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Manufacturing an Integrated Hammer Mill Unit for Grinding Rice Straw Intended for Multiple Applications

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ABSTRACT

A rice straw milling unit manufactured in local workshop and the experimental evaluation was carried out in rice straw assembly station. The obtained result data indicated that the manufactured rice straw unit created solutions for all the problems faced the regular hammer mill machines in dealing with rice straw. The operation parameters under investigation and evaluation were air suction velocity of (1.97, 3.61, 5.37 and 6.91m/s), Number of hammers (54, 81 and 108 hammers) and Hammers thickness (2 and 5mm).The obtained results were for production the very low milled rice straw particle size applications such as MDF, papers making, silica jell and ethanol production must use air suction velocity of 5.37 m/s with number of hammers of 108 hammers with hammer thickness of 2mm. As this operation parameters obtained the following results 1.17 Mg/h main production rate in first cyclone, 43.95 kg/h, very fine product (straw dust) in second cyclone , 29.17 kW.h/Mg specific energy (SE), 153.63kg/m3 milled straw bulk density,0.43% losses in machine chamber, 1.93%losses with air blower output and particle size distribution percentage of 36.41% , 25.97% and 9.33% for particle size of (<2.00->1.00mm), (<1.00->0.60mm) and (<0.60mm) respectively. The results showed also for milling the rice straw as raw material for animal feed pellets or bio fuel as thermal energy better use air suction speed of 5.37m/s , 54 hammers number with 2mm hammer thickness, this operation parameters obtained the following results 0.83 Mg/h main production rate in first cyclone, 32.45 kg/h very fine product (straw dust) in second cyclone , 32.18kW.h/Mg specific energy (SE),112.29kg/m3 milled straw bulk density,5.94% losses in machine chamber, 1.23 %losses with air blower output and particle size distribution percentage of 32.43% ,37.07% for particle size of (<3.75- >2.80mm) and (<2.80- >2.00 mm) respectively.

Keywords*:* Rice straw- hammer mill- drum-air suction velocity- hammers number -hammer thickness and straw particle size.

INTRODUCTION

The problem of field wastes accumulation has become one of the greatest problems lately. Eliminating them through burning causes environmental pollution, in addition to losing the economic value of recycling theses wastes. The quantity of field wastes is estimated at18-25 million tons, 30-50% of which is burnt (Economic Affairs Sector statistics - Ministry of Agriculture, 2017). Burning these wastes is a result of the reasons such as the desired to empty the field fast to cultivate the crops in the suitable time, getting rid of the pesticides found deep in these wastes that affect other crops, the difficulty of moving, storing and handling these wastes, lack of suitable transformational industry that helps in getting rid of these wastes and the high cost of collecting and compressing the wastes is a main factor to burn them. Farmers try to get rid of fire the residue which reduces the environmental pollution load. It also reduces the health risks of burning waste. Rice straw consists of many important components such as cellulose, hemicelluloses, this chemical analysis giving an opportunity to be a good raw resource for the paper industry and other products (FAO, 2013). There are two main kinds of wastes from rice - rice straw and rice husk. Rice straw often used in animal feed application and as raw material for paper making and compost production.

This will lower the environmental impact. It can also be used for the production of biofuels, and can be used in bio-ethanol production and as add value and provide green energy solution to cover the increasing energy demand. In addition, it can be converted into plastics or adhesives in near future, several industries would be utilizing the rice straw as a bio refinery and it would be commercial reality (El Mekawy *et al*., 2013 , Abo-State *et al*., 2014 , Renu *et al*, 2016 and Amith *et al*, 2016). It is right time to develop the economics with low handicap to environmental and to save for future. It utilize in many application and recycle the amount of residues as raw material in many agriculture and industry applications. Agro residues are very good choice of wood scarce countries (Hosseinpour *et al*., 2014). Biomass and feed stocks like rice straw need to be milled into low particles before briquetting, the particle size has high effects on final product quality and energy consumption (Wang, *et al*, 2016)**.**

Aditya *el al.* (2015) reported that, the effect of milling parameters such as the screen holes size, and drum speed on the particle size distribution of the milled product for a conical screen mill machine and a hammer mill. Generally, the conical screen mill was more sensitive to changes in drum speed compared with the hammer mill. Meanwhile, the increasing drum speeds led to increase the size reduction, for the same screen holes size. Size reduction is the most energy unit operation in mineral processing.

Size reduction coarse range (crushing) requires comparatively less energy than that in the finer range (grinding). During feeding material inside the hammer mill it is shattered by the impact with the rotating hammers first and then by striking against the inner surface(concave plate) of the hammer mill that help in producing a fairly uniform size distribution which is much finer than the feed size distribution. (Tavares, 2004).

Gil *et al*. (2013) studied the influence of several operational parameters and the biomass kinds on milling energy consumption and milled product size distribution. They tested wheat straw and corn stover under the variable milling knives and screen size from 12.7 to 50.8mm, with feed rate from120 to 660 kg/ h and operating drum speed between 250 to 500 rpm.The bio mass has moisture content (>20%) increased the specific energy requirements by 50%. (Miao *et al*, 2011).

Tumuluru *et al*.(2014) studied the specific energy for milling and physical properties of wheat, canola, oat and barley straw grinds size reduction experiments were conducted in two steps: first : a chopper without a screen, second milling by a hammer mill using three screen different hole sizes of 19.05, 25.4, and 31.75 mm. The lowest milling energy were (1.96 and 2.91 kW.h./t) for canola straw using a chopper and hammer mill with 19.05mm screen size, whereas the highest energy were recorded (3.15 and 8.05 kW.h./t) for barley and oat straws. The physical properties of the chopped and hammer-milled indicated that smaller particle sizes can produce higher density briquettes, but more energy consumed to grind the raw materials. Hammer mill screen with low holes sizes resulted in higher durability briquettes. Many studies found that, biomass feed stocks size reduction lead to increase the touch surface area, pore size between the particles , and number of contacts points for particle bonding through briquettes operations . Hammer mills is the most commonly used as a size reduction equipment.(Soucek *et al* ,2007 and Adapa *et al* ,2011).The wood chips size reduction of (0.2- 0.6 mm) required 20-40 kWh./t, whereas, size reduction of (0.15-0.3 mm) required 100-200 kW.h./t of grinding energy consumed (Datta 1981, , Bitra *et al*, 2009). Measuring alfalfa size reduction energy consumption could be very important for the processes. Alfalfa chops passed through sieve sizes of 18mm, 15 mm and 12 mm were milled using 1.1 kW hammer mill power for four milling screens sizes of 1.68, 2.38, 3.36 and 4.76 mm. Results indicated that alfalfa chops with sizes of 18mm and 12mm had the highest and lowest specific energy (30.96 and 5.06 kJ kg^{-1}), respectively (Ghorbani *et al*, 2010).

Vigneault *et al*. (1992) observed that a saving in total specific energy requirement by 13.6% with an increase in grinding production rate by 11.1% when using thin hammers (3.2 mm) instead of thick hammers (6.4 mm)for corn grind by hammer mill. The specific energy requirement of biomass milling depends on the percentage of particle size distribution of raw materials before and after milling, moisture content, bulk density, the feeding rate, and machine mechanical operating parameters. Energy consumption for milling wheat straw, corn haulm and rice straw increased by changing the screen holes size from wide to finer (Lopo, 2002). Bulk density is a major physical property in the logistic systems for biomass handling. (McKendry 2002 and Lam *et al*, 2008).They concluded that biomass material density dependents on size, surface characteristics, shape, moisture content, and particles density.

Gangil (2015) found that the moisture content and bulk density of received raw rice straw were 10 ± 3% and 135 ± 25 kg\ m^3 respectively. The particle size of milled rice straw after milling by hammer mill was < 1 mm. The moisture content and bulk density of powdery material were 8 ± 4% and 145 ± 20 kg \m^3 respectively.

The rice season became a nationally obsession, how to stop the spread of fires in the rice-growing areas in Egypt and the failure of the black cloud affect the Egyptian environment, and for many years did not stop thinking and try to find solutions to exploit the straw backward for agriculture. The first step in recycling plan of rice straw depends on make a size reduction for this amount of rice straw wastes to reduce the volume and prepare the raw material to be able to use in many application. Many researches have been interested in this field by manufacture and development many kind of chopper machines, but all have succeeded in the rice straw size reduction between 6 cm to 2cm as maximum, these sizes are suitable in limited applications such as compost production or direct animals feed after mixing the straw with some additives. The main problem in rice straw grinding to low degrees particle size to be suitable for use in other multi-organic and industrial applications, is that the straw stalks occurring what we called elastic cushion its absorbs the hammering force and expand again without reaching the levels of finesse less than the size of sieve grinding holes diameter , In addition to the rice stalks wrap around the milling drum, which leads to the self-ignition due to high friction and increase the motor load which inevitably leads to motor damage.

The main target of the research is manufacture and evaluation a particular hammer mill machine that can grind rice straw to low degrees particles size in one process without pre-operations (Chopping).Also evaluate the hammer mill performance by studying some of operational factors affecting the machine productivity, machine efficiency, milled rice straw density and specific energy consumed.

MATERIALS AND METHODS

The idea for recycling rice straw is development a hammer mill machine equipped with particular milling drum design such as hammers number and thickness, machine concave design and concaves position inside milling chamber, the machine completely manufactured locally and totally different than chopper machine. The Experiments and measurements were carried out at a station to collect rice straw in the village of Harya Razna, Sharqiya Governorate.

Material

The rice straw raw material varieties and chemical analysis:

The experiments were carried out using Giza 176 and Giza 177 of rice straw varieties that planted in Sharqia Governorate. The rice straw reached the collection station as bales of hay each has 20-23 kg mass has average moisture content of 11.32-9.06%. A chemical analysis of the raw and milled straw were performed at the Central Feed Lab - Egyptian Ministry of Agriculture. (Table 1).

Table 1. Average total composition of raw and milled rice straw

Sample	Protein %	Fiber %	Fats %	Minerals matter %	Free N extract %	Dry matter %
Raw rice straw	3.9	35.5	1.4	14.5	36.4	91.70
Milled rice straw	4.05	28.17	2.04	13.62	45.62	93.5

The problems were taken into consideration when developing and manufacturing of the rice straw milling unit:

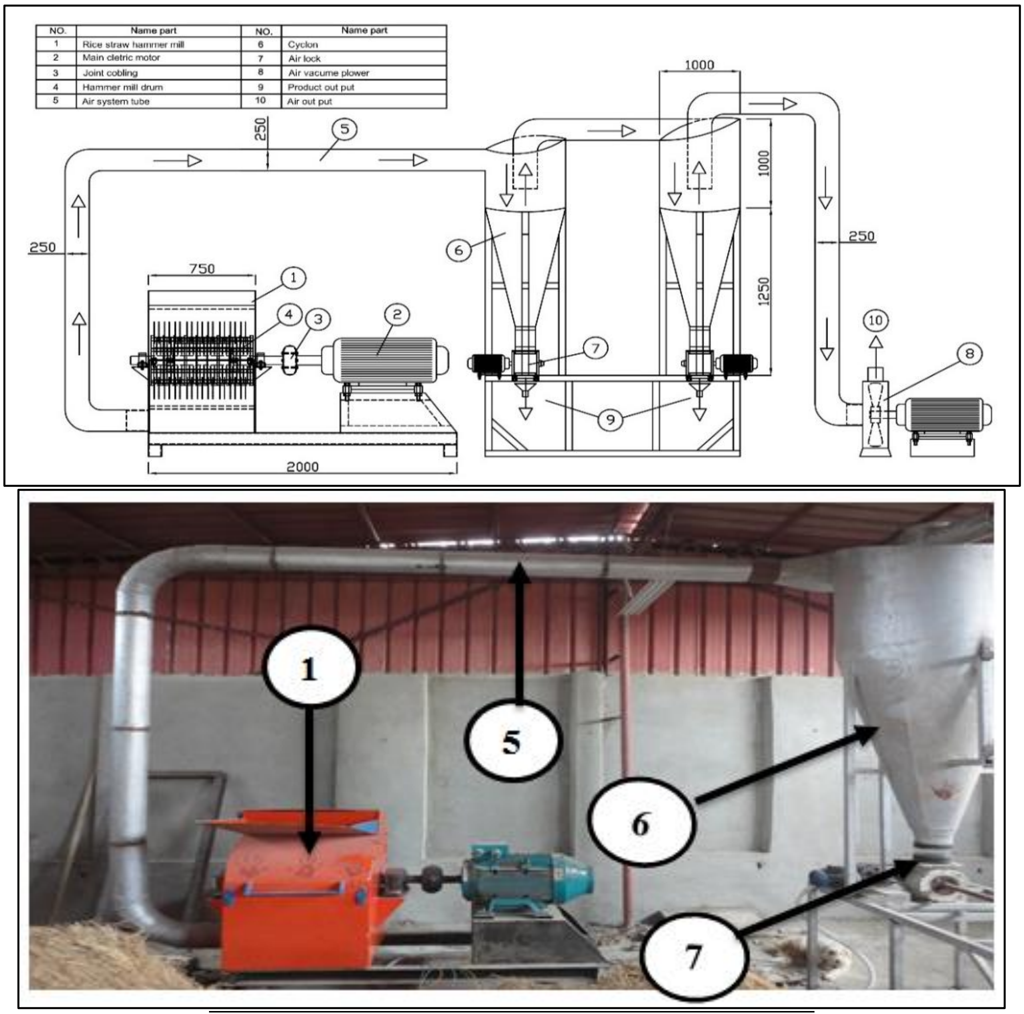
After the failure of traditional hammer mill grinding units in grinding the rice straw to low degrees size reduction and after studying and determination the problems facing grinding operations. We can summarized the problems in the following points:

- The machine feeding gate of traditional hammer mill not suitable for feeding the rice straw stalks without chopping.
- The flexible pillow, which are made by rice straw stalks in the grinding chamber above the sieve.

- The weak flow of milled rice straw from the grinding chamber through sieve holes, also the accumulation of milled rice straw down the sieve, which increases the machine load and makes the hammer mill working under high pressure.
- Milling rice straw generate a lot of dust from the hammer mill unit and that lead to harm the environment as well as the workers' health and increase the milling machine losses percentage

Hammer mill unit lay out:

The hammer mill unit lay out consists of several parts, Fig (1) showed the hammer mill machine with mean motor direct drive by coupling, air suction tubes connecting the hammer mill with air separators (cyclones), cyclones two pieces with air locks , air suction blower



N	ITEM	N	ITEM
1	Rice straw hammer mill	6	Air cyclones
2	Main motor 55kW	7	Air lock
3	Connecting coupling	8	Suction blower
4	Dynamic milling drum	9	Products outlet
5	Air suction tubs	10	Clean air outlet

Fig. 1. Rice straw milling unit layout

Rice straw hammer mill unit

Hammer mill base and chamber

The rice straw hammer mill system consists of machine base has dimension of 2500mm length and 1250mm width made from I shape steel bars 25mm thickness. The base including the main motor base plate (750x500x5) mm. The milling chamber consists of the upper and bottom chambers connected together by tow hinges. The upper chamber has the feeding gate with dimension of (750x250) mm. The top of upper chamber has carved shape compatible with milling drum shape, the outer dimension of upper chamber is (1000x750x500) mm which made from steel sheet with 12mm thickness. The back side of the upper chamber is fitted with a milling concave has of ellipse shape made from 12 hard steel strips with a square section dimension of (10x10) mm. The bottom chamber has same upper chamber dimension and has conic shape from bottom to collect the milled product under the milling screen with cycle end has diameter of 200mm. The bottom chamber also is fitted with a milling concave has of ellipse shape has same dimension of upper concave . The bottom chamber has a cavity in each side to install the milling sieve below the milling drum, the bottom chamber also has air suction gate 250 mm Ø connecting with air suction pipes and from another side there is another opening gate with cover has 150mm Ø to control the air suction velocity inside the hammer mill Fig (2).

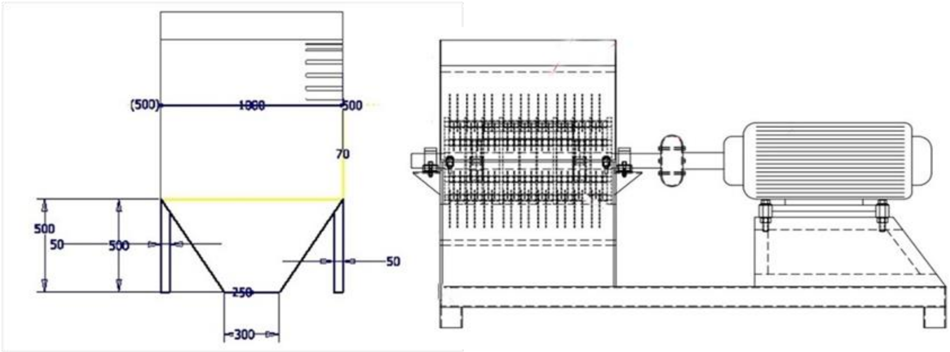


Fig. 2. Hammer mill base and chamber

Milling drum

The milled drum of rice straw hammer mill designed totally different than grains hammer mills the milling drum consists of A- The main shaft has length of 1270mm and graduated diameter as 830 mm length in middle has 85mm Ø, 160mm in both sides has70mm Ø for the 2 side bearings and 120mm has 50mm Ø in motor side connecting with the motor through rubber coupling. B- The drum consists of 8 discs each has 450mm Ø, the outer discs has 16mm thickness the middle discs has 6mm thickness the distance between the discs were 110mm, the discs connecting together by 6 axes called knives holder axes made from hard steel C52 each one has 25mm Ø the axes hold the milling knives each knife (170x50x2 or 5 thickness) mm. Fig. (3)

Air suction system

The air suction system included the air suction tubes connected the hammer mill from the bottom chamber at air suction gate the tube made from galvanized steel 450 galvanized degree has 250mm Ø and 2 elbow 45^{o} to connect the first cyclone at the entry slot side and there is another tube same diameter connect the first cyclone air out put in the center with second cyclone inlet gate , the second cyclone outlet center tube connected with the air suction blower with the center of blower propeller. Fig (1).

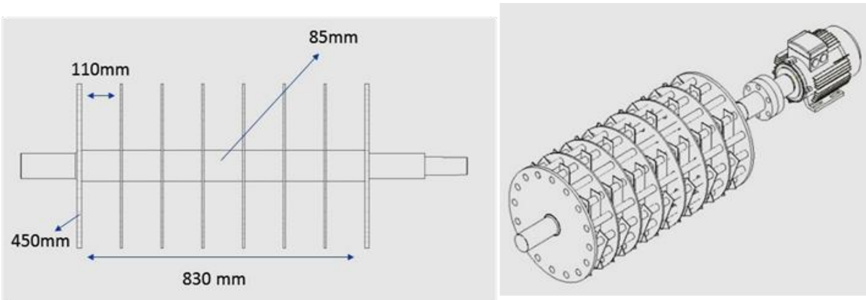


Fig. 3. The rice straw milling drum

The cyclones has conical shape made from steel sheet 1.5mm thickness with total highest of 2500mm and 1250mm Ø the upper part 1000mm and conic part 1500mm,the intake gate of cyclone has 250mm Ø, the output gate has 250mm Ø fixed with air lock Fig (1).

Power transmission and control panel unit

The power transmission system of rice straw hammer mill unit consists of the main electric motor 55kW 380V high speed of 3000 rpm direct connect with milling drum through rubber coupling as an additional protection element for the engine in the event of an any defect in the grinding chamber. The power transmission of air suction system including the 2 air lock electric motors each 1.5kW, 380V, with gearbox the output speed were 35 rpm, while the air suction blower electric motor were 11kW, 380V and 3000 rpm speed. The rice straw hammer mill has full control panel including motors current, voltage, and amber digital screen with motors over load and sequence system in motors start up and shut down.

Methods

1. Experiment's conditions

The development of the hammer milling machine that be able to grind the rice straw in one process was evaluation under, the flowing parameters:

1- Air suction velocity of (1.97, 3.61, 5.37 and 6.91m/s)
2- Number of hammers (54, 81 and 108 hammers).
3- Hammers thickness (2 and 5mm).

The constant parameter were obtained from the first prototype and previous research's such as drum speed were 3000 rpm because it is clear to know the low drum speed which lead the rice straw to make the flexible pillow and wrap the straw stalks around the milling drum which lead to increase the fraction and temperature so lead to ignition the rice straw inside the machine chamber. Another constant parameter were the clearance between the hammers and milling concave that evaluated by try and error methods that found 2 mm to get best milling performance and the screen holes size were 4 mm Ø. The mas were 100kg per each treatment feed continuous with calculate the treatment time consumed.

The instrument were;

- Rotating speed measuring device leaser tachometer made in china
- Multi kit for measure voltage, current and amber device.
-. Stop watch Casio FX53
-. Weighting scales maximum weight (200 kg).
- Weighting scale maximum weight (20 kg).
- Mechanical shaker with sieves set made in USA

Evaluation of hammer mill machine performance:

Machine production rate

Measured for each treatment by collect sample for 2 min after machine running steady, the production rate measured in both cyclones, first one for, main of production and second one for very fine product.

Specific energy (SE)

The energy requirement in (kW.h/Mg) was calculated by the following

Consumed power: $$P = \frac{\sqrt{3} \quad I \quad V \quad \eta \quad \cos\theta}{1000}$$

Where:

P = total consumed power, kW
I = Line current strength in amperes.
V = Potential difference (Voltage) being equal to 380 V.
Cos θ = Power factor (being equal to 0.84).
η = Mechanical efficiency assumed (assumed 90 %).

$$Energy\ requirement = \frac{P}{Q} = kW.h / Mg$$

Where:

P = the consumed power for mixing ration, kW
Q = Machinery line productivity, Mg/h.

Milled rice straw bulk density:

Was calculated using Standard method of fed manufacturing (AACC, American Feed Industry Association, Inc., 2000).

Milled rice straw losses:

The losses in rice straw hammer mill unit can be divided to 2 kind of losses, main losses that collected inside machine bottom chamber after treatment, dust losses that collected in suction blower output by cylindrical lint filter.

Milled rice straw particle size distribution:

Using the mechanical shaker1 kg sample from each treatment shake for 5 min using6 sieves set and measured the mass up of each sieve and calculate the percentage of each particle size by the following equation:

$$Particle\,\% = \frac{M_A}{M_B} x100$$

Where: **M_B and M_A, The mass before and after treatment (g.)**

From measured the milled rice straw particle size distribution we can know the percentage of each particle size which is convenient for the different applications such as compost, animal feed, bio fuel, paper industries, and silica jell and ethanol production .

RESULTS AND DISCUSSION

Milled rice straw production rate

From rice straw hammer mill unit design there are two product out put under the both cyclones, the most quantities of product collected from first cyclone and the very fine product collected from the second cyclone. Data in Fig (4) showed the effect of air suction velocity on milled rice straw production rate for first cyclone, increasing the air velocity from 1.97 to 5.37 m\s increased the main production rate from 0.49 to 0.83, from 0.61 to0.96 and from0.83to 1.169 Mg/h using hammers 2mm thickness at 54, 81and 108 hammers respectively. Same trend with using hammer mill thickness of 5mm it is increased from 0.39 to 0.73, from 0.52 to 0.86, and from 0.73 to 1.09 Mg/h at 54, 81 and 108 hammers respectively.

While increasing the air suction velocity up to 6.19m/s lead to light decrease in main production rate to 0.8, 0.91 and 1.12 Mg/h using hammers 2mm thickness at 54, 81 and 108 hammers respectively, and decreased to 0.71, 0.83 and 1.06Mg/h using hammers 5mm thickness at 54, 81 and 108 hammers respectively. The increase in main production rate in first cyclone by increasing the air suction velocity from 1.97 to 5.37 m/s could be due to the increase in suction air velocity which lead to reduce the milled rice straw losses in machine bottom chamber while low velocity left some heave products in machine chamber.

While increase the air suction velocity up to 6.19m\s decreased a little in main production rate because at this velocity the air take all the milled product from machine chamber and send to first cyclone under high pressure, so the milled product mixed with air generated high dust inside the first cyclone and not all milled straw down up of the air lock by gravity so some of milled product moved with air out of first cyclone to second cyclone or to air suction blower output.

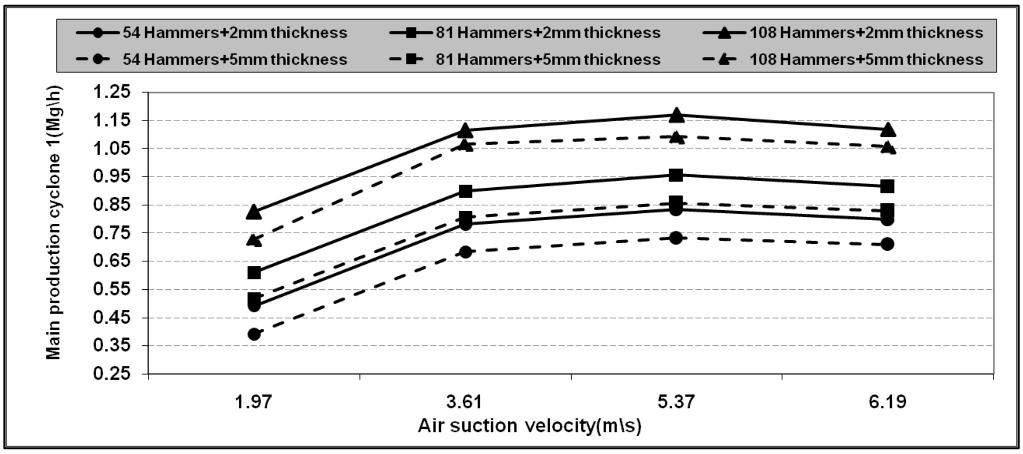


Fig. 4. The effect of air suction velocity, number of hammers, and hammers thickness on milled rice straw for first cyclone.

On the other hand the effect of number of hammers on machine main production rate Data in Fig (4) indicated that increase the number of hammers from 54 to 81 hammers increased the production rate as positive relationship by 19.6% and 22.11% as average when it increased by 26.5% and 30.11% as average by increasing the number of hammers from 81 to 108 hammers using hammers thickness of 5 and 2mm at all air suction velocities. The increase of production rate by increasing the number of hammers from 54, 81 to 108 hammers could be due to the increase in the roads rate in the constant volume of milling chamber with the increase of touch surface area between the straw and the hammers in the element of time, that lead to increase the size reduction.

Meanwhile, the effect of hammers thickness on main production rate data in same figure showed changing the hammers thickness from 5mm to 2mm increased the production rate by 12.40- 22.54% as average for all numbers of hammers with all air suction velocities. The increase in machine main production rate by reducing the hammers thickness from 5mm to 2mm could be due to the shearing force and cutting face more influential on straw and stalks than the road force for best size reduction, so the low thickness of hammers increasing the size reduction per time and increase the production rate.

Data in Fig (5) showed the effect of different parameters on a very fine milled rice straw in second cyclone. Increasing air suction velocity from 1.97 to 6.19m/s increased the production rate in second cyclone from 24.54 to 33.66, from 29.19 to 38.92 and from 37.04 to 45.07 kg/h using hammer thickness of 2mm and numbers of hammers of 54, 81 and 108 hammers respectively. With changed the hammers thickness to 5mm there is no change in the results direction, the increase in air suction velocity increased the production of fine milled straw from 19.22 to 28.34, from 25.57 to 35.30 and from 35.07 to 43.10 kg/h using numbers of hammers of 54, 81 and 108 hammers respectively. The positive increase in fine milled rice straw by increasing the air suction velocity could be due to the high velocity air suction lead to take most of fine milled straw with low mass from first cyclone to second cyclone so increase the mass production in second cyclone.

Same figure indicated that the effect of number of hammers on the fine milled rice straw production, data showed increase the number of hammers from 54 to 81 hammers increased the production in second cyclone by 13.51and15.93% as average and increasing the number of hammers to 108 hammers increase the production rate by 13.61and 21.11% using hammers thickness of 5 and 2mm respectively, at all of air suction velocities. The increase in production rate by increase the hammers number could be due to more hammers lead to increase the percentage of low particle size in time unit. The effect of hammer thickness on fine milled straw production can see clear in Fig (5), data showed decrease the hammers thickness from 5mm to 2mm increase the fine production rate by 22.36% as average with all of air suction and number of hammers .the increase in production rate by decrease the hammers thickness for same reason explained before.

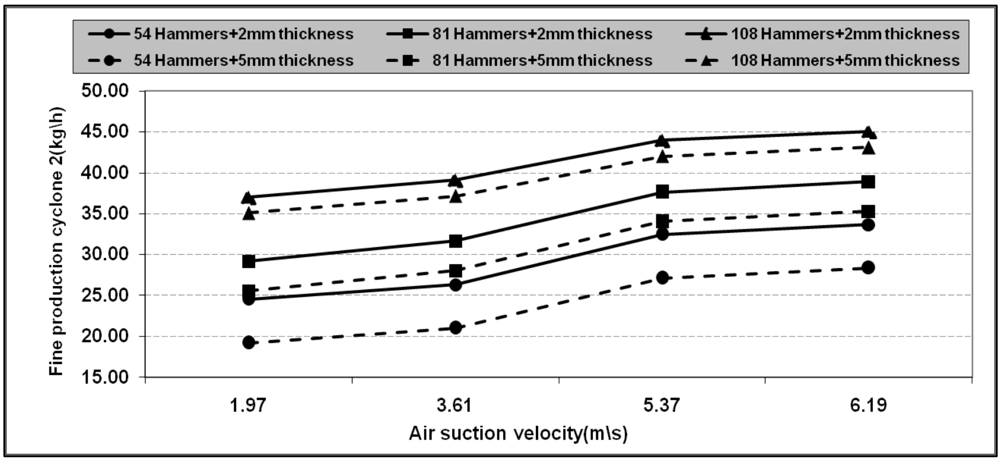


Fig. 5. The effect of air suction velocity, number of hammers, and hammers thickness on fine milled rice straw for second cyclone.

Specific energy (SE):

Specific energy very important calculation for any industry, rice straw milling unit energy requirement affecting by several parameters. Data in Fig (6) showed the effect of air suction velocity on SE, increasing the air velocity from 1.97 to 3.61m/s decreased sharply the SE by 65.26% as average for all numbers of hammers using 2mm hammers thickness and by77.71% using 5mm hammers thickness,. While increasing the air suction velocity from 3.61 to 5.37 m/s indicted slit decrease in SE 12.96 and 11.54% at all number of hammers using 2mm and 5mm hammers thickness respectively.

But increasing the air suction velocity up to 6.19 m\s increased a little again the SE by 1.79% using 2mm hammer mill thickness and decreased by 11.41% at 5mm hammers thickness. The sharply decrease in SE by increase the air velocity to 3.61m/s could be due to the highly increase in machine production rat with low increase in power consumption. When the reason for slight decrease in SE by increasing the air suction velocity to 5.37 m/sec could be due to the little high in production more than the increase in power consumption, on the other hand the slight increase in SE by increase the air suction velocity up to 6.19 m/s could be due to, at this air velocity no any milled rice straw still in machine chamber so no increase in production rate with increase in power consumption.

Regarding to the effect of numbers of hammers on SE, data in Fig (6) showed that increasing the number of hammers from 54 to 81 hammers decreased the SE as average for all air suction velocity by 1.43 and 13.8%, while increase the numbers of hammers to 108 hammers the SE decreased by17.98 and 21.19% using 2 an 5 mm hammers thickness respectively.

The decrease in SE by increase the numbers of hammers could be due to the increase in machine production than the increase in power consumption by more load of hammers. However the effect of hammers thickness in SE, same data in same figure indicated that changed the hammers thickness from 5mm to 2mm decreased the SE by 28.92, 19.16and 16.00% as average for all air suction velocity using numbers of hammers of 54 , 81 and 108 hammers respectively. The decrease in SE by change the hammers thickness from 5 to 2 mm could be due to the increase in machine production with decrease of machine power consumption by decreases the hammers weight, that lead to decrease the specific energy requirement.

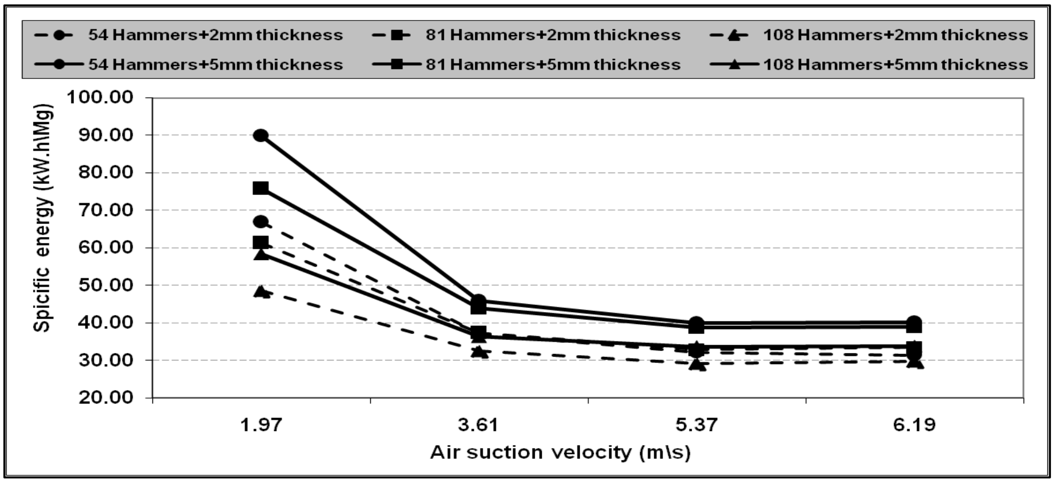


Fig. 6. The effect of air suction velocity, number of hammers, and hammers thickness specific energy (SE)

Rice straw milling machine losses percentage:

Through the measurements, the rice straw milling machine losses can be divided into, the milled straw inside machine chamber losses and fine milled straw with air losses. The milled straw inside machine chamber were left by air suction we can be summarized in Fig (7), data showed that the most affecting factor in the losses were the air suction velocity, it is clear to see increasing the air suction velocity from 1.97 to 5.37m/s reduces losses dramatically at all hammers numbers and thickness from 19.44 to 5.94%, from 16.74 to 3.27% and from 13.01 to 0.43% using hammers thickness of 5mm, from 21.56 to 8.22%, 18.39 to 4.95% and from 15.91 to 2.57% using hammers thickness of 2mm.at hammers numbers of 54,81 and 108 hammers respectively. While increase the air suction velocity from 5.37 to 6.19m\s decreased the losses percentage slightly unnoticeable to 1.90, 0.98 and 0.00% using hammers of 5mm thickness and to 1.97, 0.00 and 0.00% using hammers of 2mm thickness at numbers of hammers of 54,81 and 108 hammers respectively. The obvious decrease in losses inside the machine chamber by increase the air suction velocity from 1.97 to 5 .37 m/s owing to the high suction velocity generate high suction force take more quantities from milled rice has large particle size and mass from machine chamber under the screen. But increasing the suction velocity to 6.19m/s did not lead to a significant decrease because the air suction velocity of 5.37m/s pulled most of milled product from machine chamber and left a little amount of high mass particles inside machine. When we looking to the effect of number of hammers on losses inside the machine from same figure we can see change the number of hammers from 54 to 81 and 108 hammers reduced the losses as average between 2.63 – 3.11% at all air suction velocities and hammers thickness.

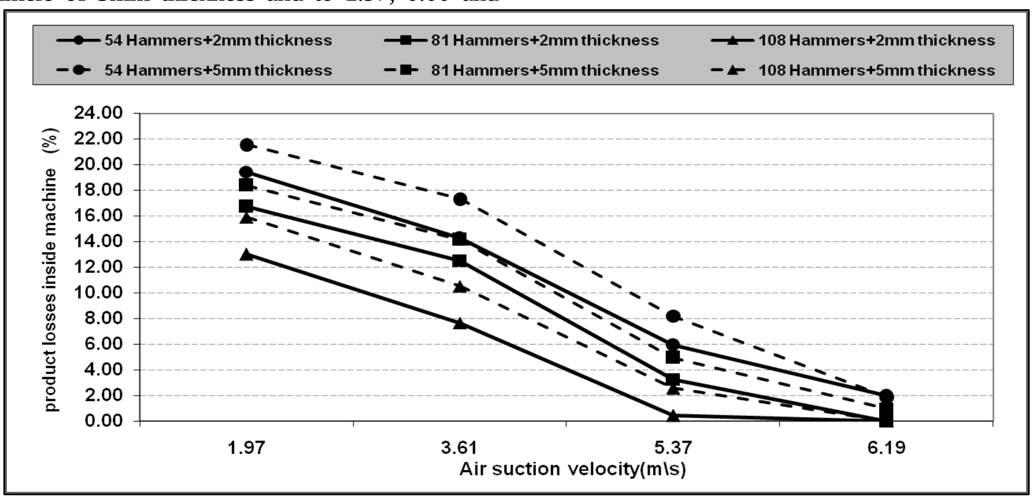


Fig. 7. The effect of air suction velocity, number of hammers, and hammers thickness on losses percentage inside machine chamber.

As well as the effect of knife thickness, it is a weak effect compared to the effect of air suction velocity, data showed change the hammers thickness from 5mm to 2mm reduce the losses as average between 0.89 – 2.75% using all air suction velocities and number of hammers.

The decrease of losses by increased the hammers number or by reduce the hammers thickness refer to the same reason, that both factors lead to increase the size reduction and increase the percentage of fine particles with low mass that help the air suction to pulled more quantities of milled product out the machine chamber to air tubs and cyclones.

The second kind of losses were the low particle size losses with air out put in blower, Data in Fig (8) indicated that air suction velocity most affecting parameters in the fine particles losses measurement. Increasing the air velocity from 1.97 to 6.19m/s increased gradually the losses with air by varying proportions from 0.37% as minimum using air velocity of 1.97m/s, 54 hammers and 5mm hammers thickness to 4.56% as maximum using air velocity of 6.19m/s , 108 hammers used and 2mm hammers thickness.

The above results show that increasing the air suction velocity leads to increase the losses with air out of the hammer mill unit and this is due to increasing suction force then the air arrive to cyclones under high pressure and velocity so take some low particles out the cyclones to the blower air output gate, as well as increasing the number of hammers or reduce the thickness of the hammers leads to increase losses also because these elements lead to increase the percentage of law particles and that facilitate pull it out of cyclones to the air suction blower output.

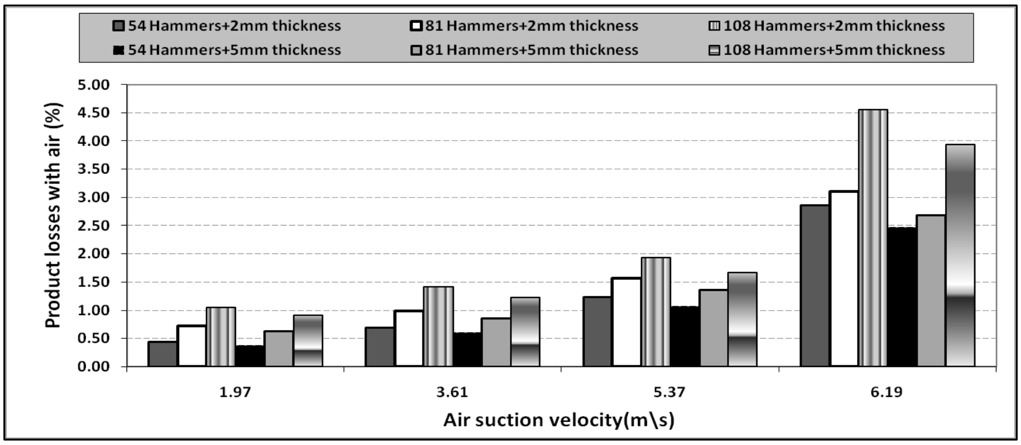


Fig. 8. The effect of air suction velocity, number of hammers, and hammers thickness on losses percentage with air output.

Milled rice straw bulk density:

Bulk density of milled rice straw products is one of the most important measurements for after production operation such as trading, transportation and storage, as well as the matching the milled straw bulk density for the density index for any utilizing into transformation industries. Data in Fig (9) indicated that air suction velocity not too much affecting the product bulk density, increasing the air velocity from 1.97 to 6.19m/s decreased slightly the bulk density as minimum recorded 101.10 kg/m^{3}using air suction velocity of 6.19m/s , number of hammers of 54 hammers and hammers thickness of 5mm, however it recorded as maximum 163.31 kg/m^3 using air suction velocity of 1.97 m/s, with 108 hammers and hammers thickness of 2mm.The slight decrease in bulk density by increasing the air suction velocity that owing to the high air suction velocity pulled compulsively the straw from milling chamber up the milling screen before it grind as screen holes size, and that decrease the product mass in volume unit .Clear to understand that the air suction not affecting the milling process it is just transmission method to move the product from the hammer mill to cyclones.

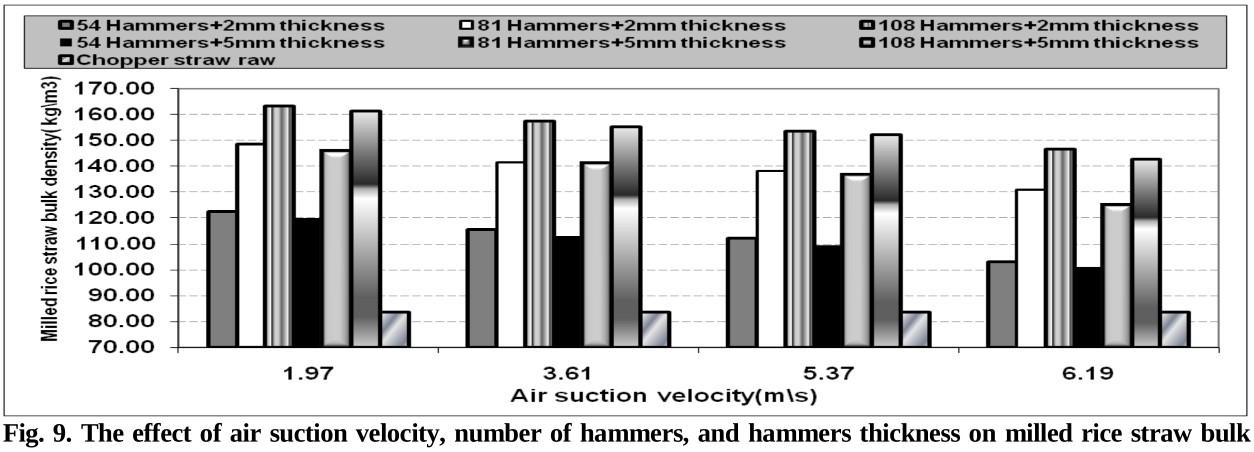


Fig. 9. The effect of air suction velocity, number of hammers, and hammers thickness on milled rice straw bulk density.

Nevertheless, the number of hammers has a positive and great impact on product bulk density, data in same figure showed that increasing the number of hammers from 54 to 81 and 108 hammers increased the product bulk density as average for all air suction velocities by19.15 and 10.31% using hammers thickness of 5mm and by 18.91 and 9.93% using hammer mill thickness of 2mm.On other hand change the hammers thickness from 5mm to 2mm increased the product bulk density as average for all air suction velocities by 2.20, 1.90 and1.50% using numbers of hammers of 54, 81 and 108 hammers respectively. The increase in milled rice straw bulk density by increasing the number of hammers or by change the hammer thickness to then hammers 2mm could be due to the high percentage of small particle size in final product at this treatments and that lead to increase the mass in volume unit so increase the bulk density of the milled rice straw comparing with chopping rice straw bulk density of 83.74 kg/m^3.

Milled rice straw particle size distribution:

Milled rice straw particle size distribution is the measurement that determines the different degrees percentage of particle size of milling products as indicate for the possibility of utilizing them in different applications. Data in Fig (10) and Table (2) showed that the effect of number of hammers and hammers thickness on milled straw particle size distribution at constant air suction velocity of 5.37m\s, the treatment samples were one kg of final product from each treatment. the degrees of particle size were (>3.75mm,<3.75- >2.80mm,<2.80- >2.00 mm,<2.00- >1.00mm,<1.00- >0.60mm and <0.6mm).

The analysis of the data in Table 2 and Fig (10) indicated that increasing the numbers of hammers from 54 to 81 and 108 hammers also decreased the hammer thickness from 5 to 2 mm , increased the fines particles percentage of 2.80- >2.00 mm, <2.00- >1.00mm and <1.00- >0.60 degrees. As well as the data showed clear the percentage of large particles of >3.75mm is very low percentage under all the machine hammers numbers and hammer thickness. The previous results showed that the hammer mill unit successfully in grinding the rice straw to low degrees particle size, which allows it to use in many applications that were previously unavailable or available in low quality.

Table 2. The treatments particle size distribution of milled rice straw.

Particle size	**54hammes *5mm**	**81hammes *5mm**	**108hammes *5mm**
>3.75mm	8.53	6.23	4.86
<3.75- >2.80mm	37.95	30.23	13.81
<2.80- >2.00 mm	32.42	26.79	21.75
<2.00- >1.00mm	17.57	22.91	31.93
<1.00- >0.60mm	2.47	11.3	20.46
<0.6mm	1.06	2.54	7.19
Particle size	54hammes *2mm	81hammes *2mm	108hammes *2mm
>3.75mm	4.34	2.87	0.41
<3.75- >2.80mm	32.43	24.31	7.34
<2.80- >2.00 mm	37.07	28.84	20.54
<2.00- >1.00mm	20.64	25.83	36.41
<1.00- >0.60mm	4.13	13.42	25.97
<0.6mm	1.39	4.73	9.33

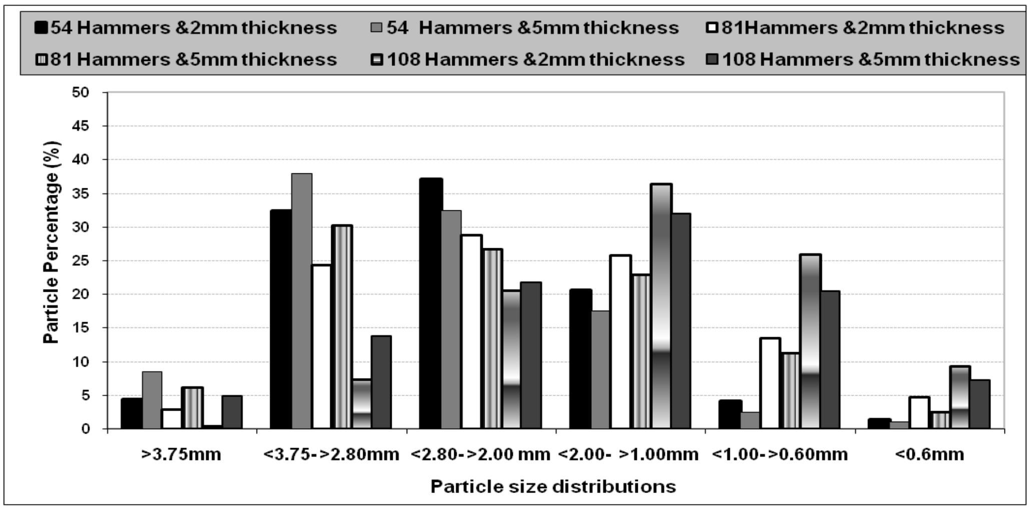


Fig. 10. The effect of the number of hammers, and hammers thickness on milled rice straw particle size distribution.

To understand the optimum operation parameters for each application such as compost, animal feed pellet, biofuel thermal pellets, silica jell production, papers making and ethanol production. Data in Fig (11) showed that the optimum operation parameters of rice straw milling unit suitable for each application.

The data showed that , the optimum operating parameters for produce milled rice straw can be used in compost production has particle size up of (>3.75mm) were 54hammers with 5mm thickness by percentage of 8.53%.

While the optimum operating parameters for produce milled rice straw can be used in animal feed pellets production has particle size of(<3.75- >2.80mm) were 54 hammers with 2mm thickness by 32.43% , 54 hammers with 5mm thickness(<2.80- >2.00 mm) by 37.95% and 81 hammers with 5mm thickness has particle size of(<3.75- >2.80mm) by 30.23%. For MDF production has particle size (<2.00->1.00mm) the optimum parameters were 108 hammers with 5 and 2mm thickness by 31.93 and 36.41 % respectively.

Meanwhile the optimum operation parameters for paper making industries108 hammers with 5 and 2mm thickness has particle size of (<1.00->0.60mm) by 20.46 and 25.97 % respectively.

Finally the optimum operation parameters for silica jell and ethanol production were 108 hammers with 5 and 2mm thickness has particle size of (<0.60mm) by 7.19 and 9.33 % respectively.

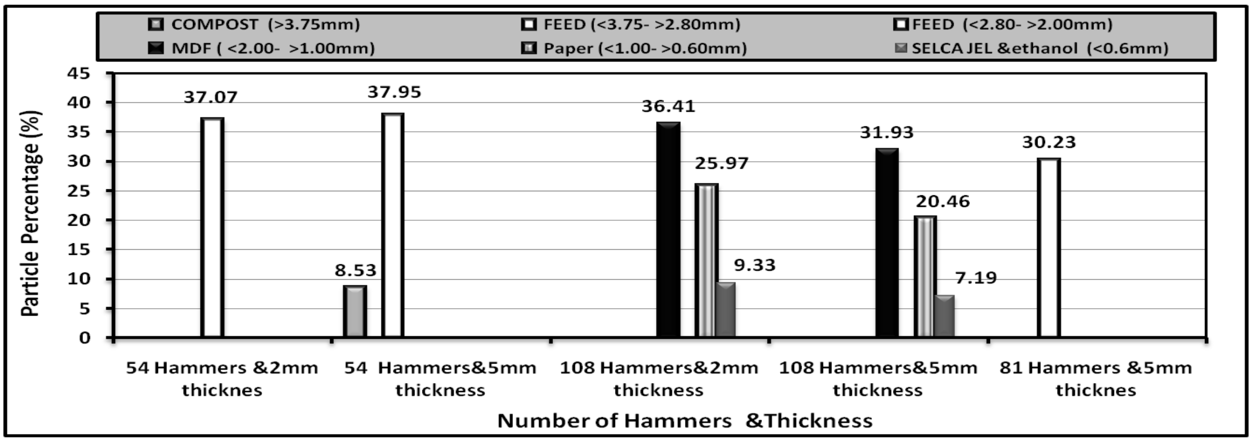


Fig. 11. The effect of operation parameters of rice straw milling unit on particle size distribution suitable for different application.

CONCLUSION

A rice straw milling unit manufactured in local workshop and the experimental evaluation were carried out in rice straw assembly station, from the obtained result data indicated that the manufactured rice straw unit created solutions for all the problems faced the regular hammer mill machines in dealing with rice straw, and succeeded in grinding the straw to low degrees of particle size in one process. It has become difficult to identify general ideal operation parameters of the machine, because it will depends on the purpose of the milling or the particle size target which according to the nature of the product, and what is the applicant will use the milled rice straw to produce it. Generally, the optimum air suction velocity were 5.37 m/s can be used for all of target application particle size .we recommended for production the very low milled rice straw particle size applications such as MDF , papers making, silica jell and ethanol production must use air suction velocity of 5.37 m/s with number of hammers of 108 hammers with hammer thickness of 2mm as this operation parameters obtained the following results 1.17 Mg/h main production rate in first cyclone, 43.95 kg/h very fine product (straw dust) in second cyclone , 29.17 kW.h/Mg specific energy (SE), 153.63 kg/m^3 milled straw bulk density,0.43% losses in machine chamber, 1.93%losses with air blower output and particle size distribution percentage of 36.41% , 25.97% and 9.33% for particle size of (<2.00->1.00mm), (<1.00->0.60mm) and (<0.60mm) respectively. We recommended too for milling the rice straw as raw material for animal feed pellets or bio fuel as thermal energy better use air suction speed of 5.37m/s , 54 hammers number with 2mm hammer thickness, this operation parameters obtained the following results 0.83 Mg/h main production rate in first cyclone, 32.45 kg/h very fine product (straw dust) in second cyclone , 32.18 kW.h/Mg specific energy (SE),112.29 kg/m^3 milled straw bulk density,5.94% losses in machine chamber, 1.23 %losses with air blower output and particle size distribution percentage of 32.43% ,37.07% for particle size of (<3.75- >2.80mm) and (<2.80- >2.00 mm) respectively.

Also recommended, for compost production we need to change the hammer mill screen holes diameter up to 6mm at least to increase the economic production.

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تصنيع وحدة طحن بالطرق متكاملة لطحن قش الأرز للعديد من الاستخدامات

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تعتبر مشكلة تراكم المخلفات الحقلية من أهم المشاكل التي ظهرت في الآونة الأخيرة والتخلص منها بالحرق يعرض البيئة للتلوث مع فقد القيمة الاقتصادية الناتجة عن إهمال تدوير هذه المخلفات وقد أصبح هاجسا قوميا في موسم الأرز كيفية إيقاف إنتشار الحرائق في مناطق زراعة الأرز في مصر وما تخلفه من سحابة سوداء تؤثر على البيئة المصرية، ولسنين لم نتوقف عن التفكير في حلول لإستغلال القش المتخلف عن الزراعة والذي يقوم المزارع بحرقه لعدم قدرته على إستخدامه بالشكل الأمثل وإرتفاع تكلفة نقله لإنخفاض وزنه مقارنة بحجمه. وتعتمد فكرة هذا البحث علي تصنيع وحدة متكاملة لطحن قش الارز ذات مواصفات تصنيعية خاصة ومن مرحلة واحدة دون الحاجة الي اجراء عمليات التقطيع المبدئ اولا وتستطيع هذة الوحدة التعامل مع قش الارز والتغلب علي المشكلات التي تواجه معدات الطحن بالطرق التقليدية عند طحن قش الارزوقد تم دراسة مجموعة من العوامل التي تؤثر بشكل بالغ في معدل اداء الوحدة وهي : سرعة الهواء المستخدم في سحب نواتج الطحن وهي(1.97و3.61,و 5.37و 6.19 م\ث) و عدد مطارق الطحن (54- 81 – 108 مطرقة) و سمك المطرقة (5 -2 مم) وقد اظهرت النتائج نجاح للوحدة في طحن سيقان قش الارز من عملية واحدة لدرجات متدنية تفتح افاق جديدة لاستخدامة في العديد من التطبيقات وتم تحديد عوامل التشغيل المثلي لكل تطبيق او مجموعة تطبيقات ففي حالة انتاج قش ارز مطحون لدرجات متدنية لاستخدامة في صناعة الورق – انتاج السيلكا جل – الخشب المصنع (MDF) -استخدام القش المطحون في انتاج الايثانول كانت العوامل المثلي هي سرعة الهواء 5.37 م\ث و عدد مطارق 108 مطرقة بسمك 2 مم واعطت النتائج التالية: (1.17) ميجا جرام \ ساعة انتاجية الاساسية في السيكلون (43.95) كجم \س انتاجية للقش المطحون شديد النعومة(غبار قش)- (29.17)كيلو وات *ساعة\ ميجا جرام للطاقة المستهلكة لوحدة الكتلة (153.63) كجم \م^3 كثافة القش المطحون- 0.43% نسبة الفواقد المتروكة داخل الالة بفعل هواء السحب- 1.93% نسبة الفواقد مع الهواء عند فتحة طرد مروحة الشفط وكانت نسب توزيع الحبيبات طبقا للقطر (36.41% , 25.97% 9.33%) عند درجات نعومة (<2.00->1.00mm) و (<1.00->0.60mm) و (<0.60mm) علي الترتيب وكانت عوامل التشغيل المثلي عند انتاج قش مطحون يصلح في انتاج اعلاف الماشية او مكعبات الطاقة هي : سرعة الهواء 5.37 م\ث و عدد مطارق 54 مطرقة بسمك 2 مم واعطت النتائج التالية : (0.83) ميجا جرام \ ساعة انتاجية الاساسية في السيكلون (32.45) كجم \س انتاجية للقش المطحون شديد النعومة(غبار قش)- (32.18)كيلو وات *ساعة\ ميجا جرام للطاقة المستهلكة لوحدة الكتلة (153.63) كجم \م^3 كثافة القش المطحون- (5.94%) نسبة الفواقد المتروكة داخل الالة بفعل هواء السحب- (1.23%) نسبة الفواقد مع الهواء وكانت نسب توزيع الحبيبات طبقا للقطر (32.43% ,37.07%) عند درجات نعومة (<3.75- >2.80mm)و (<2.80- >2.00 mm) علي الترتيب و قد اوصي عند استخدام الوحدة لطحن القش لانتاج الكمبوست بتغيير ثقوب غربال الطحن ال 6 مم علي الاقل