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Manufacturing and Performance Evaluation of Aloe Vera Gel Extraction Machine

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ABSTRACT

The present research aims to mechanically separate the gel from Aloe vera plants. Theoretical analysis was conducted to design a simple gel-extracting machine from local material taking into consideration its effectiveness. The machine performance was evaluated as a function of change in leaf thickness (less than 15, between 15 to 20, more than 20mm) and extracting roller rotational speeds (30, 60, 90 and 120 rpm) and evaluated in terms of machine output, gel recovery, residual gel, expulsion efficiency, specific energy requirements and cost. The designed machine is fabricated with an extraction roller diameter of 150 mm and a 35 mm roller shaft diameter. The optimum machine performance is 105.4 kg/h machine productivity, 56.9% gel recovery, 95.1% expulsion efficiency and 5.5% residual gel with minimum energy requirements of 0.0057 kW.h/kg and 0.0160 Us$/kg production cost obtained at a 60rpm (0.11 m/s) roller speed and leaf thickness ranges from 20 to 25mm.

***Keywords**:* Aloe vera, Gel extracting machine, Gel recovery, Expulsion efficiency, Energy requirements, Production cost

INTRODUCTION

Aloe vera (*Aloe barbadensis* Miller) is a Liliaceae annual plant with rosette-like turgid green leaves. More recent studies and clinical trials have shown that this impressive plant has many more benefits, including boosting immunity, regulating blood sugar, and delivering pain relief. Most of the gel available in the market is named fillet gel. (Lawless and Allen, 2000) noted that Aloe vera has two primary fluid sources, yellow latex (exudate) and transparent gel (mucus). Aloin is the yielding yellow juice of aloe; it is a part of a complex of anthraquinones. The mucilage jelly derived from plant parenchymal cells is Aloe vera gel. Regarding gel extraction, mechanical extraction is widely used nowadays instead of the manual method to reduce labor hours and costs.(Huang, 2000) developed equipment that removes only cuticles from the leaves and brings out a complete gel bar from the Aloe by their various shapes. (O'Brien, 2006) stated that mechanical filleting was the most commonly used method in the industry for gel extraction from the leaves.(Chandegara, 2012) concluded that maximum gel recovery rate, minimum residual gel percentage, highest expulsion efficiency and maximum output capacity; expulsion of leaves should be carried out at 75rpm drum speed and 25-30mm thickness.(Vikaspedia, 2014) developed a gel extracting machine consisting of three pairs of rolls. The gap between the front pair is larger than the gap of the back pair. The front pair only compresses the leaves, while the back pair helps to discharge.(Chandegara and Varshney, 2014) designed and made a leaf splitter for the gel expulsion machine. The splitting unit consisted of a grip roller, a reciprocating knife, a rotating disk and an eccentric drive. It has been found that for maximum gel recovery, minimum residual gel content, maximum expulsion and output efficiency, the leaves should be split in a splitter and the gel discharging should be done at 75rpm roller speed for 25-30mm leaf thickness.(Gajbhiye et al., 2017) designed a gel separation machine that includes an automatically adjusted gripping roller, a mouthpiece or front edge cutter, a scraper and a drive unit. The picking roller is equipped with inclined trapezoidal teeth to increase the friction between the leaf and roller. It was concluded that for a maximum recovery rate of coarse gel, the minimum residual gel percentage and the maximum discharge efficiency, leaves should be fed at 75 rpm for leaves greater than 20mm thick.(Nagaratna, C. T et al., 2017) evaluated the aloe leaf slicer performance at three belt conveyor speeds and three-knife counts. It is found that 0.251m/s speed is the best condition for the belt conveyor with 8 knives. The time required to cut Aloe vera into equal lengths with a machine was 24 times less than the manual process. The slicing efficiency is about 90.46%, and the effective capacity is 648.21kg/h.(S. R. Karimi Akandi et al., 2017) evaluated the compression and shear characteristics of (*Aloe vera* L.) leaves for gel extraction for design processing equipment and improving gel production with product quality. The best load combination for extracting gel from leaves is 20°C temperature, 14cm load head diameter and 100mm/min load speed.(Dinesha et al., 2019) used a gel extractor to extract the gel from Aloe leaves. When 0.153m/s roller speed and 5 mm roller gap are kept, maximum gel extraction efficiency is 98.06%, minimum gel extraction loss is 1.58%, the maximum gel recovery rate is 43.57% and capacity is 158.06kg/h. The cost of extracting gel from extracting machine was compared with manual extraction which, manual and machine cost was estimated to be 20.67 R.s (Rupees)per kg with a benefit ratio of 2.42:1 and 13.36 R.s per kg with a benefit of 3.74:1, respectively.

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Therefore, the present work aims to mechanically separate the gel from aloe vera plants through a fabricated gel extraction machine and evaluate its performance. To achieve the ultimate goal, the following criteria were taken into consideration:

Carry out design theoretical analysis to estimate the diameters of both extraction roller and the extracting shaft of the fabricated machine.

Optimize some operating parameters affecting the extraction machine performance.

Evaluate the fabricated extraction machine from the economic point of view.

MATERIALS AND METHODS

Experiments were conducted at a private local workshop, Zagazig, Sharqia Governorate, Egypt.

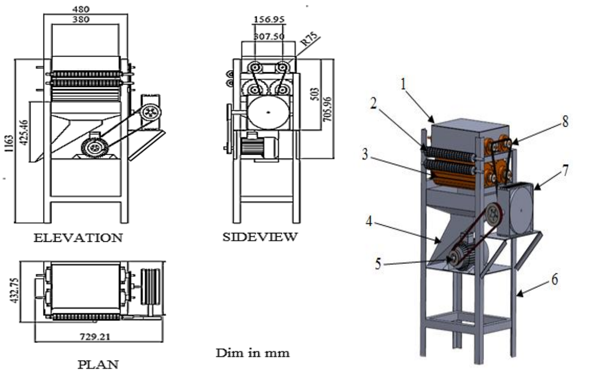
1. Experimental setup

Aloe vera

The used fleshy leaves of aloe vera were collected, well-washed and prepared for mechanical extraction. Some properties of leaves were determined as 400mm average leaf length, 70mm width, 20mm thickness, 180g leaf mass and 0.37 poise gel viscosity.

The designed extraction machine

An extraction machine (Fig. 1), suitable for extracting gel from Aloe vera, was designed and fabricated from local material to overcome the high-cost requirements under the use of the imported machines. It consists of the following parts:



1. Top cover	**2. Feeding rollers**
3. Extracting roller	**4. Gel collecting unit**
5. Electric motor	**6. Frame**
7. Speed reducer	**8. Transmission system**

Fig. 1. Aloe vera gel extraction machine

- ***Feeding unit***

Two grip rollers were fed manually by leaves and transmitted to the expulsion unit for extracting and coated by a corrugated Teflon layer to hold the leaf without breaking the rind. The two grip rollers were designed based on leaf specifications, so the diameter of each roller was 10cm with 30cm length while the clearance between the two grip rollers was adjusted to be 25% less than the leaf thickness to ensure that the process of gel expulsion from the aloe vera leaves occurs and that no leaves pass without extraction.

- ***Extraction unit***

Four corrugated rollers made of Artelon material, every group had a pair of rollers, which turned in the opposite direction of each other with 30cm length and 15cm diameter according to the length of aloe vera leaf and coating layer. Through the extraction, the gel fell into the gel container, while the rinds fell behind the machine to the rind collection container. The power is transmitted to the extracting rollers by chains and sprockets. A scraper was installed below the rear rollers to get rid of all remaining rinds through rollers rotation.

- ***Gel collection unit***

It was mounted below the expulsion rollers with 40×30cm dimension and inclined for easy flow of gel to the container pan.

- ***Power source***

The gel extraction machine was powered by 1.5hp (1.1kW) electric motor, this power is transmitted to every part of the machine by the transmission system.

- ***Transmission system***

The transmission system consisted of chains and sprockets, pulleys and belts. The power is transmitted from the motor shaft to the speed reducer by pulley and belt. Chain and sprockets were employed for giving the opposite rotations to the expulsion corrugated rollers. Pulley and belt were used between grip and expulsion rollers.

- ***Frame***

The machine frame was installed from local steel at which all the previously mentioned parts were fixed.

2. Theoretical analysis

Small workshops and manufacturers produce extraction machines without any scientific guidance. For this reason, such care had to be taken to apply a scientific basis during constructing, developing and operation. During the machine construction, it is important to design and adjust its main parts to achieve maximum working efficiency.

- ***Extracting roller diameter***

As shown in (Fig. 2-a), for the leaf piece to enter the throat of the roll, the friction force component must be equal to or greater than the horizontal component of the normal force.

$$F / P_r \geq \sin\alpha / \cos\alpha \geq \tan\alpha \quad (1)$$

$$F = \mu . P_r \quad (2)$$

If tanα > μ, the work-piece cannot be drawn. If μ = 0, rolling cannot occur.

In flat rolling, the work is squeezed between two rolls so that its thickness is reduced by an amount called draft (d):

$$d = t_i - t_f \quad (3)$$

where: t_i: Starting thickness and t_f : Final thickness

A large diameter roll will permit a thicker slab to enter the rolls than a small diameter roll.

$$L_P^2 = 2Ra - a^2 \quad (4)$$

As a is much smaller than R, a^2 can be ignored,

$$L_P \approx \sqrt{2Ra} \approx \sqrt{R\Delta h} \quad (5)$$

$$\Delta h = h_i - h_f = 2a \quad (6)$$

$$\mu = \tan\alpha = (L_P / R) - (\Delta h / 2) \approx (\sqrt{R\Delta h} / R) - (\Delta h / 2) \approx \sqrt{(\Delta h / R)} \quad (7)$$

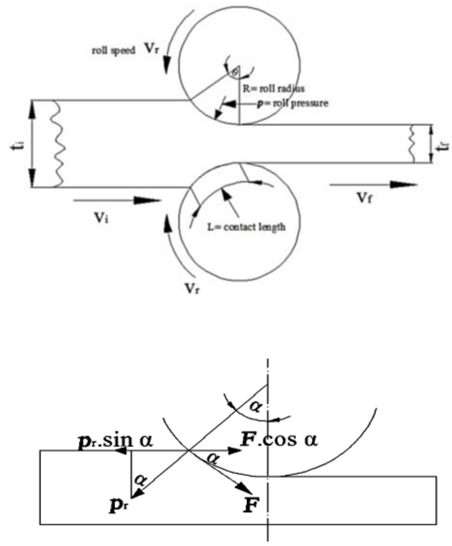
$$\therefore\ d_{max} = \Delta h_{max} = \mu^2 R \quad (8)$$

For maximum gel extraction percentage, d_{max} value is greater than possible when h_f value is smaller or equal to the leaf thickness, which is about 1.92 mm according to the physical properties of aloe vera leaf. The friction coefficient is 0.160, so the roller radius is 75 mm.

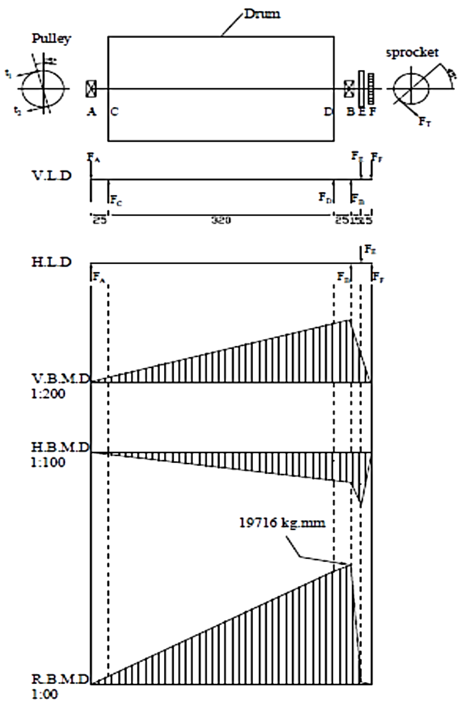
Based on the above analysis, the extracting roller designed with a diameter of 150 mm, is compatible with (Gajbhiye et al., 2017). The roller length was based on maximum leaf width, it was taken as 300mm to prevent blocking.

- **Extracting roller shaft**

The roller shaft is supported by two bearings at A and B. V-shape belt is fixed on the pulley in the shaft to transport load (F_E). An endless chain has engaged the sprocket teeth at the end of the same shaft to transport load (F_F). Added to that the leaf compressive forces are distributed along two rollers acting at points C and D vertically (F_C and F_D).



R: Roller radius, P: Roll pressure,
L: Contact length,
α : Contact angle, v_r : Roll speed,
t_i:Initial plate thickness, t_f : Final plate thickness,
v_i: Plate entry speed, v_f: Plate exit speed



a: Force analysis of extracting roller **b: Bending moment diagram of the extractor shaft**

Fig. 2. Theoretical design of extracting unit

Shafts stressed in torsion and bending is calculated on the combined stress. The roller shaft diameter can be calculated according to the theory of maximum shear stress (τ_{max} = 550 kg/cm^2) as follows (Khurmi and Gupta, 2005):

$$\tau_{max} = (16/\pi d^2)\sqrt{k_m^{\,2} M^2 + k_t^{\,2} T^2} \text{ ………………………(9)}$$

where: σ_b: Bending stress (N/cm^2), τ_{tor}: Torsion stress (N/cm^2), M: Maximum bending moment (N.cm), T: Maximum torque (N.cm), d: Shaft Diameter (cm), K_m: Shock factor for bending (K_m = 2.0), K_t: Shock factor for torsion (K_t = 1.8).

To determine both M and T, the forces F_C, F_D, F_E and F_F acting on the shaft must be calculated.

Pulley force at E (F_E):

Force F_E represents tension forces on the pulley which have two components acting in vertical and horizontal directions, added to the pulley weight as:

$$F_1 = t_1 + t_2 + W \text{ ……………………………………(10)}$$

where: t_1: Maximum tension, t_2: Minimum tension, W: Pulley mass.

$$T = (t_1 - t_2) \times r_1 \text{ ………………………………(11)}$$

$$2.3log(t_1/t_2) = \mu.\theta \text{ ………………………………(12)}$$

$$\theta = (180 - 2\alpha) \times (\pi / 180) \text{ ………………(13)}$$

$$sin\alpha = (r_1 - r_2)/x \text{ ………………………………(14)}$$

where: t_1 and t_2 : Tensions in the tight side and slack side of the belt, respectively. T: Torque, μ: Friction Coefficient (0.3 for rubber belts), θ : Contact angle (2.94), r_1: Radius of a larger pulley (30 mm), r_2: Radius of a smaller pulley (15mm), x: Distance (15mm).

$$t_1 = 2.5t_2 \quad \therefore t_1 = 597.5kg \quad \& \quad t_2 = 239kg$$

$$\text{Vertical force } (F_{EV}) = F\sin\theta + W = 217.25kg$$

$$\text{Horizontal force } (F_{EH}) = F\cos\theta = 808kg$$

Sprocket force at F (F_F):

The tangential force acting on the chain sprocket, which has two components acting in vertical and horizontal directions (F_{FV} and F_{FH}), was determined according:

$$F_T = (P \times K_c)/V \text{ ………………..…(15)}$$

where: P: Transmitted power, V: Velocity, K_c: Operating conditions factor (1.5)

$$\text{Vertical force } (F_{F_V}) = F\cos\theta + W = 568.73kg$$

$$\text{Horizontal force } (F_{FH}) = F\sin\theta = 568.23kg$$

Compressive forces at C and D (F_C and F_D):

The leaf compressive force is about 34kg according to the compression test performed by (Chandegara and Varshney, 2014) and distributed along two rollers, so the forces act at points C and D vertically (F_{CV} and F_{DV}).

F_{DV} = 8.5 - 3.5 = 5kg **F_{CV} = 8.5 - 3.5 = 5kg**

By using the loading diagram (Fig. 2-b), the reactions (R_A & R_B):

Vertical direction: R_A= - 59.92kg R_B = 835.11kg
Horizontal direction: R_A= 13.30kg R_B = 226.50kg

From the bending moment diagram, the maximum moment (M_B = 19716 kg.mm).

The maximum torque can be calculated from transmitted power (1.5hp) and rotational speed (100 rpm) using the following equation (Khurmi and Gupta, 2005):

$$Power = 2\pi\, N\, T\, /\, C \text{ ……………………………(16)}$$

T = 10748.4 kg.mm

By applying the maximum shear stress theory, the roller shaft is designed at a 35 mm diameter.

3. Experimental procedure

Experimental Conditions

From preliminary experiments at 30rpm roller speed with a leaf thickness of less than 15mm, 10mm clearance between the first rollers and 5mm between the second rollers gave the highest gel recovery (52.4%) with the least residual gel percentage (4.4%). The front rollers were adjusted to be with high clearance than the rear rollers. They took the leaves from the feeding unit and pressed them lightly and then, pushed them to the rear rollers that had a great effect of complete compression as a pressing roller to ensure complete gel disposal. This is in agreement with (Vikaspedia, 2014) and (Dinesha et al., 2019).

The extraction machine performance was experimentally done under the following parameters:

- Three thicknesses of leaves (less than 15 mm, between 15 to 20 mm and more than 20 mm)
- Four rotational speeds of rear roller (30, 60, 90 and 120 rpm), corresponded to 0.05, 0.11, 0.16 and 0.22 m/s, respectively.

Measurements

Leaves were fed into feeding grip rollers and then passed through the extraction chamber and the machine was allowed to operate until the material was completely fed and extracted. The gel was collected in a separate tank through the extraction process, while the rinds came out from the machine back.

The following indicators were taken into consideration through performance evaluation:

- ***Machine productivity***

The extraction machine productivity (M_p, kg/h) was determined by:

$$M_P = W_t/T \qquad (17)$$

where: W_t: Total mass of feeding leaves and T: Time required to expulse gel.

- ***Gel recovery***

The gel recovery (Gr, %) was calculated as:

$$Gr = (W_g/W_t) \times 100 \qquad (18)$$

where: W_g: Mass of the gel expulsed from the leaf.

- ***Residual gel percentage***

The residual gel percentage (R_P, %) was determined using the following equation:

$$R_p = [(W_{ag} - W_{tg})/W_t] \times 100 \qquad (19)$$

Where: W_{ag}: The mass of the gel obtained by machine and W_{tg}: The maximum mass of the gel can be obtained manually

- ***Expulsion efficiency***

Gel expulsion efficiency (η_e, %) was calculated as the ratio of actual to theoretical gel recovery:

$$\eta_e = [(W_{ag}/W_t)/(W_{tg}/W_t)] \times 100 \qquad (20)$$

where: W_{ag}: Mass of the gel obtained by machine and W_{tg}: Maximum mass of the gel can be obtained manually.

- ***Specific energy requirements***

Specific energy requirements (kW.h/kg) can be calculated by dividing the required power by machine productivity.

The required power (P, kW) was estimated according to the following equation:

$$P = (\sqrt{3}\ \cos\varphi \times I \times V)/1000 \qquad (21)$$

where: I: Current intensity, V: Voltage (380 V) and cos φ is 0.7.

- ***Production cost***

The machine's hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While production cost (P.C, $/kg) was calculated by dividing the machine's hourly cost ($/h) by productivity (kg/h).

RESULTS AND DISCUSSION

Results will be discussed under the following heads:

1. Machine productivity

The productivity was increased by 15.41, 12.62 and 14.97% at leaf thickness of less than 15 mm, from 15 to 20mm, and more than 20 mm, respectively as represented in Fig. 3. It was clear that the machine productivity increased with the increase in roller speed because of the faster movement of leaves into gel extractor, resulting in less consumed time, therefore machine productivity was increased. These results are identical to those (Dinesha et al., 2019). At 120rpm rotational speed, the productivity values were 104.1, 113.3, and 109.8kg/h by the use of leaves with thicknesses less than 15 mm, 15 to 20mm, and more than 20mm, respectively. Increasing the leaf thickness by more than 20mm, tended to the more required time for gel extracting and subsequently, the output machine productivity was decreased. These results are compatible with those (Chandegara, 2012).

2. Gel recovery

The highest gel recovery rate was 61.7% at 60rpm rotation speed with leaf thickness greater than 20mm as represented in Fig. 4. It was observed that as the speed increased from 30 to 60rpm, the gel recovery rate increased. However, if the roller speed was further increased above 60rpm, the gel recovery rate was decreased. The decrease in the gel recovery rate at higher speeds may be back to the shorter extraction time, which leads to an increase in residual gel amount in the leaf exudate. Increasing leaf thickness from less than 15mm to more than 20mm can improve the gel recovery rate. At 60rpm roller speed, the gel recovery rates were 52.4, 65.9, and 61.7%, respectively in the order of less than 15mm, from 15 to 20mm, and greater than 20mm. These results are compatible with those (Chandegara, 2012) and (Gajbhiye et al., 2017).

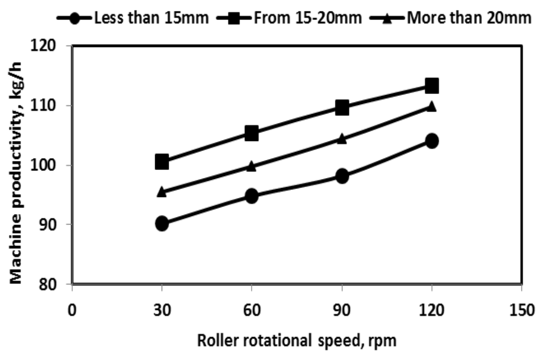


Fig. 3. Aloe vera machine productivity

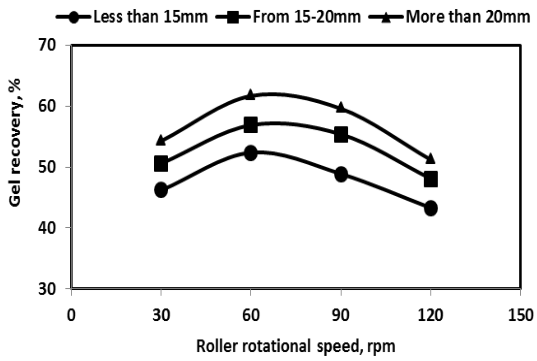


Fig. 4. Gel recovery under different roller speeds with leaf thickness

3. Residual gel percentage

As shown in Fig. 5, when the leaf thickness was greater than 20mm, the maximum residual gel percentage at 120rpm was 11.1%, these results in a higher percentage of residual gel because the leaves contained more pulp than leaves with a smaller thickness. The residual gel decreased with increasing the roller rotational speed from 30 to 60rpm, and then increased by a further increase in roller speed from 60 to 120rpm. Leaves got less time at higher speeds, resulting in higher residual gel in the leaf exudate. Based on data, 60 rpm roller speed with leaves less than 15mm, the residual gel was lower. These results are consistent with (Chandegara, 2012).

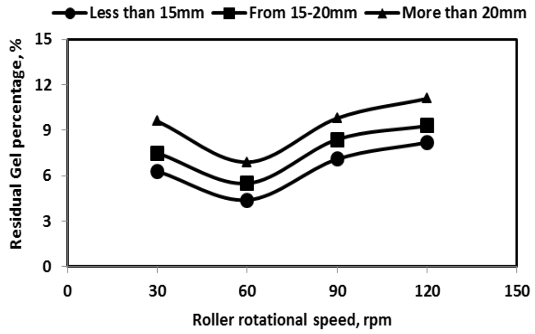


Fig. 5. Residual gel percentages under different leaf thicknesses

4. Gel expulsion efficiency

A leaf thickness of more than 20mm has the highest gel discharge efficiency (96.8%) at 60rpm, while leaves with a thickness of less than 15 mm have the lowest gel discharge efficiency of 81% at 120 rpm as explained in Fig. 6. This may be because since the blades require less processing time when extracting at higher speeds higher than 60rpm, which results in a higher residual gel content and therefore reduced discharge. The expulsion efficiency was decreased at a lower speed because since the leaf was split having corrugation made by a corrugated expulsion roller, resulting in low expulsion efficiency (Chandegara, 2012) and (Gajbhiye et al., 2017). The decrease in gel discharge efficiency may be due to the higher pulp content in the leaf, which produced a higher residual gel in the leaf exudate. These results are consistent with (Chandegara and Varshney, 2014). Considering these two factors comprehensively, it can be concluded that the gel discharge of aloe leaves should be performed at a 60 rpm speed and the leaf thickness should be in the range of 15 to 20mm to improve the gel discharge efficiency.

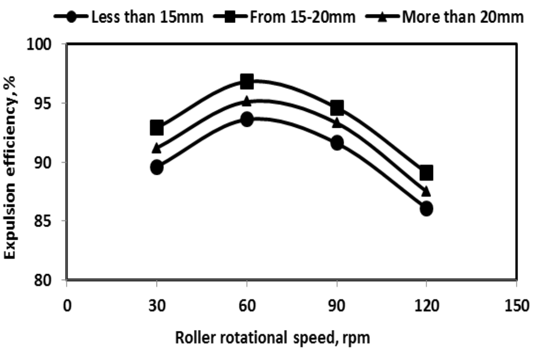


Fig. 6. Effect of roller speeds and leaf thicknesses on expulsion efficiency

5. Specific energy requirements

The specific energy was decreased by increasing the rotational speed up to 60 rpm and then increased up to 120rpm as illustrated in Fig. 7. The increase in the specific energy was due to the increase in the required power by increasing the roller speed from 60 to120rpm. The lowest energy was obtained at 60rpm roller speed. This is because the increased rate of machine productivity was higher than the required power. The lowest specific energy was obtained by leaf thickness ranging from 15 to 20mm, this was due to the increase in machine productivity.

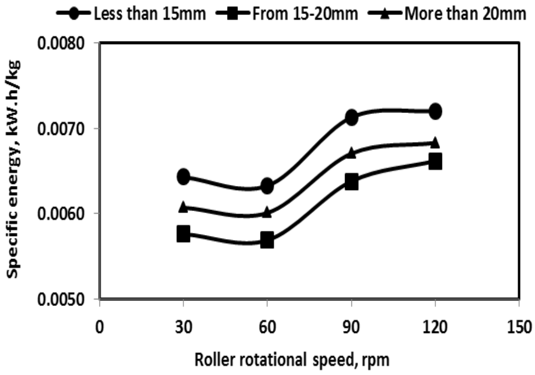


Fig. 7. Energy requirements under variations of roller speeds and leaf thicknesses

6. Cost analysis

A complete cost analysis was made at different operating conditions and related to machine productivity as illustrated in Tables 1 and 2. The lowest production cost was obtained at 60rpm roller rotational speed with leaf thickness ranging from 15 to 20mm. The production cost was decreased by increasing the roller rotational speed up to 60 rpm and then, increased, this was due to a higher rate of machine productivity by increasing roller speeds.

The values were 0.0162, 0.0160, 0.0161 and 0.0167 US $/kg for leaf thickness from 15 to 20mm under 30, 60, 90 and 120rpm roller speeds, respectively. Increasing the machine productivity by increasing the leaf thickness from 15 to 20mm, reducing the production cost. These results were compatible with (Chandegara, 2012).

Table 1. Cost analysis of the manufactured extraction machine

Fixed cost (US $)	
Extraction machine	953.56
Leaf washing	3.18
Depreciation (10 %)	95.36
Interest (12%)	114.43
Repair and maintenance (1%)	9.54
Fixed cost per day (assume 340 operating day/year)	3.47US $/day
Variable cost (US $)	
Labor charges (one person for operating)	9.54
Electricity cost	0.51
Variable cost	10.05US $/day
Total cost	13.52US $/day
Total cost (assume 8h operating hours) at roller speed of 60rpm	1.69US $/h

Table 2. The production cost of extracting Aloe vera gel

Roller speed, rpm	Extraction cost, US $/kg		
	Leaf thickness, mm		
	Less than 15	From 15 to 20	More than 20
30	0.0181	0.0162	0.0171
60	0.0178	0.0160	0.0169
90	0.0180	0.0161	0.0170
120	0.0182	0.0167	0.0172

CONCLUSION

To obtain the highest performance of the designed gel extraction machine, it is concluded that:

Adjust the front extraction roller's clearance to be 10mm more than the crushing rear rollers (5 mm), to obtain 52.4% gel recovery with 4.4% residual gel percentage.

The machine is preferred to be designed with an extraction roller diameter of 150 mm and roller shaft diameter of 35mm to be agreed with the theoretical analysis.

Operate the machine at 60 rpm (0.11 m/s) extraction roller speed with leaf thickness ranging from 20 to 25mm to achieve optimum machine productivity of 105.4kg/h, 56.9% gel recovery and 95.1% expulsion efficiency and 5.5% residual gel with minimum specific energy requirements of 0.0057kW.h/kg and production cost of 0.0160 Us$/kg.

Competing Interest Statement

The authors declare no conflict of interest.

Funding Statement

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تصنيع وتقييم آداء آلة لاستخلاص جل الصبار

كمال إبراهيم وصفي ، ريهام صبري عطية و علاء عونى

قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق

الملخص

يهدف هذا البحث الى فصل الجل من أوراق نبات الصبار ميكانيكيا. تم إجراء التحليل النظري للوصول إلى الأبعاد الهامة لتصميم آلة محلية الصنع لفصل جل نباتات الصبار. بعد ذلك تم التصنيع وإختبار وتقييم آداء الألة من حيث كلا من إنتاجية الالة، نسبة الجل المستخلصة، نسبة الجل المفقودة، كفاءة عملية الاستخلاص، احتياجات الطاقة اللازمة لعملية الاستخلاص وتكلفة الاستخلاص وذلك تحت تأثير عدة متغيرات وهي 3 قيم مختلفة لسمك ورقة نبات الصبار (أقل من 15، من 15 الى 20 و أكبر من 20 مم) و4 قيم مختلفة للسرعة الدورانية لدرفيل وحدة الاستخلاص(30، 60، 90و120 لفة/دقيقة). من التحليل النظري أوضحت النتائج أن أفضل قطر لدرفيل وحدة الاستخلاص هو 150مم وقطر العمود المثبت عليه 35مم بطول 300مم ومن تجارب اختبار وتقييم أداء الآلة أظهرت النتائج أن أفضل إنتاجية للآلة كانت 105 كجم/س، أفضل نسبة جل مستخلصة كانت 56.9%، أقل نسبة جل مفقودة كانت 5.5%، أعلى كفاءة استخلاص كانت 95.1%، أقل احتياجات للطاقة لعملية الاستخلاص كانت 0.0075كيلووات.ساعة/كجم وأقل تكلفة بلغت 0.016 دولار/كجم وذلك عند متغيرات تشغيل 60 لفة /دقيقة لدرفيل وحدة الاستخلاص وسمك ورقة نبات الصبار يتراوح ما بين 20 و25 مم