J. Agric. Sci. Mansoura Univ., 29(5): 2585 - 2597, 2004

DESIGN OF A MECHANICAL WASHING MACHINE FOR SOME FRUITS AND VEGETABLES

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ABSTRACT

Wet cleaning "washing" was found to be a necessary operation to maintain the quality of fruits and vegetables, improve their marketability, and increase their shelf life.

The main objective of the present work is to introduce an economic, locally made washing machine for fruits and vegetables producers, especially who own medium and small holdings.

The prototype was evaluated using orange and tomato fruits and taking into account the effective design parameters such as, speed of fruits conveying and transporting 0.8, 1.0, 1.2.and 1.4 m/s., number of brushes (2, 3, and 4), and the interference distance between the brushes hair used while washing and the fruit surface (0, 3, 6, and 9 mm).

The results indicated that the maximum machine productivity was 1.29 ton/h and 2.28 ton/h with cleaning efficiency of 97 and 98 % obtained when washing oranges and tomatoes, respectively, while the corresponding values of the consumed energies were 2.08 kW.h/ton and 1.18 kW.h/ton. Maximum operating cost was found to be about 4.30 and 3.10 LE/ton in case of washing orange and tomato fruits, respectively.

INTRODUCTION

Technology currently available for cleaning fruits and vegetables includes a lot of techniques for dry and /or wet cleaning. Wet cleaning (washing) could be carried out by dip washing, spray washing or both.

Dauthy (1995) indicated that harvested fruits are washed to remove soil, micro-organism and pesticide residues, and that washing efficiency could be gauged by the total number of micro-organisms present on fruit surface before and after the washing. The water from the final wash should be free from moulds and yeasts.

On the other hand small quantity of bacteria is acceptable. It was recommended to use a combination of immersion and spray process to get the best results.

Tariq *et al.* (2001) indicated that the unwashed fruits had higher weight losses than washed fruits. High values of $O2$ and $CO2$ were recorded in washed and sealed fruit bags than in unwashed and sealed fruit bags.

El- Sharnouby and Hoda (2003) studied the accumulation of Lead (pb) and cadmium (cd) in 19 different types of fresh fruits and vegetables. They collected fresh samples from two super markets and two open markets in Alexandria and Damanhur cities. They found that, washing fruits and salad vegetables using tap water reduced the accumulation of pb by 30 – 81 and 39 – 90 % and of cd by 21 – 58 and 7 – 45 %, respectively.

Shokr *et al.* (2002) showed that the unwashed Guava fruits contained 1.35 ppm dimethoate 18 days after harvest while washed Guava fruits contained 0.78 ppm after 9 days.

Krishna *et al.* (2001) showed that postharvest losses through rot in squash fruit resulted in poor quality or rejected fruit. Mechanical washing helped in the removal of soil, micro-organisms and other debris from fruit surfaces and reduced the incidence of rots by about 42 % compared with unwashed squash.

Trials for introducing suitable washing methods and / or machines to suit different technological levels were carried out.

Mendenhall et al. (1988) discussed several approaches to vegetable washing, concepts similar to the washing action of common machines such as household dishwashers, top and side loading clothes washers, an automobile washer, and ultrasonic methods. For a horizontal, rotating drum, in which the vegetables would be partially submerged, they expected incomplete cleaning for non-spherical vegetables.

Jarimopas and Therdwongworakull (1994) designed a washing machine for Mango crop, which consisted of a roller conveyor and washing room equipped with sprayers and brushes. They indicated that the machine removed out the dirt from the fruits compared with hand washing and the fruit damage percentage was about 0.6%.

Lisa Kitinojia and Abdel-Kader (1995) used steel drums to make a simple washing stand. The drums were cut in halves and fitted with drain *holes and all the metal edges were covered* with split rubber or plastic hose. The drums were set into a sloped wooden table constructed from wooden slats and was used as a drying rack before packing.

Petracek *et al.* (1998) investigated the effect of high pressure washing on the morphology and physiology of citrus fruits surfaces. It was found that using 345 kpa of water pressure had little effect on peel wax fine structure of the fruit surface, while most epicuticular wax platelets were removed from the fruit surface using the veejet nozzle at 1380 or 2760 k pa

Moos et al. (2002) developed a non -immersion, rotary washing system with low-pressure spray for carrots washing. The mechanical washer indicated that a considerable improvements in sample processing speed and reduced labor requirements with no reduction in carrot quality compared with manual washing.

Mulugera *et al.*(2002) pointed that washing nozzles system must be identified to save drinking water and applied energy ,at the same time increase the washing efficiency.

Problem statement

The problem of increased losses of vegetables and fruits after harvest period was recognized as a severe problem facing all producers of horticultural crops, especially in the newly reclaimed lands. Hence the need of introducing washing systems was recognized as one of the necessary post harvest operations for minimizing these losses. On the other hand, it was realized that the imported systems *or machines will not suit the medium or* small farms because of their large size machines of heavy structures, and high investment costs.

Therefore, efforts in the present work were devoted to design and fabricate a fruits and vegetables washing machine suitable for small and medium size holdings.

MATERIALS AND METHODS

Machine Fabrication

The construction feature of the designed mechanical washing machine mainly consists of the following units Fig. (1).

1-The conveying rollers/belt:

The conveying rollers/belt used for the transporting mechanism of fruits consists of 16 PVC rollers (6 cm diameter and 60 cm length). The rollers were horizontally leveled with 4 mm spacing between each other. In the case of washing tomatoes the 16 rollers were covered by rough rubber flat belt 50 cm wide and 250 cm length to increase friction coefficient between fruit and belt. A steel basin was fitted directly under the conveying rollers/belt mechanism to collect water after the washing operation and drain it through flexible plastic hose.

2-Washing unit:

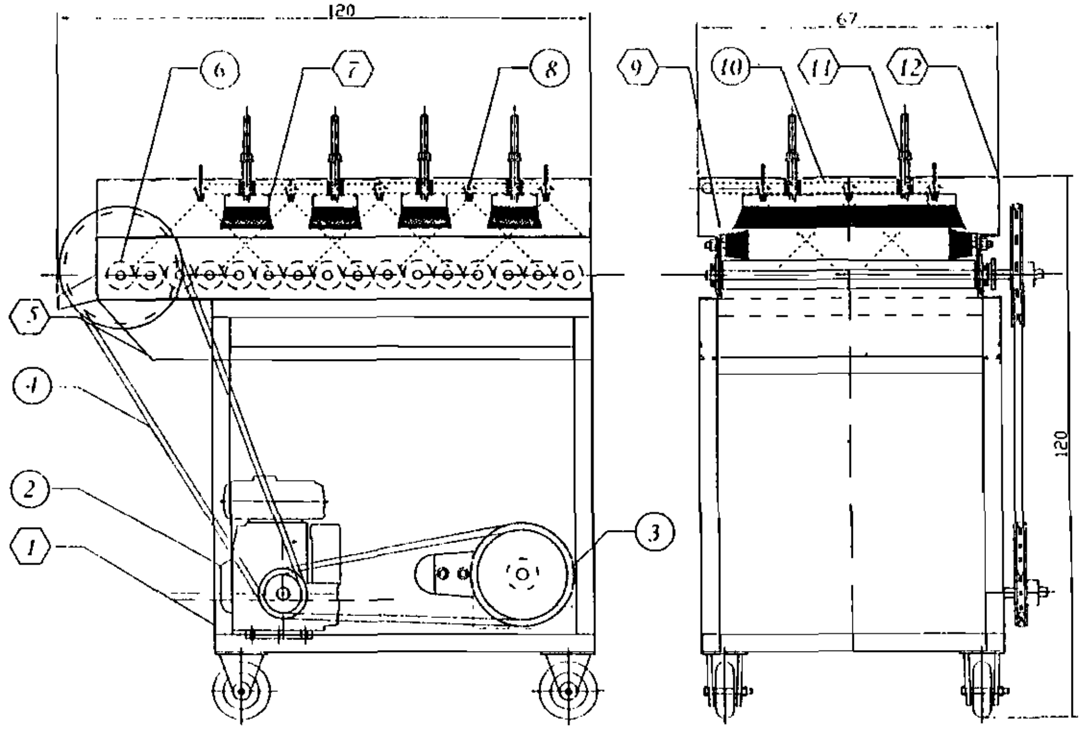
Washing unit consists of group of four plastic brushes and spraying mechanism of fifteen nozzles and a reciprocating pump. Brushes were arranged in four rows and fixed on the brushes stand which was designed to control the depth of brush interference hair with the fruit surface easily. Nozzles were arranged on five rows and fixed on the water spray pipe. Each row was connected with the main water pipe.

3- Power unit:

A small kerosene engine (Honda, GK400 model, 3600 rpm rotational speed at 5.5 kW rated power was used to operate the washing machine through group of pulleys to obtain different rotational speeds of rollers and the flat belt. Also the washing pump was operated through two pulleys and v-belt.

Washing operation procedure

Washing was carried out through giving any fruit a linear and angular motion at the same time ($\frac{1}{2} mv^2 + \frac{1}{2}\, 2/5\, mr^2\omega^2$) as shown in Fig. (2) .At the beginning of the fruit motion over the first three rollers, the fruit turns around under the spraying nozzles of water showers (at constant water pressure of 1 bar) for many times/sec., then the fruit passes through the brushes at four stations parallel to the rollers in order to separate the foreign materials and debris from the fruit surfaces. This operation was mainly done to assume better performance of the washing operation, which is completely done at the end of the roller conveyor.



No.	Name of parts
1	Main frame
2	Engine
3	Spray pump
4	Drive belt
5	Water basin
6	Conveying drums (Rollers)
7	Top washing brush
8	Spraying Nozzles
9	Horizontal brush
10	Water supply pipes
11	brush interferance adjustable holder
12	Machine cover

Fig. (1): Schematic Diagram of washing machine.

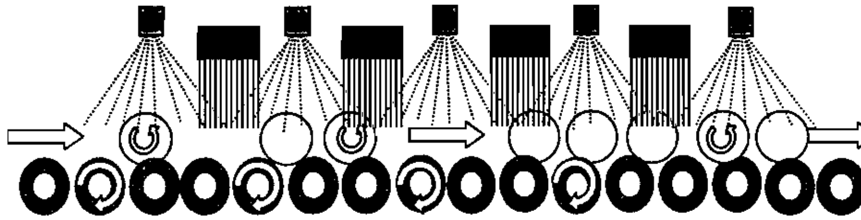


Fig. 2: Schematic diagram of round fruits washing procedure.

Study parameters

The performance of the designed washing machine was evaluated under the following parameters:

1. Four speeds of conveying rollers/belt, namely; 0.8, 1.0, 1.2.and 1.4 m/s.
2. Number of brushes (2 .3.and 4).
3. Four different length interference of brushes hair with fruit surface, namely; 0, 3, 6 and 9 mm.
4. Two crop (orange and tomato) fruits.

Measurements

During field evaluation of the designed washing machine the following items were measured: -

1- Physical and mechanical properties of fruits:

Some physical and mechanical properties of orange and tomato fruits used in this study were measured and listed in the Table (1):

Table (1): Average physical and mechanical properties of orange and tomato fruits.

Items	Orange fruits (Washingtonian variety)	Tomato fruits (Kilopatra variety)
Major diameter, mm	75.10	69.67
Minor diameter, mm	74.22	43.91
Mass of fruit , g	238.33	91.37
• Penetration force, N	6.3	0.97
• Firmness N/cm^2	73.39	35.92

• Digital force gauge (Shimpo) FGC – 50 kg$_f$ (500 N) was used to measure penetration force in Newton and firmness in Newton /sq.cm. of fruits.

2- Quality of brushes:

Brush hair filament diameter was measured using digital Micrometer (Mitutoyo) ranged from 0 – 25 mm with an accuracy of 0.001 mm. The filament length (L) and diameter (D) were measured as well as ratio of L/D were determined. Pre studies were carried out to choose the suitable filament length and diameter, which have no effect on fruit damage and give the high cleaning efficiency. Filament diameter of 0.233 mm with length of 5 cm was used in the fabricating brush hairs.

3- Machine productivity:

The productivity of washing machine for the investigated fruits (orange and tomato) was calculated as follows:

$$\text{Machine productivity, ton/h} = \frac{Ws * 60}{t * 1000}$$

Where:

W_s = weight of fruit sample, kg;

T = washing time of the sample, min.

4- Cleaning efficiency:

Cleaning efficiency was used as a performance evaluation criterion for the designed washing machine. The quantity of removed dust, dirt and / or foreign materials from the fruit surface was determined using filtration technique described in soil analysis. Washing water used for cleaning a sample of 10 kg of fruits at each washing treatment was collected, filtered using filtration papers, then the quantity of removed dust, dirt and / or foreign materials was weighed (Wa), using an electric digital balance with an accuracy of 0.0001 g. The previously mechanically washed sample was washed carefully again by hand, the dust, dirt and / or foreign materials were determined using the same previous technique (Wb). Adding Wa to Wb indicate the total removed materials (Wc). Relating Wa to Wc illustrate the percentage of cleaning efficiency as follows:

$$Cleaning\ efficiency\% = \frac{Wa}{Wc} \times 100$$

5- Fuel and power consumption:

A measured volume of fuel was put into the fuel tank of the engine before operating for a specific period. After the work was over, the volume left in the fuel tank was measured. From these observations the volume of fuel consumed was determined and the rate of fuel consumption was calculated.

The total power consumed by the washing machine was calculated by using the measured fuel consumption during washing operations under the different variables of the study. The following formula was used to estimate power consumption by the washing machine according to *Embaby (1985)*.

$$EP = \left(F_c \times \frac{1}{60 \times 60}\right)\rho_f \times L.C.V. \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}\ \text{(kW)}$$

where:

Ep = estimated power consumption;

F_c = fuel consumption, l/h;

ρ_f = density of the fuel (0.82kg/l for kerosene fuel);

L.C.V= lower calorific value of fuel (10500 kcal/kg for kerosene fuel)

427 - thermo-mechanical equivalent, kg.m/k cal;

η_{th} = assumed thermal efficiency of engine,(25%);
η_m = assumed mechanical efficiency of engine,(80%).

Estimation of the energy required for washing process was carried out using the following equation:-

$$Energy\ requirements\ (kW.h/ton) = \frac{Power\ requirement\ (kW)}{machine\quad productivity\ (ton/h)}$$

6- Cost estimation

The total hourly cost of washing process for the designed washing machine during washing orange and tomato fruits could be estimated using the following equation according to *El-Awady, (1978)* as follows:

$$C = \frac{P}{h}\left(\frac{i}{L} + \frac{i}{2} + a + r\right) + (0.9W \times F \times U) + b$$

Where :

C = cost per hour of operation, (LE/h);
P = estimated price of the machine, (5000LE)
h = estimated yearly hour operation, (1000 hrs);
L = expected life of the machine, (10 years);
i = annual interest rate, (10%);
a = annual taxes and overheads, (2%);
r = annual repair and maintenance rate, (18%);
0.9 = a correction factor for rated load ratio and lubrication;
W = engine power, (7.5 hp);
F = Specific fuel consumption, (L/hp.h);
U = Fuel price, (0.40 LE/L);
b = hourly labor wage, (3 LE/h).

The designed and developed washing machine prototype was field tested at Meet El-Amel village, Dakahlia Governorate, using orange and tomato crops.

RESULTS AND DISCUSSION

The evaluation of the designed mechanical washing machine was carried out under study parameters of 4 different conveying rollers/belt speed, 4 different length interference of brushes hair with fruit surface and 3 numbers of brushes through the following item:

1- Machine productivity:

The effect of interference length between brush hair and fruit surfaces, number of brushes and the speed of rollers/belt on washing time (min/ton) for Orange and Tomato fruits were illustrated in Fig.(3 & 4).

A positive correlation could be seen between washing time and length of brush hair interference with fruit surfaces. Increasing the interference tends to increase washing time for both types of fruits. However the rate of

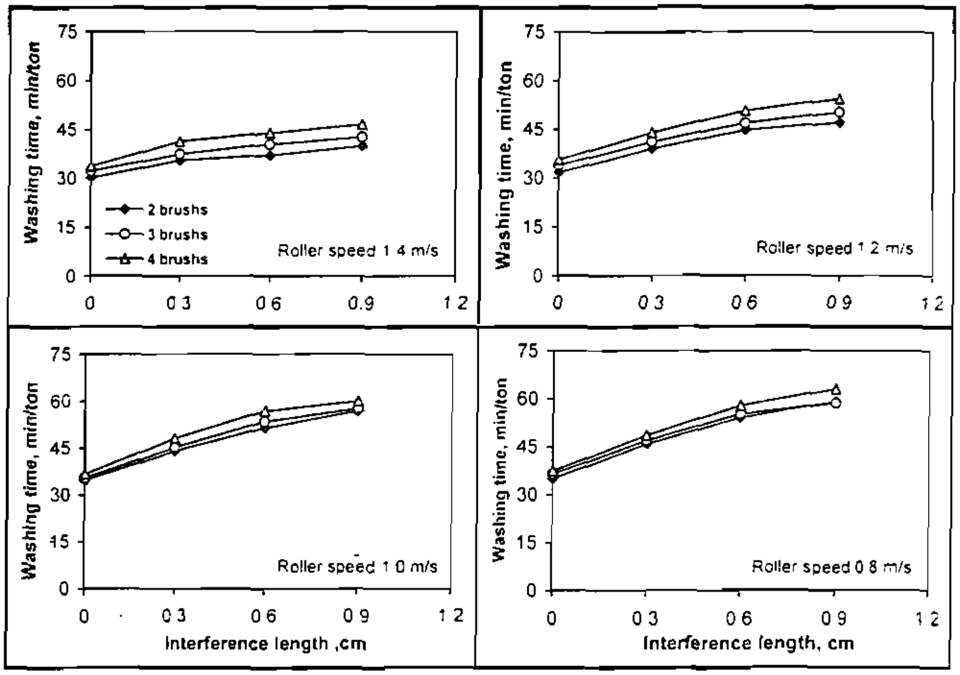


Fig. (3): Effect of interference length of brush hair on washing time for three numbers of brushes at four different speeds of conveying rollers for orange fruits.

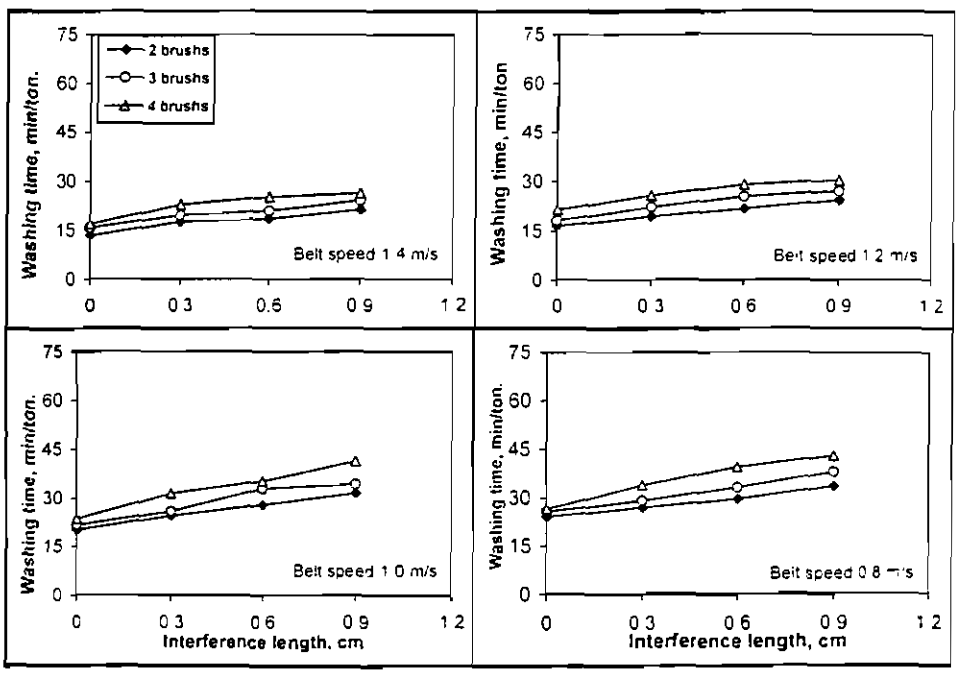


Fig. (4): Effect of interference length of brush hair on washing time for three numbers of brushes at four different speeds of conveying belt for tomato fruits.

increment in washing time due to increase brushes hair interference from 0 to 3 mm was higher than from 3 to 6 or from 6 to 9 mm. It could be attributed to increase brushes hair interference, which may increase of vertical load of brushes on fruits surfaces, i.e. increase friction coefficient between fruit surface and the conveying surface. This may lead to increase the fruits linear speed, which in turn decrease the staying time of fruits under brushes.

Generally washing time was found to be highly affected with the number of used brushes. Increasing brushes from 3 to 4 tend to increase washing time with an increment percentage higher than that obtained when increasing the number of brushes from 2 to 3 either with orange or tomato fruits for all rollers/belt speed levels used in the study.

As seen with 1.0 m/s conveying roller speed, increasing the number of brushes from 2 to 3 increased the needed time for washing orange fruits from 46.75 to 47.94 min/ton. While the time increased from 47.94 to 50.42 min/ton, by increasing the number of brushes from 3 to 4 .The same trend was noticed when washing tomato fruits, washing time was increased from 26.03 to 28.75 min/ton and from 28.75 to 32.97 min/ton at 1.0 m/s conveying belt speed by increasing the number of brushes from 2 to 3 and from 3 to 4, respectively.

Regard to the effect of the conveying roller speed on washing time for orange fruits. It was noticed that, increasing the conveying roller speed from 0.8 m/s to 1.4 m/s decreased the washing time from 49.85 to 38.48 min/ton as an average.

The same trend was noticed with tomato fruits, where washing time was decreased from 31.92 to 20.29 min/ton by increasing conveying belt speed from 0.8 m/s to 1.4 m/s, respectively.

The productivity of washing machine was determined under different conveying rollers/belt speeds, the maximum number of brushes (4) and the highest interference length (9 mm) of brush hair with fruit surfaces .The obtained results were summarized in the Table (2). Machine productivity was ranged from 0.95 to 1.29 ton/h according the roller speeds used with orange fruits. In case of tomato fruits the machine had a productivity values ranged from 1.40 to 2.28 ton/h at conveying belt speeds ranged from 0.8 to 1.4 m/s, respectively. The maximum obtained productivity values were 1.29 for washing oranges and 2.28 ton/h for washing tomatoes.

2- Cleaning efficiency:

Cleaning efficiency of the designed machine for orange and tomato fruits were investigated under four different interference length of brushes hair with fruit surface, three number of brushes and four levels of conveying rollers/belt speed (m/s). The obtained results, shown in Fig. (5&6), showed a positive correlation between interference length of brushes hair with fruit surfaces and cleaning efficiency for both investigated types of fruits. It was noticed that the cleaning efficiency had a higher increment at the interference length of 3 mm than that of 6 or 9 mm, since most of dirt and foreign material were removed at that interference. Also, the obtained results indicated that 9 mm interference length of brushes hair with fruit surfaces achieved the high percentages of cleaning efficiency.

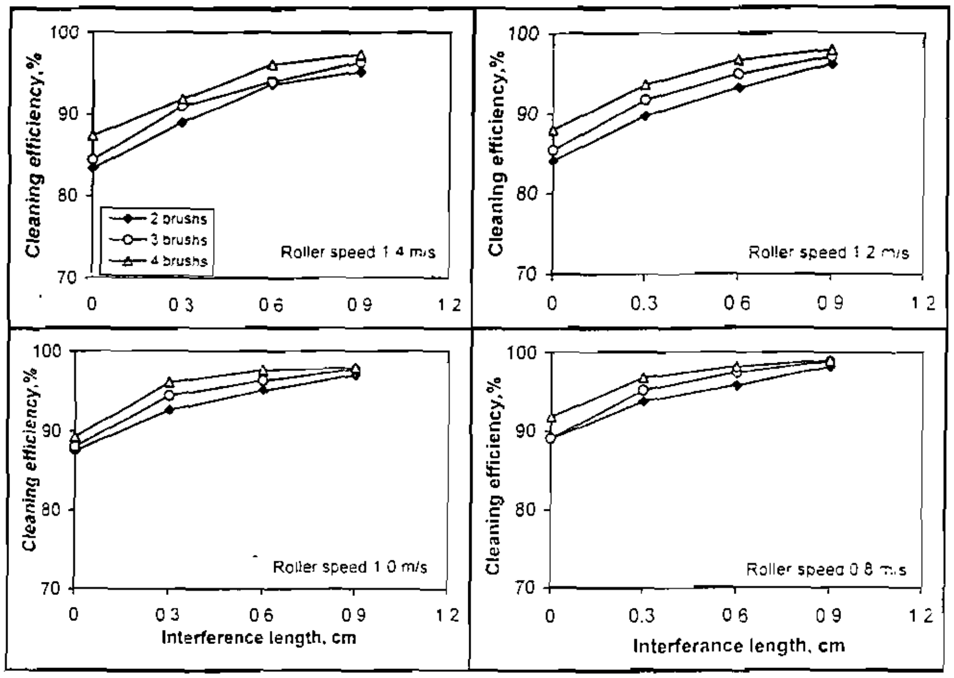


Fig. (5): Effect of interference length of brush hair on cleaning efficiency for three numbers of brushes at four different speeds of conveying rollers for orange fruits.

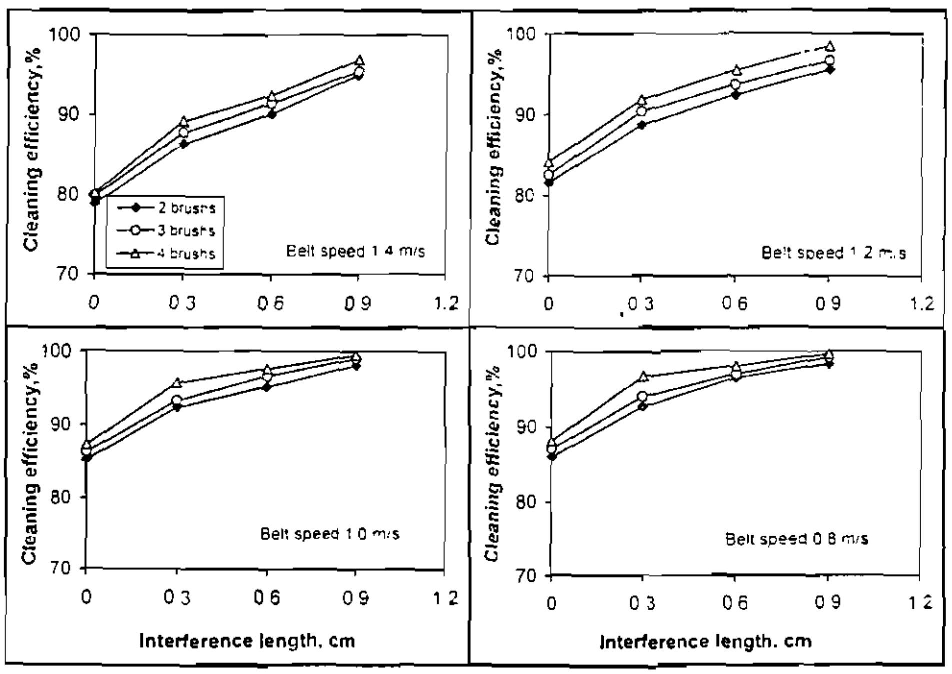


Fig. (6): Effect of interference length of brush hair on cleaning efficiency for three numbers of brushes at four different speeds of conveying belt for tomato fruits.

Cleaning efficiency for orange fruits ranged from 83.38 to 98.96%. In case of washing tomato fruits, cleaning efficiency ranged from 78.93 to 99.67%.

In general, as indicated in Figs (5 and6) increasing the number of brushes from 3 to 4 tends to increase the cleaning efficiency with an increment percentage higher than when increasing the number of brushes from 2 to 3 for washing orange fruits. The same trend was obtained when washing tomato fruits.

As seen with 1.4 m/s conveying rollers speed, increasing the number of brushes from 2 to 3 increased the cleaning efficiency for orange fruits from 90.30 to 91.45 % and from 91.45 to 93.16% by increasing the number of brushes from 3 to 4, respectively. The same trend was noticed when washing tomato fruits, cleaning efficiency was increased from 87.60 to 88.65% and from 88.65 to 89.72% by increasing the number of brushes from 2 to 3 and from 3 to 4, respectively.

On the other hand, the results showed that, increasing the conveying roller speed from 0.8 m/s to 1.4 m/s decreased the average values of cleaning efficiency from 95.26 to 91.64% during washing orange fruits. Cleaning efficiency during washing tomato fruits were decreased from 94.48 to 88.66% by increasing conveying belt speed from 0.8 m/s to 1.4 m/s, respectively.

3- Power consumption and energy requirement:

The power consumption and energy requirement were calculated for washing machine under different conveying rollers/belt speeds using 4 number of brushes and 9 mm interference length between brush hair and fruit surface during washing orange and tomato fruits. The obtained results were listed in Table (2). The consumed power and energy requirement were increased by increasing the conveying rollers/belt speed. The average values of the power consumption of 2.68, 2.31, 1.60 and 1.39 kW were obtained for washing orange/tomato fruits using rollers/belt speed of 1.4, 1.2, 1.0 and 0.8 m/s respectively.

The energy requirement decreased from 2.08 to 1.47 KW.h/ton by decreasing the roller speed from 1.4 to 0.8 m/s in case of washing orange fruits. In case of washing tomato fruits the energy requirement decreased from 1.18 to 1.02 KW.h/ton. The highest values of power consumption and energy requirement of 2.68 kW and 2.08kW.h/ton for washing orange fruits, 2.68 kW and 1.18 kW.h/ton for washing tomato fruits were obtained at 1.4 m/s rollers/belt speed, 4 brushes and 9 mm interference length between brush hair and fruit surface.

4- washing cost

Washing costs using the designed machine was calculated for orange and tomato fruits at 0.8m/sec.rollers/belt speed, using 4 brushes and an interference length of 9 mm between brushes hair and fruit surface.

The maximum washing cost/ hour was found to be 4.30 LE/h and hence costs per ton was 4.5 LE/ton for orange and 3.10 LE/ton for tomato fruits.

Table (2): Productivity, power consumption and energy requirement for washing machine

Speed, m/s	Orange fruits		
	Productivity, ton/h	Power consumption. ,kW	Energy requirement, kW.h/ton
1.4	1.29	2.68	2.08
1.2	1.12	2.31	2.07
1.0	1.0	1.60	1.60
0.8	0.95	1.39	1.47
Speed, m/s	Tomato fruits		
1.4	2.28	2.68	1.18
1.2	1. 98	2.31	1.13
1.0	1.45	1.60	1.11
0.8	1.40	1.39	1.02

CONCLUSIONS AND RECOMENDATIONS

The conclusions of this study are summarized as follows: -

1. The designed washing machine could be used for washing fruits and vegetables with high cleaning efficiency (98% and 99%) at rollers / belt speed of 0.8 m/sec., 4 brushes and 9 mm interference length of brush hair with fruits surfaces for orange and tomato fruits respectively.
2. Maximum machine productivity was 1.29 and 2.28 ton/h for orange and tomato fruits respectively.
3. Maximum energy requirement was 2.08 for oranges and 1.18 Kw .h/ton for tomatoes.
4. The maximum washing costs per unit production were 4.5 LE/ton for oranges and 3.10 LE/ton for tomatoes.

REFERENCES

Awady M.N (1978) .Tractors and Farm machinary ,Text book,Col.Agric.Ain Shams University 164-167

Dauthy M. E. (1995). Fruit and Vegetable Processing FAO Agricultural services bulletin 119 Rome.

El – Sharnouby S. A. and M.A.E.A. Hoda (2003) .Influence of markting and preparation on lead (pb) and cadmium (cd) residues of som fresh vegetables and fruits..Arab universities Journal of Agricultural Scienc 11: 2, 563 – 577.

Embaby, A. T., (1985). A comparison of the different mechanization systems for cereal crop production. Unpub. M.Sc. Thesis. (Agric. Eng.), Cairo Univ. The filament diameter of 0.233 mm

Jarimopas B. and A. Therdwongworakull (1994). Postharvest mechanical drenching and disease control of mango . Kasetsart-Journal,-Natural-Sciences. 28: 4, 616-625.

Krishna H. ; A. Carpenter ; F.Potter and S. M. Zydenbos.(2001). Effect of washing additives on the incidence of rots and an enumeration of surface microbes in stored squash.New zealand plant protection volum 54 ,76 –79

Lisa Kitinojia and Abdel A Kader (1995). Small-scale post harvest handling practices A manual for horticultural crops 3rd edition .Department of pomology university of California – Davis, California 95616

Mendenhall, T. J., T. D. Negusse, S. G. Solomon, Jr., and R. R. Price. (1988). Design of a vegetable washer for the foodservice industry. J. Foodservice Syst. 5: 43-65.

Moos J. A., D. D. Steele and D. C. Kirkpatrick (2002). Small-Scale Mechanical Carrot Washer for Research Sample Preparation. Applied Engineering in Agriculture Vol. 18(2): 235-241

Mulugeta E. , M. Geyer , B. Oberbarnscheidt and M. Lipthal (2002). Development of wash nozzle for more efficient vegetable cleaning. Landtechnik 57 : 4. 220 – 221.

Petracek P.D., D.F. Kelsey and C. Davis (1998). Response of citrus fruit to high pressure washing. Journal of the Amirican Society for Horticultural Science 123 ;4 ,661 – 667

Shokr S. A. , A. A. A. Sallam and S.T.I. Abdel- Rahman (2002).Determination of dimethoate and malathion residueces on and in Guava fruits.Assiut Journal of Agricultural sciences 33 :3,41-48

Tarq M. A. and E. M. Tahir, A. A. Asi and I. Javed (2001).Effect of washing and seal packaging on scuffing damage citrus fruit quality. International Journal of Agricultural and Biology 3;4, 461 – 463.

تصميم نظام آلي لغسيل بعض ثمار الخضر والفاكهة

صفوت الخواجة
معهد بحوث الهندسة الزراعية – الدقى – الجيزة

أشارت الدراسات الحديثة إلى ضرورة التوجه نحو تصنيع بعض المنتجات الزراعية وانتاج آلات تصلح لهذا الغرض خاصة لمزارعي الأراضي الجديدة حيث يزداد مقدار الفاقد في الحاصلات الزراعية أثناء عملية التسويق والنقل والتعبئة (ورشة عمل معهد بحوث الإرشاد الزراعي ٢٠٠٢) كما أشارت ورشة عمل معهد بحوث تكنولوجيا الأغذية ٢٠٠٢ إلى وجود فاقد كبير في محاصيل الخضر فلقد وصل مقدار الفاقد من محصول الطماطم نحو ٣٠% وقدر هذا الفاقد بما قيمته ٣٠٠ مليون جنية مصري ونظرا لأن إنشاء مصانع تصنيع المنتجات الزراعية الحديثة يتكلف مبالغ طائلة. الأمر الذي ترتب علية سرعة مواكبة هذه التغيرات. لذا تهدف الدراسة إلى تصميم وتطوير آلة لغسيل معظم ثمار حاصلات الخضر والفاكهة للتخلص من الأتربة والكائنات الدقيقة العالقة بالثمار لحما يه الثمار والمحافظة عليها من التأثير الضار للبكتيريا والفطريات والتربة المتواجدة معها نتيجة لاختراق هذه المواد لأسطح الثمار وتعد هذه الآلة ضرورية لاعداد الثمار للتسويق بغرض الاستهلاك الطازج أو التصنيع وهي في متناول المنتج البسيط والمتوسط . وتتلخص فكرة عمل الآلة علي إعطاء حركة دورانية وخطية للثمار من خلال تركيب عدد من الدرافيل الدوارة الحاملة للثمار أو(سير ناقل) يتم معها في نفس الوقت رش الماء علي أسطح الثمار بكمية وضغط كافيين يتم بعدها مرور الثمار علي مجموعة من الفرش للتخلص من الأتربة والكائنات الدقيقة .وبناءا علي الدارسات التمهيدية, فلقد تم استخدام شعر فرش الغسيل بقطر ٢٣٣,مم بطول ٥ سم والذي يتناسب مع عملية غسيل الخضر والفاكهة لعدم احداثة ضررا للثمار والذي أعطي أيضا كفاءه تنظيف عالية للثمار .وقد تم تقييم أداء الآلة المصممة عند أربع سر عات خطية للغسيل (١,٤-١,٢-١,٠- ٨, م/ث) و ٤مجموعات لفرش الغسيل(٢و٣و٤) و ٤ مستويات تداخل لشعر فرش الغسيل مع أسطح الثمار(صفر-٣ -٦ -٩ مم) علي ثمار محصولي البرتقال و الطماطم.

وتشير النتائج المتحصل عليها إلى إمكانية استخدام الآلة المصممة بكفاءة عالية حيث وصات الإنتاجية إلى ١,٢٩و ٢,٢٨ طن / الساعة بكفاءة تنظيف ٩٧و ٩٨% لثمار البرتقال و الطماطم علي الترتيب. ولقد بلغت مقدار الطاقة المستهلكة ٢,٠٨ و ١,١٨كيلو وات ساعة/طن لغسيل ثمار محصولي البرتقال و الطماطم علي الترتيب بتكلفة تقديريه للتشغيل ٤,٥ و٣,١٠ جنية / طن.