RESEARCH ARTICLE

Ergonomic Evaluation of Ergo Refined Fruit Harvester

Manikandan G[1*] and Anantha Krishnan D[2]

[1*& 2] Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore- 641 003

ABSTRACT

The conventional type of fruit harvesting causes drudgeries and workers face many musculoskeletal problems. Wrist pain, shoulder pain, and neck pain were the main problems reported by fruit harvesting workers. The present study aimed to valuate ergo refined fruit harvester. The results revealed that laboratory test proved that 3 mm blades required minimum cutting force compared to 2 and 5 mm. also, the combination of 30º bevel angle with 3 mm blade gave the minimum cutting force of mango, sapota, and guava for 1240.35, 340.00, and 400.25 N. Fruit harvester was made with high strength light weighing 1620 g. The fruit harvester helped reduce the stresson workers and reduce the body pain and musculoskeletal problems of fruit harvesting workers. The field evaluation showed that new models of ergo refined fruit harvesters N_1, N_2, and N_3 reduced the energy expenditure by 20%, 14%, and 18%, respectively. In the case of oxygen consumption as a percentage of VO_2 max, the ergo refined fruit harvesters N_1, N_2, and N_3 showed a reduction of 21%, 9.4%, and 12% respectively. According to ΔHR result, it was observed that the ergo refined fruit harvesters N_1, N_2, and N_3 showed a reduction of 25%, 12%, and 14%, In the case of ODR, it was 11%, 15%, and 17% respectively. The BPDS score also indicated a 12% to 23% reduction from the conventional type fruit harvesters. The above result confirmed that the N1 model fruit harvester performed better than others.

Keywords: *Ergonomics; Fruit harvester; Overall discomfort rating; Energy cost; AWL, LCP; BPDS*

INTRODUCTION

Fruits, fresh or dried, have been the natural staple diet of humans since ancient times. Fruits are consumed in raw and ripe form. Cooking fruits is normally avoided as there will be a loss of nutrients and carbohydrates. It is ideal to eat one kind of fruit at a time. Many prefer to take fruits for breakfast with milk. Mango, sapota, and guava are the major fruit grown and consumed in Tamil Nadu. Fruits are harvested by conventional type fruit harvesting. They are shaking the tree manually, climbing it manually, and pushingfruits from the bottom using a local device. The conventional type of fruit harvesting causes drudgeries and workers face many types of musculoskeletal problems. Wrist pain, shoulder pain, and neck pain were the main problems reported by fruit workers. Because of these problems, an ergonomic study was conducted on fruit harvesting operations with various conventionally available harvesters. Three ergo refined fruit harvesting tools were developed which would help to reduce the drudgery of a worker. It improved the efficiency of the fruit harvesting operations.

Corresponding author mail id: kandan.mani15@gmail.com

The fruits are harvested by shaking the tree manually or by plucking the fruits manually by climbing the tree. The fruits are allowed to fall on the ground and then picked up. This causes internal injury to the fruits and subsequent spoilage during ripening. The fruit is held between the frame and the pole and gets detached while pulling the harvester (Gowda *et.al* 1995). A investigated the drudgery reduction using scientifically designed mango harvesters over conventional methods. They evaluated the UAS model and IIHR model fruit harvesters. The local model harvested fruits without pedicel resulted in oozing out of sap thereby reducing the shelf life and had a high percentage of damage to fruits as they were dropped to the ground, whereas the UAS model was said to have a weak net with higher drops and harvested fruits without pedicel and pulled the branches with high chances of breakage. The IIHR model was observed to be slightly heavy and difficult to harvest fruits from high trees, but harvested fruits with pedicel, thereby increasing the shelf life of the fruit. IIHR model was comparatively highly suitable for harvesting the fruits for export Savita *et al*., (2010). Designed pepper plucking equipment to facilitate pepper harvesting. It increased productivity and flexibility. It improved the safety of the worker and allowed workers to harvest more independently Rahul M. *et al*., (2012). Designed a black pepper harvester. They reported that three models of pepper harvester were fabricated and evaluated based on efficiency in the cutting action and easiness in operation. All three models basically consisted of a mild steel cutting unit, aluminium conveying pipe, and a collecting basket. The main concepts adopted for the fabrication were impact, shear, and pulling action for the proper insertion and cutting of the spikes and collection Aneeshya *et al*., (2013).

MATERIAL AND METHODS

Crop parameters

Major crop parameters that influence the harvesting of fruit include height of the tree, pedicel diameter, fruit size, and fruit weight. The trees of common fruit crops viz., Mango, Sapota, guava were randomly selected for the measurement of different crop parameters.

Harvesting tool parameters

Major parameters affecting the performance of the fruit harvesters are the dimensions of the pole, basket, blade, and weight of the tool. The dimensions include the length, diameter, and wall thickness of the pole, diameter of the opening of the collection basket, length, thickness, and bevel angle of the cutting edge of the blade.

Five models of the commercially available conventional fruit harvesters *viz*., scissor type harvester (H_1), 'V' knife harvester with cotton net basket (H_2), 'V' knife harvester with star wheel catcher and nylon basket (H_3), harvester with MS rod collector (H_4) and harvester with bottle shape collector (H_5) were selected and all the major parameters affecting the performance of the fruit harvesters were measured. The conventional fruit harvesters are shown in Figure 1.

Anthropometric criteria used in fruit harvesting tool design

Human parameters *viz*., anthropometric data have to be considered in the design of fruit harvesting tool and the way in which it is used decides the performance of the tool. All pertinent anthropometric data were taken from "Anthropometric and strength data of Indian agricultural workers for farm equipment design" (Gite *et al*., 2009), published by CIAE, Bhopal. Important anthropometric data used for the design and their definitions are given in Table 1.

Development of fruit harvester for anthropometric data

The fruit harvester is developed based on anthropometric data. It is consist of a telescopic pole, telescopic lock pin, chute, and cutting blade. The developed ergo refined fruit harvesters are shown in Figure 2.

a. Telescopic pole

The telescopic assembly features two concentric aluminium poles. Also, this telescopic assembly has a retracted length of 1372 mm while extended this pole reaches 2743 mm. This retraction and extension features were provided to vary the height according to the height of the bearing of fruits and the user. The base diameter of this assembly is 24 mm while the top telescopic pole diameter is 22 mm. We can fix the pole height at five different positions with 21 mm differences between heights.

b. Telescopic lock pin

The fruit harvester has a telescopic assembly that sets the harvesting pole at different heights. The telescopic lock pin contains a spring-loaded pin and pressing the lever. With the help of a lock pin and lever, the height of the pole can be retracted or extracted according to the height of the fruit in the tree.

c.Chute

The chute is provided for catching the harvested fruits and transferring them to the ground level without damage with easy handling. Chute design is a novel approach to ing problems like collapsibility and durability concerns. Chutes are designed so that they would not entangle in between tree branches and at the same time not add too much weight to the fruit harvester assembly. Based on the physical parameters of the fruits such as weight, size, and shape, the material and dimensions of the chute were selected.

d. Cutting blade

The fruit harvester must retrieve the fruit by means of cutting the fruit pedicel off from the tree branch. During the preliminary design phase, the design was urged to use off-the-shelf shears to eliminate any possible lead time and complications that would arise when attempting to design a shearing feature.

Ergonomic evaluation of the fruit harvesting operations

Ergonomic evaluation of the fruit harvesting operations was conducted to assess their suitability with the selected five subjects. The evaluation was carried out in terms of the following parameters.

i. Heart rate (HR) and oxygen consumption rate (OCR)
ii. Energy cost of operation
iii. Acceptable Work Load (AWL)
iv. Limit of Continuous Performance (LCP)
v. Overall Discomfort Rating (ODR)
vi. Overall Safety Rating (OSR)
vii. Overall Ease of Operation Rating (OER)
viii. Body Part Discomfort Score (BPDS)

RESULTS AND DISCUSSION

The evaluation of conventional type cutting blades showed that 2, 3 and 5 mm blades were commonly available in the market. Laboratory tests proved that 3 mm blades required minimum cutting force compared to 2 and 5 mm. Also, the combination of a 30º bevel angle with a 3 mm blade required minimum cutting force of mango, sapota, and guava for 1240.35, 340.00, and 400.25 N. Hand grip of the harvesting tool was fixed as 30 mm based on anthropometric data available in anthropometric data book prepared by CIAE Bhopal. Fruit harvester was made of a light aluminium pole weighing 1620 g. The fruit harvester helped reduce the stresson workers and reduce the body pain and musculoskeletal problems of fruit harvesting workers. Ergonomically comparison of conventional type fruit harvesting with ergo refined fruit harvesters results shown in Table 2. The ergo refined fruit harvesters were evaluated in the field Figure 3.

The comparison between the conventional type fruit harvester and the ergo refined model fruit harvester shows that the ergo refined model fruit harvester gives better performance. N_1 (New model I) performs better among these new models. The new model I (N_1) has less weight compared to other models.

The field evaluation showed that new models of ergo refined fruit harvesters N_1, N_2, and N_3 reduced the energy expenditure by 20%, 14%, and 18% respectively. In the case of oxygen consumption as a percentage of VO_2 max, the ergo refined fruit harvesters N_1, N_2, and N_3 showed a reduction of 21%, 9.4%, and 12%, respectively. According to ΔHR result, it was observed that the ergo refined fruit harvesters N_1, N_2, and N_3 showed a reduction of 25%, 12%, and 14%, In the case of ODR, it was 11%, 15%, and 17% respectively (Figure 4 & 5). The BPDS score also indicated a 12% to 23% reduction from the conventional type fruit harvesters. The above result confirmed that the N1 model fruit harvester performed better than others.

H1 H2 H3 H4 H5

Figure 1. Different conventional fruit harvester

N1 N2 N3

Figure 2. Ergo refined fruit harvester

Figure 3. Ergo refined fruit harvesters were evaluated in the field

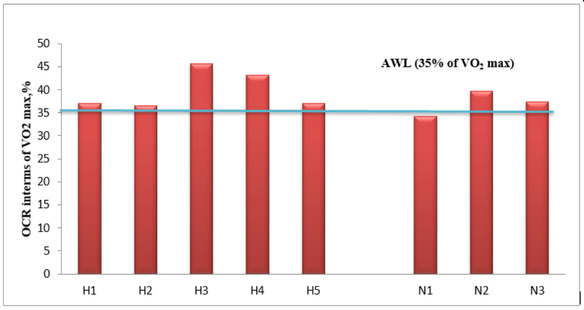

Figure 4. Mean oxygen consumption rate in terms of VO2 max of selected subject for fruit harvesting operation

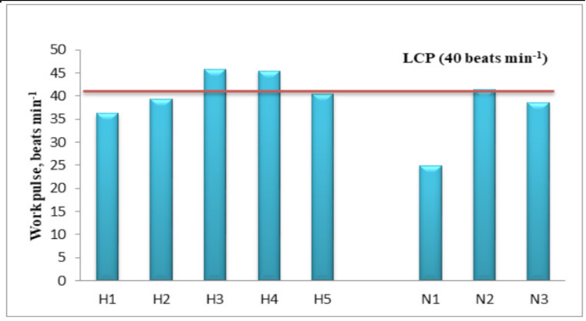

Figure 5. Mean work pulses of selected subject for fruit harvesting operation

Table 1. Human parameters required for the design of fruit harvester tool

S.No	Parameter	Percentile values		Range of values		Mean
		5th	95th	Maximum	Minimum	
1	Vertical grip reach, mm	1856	2126	2251	1703	1991
2	Hand length, mm	164	197	214	148	181
3	Grip diameter (inside), mm	43	56	62	37	49
4	Hand breadth across thumb, mm	86	111	135	74	72

Table 2. Ergonomically comparison of conventional type fruit harvesting with ergo refined fruit harvesters

Harvesting operation using different harvesters	The mean heart rate, beats min-1	VO2, l min-1	Energy expenditure, KJ min-1	Oxygen consumption rate as percent of VO2 max (%)	Acceptable workload (35% VO2 max)	ΔHR beats min-1	LCP 40 beats min-1
i.	Conventional type fruit harvesters						
H1	104	0.92	19.2	34.8	>AWL	36.2	<LCP
H2	103	0.91	19.0	34.1	>AWL	39.4	<LCP
H3	115	1.14	23.8	43.6	<AWL	45.8	>LCP
H4	112	1.08	22.5	41.1	<AWL	45.4	>LCP
H5	104	0.93	19.4	34.8	> AWL	40.4	>LCP
i.	Ergo refined model fruit harvesters						
N1	100	0.70	14.6	31.7	<AWL	24.8	<LCP
N2	107	0.99	20.6	37.3	>AWL	41.4	>LCP
N3	104	0.93	19.4	34.9	<AWL	38.6	<LCP

CONCLUSION

This study was taken up to reduce the musculoskeletal problems and energy expenditure in fruit harvesting. This study includes the investigation of different crop parameters of fruit trees, tool parameters, cutting energy required for cutting the fruit pedicel with a different blade, evaluation of the conventional method of fruit harvesting, refinement of conventional fruit harvesters, and evaluation of the ergo refined fruit harvesters. The field evaluation showed that new models of ergo refined fruit harvesters N_1, N_2, and N_3 reduced the energy expenditure by 20%, 14%, and 18% respectively. In the case of oxygen consumption as a percentage of VO2 max, the ergo refined fruit harvesters N_1, N_2 and N_3 showed a reduction of 21%, 9.4% and 12% respectively. According to ΔHR result, it was observed that the ergo refined fruit harvesters N_1, N_2 and N_3 showed a reduction of 25%, 12% and 14%, In the case of ODR, it was 11%, 15% and 17%, respectively. The BPDS score also indicated a 12% to 23% reduction from the conventional type fruit harvesters. The above result confirmed that the N_1 model fruit harvester performed better than others.

Funding and Acknowledgment

The authors would like to thank professor Dr. Anantha Krishnan D, Dr. Prabhu, Farm Machinery workshop, AEC & RI, TNAU, Comibatore and HC & RI, TNAU, Coimbatore a for providing mango orchard for field trail.

Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Originality and plagiarism

This is original research work and any work and/ or words of others, have been appropriately cited.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content

Data availability

All the data of this manuscript are included in the MS. No separate external data source is required. If anything is required from the MS, certainly, this will be extended by communicating with the corresponding author through corresponding official mail; usiva@ tnau.ac.in.

Author contributions

Research grant-US,Idea conceptualization-US, Experiments- GM, MVR, ST ,Guidance -US, ST,IM, Writing original draft - GM, MVR, IM, ST, Writing-reviewing &editing -US, IM , ST

REFERENCES

Agrawal, K. N., R. K.P. Singh and K.K. Satapathy. 2010. Anthropometric Considerations for Farm Tools/Machinery Design for Tribal Workers of North Eastern India. Agricultural Engineering International: the CIGR Ejournal. Manuscript MES 1406 Vol. XII.

Aneeshya K S K *, G K Krishnanunni and V Ganesan, 2013. Development of a black pepper harvester. Journal of Spices and Aromatic Crops, Vol. 22 (2) : 127–130.

Daulat Hussain, Murshed Alam and Md. Akhtar Hussain. 1991, Mango harvesting Techniques in Bangladesh. Agricultural Mechanization In Asian, Africa, and Latin America 1991 Vol.22 No.1

Gite, L. P., J.Majumder, C. R. Mehta and Abijit K. 2009. Anthropometric and strength data of Indian agricultural workers for farm equipment design. Coordinating cell AICRP on Ergonomics and Safety in Agriculture, CIAE Bhopal.

Gowda, S.J., et.al 1995. Comparative evaluation Mango harvesting techniques. Abstract of National Seminar on Post harvest technology of fruits, Phala Samskarana –'95, UAS, Bangalore, Aug. 7-9,5.

Rahul M., Prakash V. Unakal, Gopinath C. 2012. Design and Development of a Pepper Plucking Equipment to Facilitate Pepper Harvesting. Department of Design, M. S. Ramaiah School of Advanced Studies, Bangalore 560 058.

Savita, S.M., K.N. Srinivasappa*, S.V. Suresha**, B.G. Vasanthi*, G.M. Anand*, G.M.Sujith*, 2010. Drudgery reduction using scientifically designed mango harvesters over conventional methods. Krishi Vigyan Kendra, Hadonahaili – 561 205.