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Manufacturing and Performance Evaluation of a Local Machine for Sifting and Cleaning some Crop Grains.

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ABSTRACT

Experiments were conducted to evaluate the performance of a locally machine for sifiting and cleaning some agricultural crop grains. The performance of the sifting and cleaning machine was experimentally measured under the following parameters: two different types of crop grains: rice and wheat; four different feed rates of about 0.135, 0.155, 0.180 and 0.24 Mg/h: three different grain moisture contents (wet base) of about 18.30, 12.40, 9.20%; 15.35, 11.20, 9.00%, for rice and wheat respectively, and three different sieve speeds of 1100, 1500, 2000 rpm corresponding to 5.75, 7.85, 10.46 m/s for both rice and wheat grains . The results show that the highest machine productivity and cleaning efficiency were 0.22, 0.23 Mg/h and 86.0, 92.5% for rice and wheat, respectively. While the lowest specific energy and operating cost were 1.31, 1.22 kW.h/Mg and 84.0, 80.0L.E/Mg, for rice and wheat grains, respectively. These results were achieved under the following conditions: feed rate of about 0.204 Mg/h and sieve speed of 1500 rpm (7.85m/s), moisture content of 9.20% and 9% for rice and wheat, respectively and constant sieve inclination angle of 8 degree.

Key words: sifting, rice, wheat, grains, cleaning efficiency, energy, cost.

1. INTRODUCTION

Rice (*Oryza sativa L.*) is the most important crop in terms of total production in the developing world and the number of consumers dependent on it as a staple food. Rice is cultivated widely under flooded and upland culture and consumed mainly in Asia with < 5% entering international markets. Semi dwarf and hybrid rice contribute to increases in grain yield. Protein, carbohydrates (starch), and lipids are present in the rice grain; protein, mainly glutelin, is of good nutritive quality and starch granules have a wide range in apparent amylose content from waxy, to low, to high amylose content. The wide range in amylose content reflects different preferences for cooked rice texture in Asia and elsewhere. Glycemic index correlates negatively with amylose content. The high content of y-oryzanols and tocols in rice bran and brown rice contributes to the hypocholesterolemic and anticancer properties of rice, **Juliano (2016)**. Wheat is a cereal crop belonging to Triticum of the family of Gramineae with the Latin name as *Triticum aestivum L*., which is divided into diploid wheat, tetraploid wheat and hexaploid wheat. Since its domestication, wheat has been cultivated for more than 10000 years. Due to its wide adaptability, convenient storage, high nutritional value, and easy to make a variety of foods, wheat has become the world's most popular staple food, just like rice. At the same time, wheat is the most widely grown food crop in the world, and global wheat production is second only to corn, feeding nearly 40% of the world's population, **Jianhui (2020).** In today's dynamic agricultural sector, the need for effective and affordable machinery has become increasingly vital. Small-scale farmers face numerous challenges in crop processing, particularly in the cleaning and screening of grain crops to ensure their quality and market value. In response to these challenges, the development and evaluation of locally manufactured machines have gained significant attention. Rice a staple food crop in many regions, requires thorough cleaning to remove impurities such as husks, stones, or insect debris. Similarly, wheat a widely cultivated cereal, necessitates efficient cleaning to eliminate chaff, straw, and weed seeds. Highlights the need for specialized equipment capable of removing dirt, dust, and damaged seeds without impacting the nutritional value. **El-Sheikha *et al.* (2008)** develop a simple local device for separating small seeds and aimed to utilize the use of centrifugal force in separating seeds for minimizing the costs and losses of separating small seeds. The studied factors were three disc positions of (P_1=20, P_2=15 and P_3=10) rubber spikes fixed on its upper surface; three cylinder positions (a= without any spike, b= 7spikes in one row and c= 14 spikes in two rows fixed on its inner surface; four disc speeds of (S_1= 3.9, S_2= 5.7, S_3= 8.2 and S_4= 10.4 m/s), three levels of seed moisture content of (M_1=19.8, M_2= 15.2 and M_3= 10.3 %) and four levels of separating clearances of (C_1=1.0, C_2=1.5, C_3= 2.0 and C_4=2.5cm). The evaluation was on the following parameters: seed quality, separating efficiency and capacity. the suitable conditions for using the new prototype device were (position P_1)=20 spikes on separating disc ,(position C) = 14 spikes on cylinder, 5.7m/s disc speed, 1.5cm of separating clearance and 15.2% of seed moisture content. The previous factors gives 99.31% of seed quality, 89.19% of germination ratio, 99.34% of separating efficiency and 5.87 kg/h of separating seed capacity. **EL-Sayed and Mohamed (2017)** used a rice milling machine for separating grass seeds (Chicory and Clover Dodder) from alfalfa seeds under four treatment feed rates of 250,300,350and 400 kg/h, three seed moisture contents of 8, 10 and 12 %, four speeds of cleaning air of 4.0, 6.0, 8.0 and 10.0 m/s and four sieve oscillates speed of 200, 230, 260 and 290 rpm. Those treatments were evaluated by determination of seeds losses and damage, purity percentage, energy and production cost. The results show that, the lowest value of seed losses of 2.0, 3.0 and 8.0 % were obtained at air speeds of 4, 6 and 8 m/s and feed rate of 250 kg/h and the lowest value of seeds damage was noticed at air speeds of 4m/s, moisture contents of 8 and 10 % and feed rate of 250 kg/h. The maximum value of seeds purity of 98, 98.2, 98.3 and 98.5% was obtained used feed rate of 250 kg/h, sieve oscillations of 200, 230, 260 and 290 rpm and air speeds of 6 m/s and moisture content of 10 %. The maximum value of machine efficiency was obtained under used sieves oscillation of 200 rpm with feed rate of 250 kg/h and cleaning air speed of 4 and 8 m/s. While the minimum energy consumed of 4.5 kW.h/Mg was obtained by using cleaning air speed of 4m/s and sieve oscillation of 200rpm. The lowest cost of 265.4 L.E/Mg was recorded under air speed of 4and 6m/s, sieve oscillation of 200rpm and feed rate of 250 kg/h. **Ojediran, *et al.* (2018)** developed a locally motorized rice de-stoning machine for separating stone pebbles from milled rice. The stone separation is achieved by vertical oscillation of the reciprocating screen coupled with a suction-like air produced by the blower directly beneath the screen causing rice- mixture to float just above the screen and the stones are sucked up the reciprocating screen then discharged through the stone chute and the clean rice collected in opposite order. The de-stoning machine was designed to be powered by a high speed of 2980 rpm for electric motor 0.746 kW. It was evaluated for its efficiencies in terms of rice separation and de-stoning, the tray loss and impurity level after separation were also evaluated. The highest de-stoning efficiency was recorded between 5 to 7 mm feed gates as 99.75% and the lowest was recorded at a feed gate of 20 mm as 82.5%. The highest rice separation efficiency was recorded at 5 mm feed gates to be 98.89% and the lowest of 93.33% was at 20 mm. The highest values of impurity level and tray loss were recorded at 20 mm as 2.041% and 6.67% respectively, while the lowest values were recorded at 5 mm as 0.028% and 1.11%, respectively. The capacity also increased as the feed gate increase. This research focuses on the manufacturing and performance evaluation of a locally fabricated grain sifting machine for cleaning and sifting both rice and wheat grains for their economic and importance locally and globally.

The objectives of this research are to:

Manufacture a grain sifting machine using available locally low cost materials; investigate the most appropriate operating factors affecting sifting process; evaluate the manufactured grain sifting machine from an economic perspective; and contribute to the advancement of agricultural machinery and technology, aiming to improve crop quality, increase farmers' income, and enhance overall food security.

2. MATERIALS AND METHODS

This study was carried out through the year 2024 in Agricultural and Bio-systems Engineering Department, Faculty of Agriculture, Damietta University, Egypt to construct a locally sifting machine some grain crops. The grain sifting machine were manufactured in a private workshop in Ezbet Allahum Villages, Damietta Governorate and the samples of rice and wheat grains were bought from the farmers in Al-Sinania villages, Damietta Governorate.

2.1. MATERIALS:

2.1.1 The used crop

Both rice (Super-300 variety) having a moisture content of 18.30% (wet basis) and wheat (Giza-71variety) having a moisture content of 15.35% (wet basis) were selected in this study to be sifted using the locally manufactured sifting machine. Some physical properties of the used rice and wheat varieties under this study before sifting operation are shown in **Table (1)**.

Table (1): Some physical properties of sifted grains.

Item	Rice Super-300	Wheat Geza-71	Unit
AV. Length	12	8.04	mm
AV. Width	4.1	3.76	mm
AV. Thickness	3.35	3.45	mm
AV. Volume	86.25	54.58	mm^3
Mass of 100 grains	2.45	4.97	g
Arithmetic Mean diameter	6.48	5.08	mm
Geometric mean diameter	38.5	30.6	mm
Spherecity	1.82	1.56	%
Surface area	320.9	381.06	mm^2
Moisture content of grains	18.30	15.35	%
Angle of repose	26.6	25.5	degree
Static coefficient of friction	0.50	0.47	--

2.1.2. Construction of the locally sifting machine

The modifications of the constructed locally sifting machine were as follows as shown in **Fig.(2.1)**.

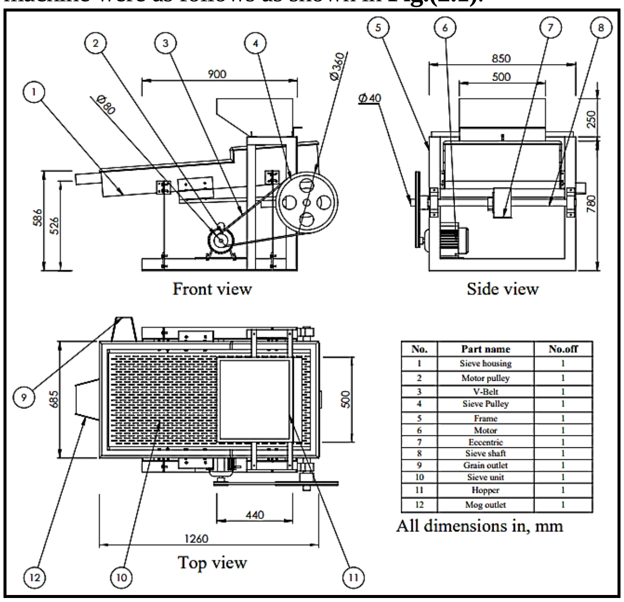

Fig.(2.1): An engineering drawing of the manufactured sifting machine.

(a) Machine frame

It was made of steel L profile equal angle section of 7×7 cm and 5×5cm. The overall dimensions of the sifting machine frame were 90, 78 and 85 cm for length, width and height, respectively to support the feeding hopper and the power source.

(b) Grain hopper

The grain hopper was designed and manufactured with controlled area acting as a hopper gate. It made from steel iron having two openings, one of which is at the top to receive grains for sifting with dimensions of 50×44×41cm for length, width and height, respectively with total capacity of 30kg. The sides of grain hopper sloped gradually to allow sliding grains and keep continuous flow at an adequate feed rate from the hopper to the sieve. The feed hopper is not welding with the main frame of the machine, but it was fixed with four Hex. Hd. bolts to facilitate disassembly and fastening. The feeding rate of grains onto the sieve is manually controlled using a sliding gate with dimensions of 23×13×0.2cm for length, width and thickness. It was fixed at the hopper bottom.

(c) Sifting and cleaning unit

It is a metal plate with dimensions of 120×60×0.1 cm for length, width and thickness, respectively slotted with longitudinal openings with a length of 30mm and width of 3.5mm to separate the grains from the impurities. The impurities exit from an outlet path having dimensions of 20×18cm for length and width, respectively at the front side, and 25×18cm for length and width, respectively at the rear side. There is a smooth metal plate constructed below the impurities exit path to collect the sifting and cleaning grains fallen from cleaning sieve through the exit path having the same dimensions of impurities exit path. The support frame of the sifting and cleaning unit made of metal shaped as L letter at an equal length of 20cm and thickness of 2mm based on four vibrating springs fixed on metal sheet having dimensions of 58×6×0.25cm for length, width and thickness, respectively. The support frame for the sifting and cleaning unit was also built with an 8 degree inclination to facilitate the smooth flow of grains onto the cleaning sieve surface.

(d) Inverter

An inverter was used to change motor rotating speed. The specifications of the used inverter were as follows: GEISC made in China, Model KE300B-0R7G-S2 with 220 - 380V, power 0.75kW, and input: 11A, AC, 1PH, 220V±15% 50/60Hz, maximum output current 4.6A AC 3PH 0~220V 0~300Hz, speed change range 1-50.

(e) Power transmission

The sifting machine was powered by a single-phase electric motor of 0.735 kW (1hp) at the maximum rated speed of 3000rpm. The electric motor transmits its rotating motion to the sifting shaft using V-belt and two pulleys; the small one located at the motor shaft with constant diameter of (8cm), while the large one located at the sifting shaft with constant diameter of (36cm). An eccentric with diameter of 10cm was fixed in the middle of the sifting shaft to convert its rotating motion to a vertical oscillation motion for the reciprocating sieve, as shown in **Fig.(2.2)**.

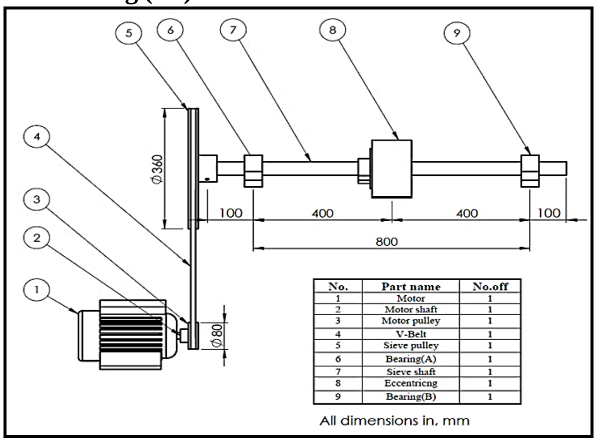

Fig.(2.2): Power transmission from electric motor to cleaning sieve.

(f) Design of sifting and cleaning shaft considerations:

The sifting shaft is supported by two bearings. The first bearing located behind the sieve pulley with a distance of 10cm from the front side and the second one located at the end of the sifting shaft with total shaft length of 100 cm, as shown in **Fig.(2.3)**. There are two loads affecting the sifting shaft; the first load (F_1) was transported from the weight of sieve pulley with tensions on the tight and slack sides of the v-belt; the second load (F_2) due to maximum sieve weight, eccentric weight and grains to be sifting and cleaning. These two loads are in a vertical and horizontal plane and directions. The sifting shaft under these loads is subjected to combine torsion and bending stresses. The diameter of the sifting shaft can be calculated according to the maximum shear theory, **(Khurmi and Gupta, 2005)** as following:

$$\tau_{max} = \frac{1}{2}\sqrt{\sigma_t{}^2 + 4\tau^2} \quad , \quad kg/cm^2$$

$$\tau_{max} = \frac{16}{\pi d^3}\sqrt{K_m Mb^2 + K_t T^2} \quad , \quad kg/cm^2 ....(2.1)$$

Where:

Z_{max} = maximum shear stress, Z_{max} = 300 kg/cm^2
σ = bending stress, kg/cm^2
τ = torsion stress, kg/cm^2
Mb = maximum bending moment, kg.cm
T = maximum torque, kg.cm
d = diameter of sifting shaft, cm
K_m = shock factor for bending stress, Km = 2.0
K_t = shock factor for tension stress, Kt = 2.0

• Determination of maximum torque, (Tmax):

The maximum torque on the sifting shaft can be calculated as following:

$$T_{max} = \frac{71640 HP}{N} = \frac{71640 \times 1}{500} = 143.28 \cong 144 \, kg.cm ...(22)$$

Where:
HP = power of Electrical motor, hp
N = maximum rotating speed of sifting shaft, rpm

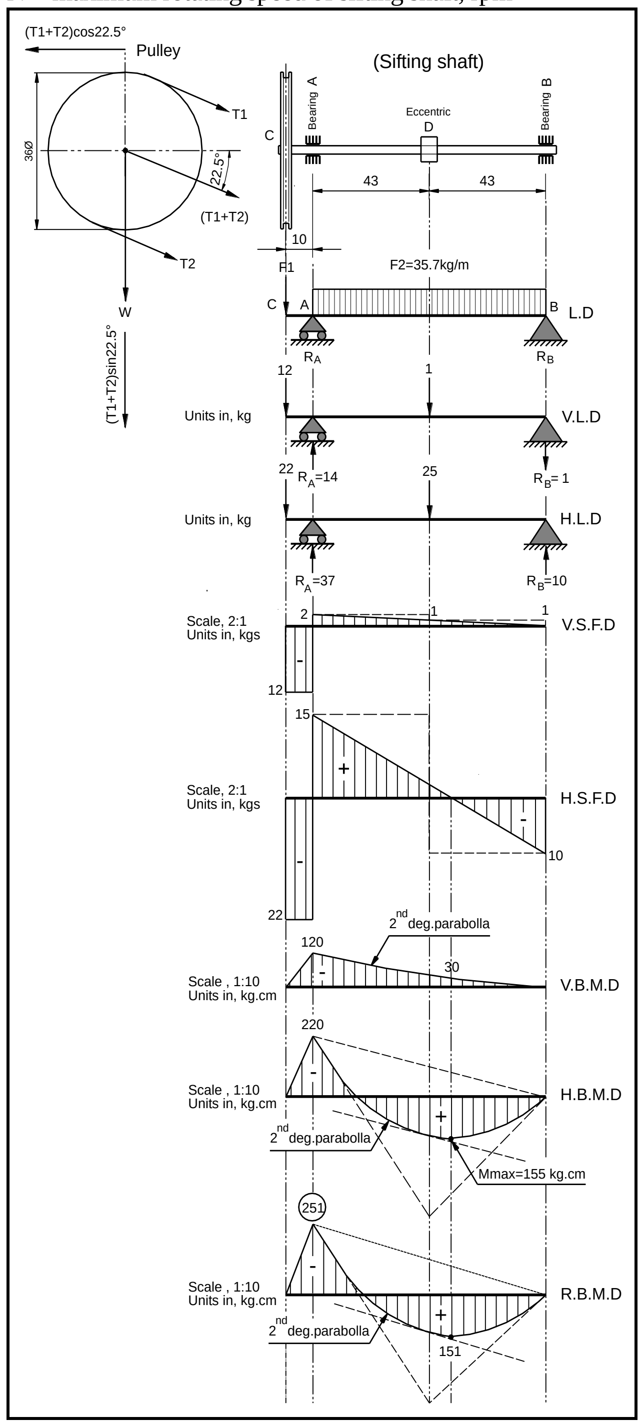

Fig.(2.3): Stress analysis on sifting shaft.

• Determination of maximum bending moment, (M_{max}):

Maximum bending moment can be calculated from (F_1, F_2):

1. Determination of (F_1):

The force acting on the sifting shaft due to the weight of the pulley and the tension on both sides of the belt, which has an inclination angle of 22.5° on the horizontal axis equal:

(F_1) at vertical direction: due to weight of pulley and belt tensions, (concentrated loads).

$F_1 = W + (T_1+T_2) \sin 22.5°$ ………. (2.3)

(F_1) at horizontal direction: due to tensions at both sides of the pulley, (concentrated load).

$F_1 = (T_1+T_2) \cos 22.5°$ ……………. (2.4)

Where: W = weight of pulley, kg

T_1 = tension on the tight side of belt, kg.

T_2 = tension on the slack side of belt, kg.

2. Determination of (F_2):

The force acting on the sifting shaft due to weight of the sieve, weight of the eccentric and also the maximum weight of grains on the sieve was 8, 2 and15, respectively which equal 25 kg, as a concentrated and uniform distributed loads, where the force transported from the eccentric to the sieve through a fixed link with total length of 76 cm and inclination angle of 2.5° at horizontal direction.

(F_2) at vertical direction = $F_2 \sin 2.5°$, (distributed load).

(F_2) at horizontal direction = $F_2 \cos 2.5°$, (distributed load).

Where:

$T_{max} = 144\,kg/cm^2$

$T_{max} = (T_1 - T_2).r \quad \therefore \quad (T_1 - T_2) = \frac{144}{8} = 8$……………(2.5)

r = pulley radius = 18cm

Where: μ = coefficient of friction, 0.3

$\because F_2V = F_2 \sin 2.5^{\circ}$

$\therefore F_2V = 25 \times 0.0436 = 1.09 \approx 1.1 kg$……………(26)

$\because \quad \theta = [(180 - (2\alpha)]\pi/180$…………………………(2.7)

$\therefore \quad \theta = [(180 - (2 \times 30)]3.14/180 = 2.1 rad$

$\therefore 2.3 \log (\frac{T_1}{T_2}) = 0.3 \times 2.1 \times \cos 30^{o}$………………(28)

$\frac{T_1}{T_2} = e^{2.3 \times 0.55} \quad \therefore \frac{T_1}{T_2} = 3.54 \;\; \& \;\; T_1 = 3.54 T_2$….(2.9)

Where:

θ = angle of contact, rad

α = groove angle of pulley, 30°

From equation (6) and (10), we get the follows:

$\therefore T_1 = 11.15\,kg \quad \& \quad T_2 = 3.15\,kg$………..(2.10)

3. Determination the force at vertical direction, (F_2V):

$\because F_2V = F_2 \sin 2.5^{\circ}$

$\therefore F_2V = 25 \times 0.0436 = 1.09 \approx 1.1 kg$……………..(2.11)

4. Determination the force at horizontal direction, (F_2H):

$\because F_2H = F_2 \cos 2.5^{\circ}$

$\therefore F_2H = 25 \times 0.999 = 24.98 \approx 25\,kg$…………….(2.12)

5. Determination vertical reactions:

From the vertical loading diagram in **Fig (2.3)**, the reactions on bearing shaft (R_A) and (R_B) with vertical direction can be calculated as following:

$\because \sum M \text{ at } B = 0$

$\therefore (R_A \times 80) = (12 \times 90) + (1.1 \times 40)$

$80R_A = 1080 \qquad \therefore \quad R_A = 13.5 \approx 14 kg \uparrow$……….(2.13)

$\& \because \sum Y = 0$

$\therefore R_B = 1.1 + 12 - 14 \;\; \therefore R_B = -0.9 \approx -1 kg \downarrow$……….(2.14)

6. Determination of horizontal reactions:

From the horizontal loading diagram in **Fig (2.3)**, the reactions on bearing shaft (R_A) and (R_B) with horizontal direction can be calculated as following:

$\because \sum M \text{ at } B = 0$

$\therefore (R_A \times 80) = (22 \times 90) + (25 \times 40)$

$\therefore \quad 80R_A = 2980 \qquad \therefore R_A = 37.25 \cong 37 kg \uparrow$………(2.15)

$\& \because \sum Y = 0$

$\therefore R_B = 22 + 25 - 37 \qquad \therefore \quad R_B = 10 kg \uparrow$…………….(2.16)

7. Determination of vertical moments:

$M_C = 0.0 kg.cm$

$M_A = -(12 \times 10) = -120\,kg.cm$

$M_B = 0 kg.cm$

8. Determine of horizontal moments:

$M_C = 0.0\,kg.cm$

$M_A = -22 \times 10 = -220\,kg.cm$

$M_B = 0 kg.cm$

9. Determination of resultant moments:

$M_C = 0.0 kg.cm$

$M_A = \sqrt{(-120)^2 + (-220)^2} = -251 kg.cm$……..(2.17)

$M_C = 0 kg.cm$

So, from **Fig.(2.3)** the maximum bending moment on the sifting shaft as a resultant moment equal M_{max}= (251kg.cm). Then the maximum shear theory is applied as follows:

$$Z_{max} = \frac{16}{\pi d^3}\sqrt{K_m M^2 + K_t T^2}$$

$$\therefore 300 = \frac{16}{3.14 d^3}\sqrt{2\times(251)^2 + 2\times(144)^2}$$

$$\therefore 300 = \frac{16}{3.14 d^3}\times 355$$

$$\therefore d^3 = 6.03 \quad \therefore d = 1.82\,cm = 18.20mm$$

So, the sifting shaft diameter was taken **20mm**.

2.2. METHOD

The main experiments were carried out to manufacture and evaluate the performance of a locally grain sifting and cleaning machine under the following parameters:

- Three sieve speeds of 1100, 1500 and 2000 rpm corresponding to 5.75, 7.85 and 10.46 m/s for both rice and wheat grains.
- Three different moisture contents of $M.C_1$= 18.30, $M.C_2$= 12.40 and $M.C_3$= 9.20%, for rice grains; and $M.C_1$= 15.35, $M.C_2$= 11.20 and $M.C_3$= 9.00%, for wheat grains.
- Four different feed rates of F_1= 0.135, F_2= 0.155, F_3= 0.180 and F_4= 0.204Mg/h; for rice and wheat grains.
- Each treatment was replicated three times to calculate the mean values under all test runs.

2.3. MEASUREMENTS

Manufacture and performance evaluation for sifting and cleaning machine was performed taking into consideration the following indicators:

2.3.1. Physical properties

A random sample of one hundred rice (Super-300) variety and wheat (Geza-71) variety grains was taken to measure the following: **(El-Raie *et al.* 1996).**

$V = \frac{\pi}{6}(L.W.T), mm^3$……….(2.18)

$D_g = 3\sqrt{L.W.T}$, mm………(2.19)

$\varphi = \frac{\sqrt[3]{L.W.T}}{3}$, (%)…………...(2.20)

$S = \frac{3\sqrt{L.W.T}}{L}\times 100, \%$ ………(2.21)

$D_a = \frac{(L+W+T)}{3}$, mm…………(2.22)

$M_C = \frac{(M_w + M_d)}{M_w}\times 100$………(2.23)

Where:

L = Mean length of grains, (mm)

W = mean width of grains, (mm

T = mean thickness, (mm)

D_a = arithmetic mean diameter of grains, (mm)

D_g = geometric mean diameter of grains, (mm)

V = mean volume of grains, (mm)

φ = mean seed sphericity, (%)

S = surface area, (mm^2)

M_C = moisture content of grains, (%)

M_W = sample mass before drying, (g)

M_d = mass after drying sample, (g)

2.3.2. Mechanical properties

- **Angle of repose**

The angle of repose can be calculated according to the following equation: **(Sahay and Singh, 1994)**.

$\theta = \tan^{-1}\left(\frac{h_o}{r}\right)$…….……(2.24)

Where:

θ = angle of repose, (degree)

h_o = height of heap, (m)

r = radius of heap, (m)

- **Static coefficient of friction**

The coefficient of static friction of samples against MS sheet surface was determined from the following equation: **(Tarighi and Alavi, 2011)**.

$\mu = \tan\theta$………...(2.25)

Where:

μ = coefficient of static friction

tanθ = angle of repose, degree

2.3.3. Machine productivity

The machine productivity was calculated during sifting operation by the following equation:

$M_p = \frac{M_s}{t}$, ………..…(2.26)

Where:

M_p = machine productivity, Mg/h.

Ms = mass of milled sample, Mg.

t = time consumed in the sifting operation, h.

2.3.4. Cleaning efficiency

The machine cleaning efficiency was calculated for sifting operation using the following equation: **(Yayock *et al.*, 2020)**.

$C_{Cl} = \frac{Go}{Go+Gcg}\times 100$ ....(2.27)

Where:

$\eta_{cl.}$ = cleaning efficiency, %

Go = weight of pure grain at the outlet, kg

Ccg= weight of foreign materials in pure grains, kg

2.3.5. Required power

The following formula was used to estimate the required power: **(Ashby, 1988)**.

$Po = \sqrt{2}\times \cos\varphi \times I \times V$…………(2.28)

Where:

Po = required power, kW.

I = current intensity, Ampere.

V = voltage, (220V). cosφ = 0.72

2.3.6. Specific energy consumed

$SE = \frac{Po}{M_p}$………(2.29)

2.3.7. Operating cost

The operating cost required for the sifting operation was estimated using the following equation: **(Awady, *et al.* 1982)**.

$$C_{op} = \frac{C}{M_p}, \ldots\ldots\ldots(2.30)$$

Where:
C_{op} = operating cost, L.E/Mg
C = hourly cost, L.E/h

$$Z_{max} = \frac{16}{\pi d^3}\sqrt{K_m M^2 + K_t T^2}$$

$$\therefore 300 = \frac{16}{3.14 d^3}\sqrt{2\times(251)^2 + 2\times(144)^2}$$

$$\therefore 300 = \frac{16}{3.14 d^3}\times 355$$

$$\therefore d^3 = 6.03 \quad \therefore d = 1.82\,cm = 18.20\,mm$$

The hourly cost for sifting and cleaning operation was determined using the following equation: **(Awady, 1978)**.

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (W.e.) + \frac{m}{192}\ldots\ldots\ldots(2.31)$$

Where:
C = hourly cost, L.E/h.
h = yearly working hours, h/year.
i = interest rate/year.
t = taxes, over heads ratio.
r = repairs and maintenance ratio.
P = price of machine, L.E.
a = life expectancy of the machine, y.
W = motor power, kW.
e = hourly kW price, L.E/kW.h.
m = monthly average wage, L.E.
192 = reasonable estimation of monthly working hour

3. RESULTS AND DISCUSSION

3.1. Machine productivity:

Related to the effect of feed rate on machine productivity for rice grains, the results in **Fig.(3.1)** show that at constant moisture content of 9.20%, increasing the feed rate from 0.135 to 0.204 Mg/h leads to increase the machine productivity from 0.094 to 0.161, from 0.145 to 0.222 and from 0.141 to 0.216 Mg/h at different sieve speeds of 5.75, 7.85 and 10.46 m/s respectively. Similarly for wheat grains, increasing feed rate from 0.135 to 0.204Mg/h leads to increase machine productivity from 0.096 to 0.167, from 0.147 to 0.238 and from 0.114 to 0.199 Mg/h at different sieve speed of 5.75, 7.85 and 10.46 m/s, respectively and constant grain moisture content of 9%. These results my due to increase the feed rate results in more grains being processed per unit time, which results in increased machine productivity. These results agree with **(Abdeen *et al.*,2021, and Abu Ali et al. 2022).**

Concerning to the effect of moisture content on machine productivity for rice grains, the results in **Fig.(3.1)** show that at constant sieve speed of 10.46m/s, decreasing grain moisture content from 18.30% to 9.20%, leads to increase the machine productivity from 0.11 to 0.141, from 0.117 to 0.149, from 0.126 to 0.176 and from 0.14 to 0.216 Mg/h at different feed rates of 0.135, 0.155, 0.180 and 0.204 Mg/h, respectively.

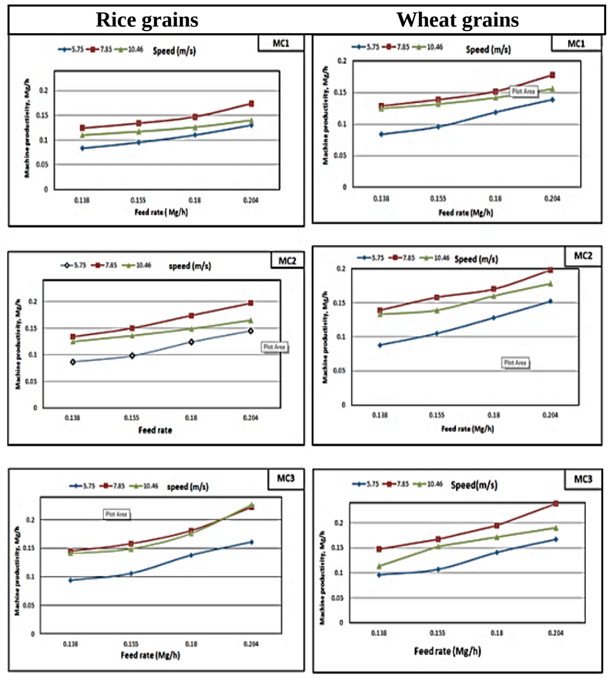

Fig.(3.1): Effect of feeding rate on machine productivity at different grain moisture contents and different sieve speeds for rice and wheat grains.

Similarly for wheat grains, decreasing grain moisture content from 15.35% to 9% leads to increase machine productivity from 0.125 to 0.114, from 0.132 to 0.153, from 0.142 to 0.172 and from 0.156 to 0.199 Mg/h at different feed rates of 0.135, 0.155, 0.180 and 0.204 Mg/h, respectively and constant sieve speed of 10.46m/s. The reason is that the time period for rice and wheat to exit is shorter due to the coefficient of friction decreased between grains and sieve metal. These results were agreed with **(Belay and Fetene , 2021).**

As regard to the effect of sieve speed on machine productivity for rice grains, the results in **Fig.(3.1)** show that at constant moisture content of 9.20%, increasing the sieve speed from 5.75 to 7.85 m/s leads to increase the machine productivity from 0.094 to 0.145, 0.106 to 0.158, 0.135 to 0.181 and 0.161 to 0.222Mg/h at different feed rates of about 0.138, 0.155, 0.18 and 0.204 Mg/h, respectively. Any further increase in speed above 7.85 up to 10.46 m/s the machine productivity decreased from 0.145 to

0.141, from 0.158 to 0.149, from 0.181 to 0.176 and from 0.222 to 0.216Mg/h, respectively under the same previous conditions. Similarly, the machine productivity for wheat grains at constant moisture content of 9%, increasing the sieve speed from 5.75 to 7.85 m/s leads to increase the machine productivity from 0.096 to 0.147, from 0.107 to 0.167, from 0.141 to 0.194 and from 0.167 to 0.238 Mg/h, respectively. Any further increase in sieve speed above 7.85 up to 10.46 m/s the machine productivity decreased from 0.147 to 0.114, from 0.167 to 0.153m, from 0.194 to 0.172 and from 0.238 to 0.199Mg/h, respectively. These results agree with **(Abdeen *et al.*,2021)** found that increasing sieve speed increases machine productivity.

It was noticed also that the machine productivity for wheat grains was higher than rice grains due to increasing grains flow through sieve slots during sifting operation since the coefficient of friction less than rice grains.

3.2. Cleaning efficiency:

Relation to the effect of feed rate on cleaning efficiency of rice grains, the results in **Fig.(3.2)** showed that at constant grain moisture content of 9.20%, increasing the feed rate from 0.135 to 0.204 Mg/h resulted in increasing the cleaning efficiency from 73.7 to 74, from 77 to 80 and from 48.5 to 51.4%, respectively at different sieve speeds of 5.75, 7.85 and 10.46 m/s, respectively. Similarly, for wheat grains, at moisture content of 9%, increasing the feed rate from 0.138 to 0.204Mg/h resulted in increasing the cleaning efficiency from 87 to 87.5, from 90 to 91.5 and from 60.3 to 77.5%, respectively at different sieve speeds of 5.75, 7.85 and 10.46m/s, respectively Increasing the feed rate increases the machine speed, improves the sorting efficiency, and reduces the cleaning time, which leads to increased cleaning efficiency.**(Abdeen *et al.*,2021)**

Concerning to the effect of grain moisture content on cleaning efficiency of rice grains, the results in **Fig.(3.2)** show that when the grain moisture content decreased from 18.30% to 9.20%, measured at different feeding rates of about 0.135, 0.155, 0.180 and 0.204Mg/h, the cleaning efficiency increased from 75 to 77, from 76 to 79, from 82.8 to 86 and from 77 to 80%, respectively at constant sieve speed of 7.85m/s. Similarly, the effect of moisture content on cleaning efficiency of wheat grains, the results show that when the moisture content decreased from 15.35% to 9%, measured at different feeding rates of about 0.138, 0.155, 0.18 and 0.204Mg/h, the cleaning efficiency increased from 87.5 to 90, from 89 to 91, from 91.5 to 92.5 and from 89.5 to 91.5Mg/h, respectively at constant sieve speed of 7.85m/s. The lower moisture content increases the grains movements over the sieve, which increases and improves the cleaning efficiency. These results agree with **(Belay and Fetene , 2021)**.

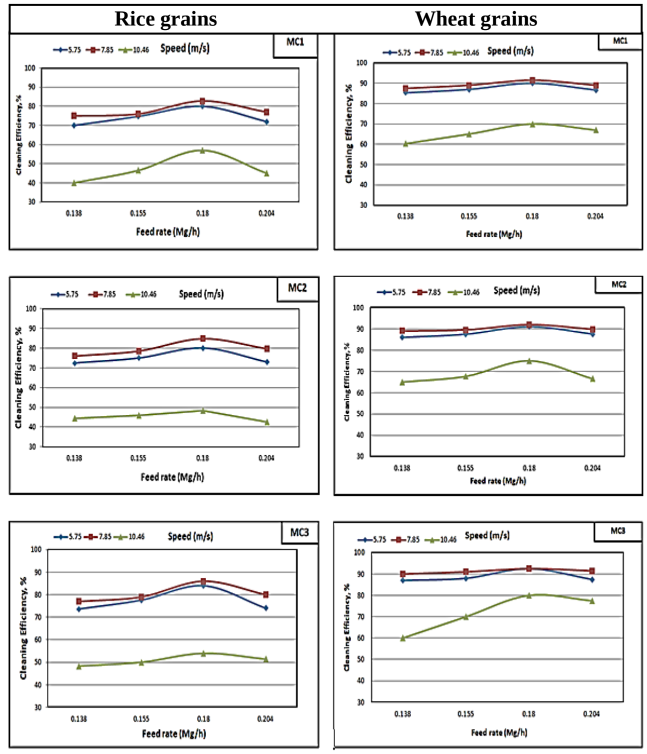

Fig (3.2): Effect of feeding rate on cleaning efficiency at different grain moisture contents and different sieve speeds for rice and wheat grains.

As to the effect of sieve speed on cleaning efficiency, the results in **Fig.(3.2)** show that at constant grain moisture content of 9.20% for rice grains, increasing the sieve speed from 5.75 to 7.85 m/s leads to increase the cleaning efficiency from 73 to 77, from 77 to 79, from 84 to 86 and from 74 to 80%, at different feed rates of about 0.135, 0.155, 0.180 and 0.204 Mg/h, respectively. Any further increase in sieve speed above 7.85 up to 10.46 m/s, the cleaning efficiency decreased from 77 to 48.5, from 79 to 50, from 86 to 54 and from 80 to 51.4%, respectively at the same previous conditions. Similarly for wheat grains, at constant grain moisture content of 9%, increasing the sieve speed from 5.75 to 7.85 m/s leads to increase the cleaning efficiency from 87 to 90, from 88 to 91, from 92.5 to 92.5, and from 87.5 to 91.5%, at different feed rates of about 0.135, 0.155, 0.180 and 0.204 Mg/h, respectively. Any further increase in the sieve speed over the 7.85 up to 10.46m/s the cleaning efficiency decreased from 90 to

60, from 91 to 70, from 92.5 to 80, and from 91.5 to 77.5 %, respectively. The cleaning efficiencies were at the higher values at sieve speed of 7.85m/s since the movement of grains over the sieve was in adequate limit compared with the lower or the higher sieve speed, which cause non-uniformity movement resulted a lower cleaning efficiencies. A Study by **(Akatuhurira *et al*., 2021)** showed that increasing the sieve speed increases the cleaning efficiency, and another study by **(Aboukarima *et al*., 2017)** found that increasing the sieve speed reduces the cleaning efficiency above a certain speed. It was also noted that the cleaning efficiency of wheat grains was higher than that of rice grains due to their rapid flow during the sifting process, as the coefficient of friction is lower than rice grains.

3.3. Specific energy consumed:

Relation to the effect of feed rate on specific energy consumed for rice grains, the results in **Fig.(3.3)** show that at constant grain moisture content of 18.30%, increasing the feed rate from 0.135 to 0.204Mg/h resulted in a decrease in specific energy consumed from 2.69 to 1.72, from 2.34 to 1.67 and from 3.05 to 2.4kW.h/Mg, respectively at different sieve speeds of 5.75, 7.85 and 10.46 m/s, respectively. Similarly, the specific energy consumed for wheat grains, at constant grain moisture content of 15.35% increasing the feed rate from 0.135 to 0.204 Mg/h leads to decrease the specific energy consumed from 2.66 to 1.611, from 2.25 to 1.634 and from 2.68 to 2.15 kW.h/Mg, respectively at different sieve speeds of 5.75, 7.85 and 10.46m/s. Reducing the time required for sifting and cleaning rice and wheat grains lead to increase the machine productivity and improving its efficiency, which reduces the specific energy consumed. These results were agreed with **(Abdeen *et al.*,2021, and Abu Ali et al. 2022).**

Concerning to the effect of moisture content on the specific energy consumed for rice grains, the results in **Fig.(3.3)** show that when the moisture content decreased from 18.30 to 9.20%, the specific energy decreased from 2.34 to 2.0, from 2.17 to 1.84, from 1.97 to 1.60 and from 1.67 to 1.31 kW.h/Mg, at different feeding rates of about 0.135, 0.155, 0.180 and 0.204Mg/h, respectively and constant sieve speed of 7.85m/s. Similarly for wheat grains, the results show that when the moisture content decreased from 15.35 to 9%, the specific energy consumed decreased from 2.25 to 1.97, from 2.09 to 1.74, from 1.91 to 1.462 and 1.634 to 1.22 kW.h/Mg at different feed rates of about 0.135, 0.155, 0.180 and 0.204Mg/h and constant sieve speed of 7.85m/s. Reducing the grain moisture content reduces the friction between parts, which reduces the specific energy consumed and improving both machine productivity and efficiency. These results were agreed with **(Belay and Fetene , 2021)**.

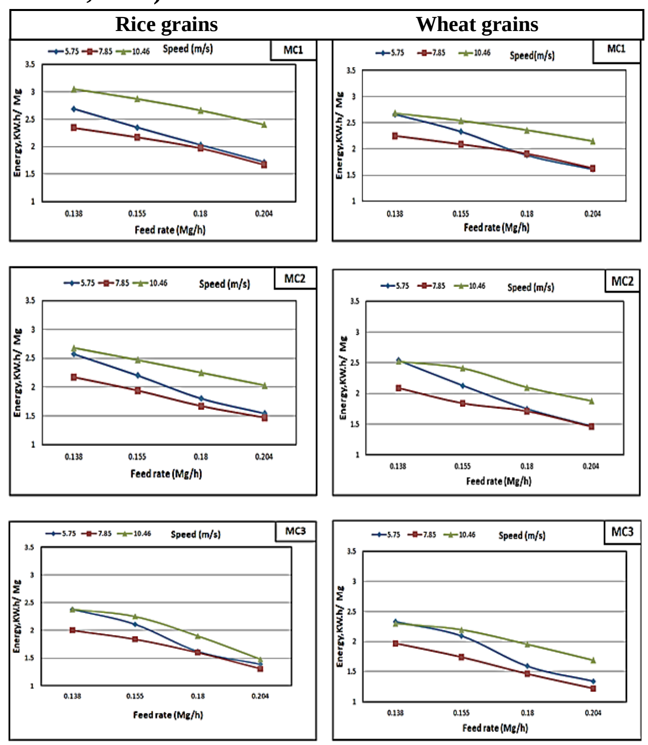

Fig.(3.3): Effect of feeding rate on specific energy consumption at different grain moisture contents and different sieve speeds for rice and wheat.

As to the effect of sieve speed on the specific energy consumed for rice grains, the results in **Fig.(3.3)** show that at constant grain moisture content of 9.20%, increasing the sieve speed from 5.75 to 7.85m/s leads to decrease the specific energy consumed from 2.38 to 2.0, from 2.11 to 1.84, from 1.623 to 1.60 and 1.391 to 1.31 kW.h/Mg. Any further increase in sieve speed above 7.85 up to 10.46m/s lead to decrease the specific energy consumed from 2.0 to 2.38, from 1.84 to 2.25, from 1.60 to 1.909 and from 1.31 to 1.48kW.h/Mg, at different feed rates of about 0.135, 0.155, 0.180 and 0.204Mg/h, respectively. Similarly, for wheat grains, at constant grain moisture content of 9%, increasing sieve speed from 5.75 to 7.85m/s, the specific energy consumed decreases from 2.33 to 1.97, from 2.093 to 1.74, from 1.588 to 1.462 and from 1.34 to 1.22kW.h/Mg. Any further increase in sieve speed from 7.85 up to 10.46 m/s the specific energy consumed increased from 1.97 to 2.3, from 1.74 to 2.196, from 1.462 to 1.953 and from 1.22 to

1.688kW.h/Mg, at different feed rates of about 0.135, 0.155, 0.180 and 0.204Mg/h, respectively. The lower or higher values than the optimum sieve speed tend to increase the specific energy due to lower machine productivity, which confirms reports in studies by **(Akatuhurira *et al*., 2021)** indicated that increasing the screen speed reduces energy consumption. Another study by **(Aboukarima *et al*., 2017)** found that increasing the screen speed increases energy consumption when a certain speed is exceeded.

3.4. Operating cost:

Related to the effect of feed rate on the operating cost of rice grains, the results in **Fig.(3.4)** show that at constant grain moisture content of 18.30%, increasing the feeding rate from 0.135 to 0.204 Mg/h resulted in a decrease in operating cost from 228.9 to 146.1, from 153.2 to 109.1 and from 172.7 to 135.7L.E/Mg, at different sieve speeds of 5.75, 7.85 and 10.46 m/s, respectively. Similarly for wheat grains, the results show also that at constant moisture content of 15.35%, increasing the feeding rate from 0.135 to 0.204 Mg/h resulted in a decrease in operating costs from 226.1 to 136.6, from 147.2 to 106.7 and from 152 to 121.7L.E/Mg, at different sieve speeds of 5.75, 7.85 and 10.46 m/s, respectively. This is due to the increase in feeding rate leads to increase the machine productivity, which reduces operating costs since the time of sifting and cleaning operation was reduced, which confirms reports in studies by **(Abdeen *et al.*,2021, and Abu Ali et al. 2022).**

Concerning to the effect of moisture content on the operating cost of rice grains, the results in **Fig.(3.4)** show that decreasing grain moisture content from 18.30 to 9.20% lead to decrease the operating cost from 153.2 to 131, from 141.7 to 120.2, from 129.2 to 104.9 and from 109.1 to 85.5L.E/Mg, at different feeding rates of about 0.135, 0.155, 0.180 and 0.204Mg/h, respectively and constant sieve speed of 7.85m/s. Similarly, for wheat grains, the results show also that decreasing grain moisture content from 15.35 to 9%, lead to decrease the operating cost from 147.2 to 129.2, from 136.6 to 113.7, from 125 to 98 and from 106.7 to 80L.E/Mg, at different feed rates of about 0.135, 0.155, 0.180 and 0.204 Mg/h, respectively and constant sieve speed of 7.85m/s. The reason is that decreasing grain moisture content leads to reducing the time required for operation, which increase the machine productivity resulting in reduction of operating cost. These results were agreed with **(Belay and Fetene , 2021)**.

As to the effect of sieve speed on the operating cost of rice grains, the results in **Fig.(3.4)** show that increasing the sieve speed from 5.75 to 7.85m/s at constant grain moisture content of 9.20% resulted in a decrease in the operating cost from 202.1 to 131, from 179.2 to 120.2, from 137.6 to 104.9, and from 118 to 85.5L.E/Mg, respectively. Any further increase in sieve speed from 7.85 up to 10.46m/s would increase the operating cost from 131 to 134.7, from 120.2 to 127.5, from 104.9 to 106.1, and from 85.5 to 84 L.E/Mg. Similarly, for wheat grains, at constant grain moisture content of 9%, increasing the sieve speed from 5.75 to 7.85m/s reduces the operating cost from 216 to 236.6, from 181 to 120.2, from 148.4 to 111.7 and from 125 to 96 L.E/Mg, respectively.

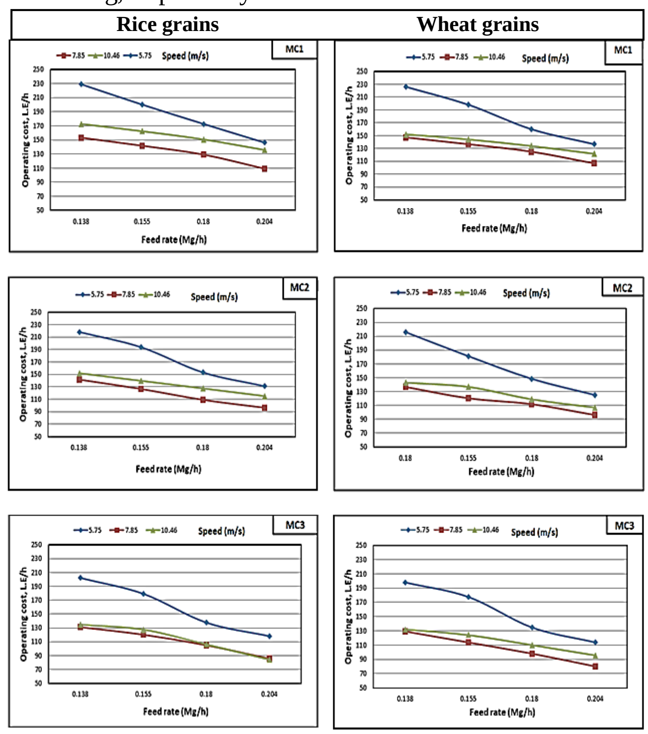

Fig.(3.4): Effect of feeding rate on operating cost at different grain moisture contents and different sieve speeds for rice and wheat grains.

Any further increase in sieve speed from 7.85 up to 10.46m/s would increase the operating cost from 136.6 to 142.8, from 120.2 to 136.6, from 111.7 to 118.7 and from 96.0 to 106.7 L.E/Mg, at different feeding rates of about 0.135, 0.155, 0.180, and 0.204Mg/h, respectively. Higher and lower values of sieve speed more or less than the optimum value tend to increase the operating cost due to decrease machine the sieve speed reduces the operating cost, and another study by **(Akatuhurira *et al*., 2021)** found that increasing the sieve speed increases the operating cost beyond a certain speed.

4. SUMMARY AND CONCLUSION

This study aims to manufacture a grain sifting and cleaning machine using locally available and low-cost materials, study the most appropriate operational

factors affecting the screening and cleaning process, evaluate the economics of a locally manufactured grain screening and cleaning machine and also contribute to the development of agricultural machinery and technology with the aim of improving crop quality, increasing farmers' income, and enhancing overall food security. The performance of the sifting and cleaning machine was experimentally measured using the following parameters: two different grain types of rice and wheat; four grain feeding rates of 0.135, 0.155, 0.180 and 0.204 mg/h for both rice and wheat; three different grain moisture contents of 18.30, 12.40, and 9.20%, and 15.35, 11.20, and 9% for rice and wheat, respectively; and three cleaning sieve speeds of 1100, 1500, and 2000 rpm, corresponding to 5.75, 7.85, and 10.46 m/s for both rice and wheat. The results obtained were as follows:
The highest machine productivity was 0.222 and 0.238 Mg/h at a sieve frequency of 7.85 m/s, grain moisture content of 9.20 and 9%, and a feeding rate of 0.204 and 0.204 Mg/h for rice and wheat, respectively. The lowest machine productivity was 0.083 and 0.084 Mg/h at a sieve frequency of 5.75 m/s, grain moisture content of 18.30 and 15.35%, and a feeding rate of 0.138 Mg/h for rice and wheat, respectively. The highest grain cleaning efficiencies were 86% and 92.5% at a sieve frequency of 7.85 m/s, grain moisture content of 9.20% and 9%, and a feed rate of 0.18 Mg/h for rice and wheat, respectively. The lowest cleaning efficiencies were 40% and 60.3% at a sieve frequency of 10.46 m/s, grain moisture content of 18.30% and 15.35%, and a feed rate of 0.138 Mg/h for rice and wheat, respectively. The lowest energy consumption was 1.31 and 1.22 kWh/Mg at a sieve frequency of 7.85 m/s, grain moisture content of 9.20% and 9%, and a feed rate of 0.204 Mg/h for rice and wheat, respectively. While the highest energy consumption was 3.05 and 2.66 kWh/Mg at sieve speeds of 10.46 and 5.75 m/s, moisture content of 9.20 and 15.35%, and feeding rate of 0.138 Mg/h for rice and wheat, respectively. The lowest operating cost was (84, 80 EGP/h at sieve frequency speed 10.46, 7.85 m/s, grain moisture content 9.20, 9% and feeding rate 0.204 Mg/h for rice and wheat, respectively. While the highest operating cost was (202.1, 226.1 EGP/h at sieve frequency speed 5.75 m/s, grain moisture content 9.20, 15.35% and feeding rate 0.138 Mg/h for rice and wheat, respectively.

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CONFLICTS OF INTEREST:

The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION

Authors developed the concept of the manuscript, shared writing. All authors checked and confirmed the final revised manuscript.

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الملخص العربى

تصنيع وتقييم أداء آلة محلية لغربلة وتنظيف بعض حبوب المحاصيل

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أُجريت هذه الدراسة في قسم هندسة النظم الزراعية والحيوية بكلية الزراعة جامعة دمياط، خلال العام 2024 بهدف تصنيع وتقييم أداء آلة محلية الصنع لغربلة وتنظيف حبوب الأرز والقمح. وذلك معالجة الفجوة القائمة في قلة توافر آلات غربلة وتنظيف الحبوب المناسبة والمصممة خصيصاً لتلبية إحتياجات صغار المزارعين من خلال التركيز على التصنيع المحلي لخفض التكاليف وتوفير تكاليف الإستيراد. وكانت أهداف هذه الدراسة: تصنيع آلة لغربلة وتنظيف الحبوب باستخدام المواد المتوفرة محلياً ومنخفضة التكلفة، دراسة العوامل التشغيلية الأكثر ملائمة والتي تؤثر على عملية الغربلة والتنظيف، تقييم آلة غربلة وتنظيف الحبوب المصنعة محلياً من الناحية الإقتصادية وكذلك المساهمة في تطوير الآلات والتكنولوجيا الزراعية بهدف تحسين جودة المحاصيل وزيادة دخل المزارعين وتعزيز الأمن الغذائي الشامل. تتكون آلة غربلة وتنظيف الحبوب المصنعة محلياً من الأجزاء التالية: الإطار، قادوس الحبوب، العاكس الكهربى (Inverter)، منظومة نقل القدرة ووحدة الغربلة والتنظيف. تم قياس أداء آلة الغربلة والتنظيف تجريبياً من خلال العوامل التالية: • نوعان مختلفان من حبوب المحاصيل هي: الأرزوالقمح. • أربع معدلات تلقيم للحبوب هي: (0.135، 0.155 ، 0.180 و0.204 ميجاجرام/س) لكل من الأرز والقمح. • ثلاثة نسب رطوبة مختلفة للحبوب هي: (18.30، 12.40 و 9.20 ٪)، (15.35، 11.20 و 9 ٪) للأرز والقمح، على التوالي. • ثلاث سرعات لغربال التنظيف هي: (1100، 1500 و2000 لفة/ق) تقابل (5.75 ، 7.85 و10.46 م/ث) لكل من الأرز والقمح . وكانت أهم النتائج المتحصل عليها ما يلى:إنتاجية الألة: أعلى إنتاجية للآلة كانت 0.222 ، 0.238 ميجاجرام/ساعة عند سرعة ترددية للغربال 7.85 م/ث ومحتوى رطوبى للحبوب 9.20 ، 9٪ ومعدل تلقيم (0.204 ، 0.204 ميجاجرام/س) للأرز والقمح، على التوالي. بينما كانت أقل إنتاجية للآلة 0.083 ، 0.084 ميجاجرام/س عند سرعة ترددية للغربال 5.75 م/ث ومحتوى رطوبى للحبوب 18.30، 15.35٪ ومعدل تلقيم 0.138 ميجاجرام/س للأرز والقمح، على التوالي. كفاءة التنظيف: أعلي كفاءة لتنظيف الحبوب كانت 86 ، 92.5٪ عند سرعة ترددية للغربال 7.85 م/ ث ومحتوى رطوبى للحبوب 9.20 ، 9٪ ومعدل تلقيم 0.18 ميجاجرام/س للأرز والقمح، على التوالي. بينما كانت أقل كفاءة تنظيف 40 ، 60.3٪ عند سرعة ترددية للغربال 10.46 م/ث ومحتوى رطوبى للحبوب 18.30 ، 15.35 ومعدل تلقيم 0.138 ميجاجرام/س للأرز والقمح، على التوالي. الطاقة المستهلكة: أقل طاقة مستهلكة كانت 1.31 ، 1.22 كيلووات. ساعة/ ميجاجرام عند ترددية للغربال 7.85 م/ث ومحتوى رطوبي للحبوب 9.20 ، 9٪ ومعدل تلقيم 0.204 ميجاجرام/س للأرز والقمح، على التوالي. بينما كانت أعلى طاقة مستهلكه 3.05 ، 2.66 كيلووات.س/ميجاجرام عند سرعة ترددية للغربال 10.46 ، 5.75 م/ث ومحتوى رطوبي 9.20 ، 15.35٪ ومعدل تلقيم 0.138 ميجاجرام/س للأرز والقمح، على التوالي. تكالف التشغيل: أقل تكلفة تشغيل كانت (84 ، 80 جنيه/س عند سرعة ترددية للغربال 10.46 ، 7.85 م/ث ومحتوى رطوبي للحبوب 9.20 ، 9٪ ومعدل تلقيم 0.204 ميجاجرام/س للأرز والقمح، على التوالي. بينما كانت أعلى تكلفة تشغيل 202.1 ، 226.1 جنيه/س عند سرعة ترددية للغربال 5.75 م/ث ومحتوى رطوبي للحبوب 9.20، 15.35٪ ومعدل تلقيم 0.138 ميجاجرام/س للأرز والقمح، على التوالى. وبالتالي توصي هذه الدراسة باستخدام آلة الغربلة والتنظيف محلية الصنع لكل من حبوب الأرز والقمح عند العوامل التالية: • إنسياب الحبوب من القادوس إلى غربال التنظيف بمعدل (0.204 ميجاجرام/س لكل من الأرز والقمح، على التوالي. • السرعة الترددية لغربال التنظيف 7.85 م/ث لكل من الأرز والقمح، على التوالى. • نسبة المحتوى الرطوبي للحبوب 9.20 و 9٪ لكل من الأرز والقمح، على التوالي، وعند زاوية ميل ثابتة لغربال التنظيف تبلغ 8 درجات.

الكلمات المفتاحية: غربلة الحبوب، الأرز، القمح، كفاءة التنظيف، الطاقة المستهلكة، تكاليف التشغيل.