Analysis of human energy expenditure in harvesting sugar palm (Arenga Pinnata Merr) in Malaysia

Zakiah Yusof[1], Darius El Pebrian[2*]

(1. Faculty of Plantation and Agrotechnology,Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia;
2. Faculty of Plantation and Agrotechnology,Universiti Teknologi MARA Melaka, 77300 Merlimau, Melaka, Malaysia)

Abstract: Sugar palm (Arenga pinnata Merr) is an indigenous plant in Malaysia, which has a great potential to be expanded into large scale plantation crop for the production of sugar and other sugar-based products. Until today, harvesting of sugar palm tree is a laborious operation, without application of any mechanization systems. It takes the largest demand for labor and time spent in the sugar palm cultivation. The main objective of the study was to investigate human energy expenditure in harvesting sugar palm in Malaysia. Workers' workload and productivity in harvesting sugar palm were also analyzed. Relevant physical properties of sugar palm tree, heart rate, and human energy expenditure and worker productivity as well as in harvesting sugar palm were recorded and analyzed. The results showed that the highest mean time of 206.67 seconds or 79.57% of the total time was spent for tapping sap. Climbing down and climbing up were the least time consuming tasks in harvesting sugar palm with a mean time of 25.67 seconds and 27.42 seconds, or 9.89% and 10.57% of total time, respectively. The highest average heart rate of 101.94 beats/min was found when the worker harvesting the sugar palm in the evening times, and the lowest rate of 100.25 beats/min/man was in the morning time. The estimated human energy expenditure for harvesting sugar palm was 2.9 kcal/min and 3.1 kcal/min in the morning and the evening times, respectively. The average field capacity of a worker in the harvesting sugar palm operation was in the range of 20 to 21 palms/h. The most convenience age of the workers to harvest sugar palm was in the range of 20 to 29 years old. Implementation mechanized harvesting of sugar palm is recommended in order to improve the productivity of workers and reduce the human energy expenditure.

Keywords: sugar palm, human energy, environment, farm mechanization, plantation crop

Citation: Yusof, Z., and D. El Pebrian. 2016. Analysis of human energy expenditure in harvesting sugar palm (Arenga Pinnata Merr) in Malaysia. Agric Eng Int: CIGR Journal, 18(1):149-157.

1 Introduction

Sugar palm (*Arenga pinnata Merr*) is an indigenous plant in Malaysia and grows productively. The crop is commonly grown on a small scale and scattered from several single trees up to several hectares of trees. The plant was known for its economic values because almost all elements of plant are valuable for human life. Besides production of palm sugar, vinegar, alcohol drink, sweet sap and other sugar-based products, the sugar palm tree has a huge uniqueness as compared to other trees (Ticoalu et al, 2011; Banhard, 2007; Effendi, 2010; Martini et al, 2011). By having its deep roots, the plant can be grown on steep, almost vertical, slopes and offering protection against erosion. The plant needs little water and it is fire-resistant. It is also resistant to pest and needs no fertilizer to grow. Its presence in forestry also enhances the soils (Smith, 2011).

As one of the native areas of palm sugar and its economic values, Malaysia has a great potential to expand the plant into large scale cultivation for the production of sugar and other sugar-based products for conversion into bioethanol. Furthermore, it can be cultivated to be a complementary industrial crop for the existing plantation industry crops such as oil palm and rubber.

Among the important operations in the cultivation of sugar palm is harvesting sap or tapping sap. Generally,

Received date: 2015-08-10 **Accepted date:** 2015-11-19
***Corresponding author: Darius El Pebrian,** Faculty of Plantation and Agrotechnology Universiti Teknologi MARA Melaka, 77300 Merlimau, Melaka, Malaysia, Tel: +6062645792; Fax:+6062645248e-mail: darius@melaka.uitm.edu.my

tapping of the sugar palm sap begins after 7 to 10 years when the palm has matured and the first inflorescence develops. Currently harvesting sap of sugar palm tree is done manually in a traditional manner. Samudra (2011) stated that the harvesting sap comprises of four activities, namely tapping preparation, knocking the inflorescences, cutting off the inflorescences, and tapping the sap. Tapping preparation involves placing the bamboo ladder for climbing the tree, cleaning the stem from any fibers and dirt materials and removing the fronds. Once this preparation is ready, the worker climbs the tree and at the peak he knocks the matured inflorescence before tapping the sap. Knocking activity is initiated at the tip inflorescence to its base and vice versa by using a piece of wood. It will be useful in enlarging the pores of inflorescence and softening its bunch to ease the flow of the tapped sap. Cutting off the inflorescence is made by using a knife. Prior of cutting, a small tank or bamboo container is hung nearby the inflorescence to accommodate the flow of the tapped sap. A specialized designed pulley and rope is placed close to the location of the tapped inflorescence to enable in lowering the container into the ground for infield transportation.

Kusumanto (2008) stated that tapping sap of sugar palm tree consumes the largest demand for labor in the sugar palm cultivation. The skilled workers are needed in harvesting the sap since he has to climb a tree up to 30 m height using a bamboo ladder and assisted with simple hand tools to tap the sap. For each tree, a worker must climb up and go down for 4 times to complete harvesting operation. If a worker is assigned to harvest 100 sugar palm trees a day, meaning that he must perform a total of 400 times climbing up and going down the trees. These works are very tedious and tiredness to the worker. Furthermore, the tree climbing operation can be dangerous if executed with improper procedures. Lack of awareness during climbing may cause in the falling of worker from the tree. On the other hand, these workers have to work under very difficult working condition due to the harsh field environment.

Numerous studies have been revealed in the research literatures to evaluate human energy in agricultural operations. Nag et al. (1980) and Nag and Dutt (1980) studied the heart rates of paddy farmers while plowing with animal-drawn wooden plows in wetlands, broadcasting fertilizer, transplanting, harrowing with a sickle, spraying pesticides, threshing rice, and winnowing. Schertz (1967) observed the human energy consumed by citrus pickers in general picking, ground zone fruit picking, ladder zone fruit picking, and carrying and setting the ladder to quantify the physiological efforts. Yadav and Srivastava (1984) described worker heart rates during harvesting of sugar cane with various knives. Harinder and Kaul (1972) assessed the human energy expenditure of workers in spading, spraying, and some manual methods of load transportation. Brun et al. (1979) reported the human energy expenditure of workers completing various agricultural tasks in Iran. Tewari et al. (1991) evaluated three commonly used weeding devices in India with respect to performance, grade of work, and workers’ comfort. Ghugare et al. (1991) estimated the ergonomics of a lever-operated knapsack sprayer that is commonly used by Indian farmers. Nawi et al (2012) studied human energy expenditure in lowland rice cultivation in Malaysia. Pebrian et al (2014) reported on workers workload and productivity in oil palm cultivation in Malaysia. Gandhi et al. (2009) investigated about harvesting of pearl millet cobs by farm women. Grimsby et al., (2012) evaluated human energy expenditure on in Jatropha oil production.

Currently, no data are presented on the human energy expenditure for the sugar palm harvesting operation in Malaysia. The available data reported in the research literature from previous studies are seen from other crops harvesting. Thus, there is a need to formulate a comprehensive and systematic field data of sugar palm harvesting operations. It is hoped that, the data can be applied to assist the implementation of an appropriate mechanization program for benefits for the worker safety and health, productivity. This study investigates the human energy expenditure in completing the sugar palm harvesting operation based on the current demographics data of the farmers. Workers' workload the basis of heart rate and human energy expenditure were analyzed. Besides that, productivity of worker during harvesting was also calculated. Finally, a mathematical modelling to for predicting human energy for sugar palm harvesting operation was formulated.

2 Materials and methods

2.1 Data collection of the materials

The comprehensive data collection on the common operations in the sugar palm harvesting operation was carried out in the month of March and April 2013 at four locations namely, Kg Peruang, Kg Chat, Kg Kekabu and Kg Tualang Padang, district of Kuala Lipis, Pahang State, Malaysia. The chosen location is one of the largest sugar palm planted areas in Peninsular Malaysia and could be represented as one of the ideal planted areas for this crop in the country. This place is situated about 75 m above sea level. The data collection exercise was carried out in the month of March and April 2013. A total of 33 productive sugar palm trees at height from 2.09 m to 14.45 m were harvested by the subjects during the study. Table 1 lists the physical characteristics of the harvested sugar palm trees. The sugar palm harvesting operation consists of the following tasks namely, climbing up (Figure1), tapping sap (Figure2) and climbing down (Figure 3).

Table 1 Physical characteristics of sugar palm trees

Physical characteristics	Mean ±SD
Diameter of trunk,m	1.32±0.11
Maximum plant height,m	7.88±3.16

Figure 1 Climbing up sugar palm tree

Figure 2 Tapping sugar palm tree

Figure 3 Climbing down sugar palm tree

A total of 16 experienced and healthy farmers from 24 to 62 years of age and with 2 to 35 years of work experience participated in the study. The subjects represented about 90 percent of population of sugar palm farmers in the study site, and they have been acclimatized with the experimental protocols in order to obtain their fullest cooperation. Anthropometric data on the subjects were measured and recorded as listed in Table 2. Body mass index (BMI) of subjects was in the range of 20.7 to 28.7 kg/m^2. About 62% of the subjects were married. Male farmers were around 94 percent of the subjects. Approximately 44% of the subjects were smokers. Around 69% of subjects had working experience less than 20 years, while the rest with more than 20 years. During the data collection, the recorded average ambient temperature was 29 ℃ and average relative humidity was 84%. The average wind speed was 4 km per hour.

Table 2 Anthropometric data of subjects involved in harvesting sugar palm

Variable	Mean ±SD
Age,years	41 ±12
Weight,kg	65 ±11
Height,cm	168 ±8
Body mass index,kg/m^2	23±2.83

The heart beat rates and human energy of the subjects while performing the respective tasks was recorded with a Polar RCX800 Heart Rate Monitor (Polar Electro, Oulu Finland). This instrument consists of heart rate transmitter and a wrist receiver. This instrument detects heart beats of the subject. Its transmitter part then picks up the signal on the subject chest and then conveys the signal containing heart rate data to the wrist receiver, which displays and stores the data. Besides, known globally for its durability and accuracy, the Polar heart rate monitor is purposely chosen for data collection on this study since this wearable device is also convenient and uncomplicated to be used for direct heart rate measurement of the subject working on outdoor and challenging field such as sugar palm plantation. With its special features and design, the Polar heart rate monitor is comfortable to be attired on the farmers' bodies even though they have to do a lot of body movements when working on harsh environments. Furthermore, Polar heart rate monitor was also considered as one of the reliable instruments to be used for recording the heart rate and other exercise data such as human energy expenditure**.** The error rate of measurements using this instrument is very small. According to the previous studies reported by Gamellin et al (2006), Kingsley et al (2005) and Ruha et al (1997), the error rate in detection of R-waves for Polar compared with the ECG system was 0.32% to 2.8%.

All the heart rate measurements for every single task involved in harvesting operation were made twice a day e.g. at 7.00 am in the morning times and 3.00 pm in the evening times. Each subject was instructed to perform the given task for 2-hours duration to ensure uniformity in the measured data. Before using this device, the Polar hear rate monitor was manually calibrated to improve the accuracy of measurements. The data on age, height, weight, BMI, gender, activity level, predicted maximum heart rate, resting heart rate, ambient temperature and maximal oxygen intake (VO2max) of individual subject were entered and saved into the instrument. The predicted maximum heart rate of subjects was determined by using the commonly used formula: 220- subject age. All these data are used by the Polar instrument to automatically calculate the energy expenditure of each subject. Once the calibration completed, the subjects were asked to stay relaxed for about 15 minutes and do not engage to any physical activity to record their resting heart rate before performing the task. Downloading the stored data in the wrist receiver of the subjects into a computer at the laboratory with Polar ProTrainer 5™ software for post processing was conducted once the field data collection completed. The time spent to complete each task in the sugar palm harvesting was also recorded using a digital stop watch. The area covered by subjects for the operations were measured using a measuring tape. Body mass and height was measured by using weighing scale and measuring tape, respectively. Computation of the recorded heart rates and estimated energy expenditures of the subjects involved in each operation were formulated by dividing the sum of the measurements by the number of workers involved in each task. The mean increase in heart rate was determined by deducting the recorded resting heart rate of subject from the recorded average heart rate of subject during performing the tasks. Computation of human energy expenditure per hour was made by dividing the subject's estimated energy expenditure by the time. The workers productivity in sugar palm harvesting operation per hour was calculated by dividing the subject's total harvested sugar palm trees by the time.

2.2 Data Analysis

Microsoft Excel histogram was used to understand the relationship between paired variable of demographic data and human energy expenditure in the sugar palm harvesting operation. The Analysis of Variance (ANOVA) of the statistical analysis produced in SAS ver. 6.12 software were employed to determine the mean effects of time taken for harvesting, average in heart rate, mean increase in heart rate, human energy expenditure and worker productivity. Whenever there was a significance value, Duncan's multiple range test (Duncan, 1955) was used to statistically compare mean values of the time taken for harvesting, average in heart rate, mean increase in heart rate, human energy expenditure and worker productivity. Relationship between energy expenditure with average heart rate mean increase in heart rate, worker productivity and plant height were also studied. Finally, a mathematical model of human energy expenditure for harvesting sugar palm was developed.

3 Results and discussion

The farmers were categorized into five (5) groups e.g. 20 to 29, 30 to 39, 40 to 49, 50 to 59 and 60 to 69 years old based on their demographics data. Figure 4 shows that the farmers within age's group of 20 to 29 years old expensed the highest human energy expenditure with an average of 3.28 kcal/man. On contrary, the farmers within age groups of 60 to 69 years old took the lowest human energy expenditure with an average of 0.83 kcal/min. The farmers within the age group of 20 to 29 years old are the youngest among the whole groups. Thus, they have high level of fitness and maximum strength and power to complete the task quicker as compared to others group. Despite, this group had lesser skill and experience in tapping sugar, nevertheless with the high level fitness, strength and power, they were able to harvest faster and hence note the largest number of harvested sugar palm per day. This agrees with William (2015), who states that the human energy expenditure depends on metabolic rate. He said that the most important factor affecting the metabolic rate is the intensity or speed of the exercise. Generally, performing exercise with faster movement, human muscles must contract more rapidly, consuming proportionately more energy. Miles (1942) and Smil (1994) also stated that the age is one of factors that determine human energy outputs. Normally, a group of young men can be expected as a group that has greater strength of swiftness and movement compared to the old men.

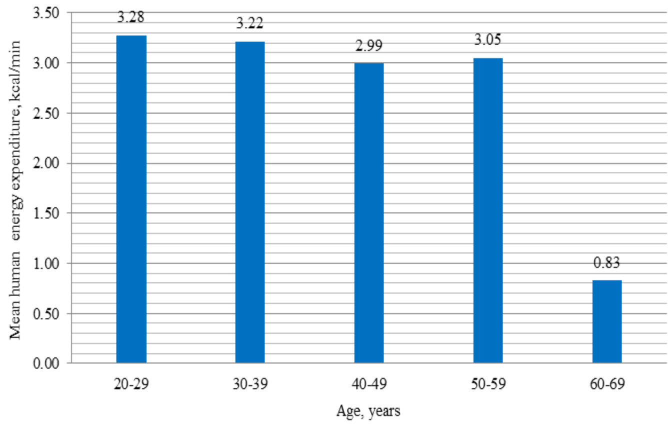

Figure 4 Mean human energy expenditure versus subjects' age

Figure 5 shows that the energy expenditure was affected by the skill and experience of farmers in completing task. Even though they are getting older, the experienced farmers can use an efficient energy as compared to the beginning farmers. The farmers having more than 20 years' experience consumed 3.2 kcal/min of energy or which was 16.63% higher as compared to 2.7 kcal/min of energy required by farmers with experience more than 20 years. Again, even though most of subjects with less than 20 years' working experience were young, energetic and productive in complete the task. However, being the beginning farmers, they frequently misuse a lot of energy due to lacking of experience, whereas one who is more skilled may tap the sugar palm with less effort, saving calories when taping the sugar palm in a given time. Conclusively, working experience influences the skill and how much human energy was consumed. This is in accordance with Williams (2015), who says that there are some other important considerations, although the intensity of the exercise is the most important factor affecting the magnitude of the metabolic rate. In some activities the increase in energy expenditure is not directly proportional to speed, for the efficiency of movement will affect calories expenditure.

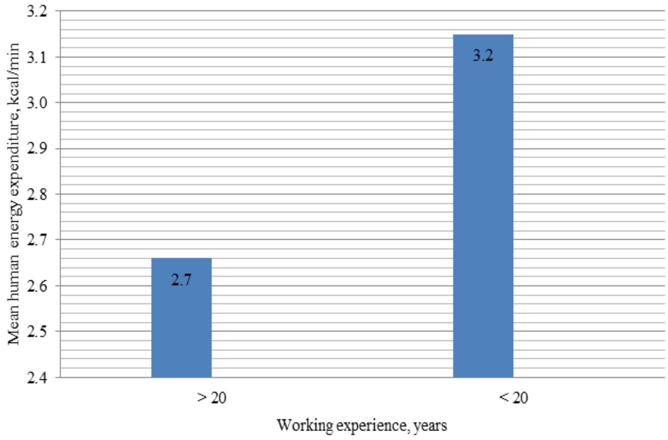

Figure 5 Mean human energy expenditure versus subjects' working experience

Based on marital status as presented in Figure 6, it shows that the unmarried farmers used lesser energy during harvesting sugar palm. The married farmers consumed 2.8 kcal/min of energy or 15.15% lower as compared to 3.3 kcal/min of energy required by unmarried. Marital status could influence energy expenditure. As stated by Gove (1973) and Gove et al (1983), the married people, especially for men are more likely to be healthy than those unmarried. Referring to this statement, it can say that generally married farmers were psychological and physiological well-being people. Under this better condition, the married farmers are highly motivated and feeling happier, more steady and calm to works. Hence, they managed to use lesser effort and save more calories than that of the unmarried.

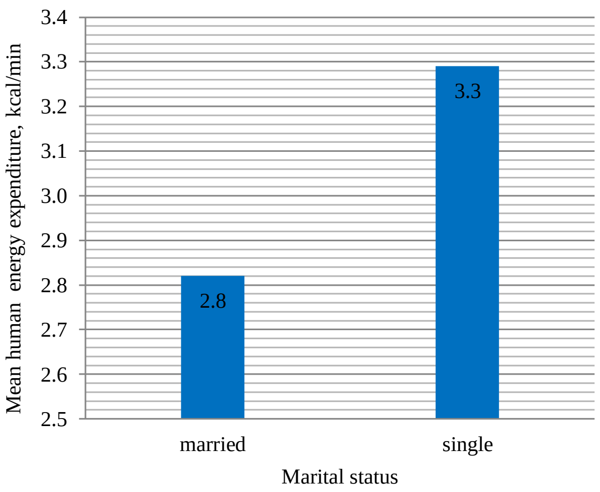

Figure 6 Mean human energy expenditure versus subjects' marital status

Based on the farmers' gender, the female farmers spent about 4.7 kcal/min of energy to complete the task or 38.29% higher as compared to 2.9 kcal/min of energy required by male farmers as indicated in Figure 7. Higher consumption of energy by the female farmers was due to differences in metabolic rate and physical characteristics such as body strength and physical fitness.

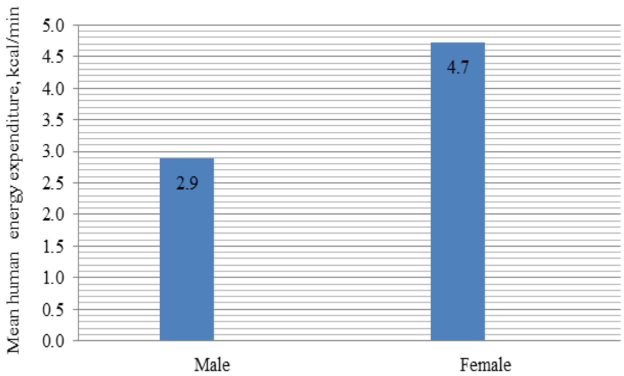

Figure 7 Mean human energy expenditure versus subjects' gender

Figure 8 shows that the percentage and energy consumed by farmers to climb was different with the different of palm height. Physical characteristics of sugar palm such as palm tree height and number of palm trees was closely related to the human energy consumption because harvesting sugar palm was conducted manually. The higher the palm tree requires the more energy for climbing up on it. Climbing up a palm tree with more than 10 m height required about 3.1 kcal/min of energy or 3.22% higher than that of the palms with less than 10 m height. This due to the distance for climbing up and down for taller palm was longer than that shorter ones. The distance of conducting an activity affects the human energy expenditure as reported by Williams (2015).

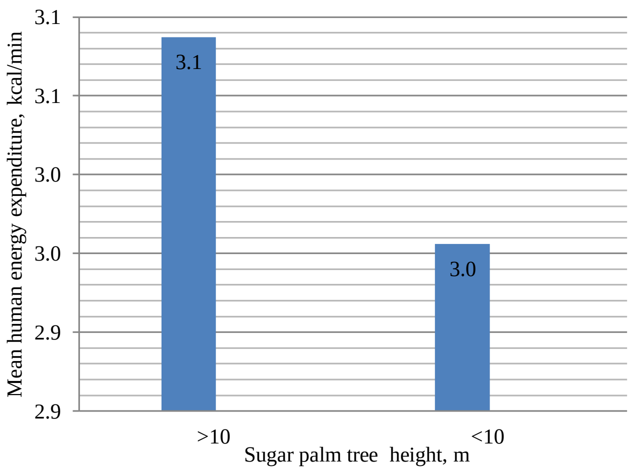

Figure 8 Mean human energy expenditure versus sugar palm tree height

Table 3 shows breakdown of average time of the subjects carrying out the individual task during harvesting operation. The task showing the highest duration proportion was considered as the most time consuming task. Duncan Multiple Range Test (DMRT) was used to statistically compare mean values of the time required for individual activities. Tapping task took mean time of 206.6 seconds/palm or 79.57% of total time was considered as the most time consuming task in harvesting sugar palm operation. During tapping, the subjects have to perform several sub-tasks such as knocking the stalk using wooden stick, changing the plastic jar for palm juice secretion, slicing the male inflorescences stalk and finally covering the plastic jar with clothed to avoid from the contamination. Also, the subject had to perform these sub-tasks by using simple hand tools or equipment that involved a lot of body movements. There were no significant differences in mean time of climbing up and climbing down. These two tasks, climbing up and climbing down were the least time consuming task in sugar palm harvesting with mean time of 25.67 seconds/palm and 27.42 seconds/palm or 9.89% and 10.57% of total time, respectively.

Table 3 Breakdown of mean time in harvesting sugar palm

Task	Mean, s/palm	Proportion of total time, %
Climbing up	27.42a	10.57
Tapping	206.67b	79.57
Climb down	25.67a	9.89
Total	259.48	100

Note: Means with the same letter are not significantly different at 0.05 probability level using Duncan Multiple Range Test (DMRT)

Table 4 shows that there were no significant different on the worker's productivity, mean increase in heart rate, and human energy expenditure when harvesting in the morning and evening times. This is because the task of climbing up was done on the early morning times, while climbing down on was the late evening times. During the times, the temperature is still at moderate level so that it did not give significant effects to physical performance of humans. This agrees with Nybo et al (2001) who states that physical performances of humans are affected by temperatures. The average human energy expenditure for harvesting in the morning and evening times could be categorized as a light operation. This is because the average human energy expenditure for harvesting on both periods was 3 kcal/min/man and falls into light work category based on Christensen (1953). From the field observation and personal communication with farmers, they felt comfortable climbing up the purposely cultivated sugar palm trees rather than the wild ones from the aspects of time, safety and energy requirement. However, they said most of purposely cultivated sugar palm trees cannot be harvested due to unproductive.

Table 4 Average heart rate, mean increase in heart rate, worker productivity and human energy expenditure in harvesting sugar palm

Harvesting time	Average heart rate ,beats/min	Mean increase in heart rate ,beats/min	Worker productivity ,palms/h	Human energy expenditure, (kcal/min
Morning	100.25a	36.05a	20.52a	2.9a
Evening	101.94a	33.15a	20.00a	3.1a

Note: Means with the same letter are not significantly different at 0.05 probability level using Duncan Multiple Range Test (DMRT)

A mathematical model was developed for predicting human energy expenditure in sugar palm harvesting. The variables to be considered in the multiple linear regression analysis for human energy expenditure (EET) of subjects were average heart rate (AVHR) and mean increase in heart rate (MINHR), and worker productivity (WP) as in Equation (1). The correlation analysis of the selected variables with EET for sugar palm harvesting operation is presented in Table 5.

$$EE = -8.095 + 0.105\ (AHR) + 0.019\ (IHR) + 0.088\ (WP) - 0.107\ (H) \quad R^2 = 0.816 \qquad (1)$$

Where:

EE = Human energy per unit time for harvesting operation, kcal/min

AHR = Average heart rate, beats/min

IHR = Mean increase in heart rate, beats/min

WP = Worker productivity, palms/h

H = Palm height, m

Table 5 Correlation matrix for heart rate and human energy expenditure for sugar palm harvesting.

Parameter	1	2	3	4	5
1. Energy expenditure (EE)	1.000				
2. Average heart rate (AHR)	0.827**	1.000			
3. Mean increase in heart rate (IHR)	0.471**	0.444*	1.000		
4. Worker productivity (WP)	0.079	-0.247	0.038	1.000	
5. Plant height (H)	-0.163	0.126	0.044	-0.274	1.000

Note: * Correlation is significant at 0.05 probability level
** Correlation is significant at 0.01 probability level

The analysis from the correlation matrix in Table 3 indicated that some variables have very strong relationship. The strongest and positive relationship was between energy expenditure and average heart rate (r=0.827). Mean increase in heart rate showed positive correlation in relationship with energy expenditure (r=0.471). Palm height was also slightly correlated with energy expenditure (r=0.163), however it was weak.

4 Conclusions

A study on human energy expenditure in harvesting sugar palm has been successfully conducted. The most continence age of workers to harvest the sugar palm was in the range of 20 to 29 years old. At this age, the productivity of the workers was higher and used lesser human energy, even though they have to harvest a large number of palms per day. Although they have less experience, but they are very young, productive, energetic and willing complete the task faster and effectively than others. Other demographic factors such as working experience, marital status, gender, educational level, smoking status, weight and height also influenced the work productivity. The highest time spent in harvesting sugar palm was tapping task with 79.57%. There were no significant differences on average heart rates of worker when harvesting in the morning and evening times. The average energy expenditure for harvesting sugar palm was 3 kcal/man and fall into light work category. However, further improvements of sugar palm harvesting technology are suggested for better farmers' comfort, saving time and minimizing human energy expenditure. Despite the samples size and measured parameters were limited, this research has given valuable information in an effort of enhancing database on human energy expenditure in various crops cultivation in Malaysia.

References

Banhard, M.R. 2007. The rehabilitation and cultivation technique of sugar palm (*in Indonesian*). Bulletin Palma

No.33. Indonesian Palmae Research Institute (IPRI). Jakarta. Indonesia.

Brun, T. A., Geissler, C. A., Mirbagheri, I., Hormozdiary, H., Bastani, J., & Hedayat, H. 1979. The energy expenditure of Iranian agricultural workers. *The American Journal of Clinical Nutrition,* 32(10), 2154-2161.

Christensen, E. H. 1953. Physiological evaluation of work in the Nykroppa Iron Works. In *Ergonomics Soc. Symp. on Fatigue* (pp. 93-108,eds. W. F. Floyd, and A. T. Walford , London, U.K.: Lewis Publishers.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics, 11(1): 1-42.

Effendi, D. E. 2010. Prospect of intensification of sugar palm (*Arenga pinnata Merr*) in fulfilling the demand on bioethanol in Indonesia (*in Indonesian*). *Perspektif,* 9(1): 36 – 46.

Gamelin, F.X., S. Berthoin, and L. Bosquet. 2006. Validity of the polar S810 heart rate monitor to measure R–R intervals at rest. Medicine and Science in Sports and Exercise, 38(5): 887-893.

Gandhi, S, M. Dilbaghi, and Bimla. 2009. Hrvesting of Bajra (pearl millet) cob by farm women of Hayana. *Journal of Agricultural Engineering*, 46 (2):1-13.

Ghugare, B. D., S. H Adhaoo, L. P, Gite, A. C, Pandya, and S. L. Patel. 1991. Ergonomics evaluation of a lever-operated knapsack sprayer. Applied Ergonomics, 22(4), 241-250.

Gove, W. R. 1973. Sex, marital status, and mortality. *AJS* 79(1)**:** 45 – 67.

Gove, W. R., M. Hughes M., and C.B. Style. 1983. Does marriage have positive effects on the psychological well-being of the individual? *Journal of Health and Social Behavior*, 24(2)**:** 122 – 131.

Grimsby, L. K, J. B. Aune, and F. H. Johnsen 2012. Human energy requirements in Jatropha oil production for rural electrification in Tanzania. Energy for Sustainable Development, 16 (3): 297–302

Harinder, S. and R. N. Kaul. 1972. Human energy requirements of selected farm operation. *Journal of Agricultural Engineering,* 9(3): 44-52.

Kingsley, M., M. J. Lewis, and R. E. Marson. 2005. Comparison of polar 810 s and an ambulatory ECG system for RR interval measurement during progressive exercise *International Journal of Sport Medicine,* 26(1):39–44.

Kusumanto, D. 2008. Establishing a sugar palm plantation with efficient use of labor for tapping sap (*in Indonesian*). http://informasibudidaya. blogspot.com/2008/08/merancang-perkebunan-aren-yang -hemat.html. Accessed on 12 September 2013.

Martini, E. ,J.M Roshetko, M. V Noordwijk, A. Rahmanulloh, E. Mulyoutami, L. Joshi, and S. Budidarsono. 2011. Sugar palm (Arengapinnata (Wurm) Merr.) for livelihoods and biodiversity conservation in the orangutan habitat, Batang Toru, North Sumatra, Indonesia; mixed prospects for domestification. *Agroforest System,* 86(3): 401-417.

Miles, W. 1942. Physiological Effects of Ageing In: Cowdry, E. V. (ed.) *Problems of Ageing*, 2nd ed., Baltimore: William and Wilkins, (1942): 756:784.

Nag, P. K. and P. Dutt. 1980. Circulo-respiratory efficiency in some agricultural work. Applied Ergonomics, 11(2), 81-84.

Nag, P. K., N. C, Subastian, and M. G, Malvankar. 1980. Effective heat load on agricultural workers during summer season. *Indian Medical Research,* 72(Sept.): 408-415.

Nawi, N. M., A. Yahya, G. Chen, S. M. Bockari-Gevao,and T. N. Maraseni. 2012. Human energy expenditure in lowland rice cultivation in Malaysia. *Journal of Agricultural Safety and Health,* 18(1):45-56

Nybo, L., T, Jensen, B. Nielsen, and J. Gonzalez-Alonso. 2001. Effects of marked hyperthermia with and without dehydration on VO_2 kinetics during intense exercise. *Journal of Applied. Physiology,* 90(3): 1057-1064.

Pebrian, D.E., A. Yahya, and T.C Siang. 2014. Workers' workload and productivity in oil palm cultivation in Malaysia. *Journal of Agricultural Safety and Health,* 20 (4): 235-253

Ruha, A., S. Sallinen, and S. Nissila. 1997. A real-time microprocessor QRS detector system with a 1-ms timing accuracy for the measurement of ambulatory HRV. *I.E.E.E. Transaction on Biomedical Engineering,* 44(3):159–167.

Samudra, A. 2011. A agribusiness system for sugar palm plantation at Mungka, in Lima Puluh Kota Distict, West Sumatra, Indonesia (in Indonesian) http://sosekpertanianunand.blogspot.com/2011/01/sistem -agribisnis-aren-di-kecamatan_23.html. Accessed on 12 September 2013.

Schertz, C. E. 1967. Human energy expenditure for picking oranges. *Journal of Agricultural Engineering Research,* 12(4): 281-284.

Smil, V. 1994. *Global Ecology: Environmental Change and Social Flexibility*. London , New York. Routledge.

Smits, W. 2011. A rain forest advocate raps the energy of the sugar palm. National Geographic Daily News. June 22, 2011.

Tewari, V. K., R. K.Datta, and A. S.Murthy. 1991. Evaluation of three manually operated weeding devices. *Applied Ergonomics,* 22(2): 111-116.

Ticoalu, A., T. Aravinthan, and F. Cardona. 2011. Experimental investigation into gomuti fibres/polyester composites. In *Incorporating Sustainable Practice in Mechanics and Structures of Materials,* ed,. S. Setunge. 451-456, Taylor and Francis (CRC Press)/Balkema,

Williams, M.H. 2015. Nutrition for Health, Fitness and Sport 8th Ed. McGraw-Hill Global Education Holdings.