

Modification and Performance Evaluation of a Millet Thresher Machine

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ABSTRACT

A millet thresher was developed with problems of poor performance including high scatter grain loss and low cleaning efficiency. This study was undertaken to modify the fan unit of the IAR millet thresher machine with the aim of eliminating the drudgery involved in the operation and to improve its performance in order to increase cleaning efficiency and reduce the percentage scatter grain loss. The machine was re-evaluated after modification by determining cleaning efficiency and percentage scatter grains loss. This was achieved by threshing millet at 2, 3 and 4 kg/min feed rate and five levels of fan speed (17.8, 20.5, 20.9, 24.7 and 25.5 m/sec). The maximum performance achieved with fan speed, federate and moisture content were 25.5 m/sec, 3 kg/min and 22.2%, respectively, while the cleaning efficiency and percentage grain loss were 89 and 1.94%, respectively. The modified prototype machine is expected to reduce drudgery associated with the traditional method of cleaning millet and therefore increase productivity of farmer.

1. INTRODUCTION

Millet is group of highly variable small-seeded grasses, widely grown around the world as cereal crops or grains for both human food and fodder. They do not form taxonomic group but rather a functional agronomic one. Millets are important crop in the semi-arid region of Asia and Africa (especially in India, Nigeria and Niger) with 97% of millet production in developing countries (Labe, 1988). Nigeria is the third leading millet producing country in the world after India with production capacity of about 4 million tons, which is about 13% of total world production (FAO, 1996). The crops are favoured due to productivity and short growing season under dry and high temperature condition. While millets are indigenous to many parts of the world, millet most likely had an evolutionary origin in tropical western African, as that is where greatest number of both wild and cultivated form exists (FAO, 1995). Millet has been an important food staple in human history, particularly in Asia and Africa, and they have been in cultivation in East Asia for the last 10,000 years (Labe, 1988). It has been reported that the air-dried grain of millet contains approximately 12.4% water, 11.6% protein, 5% fat, 67.1% carbohydrate, 1.2% fibre and 2.7% ash (Onwueeme and Sinha, 1991)

The varieties mainly grown in the savannah part of Nigeria are *Ex-Borno*, *Zango*, *Maiwa* and *Gauva*. The *Ex-Borno* variety constitute 90% of all millet grown, it grows at an annual rate of 2.1% (Agidi *et al.*, 2013). In Nigeria millet seeds have multi-purpose use by the rural communities most especially for making porridge (*fura*), *Tuwo*, *waina*, *kunu* and *pap*. In order to increase millet production, it is necessary to

modernize the production techniques and optimize the processing conditions with a view to realizing some basic quality requirements such as improved flavor and increased shelf life (Ogunlowo and Adesuyi, 1999). Traditional method of cleaning process is slow and energy consuming. Often, this local method of processing the crop leads to low quality product due to the presence of impurities like stones, dust and chaff (Agidi *et al.*, 2013). Threshing and cleaning of the grains from these impurities requires modern technology that can be easily maintained for effective utilization. Therefore, this study was undertaken to modify the fan unit of the IAR millet thresher machine with the aim of eliminating the drudgery involved in the operation and to improve its performance in order to increase cleaning efficiency and reduce the percentage scatter grain loss. The modified prototype machine is expected to reduce drudgery associated with the traditional method of cleaning millet and therefore increase productivity of farmer.

2. METHODOLOGY

2.1 Machine Description and Design Considerations

Figure 1 shows the isometric view of the millet thresher machine. It consists of the hopper, shelling cylinder, bearings, bolt and nut, concave, cleaning unit, grain outlet, pulley, shaft, prime mover seat and frame. The design considerations were: affordability, maintainability cost of material, durability, rigidity, availability of part, safety and ease of operation. The machine consists of two set of sieves. The first sieve, straw sieved has holes diameter of 3 mm while the second for cleaned sieved has diameter of 2 mm respectively. The fan unit has four blades made of mild steel supported by shaft.

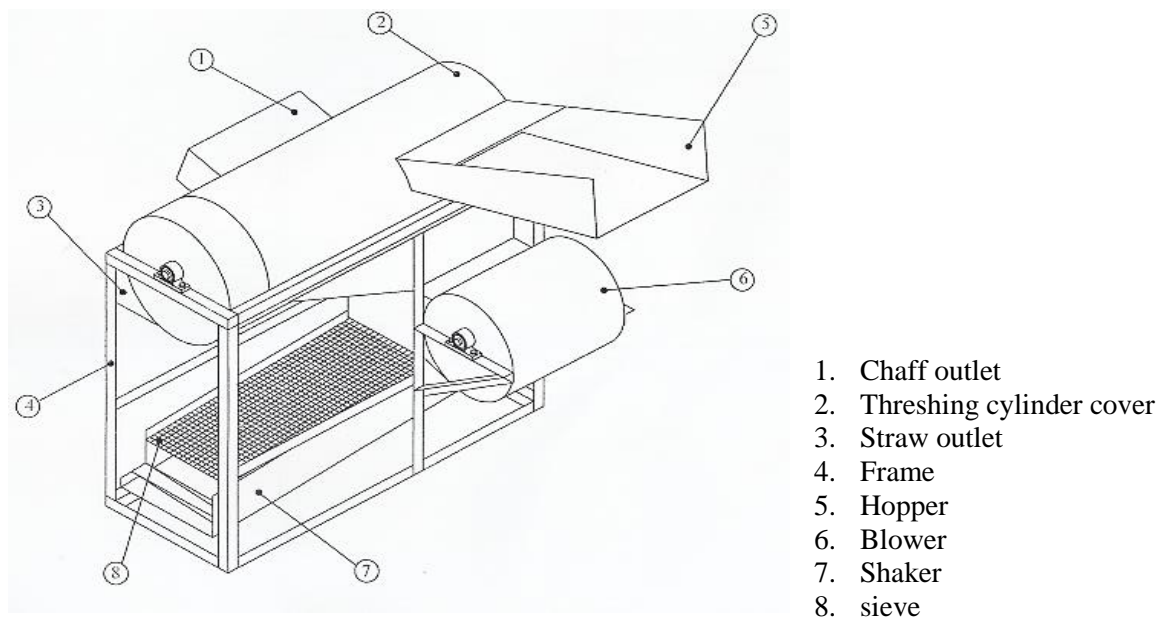


Figure 1: Isometric View of the Machine

2.2 Material Selection

The materials used for the modification of cleaning mechanism were mild steel, metals sheet, bearing, belt, pulleys, flat bars, 12 mm mild steel rod and angle iron. The materials were selected based on strength, rigidity, availability and cost. The selection was based on the resistance to all possible stress which may be subjected to during operation. Metal sheets were selected by considering failure due to shearing and crushing (Nura *et al.*, 2017). The sieve hole was chosen based on the physical properties of the millet grain as quoted by Afolabi (2015).

2.3 Determination of the Component Features

Determination of weight of the fan blades

The weight of the fan blades was determined based on relationship adapted by Mohammed (2009) as given in equation 1.

$$w_f = \delta g v_m \quad (1)$$

Where:

w_f is the weight of the fan blade (N),

δ is the density of the galvanized steel = 7850 kg/m³ as given by Khurmi and Gupta (2007)

g is the acceleration due to gravity = 9.81 m/s²

v_m is the volume of material used for the fan construction (m³).

Four (4) blades each of volume $30 \times 12 \times 1.5 \text{ mm}^3$ were used in construction.

Determination of fan air discharge rate

According to Joshi (1981), the air discharge (Q) by a blower is given by equation 2.

$$Q = V \times D \times W \quad (2)$$

Where:

Q is the air discharge (m/s)

V is the air velocity (m/s)

D is the depth of flow above the reference point (m), and

W is the width over which air is required (m)

Determination of power required in fan and shaker mechanism

The equation 3 suggested by Joshi (1981) was used for the determination of power required in fan and shaker mechanism

$$Pf = f \times V (Vf) \quad (3)$$

Where:

P_f is the power required in fan (W)

f is the force

V is the Velocity

V_f is the peripheral velocity of fan (m/s), equation 4 presents the formula for calculating V_f

$$V_f = \frac{\pi DN}{60} \quad (4)$$

Where: D is the diameter of the pulley (mm),

N is the speed of revolution in (m/s),

P_r is the power required for shaker reciprocation (W)

Determination of fan shaft torsional moment

According to Kkhumri and Gupta (2007) fan shaft torsional moment is given by equation 5.

$$M_{tf} = \frac{P \times 60}{2\pi N} \quad (5)$$

Where: M is the Shaft torsion moment (Nm),

P is the Power of required for the fan (W),

N is the Speed of the fan shaft (rpm)

Determination of fan shaft diameter

The determination of the shaft diameter was obtained ASME (1948) code, equation for solid shaft having or no little axial load, the diameter of the shaft was determined using equation 6.

$$d^3 = \frac{16}{\pi \sigma_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (6)$$

Where: d is the diameter of shaft (mm)

σ_s is the design stress ($55 \times 10^6 \text{ N/m}^2$)

K_t & K_b is the combined shock and fatigue factor applied to bending and tensional moment respectively ($K_t = 1.0$ & $K_b = 1.5$)

M_t is the tensional moment (N_m)

2.4 Determination of Pulley Size Dimension

The criteria for the selection of pulley sizes were based on speed ratio to drive the fan and the cylinder at designed speed and frequencies. The efficiency and availability of the belt were also considered. The size of pulley and speed relationship as given by Hannah and Stephen (1979) is presented equation 7.

$$N_1 D_1 = N_2 D_2 \quad (7)$$

Where: N_1 is the speed of driving shaft (rpm)

D_1 is the diameter of driving pulley (rpm)

N_2 is the speed of driven shaft (rpm)

D_2 is the diameter of driven pulley (mm)

Equation 8 is suggested by Khurmi and Gupta (2007) for angular velocity determination.

$$\omega = \frac{2\pi N_1}{60} \quad (8)$$

Where: (ω) = Angular velocity (rad/s)

The linear velocity of fan is determined by the relation given by Dash and Dash (1989) in equation 9.

$$V = r\omega \quad (9)$$

Where: V is the linear velocity (m/s),

r is the radius of pulley (mm)

ω is the angular velocity (rad/s)

Belt selection

The selection of belt sizes depends on the length, thickness and properties of the materials from which the belt is made. The belt selection as based on ASAE (1979) standard is given in equation 10.

$$L = 2C + 1.571(D + d) + \frac{1}{4C}(D + d)^2 \quad (10)$$

Where: L is the effective belt length (mm),

C is the distance between the centre of the driven and the driving pulley (mm)

D is the diameter of driven pulley (mm)

d is the diameter of the driving pulley (mm)

The cross section area is given by Hall and Hallowwank (1980) as in equation 11.

$$A = (b + C) \frac{K}{2} \quad (11)$$

Where: A is the Area (m^2),

K is the thickness of belt (mm),

b is the top width of belt (mm),

C is the bottom width of belt (mm)

2.5 Experimental Design and Procedures

The operation started by putting on the 4.12 kW prime mover. A batch of a weighed millet heads were fed into the machine through the hopper. After each operation, samples were collected at the grain outlet and non-grain outlets. Grains and non-grain materials were separated for all the samples and weighed separately in order to calculate the performance indices. Randomized complete design experiment (RCD) was used ($2 \times 2 \times 5$). A layout of 5 levels of fan peripheral speed (17.8, 20.5, 20.9, 24.7 and 25.5 m/sec) by 2 levels

of feed rates (3 kg/m and 4 kg/min) at constant moisture content (22.2%) with two varieties of millet *Ex-Borno* and *Dauro* was utilized for the experiment with the total of twenty (20) treatments.

Performance indicators

The cleaning efficiency and scattered loss were determined based on FAO (1994) guidelines as presented in equations 12 and 13.

(i) Cleaning efficiency

$$C_e = \frac{B}{D} \times 100 \quad (12)$$

Where:

C_e is the cleaning efficiency, %

B is the Weight of whole clean seed at main outlet, kg

D is the Weight of whole material collected at main outlet, kg

(ii) Scattered loss

$$S_L = \frac{W_L}{T_S} \quad (13)$$

Where:

S_L is the scattered loss, %

W_L is the Total weight of scattered seed collected, kg

T_S is the Total weight of collected seeds, kg

Determination of moisture content

The moisture content for grains was determined by oven dry method (105°C for 24 hours). It was calculated using relationship given by ASAE (2003) as presented in equation 14.

$$M_{db} = \frac{W - W_d}{W_d} \quad (14)$$

Where:

M_{db} is the Moisture content dry basis (%)

W is the Initial weight of the sample (g)

W_d is the Final weight of the sample (g)

3. RESULTS AND DISCUSSION

3.1 Effect of Fan Speed on Cleaning Efficiency at Different Feed Rates

Figure 1 shows the effect of peripheral fan speed on cleaning efficiency at different feed rates. The maximum cleaning efficiency of 89% was obtained at 25.5 m/s fan speed and 3 kg/min feed rate while the lowest cleaning efficiency of 79% was recorded at the lowest speed level of 17.8 m/sec and second feed rate 4 kg/min. The results obtained were higher than that of Agidi *et al.* (2013). The results also shows that the machine has the highest threshing and cleaning efficiencies of 63.2 and 62.7%, respectively, when pearl millet panicles were processed at 13% moisture content and at 800 rpm threshing cylinder speed. The lowest threshing and cleaning efficiencies of 40.68 and 50%, respectively, were obtained when the pearl millet panicles were processed at 17% moisture content and 600 rpm threshing cylinder speed, and at 17% moisture content and 700 rpm. Thus, the optimum operating parameters of the machine were 13% moisture content (wet basis) of pearl millet panicles and 800 rpm threshing drum speed with no specified feed rate. This could be associated with the increase in the number of sieve from one to two different sieves.

3.2 Effect of Fan Speed on Scatter Losses at Different Feed Rates

Figure 2 shows the effect of puerperal fan speed on scatter losses at different feed rates. The highest percentage scatter losses of 2.33% was recorded at 25.5 m/sec fan seed and 4 kg/min feed rate while the lowest value of 0.58% was obtained at 17.8 m/sec, fan speed and 3 kg/min federate. A decrease of scatter grain was recorded as compared with the Agidi *et al.* (2013), Afolabi (2015) and Singh *et al.* (2015). The results gave a maximum value of 27.6, 51.7% and 2% scatter losses at fan speed of 17 m/sec and 19 m/sec.

These decreased scatter grains may be due to redesigning of cleaning unit. Figure 2 also shows an increase in fan speed and feed rate results as the in scatter loss increases. This may be connected to the fact that at higher speed large amount of grain are carry away by the fan.

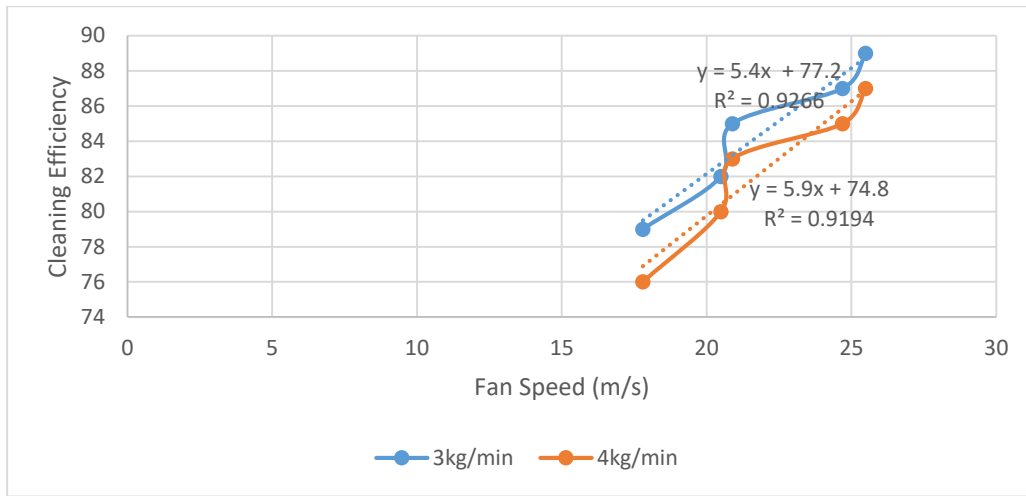


Figure 2: Effect of Fan Speed on Cleaning Efficiency

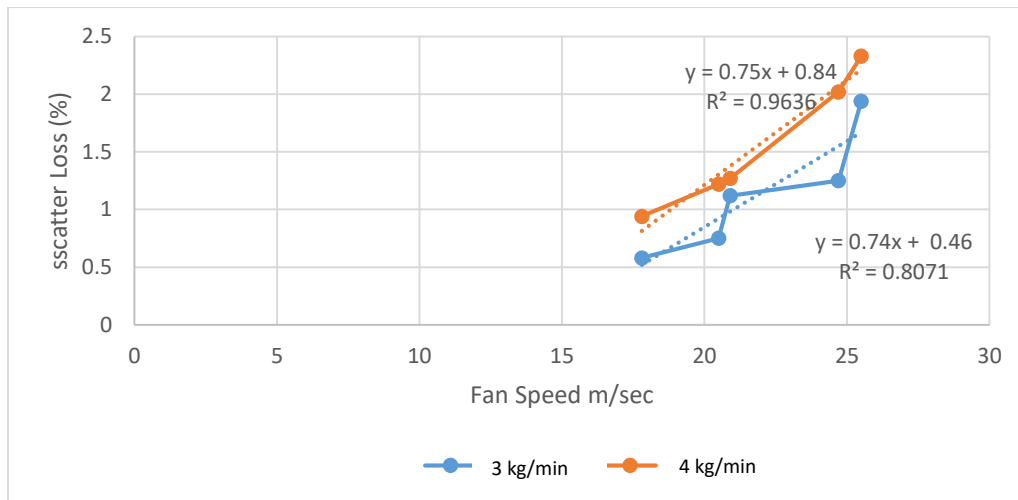


Figure 3: Effect of Fan Speed on Scatter Loss

4. CONCLUSION

The modification and performance evaluation of the existing IAR millet thresher was conducted and cleaning efficiency was observed to increase the fan peripheral speed. Scatter loss increased with an increased in cylinder speed and federate at constant moisture content. The performance achieved of the machine were 89%, 0.58% and 22.2%, for cleaning efficiency, scatter loss and moisture content, respectively.

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