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DEVELOPMENT OF AN AUTOMATIC JUICER FOR MINNEOLA FRUITS

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ABSTRACT

The aim of this research is to develop an automatic orange juicer for minneola fruits. This juicer consists of minneola feeding, minneola holding, cutting, and press mechanisms to extract minneola juice. The main results of this study can be summarized in the following points: Increasing feeder speed and angle with horizontal axes increased number of dropped minneola fruits per minutes. The number of dropped minneola-fruits per minute increased by about 27.5 to 56.14 % (from 17 – 28 to 35 – 57 fruit / minute) by increasing minneola feeding-mechanism speed from 7.54 to 22 rpm. There is no effect of the quantity of minneola fruits in hopper on number of dropped fruits per minutes.* The fill rate of grooves of two drums holding mechanism was 100 % at all feeder speeds and angles and drum speed. The extraction ratio of juice of minneola fruits decreased from 49.85 to 49.26 % by increasing press balls and drums holder speed from 13 to 38 rpm. The highest machine-capacity (31.01 kg/min of minneola fruits and 15.28 L/min of juice) was obtained by using drums and balls speed of 38 rpm, and the lowest performance rate (10.61 kg/min of minneola fruits and 5.29 L/min of juice) was obtained by using drums and balls speed of 13 rpm.

INTRODUCTION

Citrus are the major horticultural crops in Egypt. The cultivated area of citrus was 346.24 thousand feddans in 2002. The areas of orange, tangerine and lemon are about 210, 94 and 38 thousand feddans respectively. The total production of citrus in Egypt was about 2.8 million ton in 2002. The productions of orange, tangerine and lemon were about 181, 602 and 334 thousand tons respectively. Egypt citrus exports quantity increased from 195 to 416 thousand tons which gave 53.6 to 99.8 million U. S. $ from 2000 to 2003 (H. R. I., 2004).

Minneola is a citrus fruit that originated in 1931 from cross of Duncan grapefruit and Dancy tangerine by USDA in Florida. The Minneola is large in size. The fruit shape is essentially round, with a pronounced and distinctive neck, which leads to its immediate recognition by consumers. The rind has not only exceptional color, being reddish-orange, but also has a particularly fine, smooth texture. Mature Minneola may feel slightly soft, giving the puffy impression, somewhat over mature and wilted; which is not often the case. The peel is thin in relation to fruit size, and is not difficult to remove since it is only moderately tightly adhering. However, care is needed during peeling to avoid puncturing the extremely delicate segment walls. Minneola have a unique, delicious and distinctive flavor, being rich, tart and aromatic. Minneola fruit has few seeds and low sugar content, which is in favor for diabetic persons (Saunt, 1990).

Advantages of this machine attract attention. It is simple to operate, and fills the air with the fragrant aroma of freshly squeezed oranges. People won't be able to resist it. The closed design of such machines allows for fast, hygienic and convenient juice production. Moreover, anyone can use it with little or no instruction and its cleaning is quick and easy. Unlike electric juicers, no heat is produced in this mechanical juicing process, so naturally occurring food enzymes are preserved. Peel oil is completely separated and does not contaminate the juice.

Wardowski *et al.* (1986) reported that five characteristics are commonly utilized worldwide as indicators of maturity: total soluble solids (TSS), Total acidity (TA), TSS/TA ratio, juice content, and color break. The first four are internal factors, the last is an external one.

Bello *et al.* (1989) found that juice percentages were 48.85 and 43.57 for Clementine and Dancy respectively.

Davies and Albrigo (1994) reported that total soluble solids (TSS), which include carbohydrates, organic acids, proteins, fats, and various minerals, comprise about 10 to 20 % of fresh weight of fruit. Carbohydrates account for 70-80 % of the TSS in the fruit.

Kinawy (1995) found that the average peel thickness, number of segments per fruit, number of seeds per fruit, mass of 100 seeds, and juice percentage were 3.2 mm, 11, 17.9, 12.5 g and 41.5 % respectively for Baladi mandarin; and were 3.9 mm, 10.3, 11, 12.8 g and 34.2 % respectively for Ponkan tangerine.

Yehia (2001) designed, constructed and tested an automatic orange juicer for orange fruits. This machine consists of orange feeding mechanism, orange holding, cutting, and press mechanisms to extract orange juice. For the efficiency in the operation of the machine, it is capable to squeeze the oranges of diameter ranging from 50 to 80 millimeters with the squeezing speed of approx. 39-78 orange/min. The main results in this study were: The range of number of Baladi orange fruits per minute increased from 52-105 to 84-170, from 49-99 to 69-139, and from 27-54 to 47-96 by increasing horizontal feeder-angle from 83.1 to 90 degree by using three orange-grades respectively. The extraction ratio of juice decreased from 48.77 to 48.58, from 46.17 to 46.22, and from 44.93 to 44.82 by increasing press balls and drums holder speed from 13 to 38 rpm when using three grades of Baladi oranges respectively.

The objective of this present research is to develop a suitable juicer for minneola fruits. Some physical and mechanical properties of minneola, as promising fruits, used to help in developing the juicer unit. The physical and mechanical properties are incorporated in the design of the feeding mechanism, chute tube, holding and press mechanisms of the designed automatic-juicer.

MATERIALS AND METHODS

The developed juicer: The developed juicer (Yehia, 2001) was constructed and tested at a private shop in Sharkeia Gov. The view of the automatic juicer is shown in fig. 1 and photographed in fig. 2. The main specifications of this machine are: total height 186 cm, width 68 cm, depth 76 cm, and total mass 112.5 kg. The main press-system parts are as follows:

Feeding mechanism: consists of the following parts:

Fruit hopper: made of stainless steal with a diameter of 47.5 cm, height of 21.5 cm, and has a hole-gate of 11 cm diameter. The capacity of fruit hopper is about 10-15 kg minneola fruits.

Rotating disk: it uses to deliver minneola from hopper to fruit-feed tube. It is made of aluminum with a diameter of 46 cm, 4.3 cm height, and 0.3 cm thickness. Five vanes are bolted on the rotating disk with a height of 1.7 cm beside the center of disk and 1.1 cm in the edge of it.

Fruit-feed tube: made of stainless-steel wire 0.3 cm diameter. The fruit tube has about 11 cm diameter.

Holding mechanism: consists of two aluminum drums of 17 cm diameter and 8.5 cm width which have 3 spherical-grooves with 10.5 cm diameter and 5.25 cm depth. The two drums are surface treated to avoid the reaction with juice. The two wings (retainer vanes) avoiding the two halves of cut minneola to drop from grooves.

Cutting mechanism: consists of a stainless-steel knife with 0.1 cm thickness located on 0.1 cm in the bottom of the centerline of the two drums and between them. The height of the knife can be adjusted by sliding a socket.

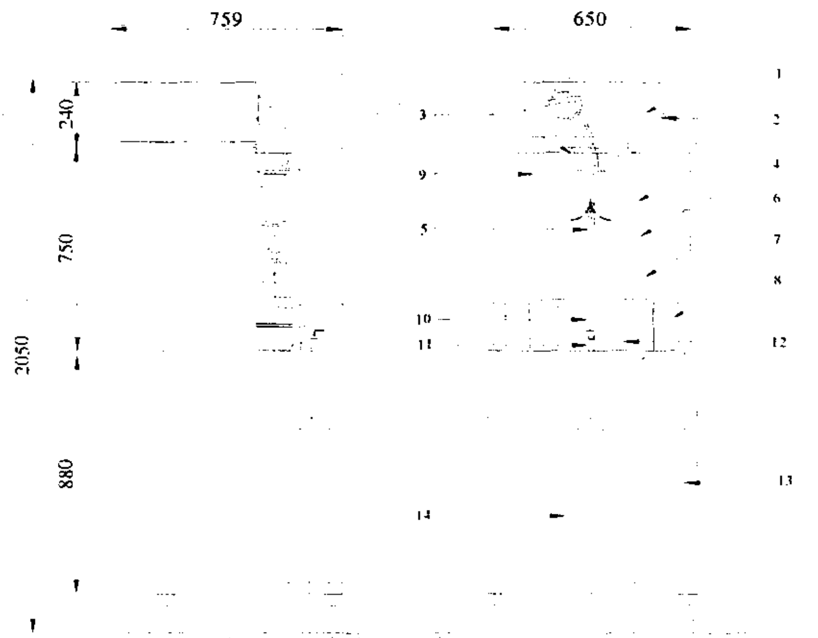

Fig. 1: Sketch of automatic minneola -juice press system.
(1) rotating disk, (2) fruit hopper, (3) fruit tube,
(4) holding mechanism, (5) cutting mechanism, (6) press mechanism,
(7) peel shover, (8) (peel channel, (9)clear front panels,
(10) juice tank, (11) juice valve, (12) juice agitator,
(13) frame, (14) peel bin.

Press mechanism: consists of two treated-aluminum drums with 3 half balls of 9.5 cm diameter and 5.25 cm height. The overlap between half-balls and grooves is 5.75 cm.
Peel shover and channel: minneola-fruit peel shoving unit consists of shover and minneola transporting channel to be discarded into a bin by shoving the minneola peels readily crushed along such discarding channel.

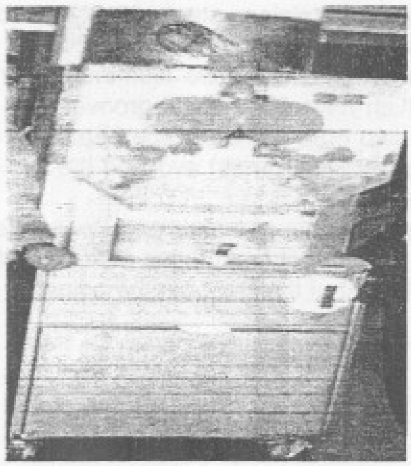

Fig. 2: Photograph of automatic minneola-juicer.

Clear front panels: allows the customers to watch as their cups of juice is being filled. It is made of plastic sheet 3 mm thickness.
The Juice tank: made of plastic sheet of 3 mm thickness, 16 cm height and 12.3 cm width with a valve. The juice tank can hold up to about 7.5 liter.
Electric motor and power transmission: Electric motor of 1 hp (0.675 kW) and 1400 rpm and four gears with 47 teeth rotate the holding and press drums, two bevel gears with 11 and 19 teeth rotate the disk feeder, wheel and belts.

Basic machine operation:

- An minneola enters the machine where it is cut into equal halves.
- The halves are then rotated through the mechanism, which extracts the juice.
- Peels are deposited into bucket intact and the Juice is ready to drink.

The developed Minneola juicer according to physical and mechanical properties:

Fig. 3 shows a schematic diagram of the juicing device. Such device was constructed by Yehia (2001) for orange. Parameters shown on the figure are essentially those to be determined for minneola through this work, for modifying the device to operate efficiently on this fruit.

Associated parameters:

(1) fruit dimensions, (2) bulk density, (3) friction and rolling angles, (4) peel thickness, (5) juice/volume ratio, (6) fruit firmness.

The physical and mechanical properties are incorporated in the design of the feeding mechanism, orange tube, holding mechanism and press mechanism of the designed automatic-juicer as follows:

Design of holding mechanism (Fig. 3):

Groove diameter = Maximum diameter of Minneola fruits = 105 mm.

Groove depth = Maximum diameter of Minneola fruits / 2 = 52.5 mm.

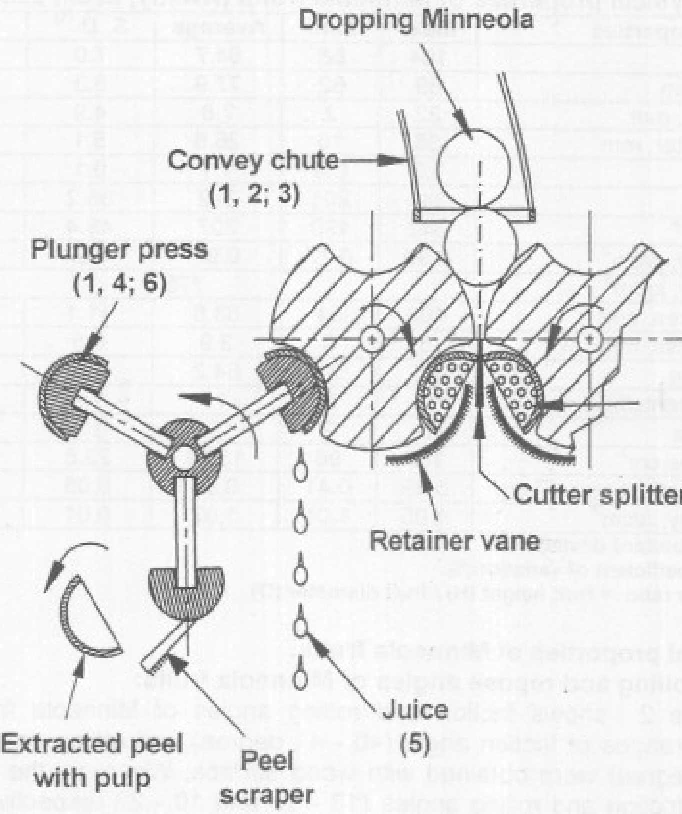

Fig. 3: Schematic of the auto-juicing device, with the number in brackets indicating parameters necessary for design of different parts.

Design of pressing mechanism:

Half ball diameter = Groove diameter – (2 x peel thickness)
= 105 - (2 x 5) = 95 mm

Half ball height = Groove diameter / 2 = 105 / 2 = 52.5 mm

The overlap between half balls and grooves = groove depth + peel thickness = 52.5 + 5 = 57.5 mm

Fruit chute tilt angle = more than maximum friction angle between Minneola fruits and stainless steal surface = more than 15^0.

Physical properties of Minneola fruits.

Table 1 shows dimensions, sphericity, mass, volume, real density, projected area, peel thickness and mass, juice volume, juice volume/fruit mass ratio and juice density of Minneola fruits. These data were measured on 100 fruit sample, according to the standards set in (Mohsenin, 1986).

Table1: Physical properties of Minneola fruits (Awady, *et al.*, 2004).

Physical properties	Max.	Min.	Average	S. D.[1]	C. V.[2]
Height, mm	104	68	84.7	7.0	5.29
Diameter, mm	89	62	77.9	5.3	6.79
Neck height, mm	22	2	7.8	4.9	63.3
Neck diameter, mm	38	15	26.6	5.1	19.3
Sphericity[3]	1.3	0.9	1.1	0.1	6.6
Mass, g	345	201	272	35.2	13
Volume, cm^3	342	120	207	49.4	23.91
Real density, g/cm^3	0.99	0.77	0.96	0.2	34.7
Bulk density, kg/m^3	775				
Projected area, cm^2	108	54	83.8	11.1	13.25
Peel thickness, mm	5	3	3.9	0.5	12.46
Peel mass, g	73	52	64.2	6.5	10.05
No. of segments/fruit	12	9	11	1.0	8.26
No. of seeds	8	2	5	1.9	37.71
Juice volume cm^3	168	96	133.2	23.6	17.26
Juice volume/fruit mass, L/kg	0.59	0.41	0.50	0.05	9.78
Juice density, g/cm^3	1.05	1.01	1.02	0.01	1.17

(1) S. D. is standard deviation.
(2) C. V. is coefficient of variation,%.
(3) Sphericity ratio = fruit height (H) / fruit diameter (D)

Mechanical properties of Minneola fruits.

Friction, rolling and repose angles of Minneola fruits:

Table 2 shows friction and rolling angles of Minneola fruits. The maximum ranges of friction angle (40 - 41 degree) and rolling angle ranges (17 - 30 degree) were obtained with wood surface. Whereas, the minimum ranges of friction and rolling angles (13 - 15 and 10 - 22 respectively) were obtained with aluminium surface.

Table 2: Friction and rolling angles for Minneola fruits with different surface types (Awady *et al.*, 2004).

Surface type	Friction angle, degree			Rolling angle, degree					
				Maximum			Minimum		
	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.
Wood	41	39	40	30	21	25.8	20	17	18.8
Metal	15	14	14.7	22	21	21.7	12	11	11.7
Galv. I.	15	14	14.8	22	21	21.8	12	11	11.8
Alum.	15	13	14.4	22	20	21.4	12	10	11.4
SS	15	14	14.5	22	21	21.5	12	11	11.5

Estimating the costs of using the machines:
Cost of operation was calculated according to the equation given by Awady (1978) as follows:

$$C = p/h\ (1/a + i + t/2 + r) + (Ec * Ep) + m/144,$$

Where: C = hourly cost, p = price of machine, h = yearly working hours, a = life expectancy of the machine, i = interest rate/year, t = taxes, r = overheads and indirect cost ratio , , Ec = Electricity consumption kW.h/h, Ep = Electricity price L.E/Kw.h, "144" are estimated monthly working hours. Notice that all units have to be consistent to result in L.E/h.

Studying factors:
(1) Feeder (rotating disk) speed: Four rotating disk (feeder) speeds of 7.54, 12.76, 17.4 and 22 m/s were tested on number of dropped minneola fruits and fill rate of grooves.
(2) Feeder (rotating disk) angle: Four feeder angles of 0, 2.2, 4.4 and 6.9 degree were tested on number of dropped minneola fruits and fill rate of grooves.
(3) Drums and balls speeds: Four drum and balls speeds of 13, 22, 30 and 38 rpm were tested on fruit damage, extraction ratio and fruit and juice machine-capacity.
(4) Drums and balls speeds: Five spacing between the knife edge and horizontal centerline of to drums holder (0, 1, 2, 3, and 4 cm) were tested on cutting

Measurements:
(1) Minneola feeding-mechanism performance:
(a) Number of dropped Minneola-fruits per minute.
(2) Minneola fruit-holder mechanism performance:
(a) Minneola-fruits damage.
(b) Filling rate of drums-holder grooves.
(3) Cutting mechanism performance:
(a) Cutting efficiency.
(b) Minneola-fruits damage.
(4) Minneola-fruit press mechanism performance:
(a) Extraction ratio of juice.
(5) Machine capacity.

RESULTS AND DISCUSSION

Minneola feeding-mechanism performance:
Number of dropped Minneola-fruits per minute.

Fig. 4 shows the effect of rotating disk (feeder) speed and angle on number of dropped minneola-fruits from hopper to minneola feed-tube. Increasing feeder speed and angle with horizontal axes increased the number of dropped fruits per minutes.

Feeder speed: The number of dropped minneola-fruits per minute increased of about 27.5 to 56.14 % (from 17 – 28 to 35 – 57 fruit / minute) by increasing minneola feeding-mechanism speed from 7.54 to 22 rpm at different feeder-angles.

Increasing feeder speed increased the number of dropped Minneola-fruits per minutes. This may be due to increased speed of the fruits passed on the outlet hole.

Feeder angle with horizontal axes: The number of dropped minneola-fruits per minute decreased by about 56.26 to 34.50 % by increasing minneola feeder angle with horizontal axes from 0 to 6.9 degree at different feeder-speeds. Decreasing feeder angle with horizontal axes increased number of dropped minneola-fruits per minutes this is due to decreasing the rolling speed that is in the opposite direction of minneola speed passed on the feeding hole.

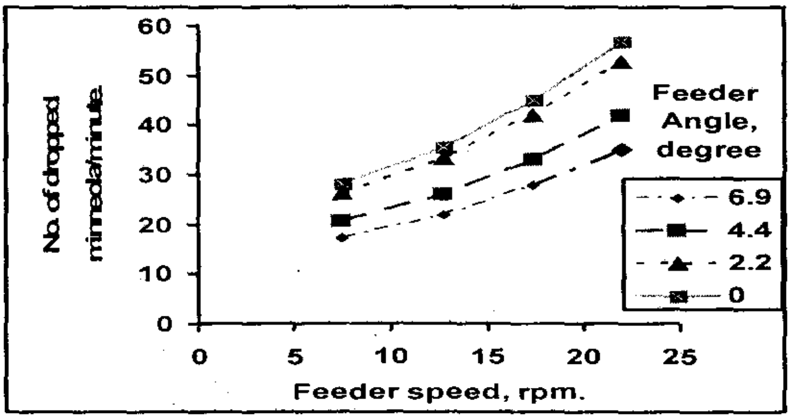

Fig. 4: Effect of rotating disk (feeder) speed and angle on number of dropped minneola fruits from hopper to fruit feed-tube..

Minneola quantity inside hopper: There is no effect of the quantity of Minneola fruits in fruits hopper on the number of dropped fruits per minutes. This may be due to that minneola fruits was dropped by the impact force of rotating-disc vanes or the fruits impact in contacting the dropped minneola fruit from back.

Minneola fruit-holder mechanism performance:

Minneola-fruits damage.

The minneola-fruit damages decreased from about 15 to 3, zero and zero % by decreasing the gap between the bottom of minneola-fruit tubes and the top of drums holder from 4 to 3, 2, and 1 cm respectively, at feeder speed of 22 rpm. The minneola damage is due to clogging the fruit between the two-drum holders in the smooth parts.

Filling rate of drums-holder grooves.

The minneola fruit filling-rates of grooves of two-drums holding mechanism were 100 by using all gaps among the bottom of minneola-fruits tube and the top of drums holder (1, 2, 3, and 4 cm), feeder speed of 22 rpm and drum speed of 38 rpm and feeder angle of 4.4 degree.

Cutting mechanism performance:

Cutting efficiency.

The cutting efficiency was 100 % at all drum-speeds, the spacing between the knife edge and horizontal centerline of the drums holder (0, 1, 2, 3, and 4 cm).

Minneola-fruits damage.

The minneola-fruit damages were 0, 0, 0, and 5.2 % at drum speed of 13 rpm and spacing between the knife edge and horizontal centerline of to drums holder of 0, 1, 2, 3, and 4 cm respectively.

Minneola-fruit press mechanism performance:

Extraction ratio of juice.

Fig. 5 shows the effect of drum holders and press balls speed on extraction ratio and machine productivity of minneola fruits and juice at feeder angle of 4.4 degree, clearance between press balls and groove bottom of 0.5 cm.

The extraction ratio of juice of minneola fruits decreased from 49.85 to 49.26 % by increasing press balls and drums holder speed from 13 to 38 rpm.

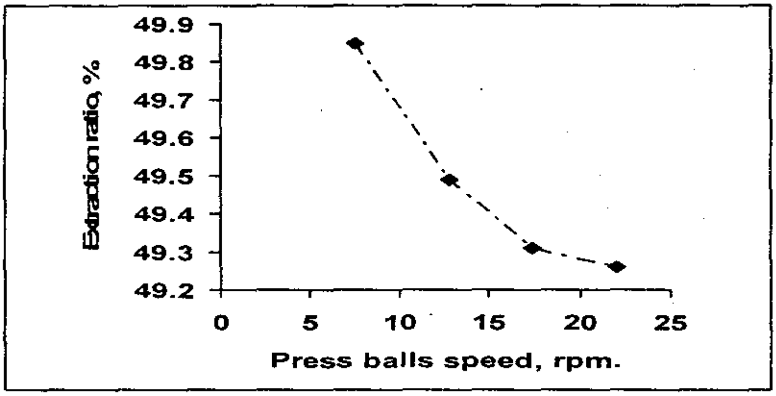

Fig.5: Effect effect of press balls speed on extraction ratio of minneola fruits and juice at feeder angle of 4.4 degree, clearance between press balls and groove bottom of 0.5 cm.

Machine capacity.

Fig. 6 shows the effect of drum holders and press balls speed on machine productivity of minneola fruits and juice at feeder angle of 4.4 degree, clearance between press balls and groove bottom of 0.5 cm.

The highest machine-capacity (31.01 kg/min of minneola fruits and 15.28 L/min of juice) was obtained by using drums and balls speed of 38 rpm, and the lowest performance rate (10.61 kg/min of minneola fruits and 5.29 L/min of juice) was obtained by using drums and balls speed of 13 rpm.

Estimating the costs of using the machines.

Table 3 shows that the operating costs of manual juicer tool, electrical juicer, and designed juicer were 2.22, 2.35 and 3.85 LE/h or 0.18, 0.08, and 0.012 LE/L of juice respectively. Reduced cost of designed juicer is due to the increase in its productivity.

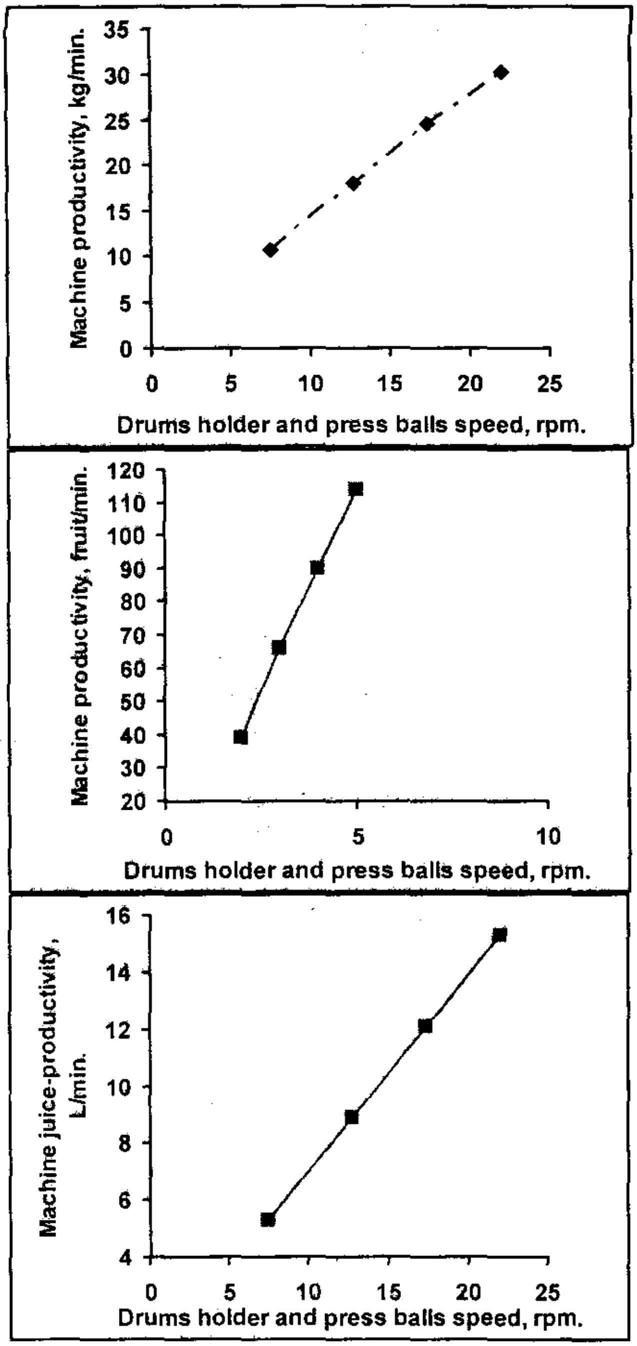

Fig. 6: Effect of drum holders and press balls speed on machine productivity of minneola fruits and juice at feeder angle of 4.4 degree, clearance between press balls and groove bottom of 0.5 cm.

A comparative criterion value is devised by Awady *et al.*, 2000 to indicate economic advantage when using the manual juicer, electrical juicer and designed juicer and watching results through to yield. The criterion value takes into account the value of resulting juice yield minus juice production expenses, with all other economical conditions kept constant for comparison. Meanwhile, juice production expenses include: juice cost (juicer cost + minneola-fruits cost) + juice losses caused by the particular juicer. It is suggested to call this value "Juice Value minus Juicing Expenses, "JVJE".

JVJE = Juice Value – Juicing Expenses
= Juice Value – (juicer cost + fruits cost + juice loss)
Juice Value (LE/h) = juice prod. (L/h) * juice sale value (LE/L)
Juice loss = Juice loss (L/h) * juice price (LE/L)

Table 3 shows that the criterion value "JVJE" has high value (1344.5 LE/h) for the designed automatic juicer than (112 LE/h) for electrical juicer and (46.25 LE/h) for manual juicer indicating the economical advantage of the designed juicer.

Table 3: Cost details of manual tool, electrical and developed juicers.

Items	Juicers		
	Manual tool	Electrical device	Developed machine
Capacity, kg/h	25	60	636.5
Capacity, L/h	12.5	30	317
Operating cost, L.E./h	10	13	54
Juicing losses, L/h	nil	nil	24
Fruit cost, L.E./h	25 x 1.5 = 37.5	60 x 1.5 = 90	636.5 x 1.5 = 955
Juice value, L.E./L	12.5 x 7.5 = 93.75	30 x 7.5 = 225	317 x 7.5 = 2377.5
Losses cost, L.E./h	0	0	24
JVJE, L. E.	46.25	112	1344.5

Conclusion

The main results in this study can be summarized in the following points:

* Increasing feeder speed and angle with horizontal axes increased number of dropped minneola-fruits per minutes. The number of dropped minneola-fruits per minute increased by about 27.5 to 56.14 % (from 17 – 28 to 35 – 57 fruit / minute)by increasing minneola feeding-mechanism speed from 7.54 to 22 rpm.
* The extraction ratio of juice of minneola fruits decreased from 49.85 to 49.26 % by increasing press balls and drums holder speed from 13 to 38 rpm.
* The highest machine-capacity (31.01 kg/min of minneola fruits and 15.28 L/min of juice) was obtained by using drums and balls speed of 38 rpm, and the lowest performance rate (10.61 kg/min of minneola fruits and 5.29 L/min of juice) was obtained by using drums and balls speed of 13 rpm.

* The profit has high value (1344.5 LE/h) for the designed automatic juicer than (112 LE/h) for electrical juicer and (46.25 LE/h) for manual juicer indicating the economical advantage of the designed juicer.

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تطوير عصارة أتوماتيكية لثمار المانيولا

جمال حسن السيد، سمير قرنى حرب،إبراهيم يحي و الأمين محمد عارف
معهد بحوث الهندسة الزراعية

تهدف هذه الدراسة إلى تطوير عصارة أتوماتيكية (Yehia, 2001) لعصر ثمار المانيولا. ويتكون هذا الجهاز من آلية تغذية، آلية مسك، آلية قطع البرتقال، آلية ضغط لاستخلاص العصير. وفكرة عمل هذا الجهاز كالتالى: يتم وضع الثمار فى قادوس فى أعلى الآلة، ثم يتم تغذيته ميكانيكياً إلى درفيلين يقومان بمسك الثمرة ويدوران فى اتجاهين متضادين بنفس السرعة، ثم يتم قطع ثمرة المانيولا إلى نصفين عن طريق سكينة ثابتة موجودة بين الدرفيلن من أسفل، ثم يتم دوران نصفى ثمرة المانيولا ويتم استخلاص العصير منهما عن طريق آلية الضغط، ثم يتم كشط القشر ونزوله لسلة داخل الآلة

و تم الحصول على النتائج التالية:

(١) **معدل التلقيم:** وجد أنه زاد عدد ثمار المانيولا الساقطة فى الدقيقة من ١٧ – ٢٨ إلى 35-57 عندما زادت سرعة جهاز التغذية من ٧,٥٤ إلى ٢٢ لفة/د. كما وجد أن كمية ثمار المانيولا الموجودة فى خزان الثمار لا تؤثر فى تغير عدد ثمار المانيولا الساقطة منه.

(٢) **نسبة إستخلاص العصير:** قلت نسبة استخلاص العصير للآلة الأتوماتيكية المصممة من ٤٩,٨٥ إلى ٤٩,٢٦ % بزيادة سرعة درفلى المسك وآلية الضغط من ١٣ إلى ٣٨ لفة/د.

(٣) **الإنتاجية:** وجد أن أعلى متوسط لإنتاجية العصير تم الحصول عليها عند إستخدام آلة العصير الأتوماتيكية المصممة (٣١٧ لتر/س) ثم يليها عصارة البرتقال الكهربائية (٣٠ لتر/ساعة)، ثم العصارة اليدوية (١٢,٥ لتر/ساعة).

(٤) **تكاليف التشغيل والتكاليف الحدية:** وجد أن أقل تكاليف تشغيل (٠,٠١٢ جنيه/لتر عصير) عند إستخدام آلة العصير الأتوماتيكية المصممة ثم يليها آلة العصير الكهربائية (٠,٠٨٠ جنيه/لتر)، ثم العصارة اليدوية (٠,١٨٠ جنيه/لتر). بينما وجد أن القيمة المحددة "JVJE" (التى تشمل قيمة العصير – مصاريف العصر) لآلة العصير الأتوماتيكية المصممة (1344.5 جنيه/ساعة) أعلى من عصارة البرتقال الكهربائية (112 جنيه/ساعة)، ثم عصارة البرتقال اليدوية (٤٦,٥ جنيه/ساعة).