of 75% at a moisture content of 15% and feed rate of 0.33kg/min. As the feed rate is increased from F1 to F3, the corresponding efficiency reduces at different moisture level.

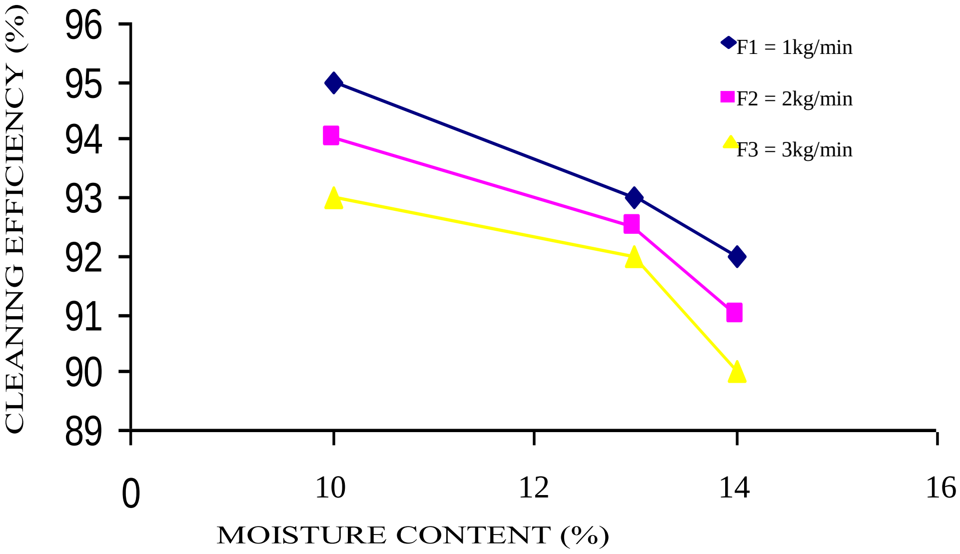

Fig. 2: Effect of moisture content on cleaning efficiency at various feed rate

Effect of Moisture Content on Grain Damage at Different Feed Rate

Fig.3 indicates that the percentage of grain that is broken during threshing increases with a decrease in moisture content and increase in feed rate. A high grain damage of 1.0% at a moisture content of 10% occurs with the highest feed rate. The lowest grain damage of 0.92% was at the highest moisture content of 14% and occurs with the lowest feed rate of 1.0 kgmin^{-1} (Nomau, 2012). This could not be compared to that of Oforka (2004) where he obtained a high grain damage of 2.86% at moisture content of 10%.

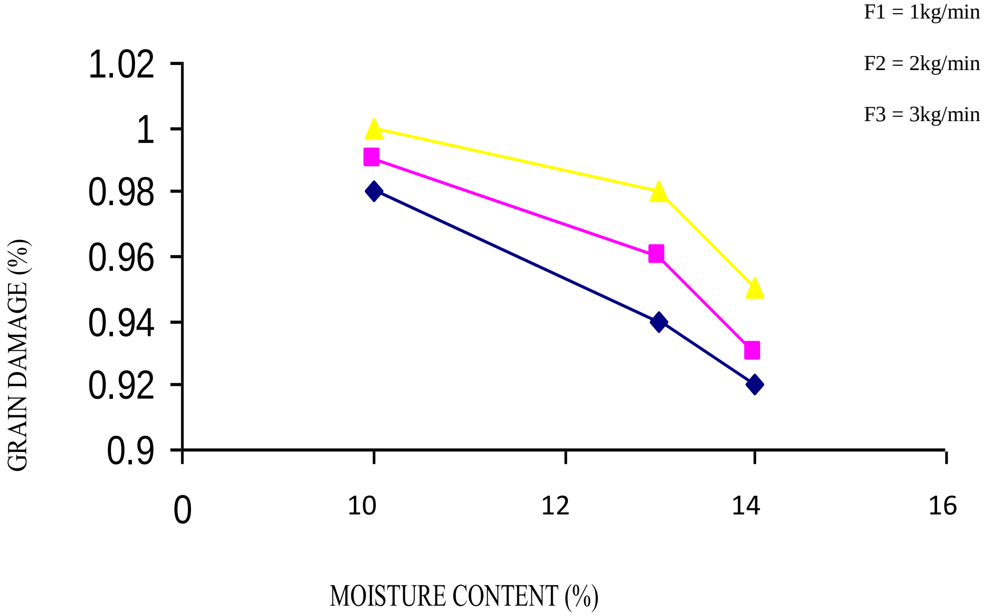

Fig.3: Effect of Moisture Content on Grain Damage at Various Feed Rate

Effect of Moisture Content on Scatter Loss at Different Feed Rate

Fig. 4 shows that an increase in feed rate at lower moisture content led to increase in scatter loss. The highest scatter loss of 2.7% occurred at a moisture content of 10% with the highest feed rate of 2 kgmin^{-1} while a low scatter loss of 2.0% occurs at the highest moisture content of 14% with the lowest feed rate of 1.0 kgmin^{-1}.

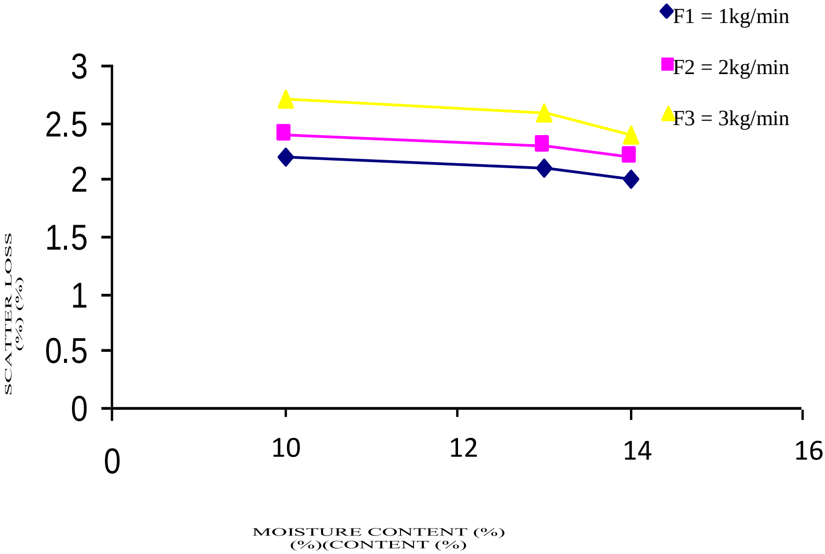

Fig.4 Effect of Moisture Content on Scatter Loss at Various Feed Rate

Effect of Moisture Content on Grain Throughput Capacity at Different Feed Rate

The effect of moisture content on the grain throughput capacity is shown in Fig.5.From the figure, it could be seen that throughput capacity increased with a decrease in moisture content and an increase in feed rate. It shows that throughout capacity increased with all level of feed rate as moisture content is reduced. A throughput capacity of 25.5kg/min was obtained at the lowest moisture content of 10% and at the highest feed rate of F3. Ofoka (2004) also obtain a throughput capacity of 33kg/hr at moisture content of 10%.

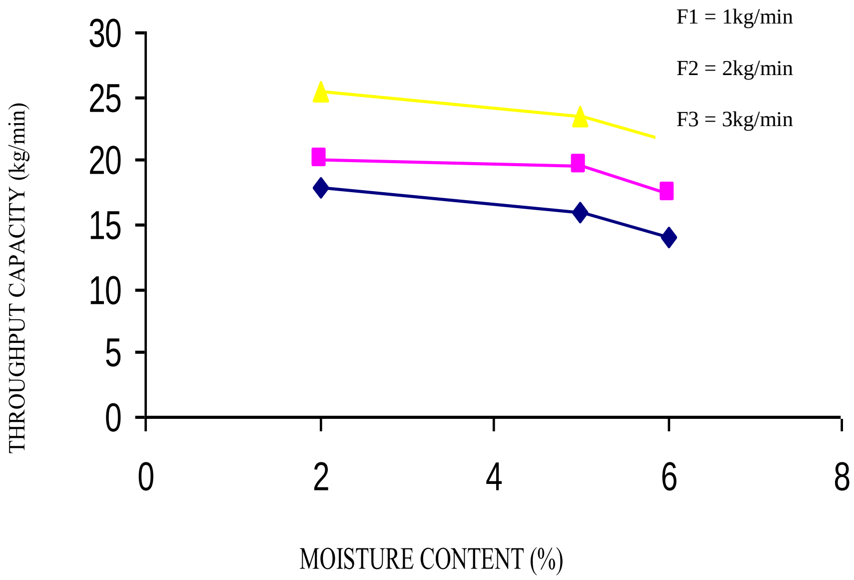

Fig.5: Effect of Moisture Content on Grain Throughput Capacity at Various Feed

Analysis of Variance of the means of Soybean Thresher Performance Parameters

The result of the analysis of variance shows that speed has a significant effect on all the indices of interest except scatter loss (Table 1).The effect of feed rate on cleaning efficiency and grain damage was not significant, however significant effects were observed for feed rate on threshing efficiency, scatter loss and throughput capacity. Moisture content did not have a significant effect on all the indices of interest. The interactions of the factors studied did not have significant effects on the indices of interest except for cleaning efficiency and for which the interactions of moisture content and speed and the interactions of the three factors together were significant.

Table 1: ANOVA of the means of the parameters of soybean threshing unit

		F-values				
Source of variation	df	Threshing efficiency	Cleaning efficiency	Grain damage	Scatter loss	Throughput capacity
Replication	2	1.237 ns	10.46 *	3.67 *	1.36 ns	0.53 ns
Feed(F)	2	9.83 *	0.70 ns	1.61 ns	8.57 *	138.5 **
Moisture(M)	2	0.01 ns	2.78 ns	0.30 ns	2.15 ns	2.30 ns
Speed(S)	4	4.56 *	3.87 *	9.98 *	2.20 ns	9.03 *
F x M	4	0.80 ns	2.90 *	8.07 *	2.99 *	3.44 *
F x S	8	1.03 ns	1.81 ns	0.27 ns	1.55 ns	0.68 ns
M x S	8	0.91 ns	2.12 *	1.71 ns	0.59 ns	2.03 ns
M x F x S	16	1.06 ns	2.17 *	1.20 ns	1.07 ns	0.68 ns
Error	88					
Total	134					

** : highly significant at 1% level, *: significant at 5% level, ns: not significant .df: degree of freedom.

CONCLUSION

The modified soybean thresher was evaluated for its performance as influenced by speed, feed rate and moisture content and from the result it was concluded that threshing and cleaning efficiency increased with decrease in moisture content and feed rate, this means that increase in feed rate at different moisture content decreases cleaning efficiency. Furthermore the amount of broken grains during threshing increased with decrease in moisture content and feed rate. An increase in feed rate at lower moisture content increases scatter loss. Throughput capacity increases with a decrease in moisture content at all levels of feed rate. The result indicates that the moisture content at which soybean is threshed is very important in the evaluation of the performance of parameters of the soybean thresher. This shows that with the level of moisture content in the soybean material to be threshed taken into consideration, the thresher has a great potential in mechanizing the threshing process of soybean.

To improve the threshing efficiency of the soybean thresher, there should always be a decrease in the moisture content and feed rate of the soybean material to be threshed.

To get a high threshing efficiency from the thresher, the moisture content of the material to be threshed should be reduced to 14% moisture level. The amount of soybean material to be feed during threshing should also be reduced to 1.0 kgmin^{-1}. To reduce grain damage at threshing, both the moisture content and feed rate should be at 14% and 1.0 kgmin^{-1} respectively. To reduce scatter loss during threshing, the moisture content and feed rate of the soybean material should be reduced.

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