ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Developed hand tool to pick Prickly pear fruit.

Abd El – Ghany[1], Horia, M.A., Ismail[2], Nahed, K., El- Bialee[3], N.M., and El- Bialee[4], N.M.

1, 2.,3 Agric. Bio-Engineering Res. Dept. Agric. Engineering Res., Institute (AEnRI). Agric. Res. Center (ARC)., Giza. Egypt.

4 Agronomy Dept. Al- Azhar Univ., Cairo. Egypt.

Manuscript Info

Manuscript History:

Received: 14 March 2015
Final Accepted: 26 April 2015
Published Online: May 2015

Key words:

Prickly pear properties, harvesting aid, labour productivity, picking cost and microbial spoilage

Corresponding Author

M.Tech Scholar

Abstract

Prickly pear (Cactus) is one of important plant for sustainable development at arid region. Enhancing picking process and reducing microbial spoilage incident during hand picking a fundamental goal, to face obstacles spread planting. Due to fruits and cladodes restrictive properties (physical and mechanical), an ergonomic pruning shear has been developed to pick fruits. Results show that, using developed aid has a significant effect ($P < 0.05$) on labour productivity and picking cost compared with hand picking**.** Picking by developed aid due to increased productivity about 7.2% and decreased cost about 0.04LE.kg^{-1}. Also, results show that microbial spoilage (total colonies count of bacteria), has an inverse proportion with cutting piece volume from cladode (mm^3)

.

INTRODUCTION

Prickly pear is one of important plant used in agriculture sustainable development as a potential alternative crop for arid and semi arid regions (Kunyanga et al., 2009., and Nefzaoui and El Mourid, 2010). Fruits pulp are usually consumed by edible freshly or after processing as jelly, jam, juice…….etc. (Reyes, 2005). The extracted pigments from fruits are used as additives in different agro-industry such as food, cosmetic and pharmaceutical preparations (Dehbi et al., 2014). Also, seed and peel can be formulated into number of commercial food product (Mobhammer et al., 2006). In addition, it looked at as a potential source of anti-polluting agents to clean dirty water, and as a source of oil (Goycoolea and Cárdenas, 2003).

Egypt cultivated four common varieties in about 3116 feddan (Feddan: Egyption unit area = 4200 m^2) . Two of them are local (Shameia and Farawla), and the other are global variety (Cristlina and Rojatilota), Produce about 244.2 Gg with average productivity about 10.09 Mg.fed^{-1} (CAAES., 2005., and EAS., 2012)].

Fruits collecting are carried out early in the day by labors wearing a plastic bag as glove or thick rubber or canvas – type gloves with special lather cloths for protection as well, to avoid the excessive annoyance of the fine hair (glochids) and spines that come away from a the epicarp (Ingles, 2010).

The traditional method of harvesting fruits may be by; a) torsion, this is done with bare hands by rotating fruit more than 90° applying pressure and detaching it with flexion, carefully off the "mother" pad, or using metal tongs. b) cut and flexion, using a sharp knife (Cantwell, 1995., and Ochoa et al., 1997).

Fruits are highly perishable and prone to deterioration caused by mechanical damage during harvesting. Damages creates sites for establishment and out growth of the spoilage microbes. Whereas, microbial spoilage is one of the major causes of quality loss in fresh fruits. Prickly pear fruit is very susceptible to microbial spoilage (Corbe et al., 2004). Where, the physical damage inflicted on the peel from finger pressure, and the stem – end by twisted off the fruit mother cladoded during harvest (Rodríguez – Félix., 1991)

Hipolito and Dietnor, 2011 stated that, the main criteria for the prototype was; 1) The worker had to be able to separate the fruit without hand touching., 2) Fruit damage ≤ damage that occurs during hand harvesting.,3) Increasing harvesting capacity compared to hand harvesting., 4) Low weight, simple to use, safe to operate, simple design for ease manufacture and repair, reliable, and have low maintenance costs. Some harvesting aids have been tried (Lara–López,1992., Durán- García et al.,2013., and Hahn, 2013).

NIOSH., 2004 and 2011., and Holstein, 2009., mentioned that, ergonomic design criteria for pruning shears include several variables could be summarized as follows; a) Handle coated with soft material (foam or flexible plastic) to keep prunes from slipping out of hands., b) Handle length must be longer than the widest part of hand- usually 4 to 6 inch (101.6 to 152.4mm) – to prevent pressing on nerve and blood vessels in the palm hand., c) Strong spring which stays put when pruning and never pops off, loaded handle to return handles to the open position, and reduce forceful exertions when opening., d) Grip span (the distance between the thumb and fingers when the pruning jaws are open or closed) must be at least 2 inch (50.4 mm) when fully closed and 3.5 inch (96.52 mm) when fully open., e) Wire – cutting to allows the clip errant wires wide guarding., f)Rubber bumper chock to absorber and cushion to protect the wrist.

Hwang et al 2011., resulted that, average total finger force (sum of all four-finger forces) for men and women about 164N. Whilst, the finger/palm balance (fpBalance) about 0.66 - calculated by the ratio between total finger force and total palm force. So, average total palm force (sum of opposite directional forces to the finger force from thenar, groove – between thenar and hypothenar region – and hypothenar regions about 248N.

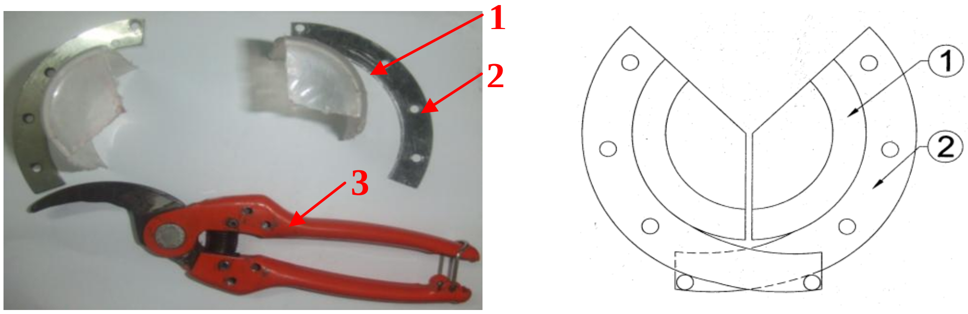
The main objective of this research is developing a sturdy harvester aid and that is both more efficient and less damage to the fruit

2- MATERIALS AND METHODS

2-1- Developed aid: is consists of two main parts. Fig. 1and 2.

2-1-1- Pruning shear

An ergonomic pruning shear bypass type with about 215mm., length and 240g.,weight. Handles PVC/steel core with about 100 mm length and about 22 and 75mm grip span when pruning jaws open and closed respectively. Jaws blade as hooked shape, high-carbon blade steel, hard chrome plated. Also, it has rubber bumper, wire-cutting notch and strong compressing spring from coil led wire, with maximum force about 29N., (See calculation 2-4-1). The required force that must be applied at pruning shears handles (upper and lower) about 34N., (See calculation No.2-4-2).



A **B**

Fig.1: Developed aid; A) Components. 1- plastic frustum of cone. 2- steel arc sheet. 3- pruning shear. B) Fruit container sketch

Fig.2: Developed aid during picking

2-1-2- Fruit container:

It is imperative that the containers size and dimensions (length and diameter) are greater than largest fruits. Container's composed from two similar parts, made from clear hard plastic. Each part in the form of a third frustum of cone shape with about 100, 35, 25 and 1mm for height , lower and upper radius and thickness, respectively. It is divided longitudinally into two equal parts. Parts are fixed into steel arc sheet with about 75, 100, 15 and 1mm for length, diameter, width and thickness, respectively. Arc steel established on pruning shear handle. So, When it close container closed. Total weight of fruit container about 120g.

2-2-Raw materials

A sample of 500 mature fruits collected randomly from local markets during 2012 summer season. Fruits rubbing under running tap water to removed glochides on the peel surface and then drained on tissue paper, the important fruits properties (physical and mechanical), that affect on the designed aid were measured immediately. Physical properties include; fruit length (F_L), upper diameter (d_u), middle diameter (d_m) and lower diameter (d_l) were measured by digital vernier calibre with an accuracy of 0.01 mm. Actual volume (v_a) determined by liquid displacement method. Whole fruit mass (F_m) was recorded by digital electrical balance with an accuracy of 0.001g. Fruits were manually peeled, pulp mass (P_m) and peel mass (Pe_m) were separated and recorded these fractions weights. The dimensions, mass, and actual volume were established in following formula to obtain, shape index (SI), pulp % (P_p), density (ρ), specific volume (ν), and surface area (A_S). (Mohsenin, 1986)

$$SI = \frac{l}{d_m} \quad \text{...(1)}$$

$$P_p = \frac{P_m}{F_m} \quad \text{...(2)}$$

$$\rho = \frac{F_m}{v_a} \quad \text{...(3)}$$

$$\nu = \frac{v_a}{F_m} \quad \text{...(4)}$$

$$A_S = \frac{\text{Fruit peel mass} \times 2}{\text{mass of } 2cm^2 \text{ of fruit peel}} \quad \text{........(5)}$$

While, mechanical properties include; shear force for fruit and cladode, were measured with a digital hand force gauge. Whilst, chemical properties include; Total soluble solids (TSS) as °Brix determined by hand digital refractometric (Carl – zeiss jena). The pH or hydrogen ion index was determined using pH meter (PYE Unican Model 295). The juice pressed from a sample of homogenized fruit slices according to Konopacka and Plocharski, 2004., and centrifuged (4000 rpm, 30 min at 4°C). Juice was stored at -20°C before using.

2-3- Aid performance

Aid performance was carried out at private farmer on 6 October region, Giza Governorate during summer season 2014.

Labour productivity ($Kg.day^{-1}$), picking cost ($LE.Kg^{-1}$), and fruit quality as microbiological activity- total colonies count of bacteria "TCCB" ($CFU.g^{-1}$), were measured during picking process, and used as an indicator to evaluate the aid performance in comparison with hand picking. Labour productivity can be calculated by using the following equations:

$$\text{Labour productivity } (Kg.day^{-1}) = \frac{\text{Colecting fruits mass (Kg)}}{\text{Total picking time (day)}} \quad \text{.........(6)}$$

Total picking time was recorded for four continuous full working days (6 working hours per day – since daylight till morn). It includes selecting, detecting and detaching fruit to be picking, collecting detached fruits in the basket and emptying it. In addition to, the time required for moving picker between shrubbery inside the field. Picking cost ($LE.Kg^{-1}$) calculated according the following equation.

$$\text{Picking cost } (LE.kg^{-1}) = \frac{\text{Cost } (LE.day^{-1})}{\text{Labour productivety } (Kg.day^{-1})} \quad \text{............(7)}$$

Where, manual cost confined on labour daily salary in case of hand picking (HP), with adding aid cost in case picking by developed aid (DA), which calculated according to FMO., 1975., equation, with exclusion overhead cost and TSII values from fixed cost and considering that the variable costs was equal 80% from fixed cost (El–Tahhan, 1991) as follow :

Developed aid cost = Labour salary + Fixed cost + 80% Fixed cost ….(8)

The quality of picking prickly pear fruits were evaluated by total colonies count of bacteria "TCCB" (CFU.g^{-1}). So, immediately after picking process (manually or using developed aid) 50 fruits were selected randomly from picking methods and dipped in 19° C solution of 1% sodium hypochlorite (NaOCl) for 5 to 10 minutes to reduce microbial population from the fruits surface and storing it for a period of four days under room temperature. Total colonies count of bacteria were determined according to Marshall, 1992., as following: Under conditions 50 g of each sample were added to 450 ml of sterilized peptone water (1g/liter) in sterilized glass blender jar and blended for 5 min. A propriety serial dilution were done and then 10 ml of every sample was plated by standard microbiological pour plate technique. The total colonies of bacteria were estimated using plate count agar medium. The plates were incubated at 37° C for 48 hours.

All data obtained were subjected to proper statistical analysis using the MSTAT statistical software as described by Sendecor and Cochran, 1989.

2-4-Calculation

2-4-1- Spring force

The maximum force for compressing spring calculated according to ASME code equation as follow:

$$\mathbf{R} = \frac{G\,d^4}{8\,n\,D^3}\ (\mathbf{L_{free} - L_{solid}})$$

where

R : Max. force for spring at solid, N.,

G: Modules of rigidity ≈ 0.385 E ≈ 80850 $N.mm^{-2}$.,

E: Modules of elasticity = 210000 N. mm^{-2}.,

d : Spring wire diameter = 1.1mm.,

n : Number of active coils = 8.,

D: Mean coil diameter = $\left(\frac{OD + ID}{2}\right)$ = 12.995mm.,

OD: Outer diameter for coil = 14.06mm.,

I D: Inner diameter for coil = 11.93mm.,

L_{free}: Spring free length = 42.85 mm.,

L_{solid}: Spring solid length = 8.76 mm.,

$$\mathbf{R} = \frac{(80850)\times(1.1)^4}{(8)\times(8)\times(12.995)^3}\times(42.85 - 8.75) \approx \mathbf{29N}$$

2-4-2-Required force at pruning shear lower handle.

Pruning shears is an example of lever class 1. It consist of two levers class 1 linked together by bolt and screw (Point A) as a fulcrum. The forces located on pruning shear analysis, to deduced required force as shown in Fig.3. So, By taking moments about Point A

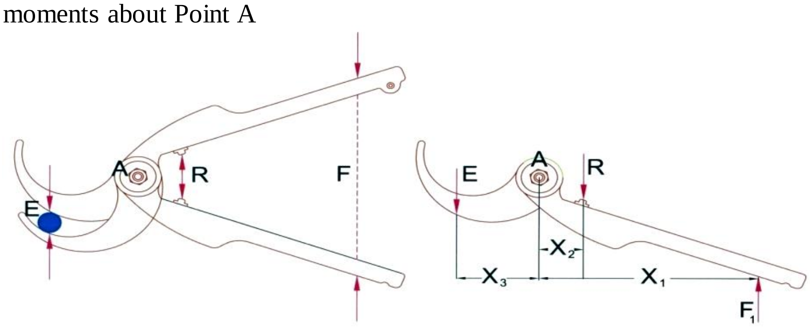


Fig.3: Distribution forces upon the pruning shear. F- required force that must be applied at pruning shear handles (upper and lower). F_1 - required force that must be applied at lower pruning shear handle (finger force). R- spring resistant (Max. force for spring at solid). A- fulcrum point. E- Max. shear force to cut cladode.

$$\circlearrowleft M_A = (F_1)(x_1) - (R)(x_2) - (E)(x_3) = 0$$
$$= (P)(121.27) - (29)(24.49) - (26)(51.88) = 0$$
$$\therefore F_1 \approx 17 \text{ N (accepted)}$$

where

F_1: required force that must be applied at lower pruning shear handle, (finger force), N.,
R: Max. force for spring at solid ≈ 29N., (calculated).,
E: Max. shear force to cut fruit ≈ 26N., (measured).

RESULTS AND DISCUSSIONS

3-1-Prickly pear properties:

Prickly pear fruit usually turbinate, sometimes spherical, cylindrical, oval, barrel, ellipsoidal or elongated – shaped. Frequency distribution histogram for fruit shape index (SI) of prickly pear fruits varieties presented in Fig.4. These results are in agreement with (Stintzing, et al., 2001., and Reyes et al., 2005).

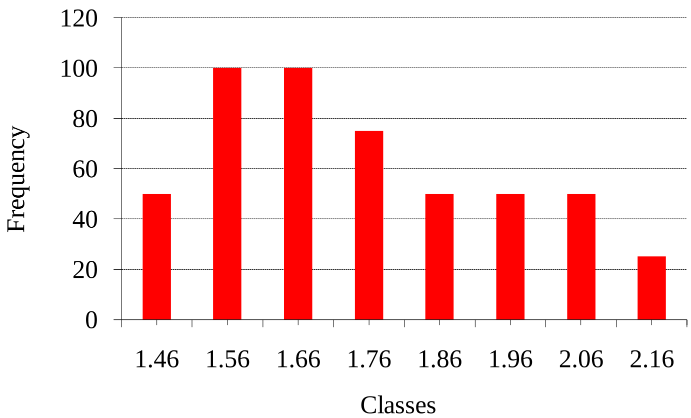


Fig.4: Frequency distribution histogram for fruit shape index (SI) of prickly pear fruits varieties

Minimum (Min.), maximum (Max.), average (Avg.), standard deviation (SD) and Coefficient of variation (C.V.) values, of some properties (physical, chemical and mechanical), for different varieties of fruits and cladodes were measured, calculated and summarized in Table 1.

Table 1: Physical, chemical and mechanical properties for different varieties of prickly pear fruits and cladodes.

Properties	Measurements	Min.	Max.	Avg.	SD	C.V%
Physical	Fruit length (F_L), mm.	51.91	95.29	73.73	12.09	16.39
	Fruit upper diameter (d_u), mm.	24.30	39.35	33.10	3.15	9.51
	Fruit middle diameter (d_m), mm.	40.20	50.68	44.00	2.62	5.95
	Fruit lower diameter (d_l), mm.	18.57	29.15	21.64	2.97	13.72
	Fruit actual volume (V_a), cm^3.	42.22	100.00	65.90	20.29	30.78
	Fruit mass (F_m), g .	41.36	115.00	65.40	17.75	27.14
	Pulp mass (P_m), g.	31.62	73.95	53.25	15.20	28.56
	Pulp percentage (P_p), %.	45..33	55.41	50.37	12.55	24.91
	Fruit density (ρ), $g.cm^{-3}$.	0.71	1.52	0.96	0.14	14.62
	Fruit specific volume (ν), $cm^3.g$.	0.66	1.42	1.06	0.14	13.21
	Fruit surface area (A_S),cm^2.	6.15	9.28	7.18	1.19	16.57
Chemical	Total soluble solids (TSS),°Brix.	6.5	16.5	10.98	2.66	24.25
	pH.	5.2	6.4	5.99	0.86	14.32
Mechanical	Fruit shear force, N.	2.1	14.40	5.95	3.61	60.62
	Cladode shear force , N.	10.40	26.00	18.20	11.03	60.61

The wide variation values intra property due to several factors, such as; plant genotype, cultivar, cultural practices, plant architecture (cladode load and fruit position within the canopy), environment (lighting periods….etc), and ripening time (Brutsch, 1992., Barbera et al.,1994., Inglese et al.,1995., Mondragon-Jacobo and Perez-Gonzalez, 1996., El- Samahy et al., 2006 ., and Inglese, 2010). Obtained results indicated that the average values of fruit length, diameter, fruit mass, pulp mass, pulp percentage, TSS and pH were agree with (Abdel-Nabey, 2001., Eliwa, 2004., Duru and Turker, 2005., Mokoboki et al., 2009., and Dehbi et al., 2014).

3-2-Aid performance:

3-2-1-Labour productivity and picking cost:

Labour productivity ($Kg.day^{-1}$), and picking cost ($LE.Kg^{-1}$), for picking process using developed aid (DA) were estimated comparing with hand pick (HP) method and illustrated in Fig.5. Obviously, labour productivity ($Kg.day^{-1}$) dependent on skill and experience of labour. It could be realized that, labour productivity by (HP) ranged from 91 to 103 $Kg.day^{-1}$ with average value 97 $Kg.day^{1}$. These values increases to 104 $Kg.day^{-1}$., by (DA) with significant effects ($P < 0.05$). These increases due to, increase collecting fruit by (DA) cause ease using and mass of pieces which it cutting with fruits from cladode. Also, results indicated that the difference between (HP) and (DP) costs were significant ($P < 0.05$) about 0.04 LE[*].kg^{-1}., in spite of adding developing aid costs

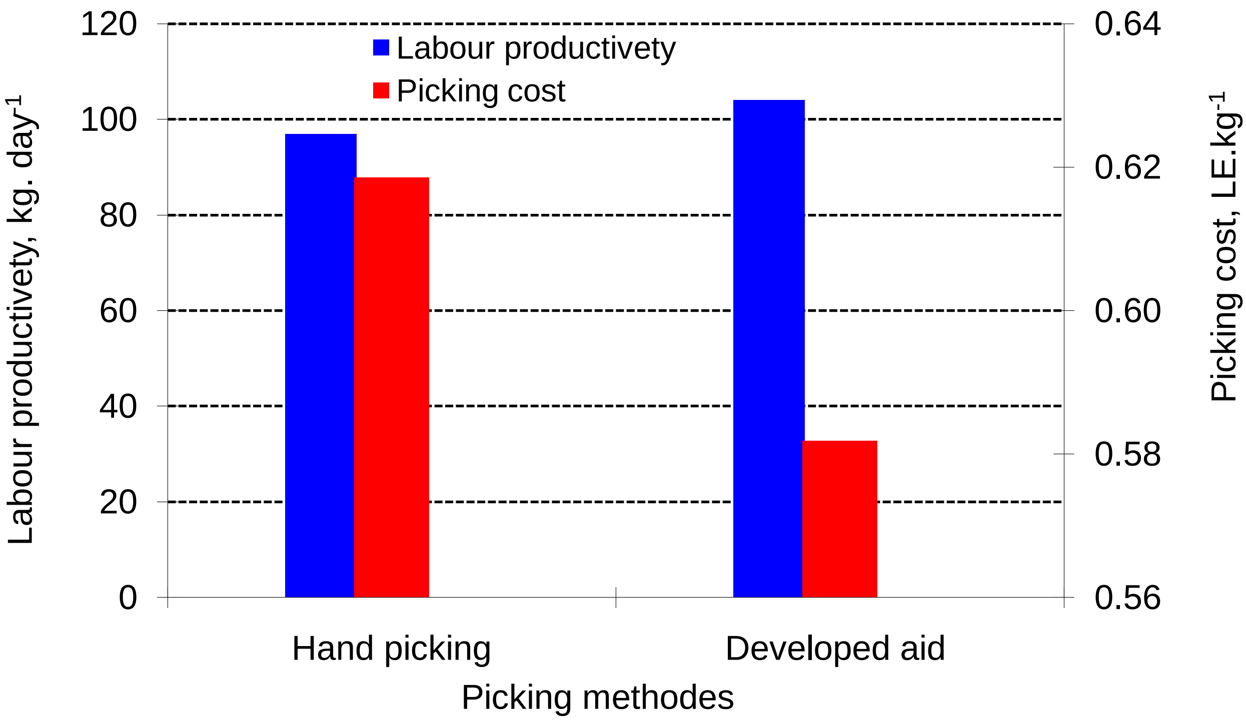


Fig. 5: Labour productivity ($kg.day^{-1}$),) and picking cost ($LE.kg^{-1}$) Vs, picking method.

3-2-2-Microbial spoilage:

High TSS and pH value on fruit pulp and low acidity make a very good medium for microbial spoilage (Francis et al., 1999., Sáenz and Sepulveda, 2001 and Cefola, 2011). Those facts explains the increase in total colonies count of bacteria "TCCB" ($CFU.10^{-3}.g^{-1}$). by increasing fruit TSS (°B) as shown in Fig.6.

Relation between total colonies count of bacteria "TCCB" ($CFU.10^{-3}.g^{-1}$). and TSS (°B) were fitted to the following equation:

$$y = 19.222\, e^{0.3169x} \text{, with } R^2 = 0.9907$$

where:

y = TCCB ($CFU.10^{-3}.g^{-1}$)., x = TSS (°B)

Results presented in Fig.7 express the relationship between "TCCB" ($CFU.10^{-3}.g^{-1}$). and cutting piece volume from cladode (mm^3) at average TSS= 12.4°B after 4 days. It could be realized that, increases on cutting piece volume from cladode (mm^3) lead to decreasing "TCCB" ($CFU.10^{-3}.g^{-1}$) on fruit base. This result in harmony with those obtained by (Rodríguez-Felix, 1991., and Cantwell, 1995), whose concluded that cutting the fruits with a very small amount of cladode attached due to reduce fruit damage by microbiological activity and avoid a rapid rot of the fruits and storing fruits under ambient conditions for long periods.

[*]One Egyptian pound (LE) =about 0.13 American dollar ($) according to Egyptian Central Bank in 13/2/2015

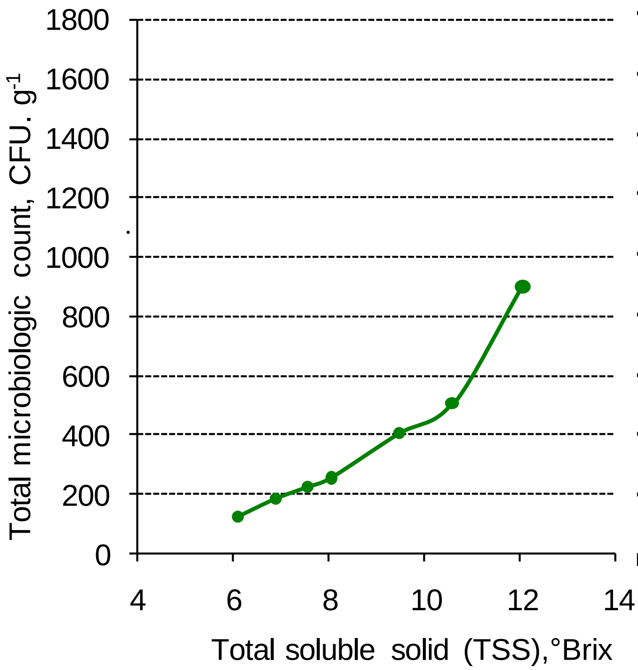


Fig.6: Relation between total colonies count of bacteria (CFU.g^{-1}) and total soluble solid "TSS" (°B).

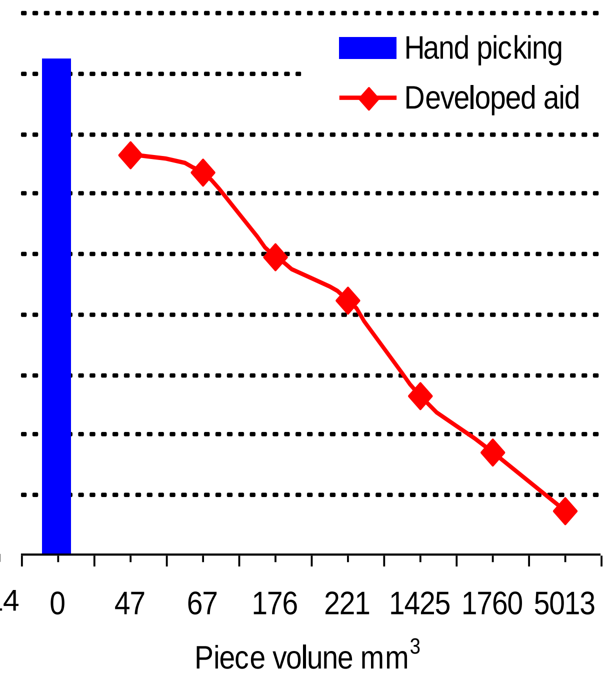


Fig.7:Relation between total colonies count of bacteria (CFU.g^{-1}) and piece volume from cladode (mm^3) at average TSS= 12.4°B after 4 days .

CONCLUSIONS

Prickly pear fruits and cladodes properties (physical and mechanical) were fundamental for developed an ergonomic pruning shear to picking different type of fruits. Obtained results shows the wide variation values intra property. Field test results show that the developed aid is easy to use (cut and detaching the fruit) without damaged, suitable for different varieties. So, labour productivity with developed aid is more than manual method by about 7.2% with significant effects ($P < 0.05$). Meanwhile, The difference between developed aid and manual costs were about 0.04 LE.kg^{-1}. Results also show that microbial spoilage as total microbiological count (CFU.g^{-1}) have a direct proportion with TSS (°B) and inverse proportional with cutting piece volume with fruits (mm^3)

REFRENCES

Abdel-Nabey, A. A., 2001. Chemical and technological studies on prickly pear (Opuntia ficus indica) fruits. Alex. J. Agric. Res., 46(3): 61-70.

Barbera, G., P. Inglese and T. La Mantia., 1994. Seed content and fruit characteristics in cactus pear (Opuntia ficus-indica Mill.). Scientia Horticulturae, 58:161-165.

Brutsch, M.O., 1992. Crop manipulation in spine-less prickly pear (Opuntia ficusindica) in South Africa. In: Proceedings of the Second International Conference on Cactus Pear and Cochineal. Santiago, Chile. pp 40-47.

CAAES., 2005. Cultivated and product Prickly pears. (In Arabic). Central Administration for Agricultural Extension Services (CAAES). Agric. Res. Center (ARC). Ministry of Agric. and Land Reclamation. Cairo. Egypt. Bulletin No., 993.

Cefola Maria., R. massimiliano., P. Bernardo., 2011. Marketability of ready – to – eat cactus as affected by temperature and modified atmosphere. J. Food Sci.Technol.

Cantwell, M. 1995. Post – harvest management of fruits and vegetable stems. In : Baebera G ., Ingles, P., Pimlenta – Barrios (eds). Agro – ecology cultivation and uses of cactus pear. FAO Plant Production and Protection Paper. Food and Agriculture Organization of the United Nations. Rome, Italy.No.132:120–143.

Corbo, M.R., C. Altieri., D. D'Amato., D. Campaniello., M. Del Nobole., M. Sinigaglia., 2004. Effect of temperature on shelf life and microbial population of lightly processed cactus pear fruit. Postharvest Biol. Tech., 31 (1):94-104.

Dehbi Fatima., H. Aziz., O. Aziz ., E. Hicham., and J. Abderrahim, 2014. Physicochemical characteristics of moroccan prickly pear juice (Opuntia ficus indica L.). International Journal of Emerging Technology and Advanced Engineering, 4 (4): 300-306.

Durán - García, H.M., R. Romero - Méndez, J.L.M.P. Delgado., O. G. García., and C. I.J.Delgado., 2013. Development and construction of an arm tool for nonselective harvest of Alfajayucan type prickly pear. Journal of Food, Agriculture & Environment, 11 (2): 358-362.

Duru, B., and N.Turker., 2005. Changes in physical properties and chemical composition of cactus pear (Opuntia ficus-indica) during maturation. J. PACD. Pp: 22-33.

EAS., 2012. Bulletin of estimates agricultural income. (In Arabic). Economic Affairs Sector (EAS). Ministry of Agric. and Land Reclamation. Cairo. Egypt, (22): 54.

Eliwa, A., 2004. Mechanical remove of prickly pear spines fruit. Misr J.Ag. Eng., 21 (1): 71-85

El-Samahy, S. K., E. A. Abd El-Hady., R. A. Habiba., and T. E. Moussa., 2006. chemical and rheological characteristics of orange-yellow cactus-pear pulp from Egypt. J. PACD. Pp: 39-51.

El – Tahan. Y.H., M.A. Hemeda and M.K. Abd El-Whab., 1991. Economical and management of machines and agricultural equipments. Textbook. (In Arabic). Ministry of Higher Teaching and Scientific Research. El-Moussel Univ. Iraq:Pp:147-157.

FMO., 1975. Fundamental of machine operation. Johan Deere Company , Moline, Illinois. 2^{ed}. USA., Pp: 94-102.

Francis, G.A., C. Thomas., D. O'Beirne., 1999. The microbiological safely of minimally processed vegetables. In. Food Sci. Tech., 34 (1): 1-22

Goycoolea, F. M. and A. Cárdenas., 2003. Pectins from Opuntia spp.: A short review. J.PACD. 17-29.

Hahn, F., 2013. Photovoltaic prickle pear harvesting tool. Natural Resources, 4: 263-265.

Hipolito, O.L., and R.K.Dietnor.,2011. Cissing a cactus: mechanical harvesting of Prickly pear. Engineering & Technology for sustainable world.

Holstein, P., 2009. How to Choose Ergonomic Hand Tools. (Accessed: January 2013).

Hwang, J., J. chang., K. M. Seung., and A. Freivalds., 2011. Design and Assessment of Ergonomics of Hand – Powered Pruning Shears based on gender – specific operating strategy. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 55:1671.

Inglese, P., G. Barbera, T. La Mantia and S. Portolano., 1995. Crop production and ultimate size of cactus pear fruit following fruit thinning. HortScience, 30:227-230.

Inglese, P., 2010. Cactus pear, Opuntia ficus-indica L. (Mill.) for fruit production: an overview. CACTUSNET NEWSLETTER. Special Issue. Improved utilization of cactus pear for food, feed, soil and water conservation and other products in Africa Proceedings of International Workshop held in Mekelle, Ethiopia, 19- 21 October 2009.Pp:82-92.

Konopacka, D., and W.I. Plocharski., 2004. Effect of storage conditions on the relationship between apple firmness and texture acceptability. Postharvest Biol. and Technol., 32: 205-211.

Kunyanga. C.N., S. Strum., S.Graham., J. Sipitiek., and J.K. Imungi., 2009. Physico-chemical methods for preservation of opuntia cactus fruit syrup. African Crop Science Conference Proceedings, 9: 333 – 337.

Lara – López, A., 1992. Mechanical principles for harvesting prickly pears Proc.3rd Annual Texas Prickley Pear Conference, Texas Prickly Pear Council, McAllen, Texas. Pp.26-28.

Marshall, S., 1992. Standard methods for examination of dairy products Amerrican public Health Association (ABHA). Washington DC, USA.

Mobhammer, M.R., F.C. Stintzing and R. Carle., 2006. Cactus pear fruits (Opuntia spp): A review of processing technologies and current uses. J. Prof.Assoc. Cactus Dev., 8: 1-25.

Mohsenin, N. N., 1986. Physical properties of plant and animal materials. Gordon of Breach science publishers, New York.

Mokoboki. K., K. Tsenolo., and M. Ntuwiseni.,2009. Evaluation of cactus pear fruit quality at Mara ADC, South Africa. African Journal of Agricultural Research, 4 (1): 28-32.

Mondragon-Jacobo, C. and S. Perez-Gonzalez., 1996. Native cultivars of cactus pear in Mexico. In Progress in new crops, J. Janick (ed.), ASHS Press, Arlington, Va, Pp. 446-450.

Nefzaoui, A., and M. El Mourid., 2010. Cacatus pear for soil and water conservation in arid and semi- arid lands. CACTUSNET NEWSLETTER. Special Issue. Improved utilization of cactus pear for food, feed, soil and water conservation and other products in Africa. Proceedings of International Workshop, Mekelle (Ethiopia),19-21 October, 2009.117-123.

NIOSH., 2004. Easy ergonomics: a guide to selecting non-powered hand tools. Department of Health and Human Services, (DHHS). National Institute for Occupational Safety and Health, (NIOSH). Publication No.164.

NIOSH., 2011. Practical Demonstrations of Ergonomic Principles. Report of investigations. Department of Health and Human Services, (DHHS). National Institute for Occupational Safety and Health, (NIOSH). Publication No.191.

Ochoa, J., C. Degano., G. Ayrault., and M.E. Alonso., 1997. Evaluation of postharvest behavior in cactus pear (Opuntia ficus-indica L. Mill.). Acta Hort., 438: 115–121.

Reyes. A.J.A., J.R. Aguirre., and H.M. Hernández., 2005. Systematic notes and a detailed description of Opuntia ficusindica (L.) Mill. (Cactaceae). Agrociencia, 39: 395-408.

Rodrriguez - Felix, A., 1991. Postharvest handling of minor fruits in Mexico. Proc. National Symposium on Postharvest physical and Technology of Horticulural Crops in Mexico. Editorial Limusa, Mexico. Pp: 305-310.

Sáenz, C., and E. Sepulveda., 2001. Cactus-Pear Juices. J. Profess. Assoc. Cactus Develop., 4: 3-10.

Sendecor, G.W., and W.G. Cochran., 1989. Statistical methods. 7th, Ed. Iowa State Univ., Press Ames, Iowa, USA., PP: 50.

Stintzing, F.C., A. Schieber., and R. Carle., 2001. Phytochemical and nutritional significance of cactus pear. Eur. Food Res. Technol., 212: 396-407.