



vol. 17 / 2023



The 7th International Conference on Science Technology

organized by
Faculty of Social Science and
Law Universitas Negeri Manado and
Consortium of International Conference
on Science and Technology

The Innovation Breakthrough in Digital and Disruptive Era

An Analysis of Physiological Workload on Pure Coconut Oil Production Process

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Abstract. This study aims to analyze the physiological workload in the virgin coconut oil production process based on energy expenditure evaluations and determine rest periods to ensure that work does not require excessive energy. Assessment of workload objectively using pulse indicators and energy consumption (energy cost) observations at the four stages of the virgin coconut oil production process, namely the process of stripping the coconut husk, the process of cutting the coconut shell, the process of grating the coconut and the process of cooking the coconut milk. The energy expenditure of workers in the coconut coir stripping section is 5,138 kcal/min, the coconut shell cutting section is 2,552 kcal/min, the coconut meat grating section is 3,575 kcal/min, and the coconut milk cooking section is 2,885 kcal/min. Hence the coco coir stripping workstation is included in the heavy workload category with an average cardiovascular load value of %CVL of 56%, which means that the work needs to be improved; the recommended work-rest cycle for workers at the coco peeling workstation is 47 minutes. The workstation for cutting coconut shells to cooking coconut milk is included in the category of moderate workload with a value of %CVL $\leq 33\%$, still within the recommended workload limit.

Keywords. Physiology, Energy Expenditure, Workload, Work-Rest Cycle, Coconut Oil

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1 Introduction

A job often demands strenuous and tiring physical activity, and workers must have adequate physical work capacity. Giving excessive workload can have an impact on workers. Several adverse effects can occur when a job's physical load has exceeded the worker's physiological capacity. [1] This negative impact is conceptually interpreted as the low energy produced through the body's metabolic processes compared to the energy needed to carry out a work activity. These events can chronically lead to excessive fatigue and affect workers' health

An excessive workload can also harm work quality and performance [2], decrease reaction time, increase decision-making errors, decrease the ability to concentrate and increase the potential for work accidents

Workload evaluation is needed in designing or improving existing work systems. Measurement of workload can be done with a physiological approach. The physiological approach is a work system design technique that requires the physical energy of human muscles as a source of energy [3].

The main parameter in determining the level of physical workload is energy consumption. Energy consumption at work can be determined indirectly (measuring blood pressure, blood flow, chemical composition in the blood, body temperature, evaporation rate, and amount of air exhaled by the lungs) [3] and can be measured by measuring the pulse [1].

Pulse rate can be used to measure the physical condition of workers as a basis for determining a worker's fatigue level. [4] The greater the pulse rate fluctuation indicates, the greater the level of a person's workload. Excessive workload in the long term can have an impact on reducing one's productivity caused by work fatigue.

The virgin coconut oil production process consists of 4 stages: stripping the coconut husk, cutting the coconut shell, shaving the coconut meat, and heating the coconut milk using the thermal method. Workers have to work in a bending posture, too high shrugging, wrists experience repeated rotation, and workers have to stand for a long time to stir coconut milk. The working conditions can be seen in Figure 1.



Fig. 1. Workstation Stage of Pure Coconut Oli

Therefore, it is necessary to analyze the workload at each workstation to determine the workload experienced by workers at UKM Sabuh Berkah. Physical work is measured by measuring energy consumption, which is the main factor and benchmark as a determinant of the weight or lightness of the workload. This research was also conducted to determine the ideal rest time workers need so that doing work does not require excessive energy.

2 Research Method

The workload assessment used indicators of heart rate and energy consumption (energy cost). This research also determines the appropriate rest time to ensure that work does not require excessive energy.

The respondents in this study were female workers in UKM Sabua Berkah food industry producing virgin coconut oil, with an age range of 30-45 years, and consisting of 4 (four) work stations, namely peeling coconut coir, cutting coconut shells, shaving coconut meat, and cooking coconut milk. Pulse measurement was carried out in 20 work cycles at each station for 5 (five) working days. Data processing in assessing the lightness or severity of physical workload is carried out in several stages, from measuring heart rate, calculating energy consumption (Metabolic Work Rate/MWR), calculating cardiovascular load %CVL, and calculating recommended work-rest cycle. Calculating the amount of energy expended during the worker's work was done using the workload equation [5].

$$MWR = -1967 + 8,58HR + 25,1HT + 4,50A - 7,47RHR + 67,8G \quad (1)$$

Where MWR is metabolic work rate (W), HRx is heart rate (bpm), HT is height (in.), A is age (yr), RHR is resting heart rate (bpm), and G is gender (M=0, F=1). The regression equation was significant ($p < 0.05$) with an R2 value of 0.797. 1 Watt equal to 0,0143 kkal/minutes.

The calculation of workload classification based on increased working heart rate compared to maximum heart rate by calculating cardiovascular load (%CVL) using the equation:

$$\%CVL = 100 \times (HR_{work} - H_{rest}) / (HR_{maks} - H_{rest}) \quad (2)$$

Maximum heart rate calculation using the equation (Astrand and Rodahl, 1997 [6])

$$\text{Max heart rate} = 220 - \text{age} \quad (3)$$

The recommended %CVL value is at most 33% [1]. The following is a workload classification table based on %CVL [7]:

Table 1. Workload Based Classification %CVL

Range	Classification
<30%	Fatigue does not occur
30% to <60%	Needs Improvement
60% to <80%	Work in Short time
80% to <100%	Urgent action need
>100%	Not allowed to move

Consider the formula for determining the amount of rest required for heavy work [8].

$$R = T(W - S) / W - 1,5 \quad (3)$$

Where R is time required for rest, as percentage of total time, W is average energy expenditure during work (kcal/min), S is the permitted energy expenditure limit, for female workers, namely 4 kcal/minute.

Classification of work (performed over an entire work shift) from “light” to “extremely heavy” according to energy expenditure and heart rate. [9].

Table 2. Energy Requirements For Each Job Classification

Classification	Total Energy Expenditure		Heart Rate
	kJ/min	kcal/min	Beats/min
Light work	10	<2,5	90 or less
Medium work	20	2,5-5,0	90-100
Heavy work	30	5,0-7,5	100-120
Very heavy work	40	7,5-10,0	120-140
Extremely heavy work	50	10,0-12,5	140-160

3 Results and Discussion

3.1 Energy Expenditure

The average energy expenditure for each workstation is a coco coir stripping workstation of 5.138 kcal/min, a coconut shell cutting workstation of 2.552 kcal/min, a coconut pulp shaving workstation of 3.575 kcal/min, and a coconut milk cooking workstation of 2.885 kcal/min. Based on Table 2 of the classification of work (Kroemer et al., 2010), it can be analysed that the work at the coco peeling workstation is a heavy job, while the work at the coconut shell cutting, shaving coconut meat, and cooking coconut milk work stations is a moderate workload. The following energy expenditure average for five days of observation at each workstation is shown in Figure 2, and the average energy expenditure data can be summarized in Table 3.

Table 3. Average Energy Expenditure Recapitulation

Workstation	Energy Expenditure Average (kcal/min)
Stripping Coconut Coir	5,138
Cutting Coconut shell	2,552
Shrinkage Coconut Meat	3,575
Warming Coconut milk	2,885

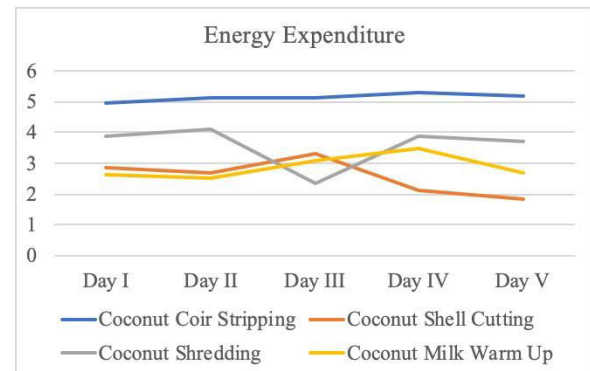


Fig. 2. The Energy Expenditure

3.2 Cardiovascular Load

%CVL for workload classification based on increased working heart rate compared to maximum heart rate. Classification of workload based on %CVL can be seen in Table 4 below.

Table 4. Classification Cardiovascular Load (%CVL)

No	Workstation	%CVL	Work Pressure Category	Classification %CVL
1	Stripping Coconut Coir	56%	Heavy	Need improvement
2	Cutting Coconut shell	33%	Medium	Need improvement
3	Shrinkage Coconut Meat	33%	Medium	Need improvement
4	Warming Coconut milk	28%	Medium	Need improvement

Based on the table of cardiovascular load classification, three work stations are at moderate workload, namely work stations for cutting coconut shells, shaving coconut meat, and cooking coconut milk with a value of %CVL $\leq 33\%$, which means that this value is still within the limits recommended for workers who work for 8 (eight) consecutive hours (Iridiastadi & Yassierli, 2014). While the work is under heavy workload, namely at the coconut coir stripping workstation with a %CVL percentage value of 56%, therefore a need for improvement during rest periods.

3.3 Recommended Work Rest Cycle

The need for rest time at the coconut coir stripping workstation based on a physiology approach is as follows:

$$R = 150(5.138-4)/(5.138-1.5)$$

$$R = (170.7 \text{ kcal/min})/(3.638 \text{ kcal/min})$$

$$R = 47 \text{ minutes}$$

By this result, the recommendation for the work rest cycle of workers at the coconut coir removal workstation is 47 minutes.

4 Conclusion

The energy expenditure of workers in the coconut coir stripping section is 5,138 kcal/min; the coconut shell cutting section is 2,552 kcal/min, the coconut meat grating section is 3,575 kcal/min, and the coconut milk cooking section is 2,885 kcal/min. So it can be concluded that the coco coir stripping workstation is included in the heavy workload category with an average cardiovascular load value of %CVL of 56%, which means that the work needs to be improved, the recommended work-rest cycle for workers at the coco peeling work station is 47 minutes. Meanwhile, the workstations for cutting coconut shells, shaving coconut meat, and cooking coconut milk are included in the medium workload category with a value of %CVL $\leq 33\%$, which means that this value is still within the recommended limits for workers who work for 8 (eight) consecutive hours.

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