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Arbitration Criteria for Garden Leftovers Pressing and Packaging

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ABSTRACT

The attempt to press and packing garden leftover parts into tiny-bales is one of the proposed efforts to reduce the volume of leftover and ameliorate its handling. For these reason a new prototype was constructed, and tested, at Lab of Ismail (2008) that establish on agric. engineering department of Mansoura University. The compacting prototype is involves; an auger-barrel with compressing-auger. While the packaging unit including a forming cylinder with controlling gate. The variable parameters contains average auger rotational speed “ARS” of 34; 44; 54 and 64 rpm, and garden leftover moisture contents “RMC” in range of 14; 16 and 64%. The evolutions of investigated prototype are conducted to measure and; bulk density ”kg m^{-3}” at four different times after packing, actual flow out rate ” m^3 h^{-1}”, machine productivity "kg h^{-1}", operating power consumed "W" and operating specific energy “kW h kg^{-1}”. The results showed that the highest tiny-bale density was obtained at a moisture level of 64% and an auger rotation speed of 64 rpm, while the highest productivity of the prototype recorded at a rotation speed of 64 rpm and lowest moisture content of the garden leftover of 14%.

Keywords: pressing and packing residual, tiny-bale, auger speed, bulk density, productivity, energy.

INTRODUCTION

Biomass as fallen plant parts “yard residues” is biodegradable material consisting of different organics such as hedge cuttings, tree pruning, small branches, leaves, grass clippings and wood debris. There are found in gardens and yards for different of reasons as variation in plants types, changing climatic conditions and ... so on. Also, there are varies in its components by both season and location. Generally, the climate, urbanization, and green space types or landscape-management are strategies largely influence the properties of fallen plant parts (Shi, *et al*., 2013). The fallen tree parts can considered as organic residue produced from the maintenance of gardens and landscaped areas. Leaves, branches, and grasses are a few examples of fallen plant parts that are being produced continuously all year round (Rahman, *et al*., 2020).

Some studies have indicated to use machines that collect and compress field plant residues of traditional crops such as cylinder and cube baling machines (Kemmerer and Liu, 2012, Liu *et al*., 2013 and Manjunatha *et al*., 2015). While, there was less interest in the manufacture and development of machines that work in gardens and green spaces. On the other sides, Goodger (2010) and Glisson (2019) indicated the possibility of collecting, mulching, and storing natural gardens residues in bags or containers. Also, Azadbakht, *et al*. (2014), defines the design of the storage unit for press residues from garden. Whereas Dunning and Saathoff (2006) and Coffey and Coad (2010) identified the formation of a machines that partially compresses garden remains and fills them in plastic bales.

The debris are collected inside the collecting container that has been engaged with the tire by means of a brush it works to push the debris over the surface. The decrease in the volume of debris inside the collection container is due to compressing mechanism (Eberle and Banowetz, 2008).Usually, the gardens leftovers can convey by some methods as freight cart and dump or back pack trucks (O’Brien, 2015). However, sometimes, the reduction in garden-leaves volume may found resulting from packing process in truck. This process provides transmittime to the manufacture (Evanylo *et al*., 2009). Rusty (2013) explained that a compressed of gardens leftovers as; leaves, grass and the other residues can pressed by a special machines. Usually, the all types of the compress machine consist of tank, chamber and die. The chamber made from steel with diameter of 15.88 cm. Azadbakht *et al*. (2014), Hamza (2021) and Ismail *et al*. (2021) designed and test a machine used for collect and transport the green leftovers, they found that the speed of the suction unit is increased to high enough to collect the leftovers. The worker directs the flexible pipe by moved, to can garden-leftover fed into the machine. Therefore, having been taken into the suction box, then by the pressure impact of the fan is then directed to the tank through the outlet (directing pipe).

For all above efforts remains the problem of how to recycle garden leftovers? So, the main object of resent paper is to judge criteria of fallen leaves for compacting and packing by investigating a new prototype able to compress the fallen leaves and forming it in a simple package form.

MATERIALS AND METHODS

The description of compacting and packing unit

Packing unit is organized to conduct the experiments at Lab of Ismail (2008) (Fig. 1). Generally, the investigated unit uses to conveyance primary process of residues and forming it as tiny-bale and packaging in plastic bag as shown in Fig. (2). on the others side, the volume reduction of fallen leaves in form plastic bags make it easily transported, handled and storage. The packing unit as illustrated by (Ismail, 2001) consists of an auger barrel, auger, and forming cylinder.

Auger barrel is a steel cylinder with main dimensions of 383× 78.27 × 25.4 mm for length, inside diameter and thickness respectively is illustrated as shown in Fig. (1).To hold out internal stress, it’s inside surface is made from very hard steel "I.C. 48" for deterioration resistance.

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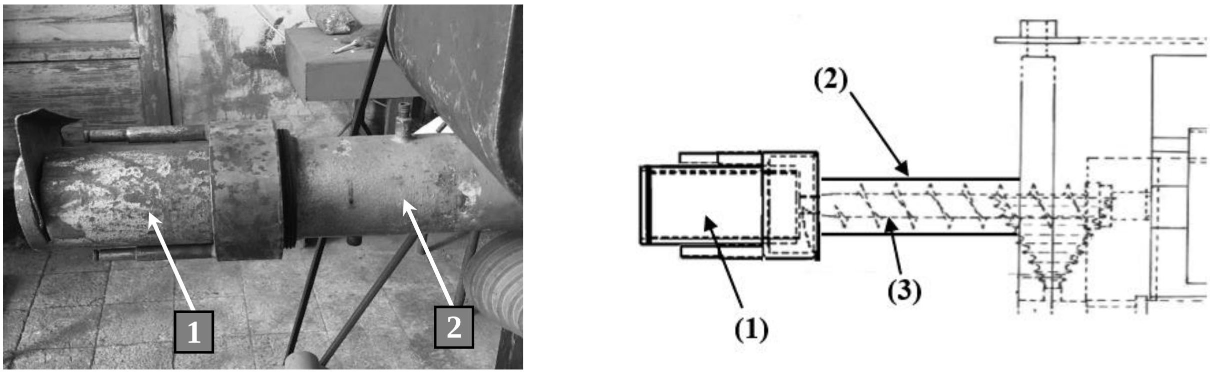


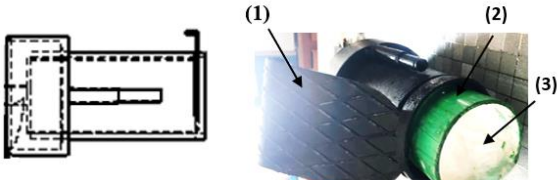
1- Forming cylinder 2- Auger barrel 3- The compress screw

Fig. 1. Compacting and packing unit

The compress screw (Fig. 1) is the moving part in compressing unit. It is a mechanism that uses a rotating helical auger "flight type" to thrust material in axial position. It is made as a single auger type with 78.016 × 500× 47 × 20 mm diameter, length, pitch, and width flight respectively. The pitch is directly related to the helix angle of 17° which angle often is used rather than pitch to describe an auger. So, pitch under all experiments considered constant.

Fig. 2. Shape of garden residue packaging

Forming cylinder is constructed to be suitable use for the both augers in laboratory and field (Fig. 3). It is consisted of two cylinders; outer one is made from iron with dimensions of 260×140×8 mm of length, diameter, and thickness respectively. It is connected with the auger barrel by the adapter. It included an open end which can be controlled packing by the gate. The inside cylinder is covered by the flexible bag having an open end which is drawn over a movable cylinder, surrounding the discharge end of the auger. When the bag is full, it will be replaced by another empty one.



1- Gate 2- The inside cylinder 3- Plastic bag

Fig. 3. Forming cylinder

Power source is three phases electrical motor of 2.98 kW (4.0 hp) with 1450 rpm.

Transmission system is constructed to convey motion to packing unit. The motion translated to auger through the gearbox to reduce the auger revolution ratio by about "1/10" which gearbox takes motion from the engine shaft by V-belt and pulleys directly. So, the auger is driving by gears and chains through transmit the rotation from the gear box.

Experimental procedures are conducted at Lab of Ismail (2008) that establish on agric. engineering department of Mansoura University (Fig. 4) to determine the parameters affecting productivity of transposition and packing unit under auger revolution of 34; 44; 54 and 64 rpm, and material moisture contents of about 14; 16 and 64%. The evolutions of investigated unit are conducted under different the following parameters; bulk density and stability, kg m^{-3} actual flow out rate, m^3 h^{-1}; and specific energy, kW h kg^{-1}.

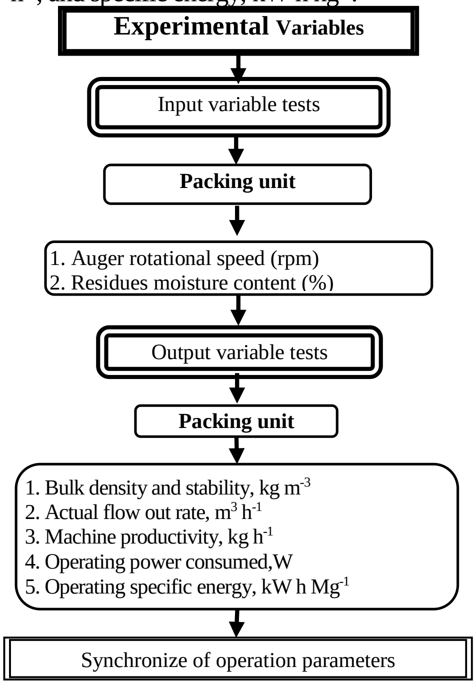


Fig. 4. The layout of the study experiments

Moisture content is identified using the oven-drying method (Briassoulis *et al.*, 2010). The samples were dried at 105°C until a constant mass was achieved. The moisture content calculated on a wet basis as follows:

$$\mathbf{RMC} = \frac{(\mathbf{WW - DW})}{\boldsymbol{WW}} \times \mathbf{100} \qquad (1)$$

Where:

RMC = Residues moisture content (%),

WW = Wet mass of the sample (g), and DW = Dry mass of the sample (g).

Performance of residues material

Bulk density "BD", were determine by were determine by taking three samples of the residue after packing processes, then it weight to determine its mass "SM". The volume after tests was determined "SV" using forming cylinder volume after packing operation with volume of 1991.58 cm^3 for. The following formula used to determine the bulk densities.

$$\boldsymbol{BD} = \frac{\mathbf{SM}}{\mathbf{SV}} \times \boldsymbol{const} = \left(\frac{\boldsymbol{kg}}{\boldsymbol{m^3}}\right) \qquad (2)$$

Performance of packing unit:

Actual flow out rate "FR" of material (through one revolution of the auger) estimated from using principle low of discharge as follows:

$$Q = V_p \times n \times \eta_e \quad (3)$$

$$V_p = A_c . P_f$$

$$V_p = L_h . P_f . W_s$$

$$L_h = \sqrt{s^2 + P_f^2}$$

$$W_s = \frac{(D - d_s)}{2}$$

Where:

Q = Actual flow out rate, m^3/min

V_p = Material volume between the strip along one pitch, m^3

n= Revolution number of screw shaft, rpm

η_e= Constant relative to the conveying efficiency

Ac= Helix outer diameter, m **P_f = Pitch length, m**

L_h = Length of helix at outer diameter, m

S = Outer diameter circumference, S=π D, m **W_s= Strip width, m**

D = Outer diameter, m **d_s= Inner diameter,m**

Machine "MP" was measured by determines the tiny bale mass "BM" and its operating time "OT" with five replicates. Then the average of it used to calculate the machine productivity in kg h^{-1}.

$$MP = \frac{BM,kg}{OT,h}, \quad kg\ h^{-1} \quad (4)$$

The consumed power (kW)is calculated from the knowledge of line current strength (I) and potential difference values (V) using the following formula:

$$Total\ \ consumed\ \ power = Load - unload = \frac{\sqrt{3} . V . \eta . Cos\theta}{746} (I_1 - I_2) \quad (4)$$

Where:

$\sqrt{3}$ = Coefficient current three-phase (being equal 1.73).

V = Potential difference (Voltage) being equal to 380 V.

η = Mechanical efficiency assumed (90 %).

Cos Θ = Power factor (being equal to 0.84).

I_1 = Line current strength in amperes (load).

I_2 = Line current strength in amperes (unload).

Operating specific energy "SE" was calculated depending on the machine production per kgh^{-1} as the following formula:

$$SE = \frac{kW}{W} = kW\ h\ Mg^{-1} \quad (6)$$

Where: kW = The consumed power to press bale, kW

W = Machine productivity, Mg h^{-1}.

Experimental design and statistical were using the complete block design in three replicates. Therefore a multiple regression equations were done for the effect of the studied variables of RMC and ARS on the BD, FR, and SE. The excel program 2017 used to obtain the best fit equations and the coefficient of determination values.

RESULTS AND DISCUSSION

Bale bulk density, kg.m^{-3}

Figure (5) shows the effect of the (ARS) on the bale bulk density (BD) at different (RMC) and at four different time periods "APT" with a time interval difference of 24 hours.The results from the figure explain the shallow differences in bale "BD" regarding to the change in "ARS" and the "APT", but the high effect concerning to the "RMC". Furthermore, the figure clearedthat, at "APT" of zero h, the average values of bale bulk density were recorded 369.69, 356.49 and722.24kg.m^{-3} for "RMC" 14, 16 and 64 % respectively. Meanwhile, at the above "RMC" the average of values were recorded 369.69, 351.94 and 719.65 kg.m^{-3} respectively, at "APT" of 24 h; 369.69, 349.91and 713.84 kg.m^{-3} respectively, at "APT" of 48 h, and 369.69, 349.39and 708.29 kg.m^{-3} respectively, at "APT" of 72 h. However, the results expose that the highest density obtained upward at a moisture content of 64% at "ARS" of 64rpm. The results clear that the shallow differences between the "BD" in tiny bales at "APT" but it stability after 24 h from the forming bale especially at "RMC" of 14%.

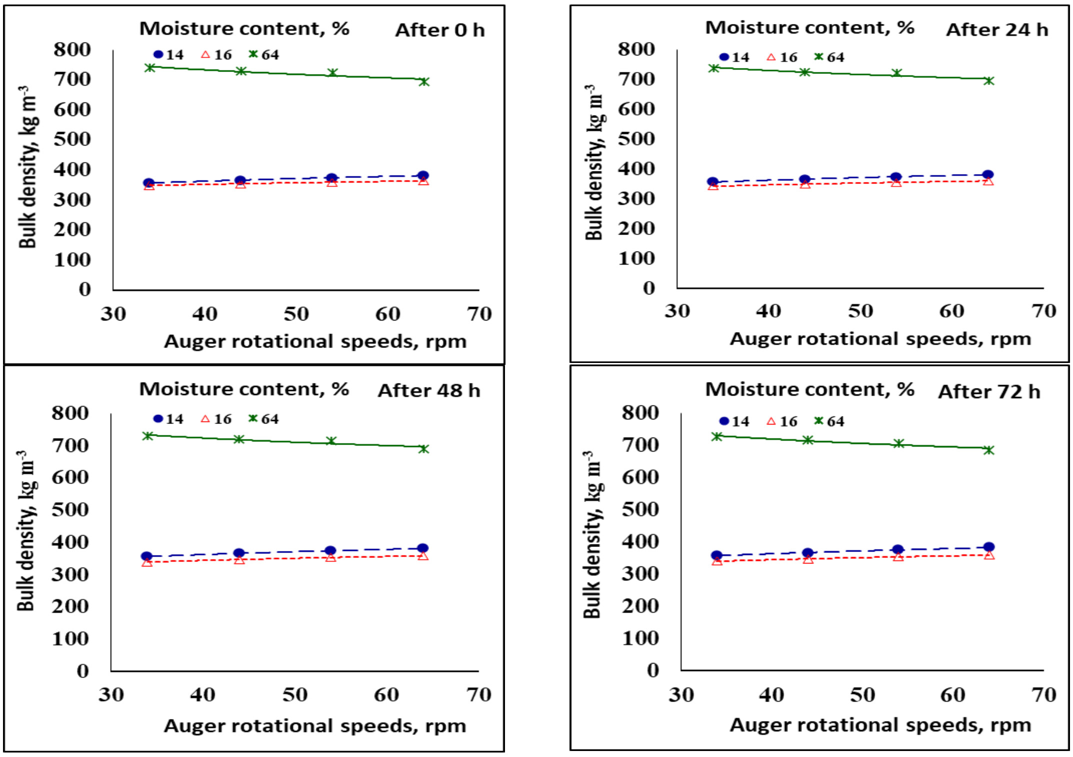


Figure 5. Effect of auger rotational speed on bulk density at different daily after packing and moisture content

The statistically analysis was showed that, the best fitting equations to explain the correlation between the packing bulk density "BD"directly after packing zero hours and after 72 h for each of packing moisture content "RMC" and auger rotational speed "ARS"may be indicated as follows:

BD_{0h}= 7.34 RMC+ 10.72 ARS – 0.1080 (ARS ^2) (R^2 = 0.99)

BD_{72h}= 7.12 RMC+ 10.63 ARS – 0.1063(ARS ^2) (R^2 = 0.99)

The analysis of variance for the data of the "BD" which measured directly after packing (BD_{0h}) and (BD_{72h}) were cleared that the highest effect factor is "RMC" followed by the

"ARS".The analysis indicated a highly significant differences between above treatments with the value of ($R^2 = 0.99$).

Actual flow out rate, $m^3 h^{-1}$

The effect of "ARS" on "FR" at different "RMC, %" is illustrated as shown in Fig. (6). Figure shows that the actual flow out rate has a directly proportional to the "ARS". By focused the data in Fig **(6),** it can explain that, the percentage of actual flow out rate regarding to the increase in "ARS" from 34 to 64 rpm was about 91.16 %. Nevertheless, increase in RMC to 16 % it raised the percentage of actual flow out rate about 60.12%. Moreover, at RMC 64% the percentage of actual flow out rate was 20.12%.Generally, the results show that the highest percentage of actual flow out rate obtained at "RMC" of 14 % and "ARS" of 64 rpm.This may due to the dry material flows faster than the high-moisture material as the high-moisture material has high attached with the inner walls of the barrel and auger.

The statistically analysis showed that, the best fit equation to explain the correlation between the actual flow out rate and each of RMC, and ARS could be indicated as follows:

FR = 2.79 + 0.05 RMC – 0.56 (RMC^0.5) + 0.02 ARS – 0.56 (ARS ^0.33)
($R^2 = 0.8049$)

The analysis of variance for the data of the actual flow out rate clears that the high effect factor is ARS followed by the combination of RMC^0.5+ARS^0.33. The analysis indicated a highly significant differences between the treatments with the value of ($R^2 = 0.8049$).

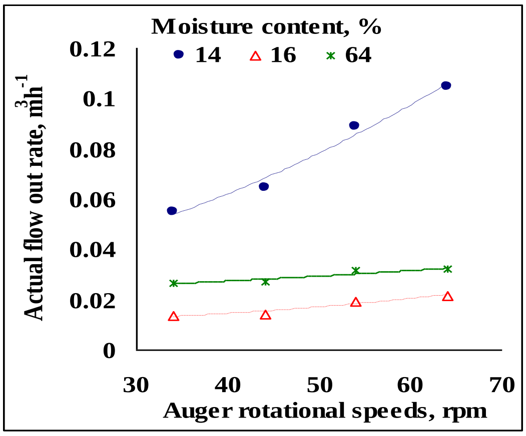


Figure 6. Auger rotational speed via actual flow out rate

Prototype productivity, kgh^{-1}

The pressing and packaging productivity of fallen leaves prototype were evaluated under four points of auger rotational speeds "ARS, rpm" and three levels of input material moisture contents "RMC, 14; 16 and 64%" during moment of actual flow out (time zero from residues packaging in tiny-bale). The prototype productivity "kg/h" is illustrated in Fig. (7), which indicated that the direct relationship between "ARS" and productivity "MP, kgh^{-1}" but the rate of increasing is lower than for "RMC" of 64% that for "RMC" of 16%. And the biggest amount of 'MP' were recorded at largest values of "ARS=64rpm" and lowest material moisture content of "14%".

Operating power consumed "W"

The power consumed in "W" for compaction and packaging of fallen leaves machine were evaluated under four points of auger rotational speeds "ARS, rpm" and three levels of input material moisture contents "RMC, 14; 16 and 64%" as shown in Fig. (8). The consumed power increasing with increasing each of "ARS, rpm" and "RMC, %" but no clear different in operating power between "RMC 14% and 16%. It may be due to low values between them.

Combination results among auger rotational speed "ARS, rpm"; input material moisture content "RMC, %" and each of machine productivity "MP, kg/h" and power consumed" PC, W" as illustrated in Fig. (7) and Fig. (8) identified that; for example at ARS of 50 rpm the machine productivity recorded about 30kg/h with consuming power of 40 W under 14 or 16% RMC. Meanwhile, under the same above ARS "50 rpm" but at RMC of 64% the machine productivity decreased to about 21kg/h and the power consumed increased to about72 W.

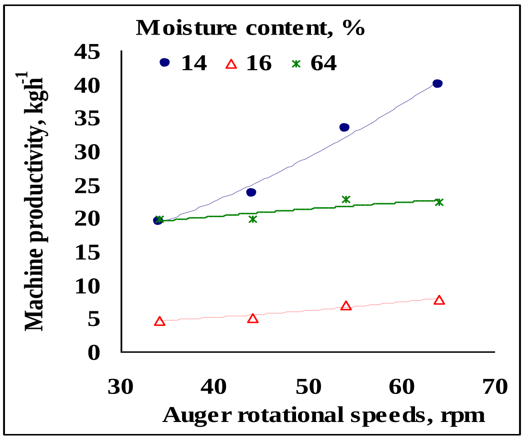


Figure 7. Effect of auger rotational speed on machine productivity

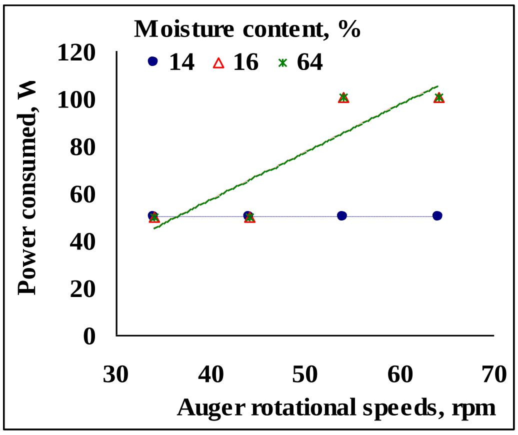


Figure 8. Effect of auger rotational speed on power consumed

Operating specific energy "kW h Mg^{-1}"

The positive relationship between the specific energy of machine operating "kWh/Mg" and auger rotational speed "ARS, rpm" is identified as indicated in Fig.(9), but residues moisture content " RMC, %" hadn't the same trend, these may be due to the natural deviation of residues during actual flow out from auger. From figure, during increasing the auger rotational speed at 34, 44, 54and 64rpm the average value of specific energy consumed were 2.58, 2.133, 1.51and 1.26 kW h Mg^{-1} respectively, at residues moisture content of 14%. While at residues moisture content of 16% the average of specific energy consumed were 10.69, 9.85, 14.61and 12.79 kW h Mg^{-1}, respectively. Finally, at residues moisture content of 64% the average of specific energy consumed were 2.53, 2.55, 4.42and 4.49 kW h Mg^{-1}, respectively. Meanwhile, increasing in RMC of 14-16 and 16- 64 % the average of consumed energy increased from 1.87 to 11.99 then decreased to 3.49 kW h Mg^{-1}at 64rpm auger rotational speeds respectively. The correlation between the specific energy "SE" and each of "RMC" and "ARS" indicated as follows:

SE = -460.35 -7.94 "RMC"+ 93.46 (RMC^0.5) – 2.26 "ARS" + 93.46 (ARS ^0.33) ($R^2 = 0.79$)

The analysis of variance for the data of the specific energy "SE" clear that a highly significant differences between the treatments with the value of ($R^2 = 0.7919$).

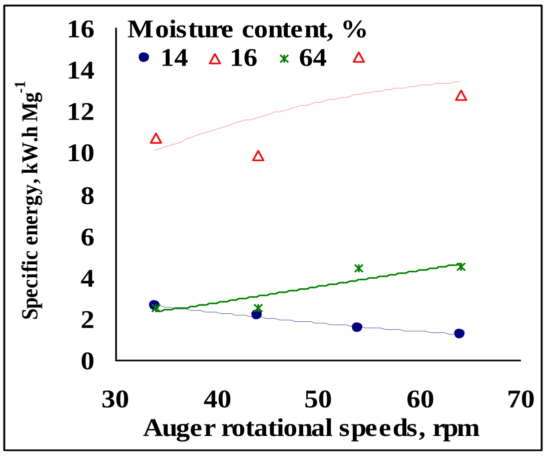


Figure 9. Effect of auger rotational speed on specific energy consumed

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معايير الحكم علي كبس بقايا الحدائق وتعبئتها

زكريا إبراهيم إسماعيل[1]، ناهد خيرى إسماعيل[2]، زينب صبرى حمزة[1] و محمد إبراهيم على غازى[1]

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إن محاوله كبس وتعبئه مخلفات الحدائق في صوره بالات صغيره من المحاولات المقترحة لتقليل حجم البقايا النباتية وتحسين تداولها. ولتحقيق هذا الهدف تم تركيب وإختبار نموذج اولي جديد قادر على ضغط بقايا الحدائق وتشكيلها في شكل بالة صغيرة. ويتكون النموذج من خزان يحتوى على البقايا النباتية ويتم سحبها بواسطة بريمة أفقية من النوع الضاغط تنقل البقايا النباتية بعد ضغطها جزئياُ إلى إسطوانة تشكيل، حيث تبطن الإسطوانة من الداخل بغلاف بلاستيك مرن يعبأ بالبقايا النباتية وعند إمتلاؤه يتم إستبداله بآخر. وللحكم على معايير تقييم البالة الناتجة تمت الإجراءات التجريبية في المختبر لتحديد المعاملات التي تؤثر على إنتاجية وحدة النقل والتعبئة تحت تأثير سرعات مختلفة للبريمة 34 ؛ 44 ؛ 54 و 64 لفة/ د ومحتويات رطوبة للمخلفات في حدود 14 ؛ 16 و 64٪. وذلك بإختبار البالات الناتجة من حيث؛ الكثافة الظاهرية كجم /م^3، معدل التدفق الفعلي م^3.ساعة$^{-1}$، إنتاجية الآلة كجم . ساعة $^{-1}$، القدرة المستهلكة واط . ساعة $^{-1}$، ومتطلبات الطاقة النوعية كيلوواط . ساعة ميجاجرام$^{-1}$. واوضحت النتائج الي ان اعلي كثافة تم الحصول عليها عند مستوي رطوبة 64% وسرعة دوران بريمة 64 لفة/د بينما كانت اعلي انتاجية للآلة عند سرعة دوران 64 لفة/د وأقل محتوي رطوبي للمخلف 14 %.