Analysis of Physiological Workload in Tofu Production Process Based on Energy Recovery at Rest

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Abstract
UD. Koder is a manufacturing company that processes raw materials into finished products in Sidoarjo. The production process is one of UD's production processes. Koder is still with manual performance. Manual production processes with flexible body movements and a lot of physical loads still depend on the ability of workers and require human labor. The assessment of the level of physical workload of workers is not clear. The purpose of this study was to examine the categories of physical stress on workers in manual production processes using physiological methods. The method used is to measure heart rate at work and at rest, as well as evaluate worker psychology in the form of consideration of heart rate reserve (%HRR), cardiovascular load (%CVL), and energy expenditure factor (KE). The results showed that the amount of energy expenditure for each worker included Faris (7.0 Kcal/minute), Muit (4.7 Kcal/minute), Budi (4.4 Kcal/minute), Gito (4.9 Kcal/minute), Sudar (5.0 Kcal/minute), Dito (4.6 Kcal/minute), Joni (4.9 Kcal/minute) resulting in an item of average energy expenditure (5.1 Kcal/minute) where all workers were at a moderate level. The recommended improvement for production workers is that the rest time is 1 minute 27 seconds each time the process is continuous.

***Keywords*:** *Physical Workload, Pulse, %CVL, %HRR, Energy Consumption.*

Abstrak
UD. Koder merupakan perusahaan manufaktur yang mengolah bahan baku menjadi produk jadi di Sidoarjo. Proses produksi merupakan salah satu proses produksi UD. Koder masih dengan performa manual. Proses produksi manual dengan gerakan tubuh yang fleksibel dan beban fisik yang banyak masih bergantung pada kemampuan pekerja dan membutuhkan tenaga manusia. Penilaian tingkat beban kerja fisik pekerja tidak jelas. Tujuan dari penelitian ini adalah untuk mengkaji kategori tekanan fisik pada pekerja dalam

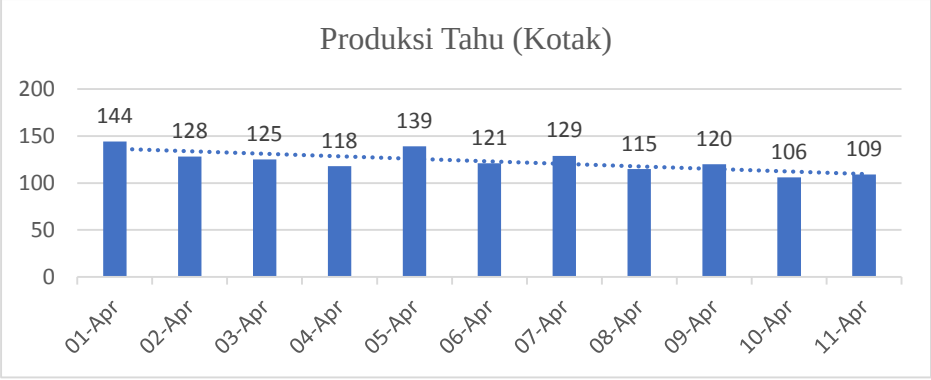
proses produksi manual menggunakan metode fisiologis. Metode yang digunakan mengukur denyut jantung saat bekerja dan saat istirahat, serta mengevaluasi fisiologi pekerja berupa perhitungan cadangan denyut jantung (%HRR), beban kardiovaskular (%CVL), dan faktor pengeluaran energi (KE). Hasil penelitian diketahui jumlah pengeluaran energi pada tiap-tiap pekerja diantaranya yaitu Faris (7,0 Kkal/menit), Muit (4,7 Kkal/menit), Budi (4,4 Kkal/menit), Gito (4,9 Kkal/menit), Sudar (5,0 Kkal/menit), Dito (4,6 Kkal/menit), Joni (4,9 Kkal/menit) dihasilkan rerata energi yang di keluarkan (5,1 Kkal/menit) dimana semua pekerja dikategorikan pada tingkat moderat. Perbaikan yang disarankan untuk pekerja produksi dimana waktu istirahat tersebut 1 menit 27 detik setiap satu kali proses secara terus menerus.

Kata Kunci: *Beban Kerja Fisik, Denyut Nadi, %CVL, %HRR, Konsumsi Energi*.

1. Introduction

Work success is influenced by several factors, namely physical work factors. The results of manual labor, and energy consumption, affect the capacity of workers. For the ability to optimize the process, it is necessary to pay attention to the energy recovery that occurs during energy-intensive work. Factors affecting energy consumption during work. These include how the work is done, the speed at which it is completed, and the attitude and conditions of the work environment. Factors that affect energy recovery include length, duration, and frequency of rest.

The energy recovery coefficient is needed in the occurrence of work process fatigue. This is due to two reasons, physical fatigue, and mental fatigue. What does fatigue mean in physiology refers to fatigue caused by changes in the body's physiological functions. Changes in body physiology from fresh to tired affect the peak performance of workers. Restoring the freshness of the body during work is an important thing to pay attention to. Factors affecting energy recovery at rest.



Source: UD. Koder Data

Figure 1. Graph of April Production Results

In contrast to workers with light loads, workers with high workloads certainly need time and frequency. If the length of rest time does not match the workload of a given, it can result in poor worker status. This situation can have negative effects such as longer processing times, product rejects, incidents, etc. UD. Koder started production in 2010 to meet the increasing demand for white tofu from Sidoarjo residents. UD. Koder starts the production process at 07.00 until 16.00. The white tofu production process takes 1 hour and the production process is carried out continuously with uncertain rest periods. Uncertainty of down time and an increase in demand, causing a decrease in production. In Figure 1, it can be seen that the decline in production experienced by UD. Koder.

Tofu is made by hand using a traditional press. Workers must stand to work with a slightly bent body. In addition, the high temperature when cooking tofu will also affect the physical strength of the workers. UD workers. Coders tire more easily when working at high temperatures. In addition, some parts of the floor have dirt due to the accumulation of water and layered combustion residue, which makes the floor surface rough and uneven. The pungent smell of raw materials and products produced is also felt in the work area. According to these problems, this study uses a method designed to analyze UD workload (cardiovascular load = %CVL) for measurement and calculation according to physiological factors. Measurement of manual labor is done by measuring the use of manual labor which is the main factor, and benchmarks determine workload. The impact of this measurement is expected to be the basis for improving work systems to reduce workload.

Workload is the amount of work divided by the physical or mental effort that is the responsibility of an employee. Workload refers to the intensity of work tasks. It is a source of employee stress (Shah et al., 2011). Specifically, the workload can be divided into two categories, namely physical workload and mental workload. Physical loads often cause loads faced by employees in the workplace related to their physiological conditions, such as noise, temperature, and humidity of the work environment, vibration (shock), and cleanliness. If working conditions are bad enough, work stress can develop along with physical symptoms such as high blood pressure, diarrhea, constipation, etc. Too many job descriptions indicate excessive physical workload due to the limited number of employees. At the same time, perceptions of job incompatibility and a stressful work environment are signs of mental overload (Zulfiqar et al, 2017).

The use of knowing the amount of work that can be physically accepted by a worker is that it can be used to determine the length of working hours according to the ability or physical strength of the worker himself. The heavier the physical workload, the less time a person can work without visible fatigue and distraction, and vice versa. Dr. Lucien Brouha presented a workload classification table according to physiological response according to work level, as shown in Table 1.

Table 1. Workload Classification and Physiological Reactions

Work Category	Energy Expenditure		Pulse
	(Kkal/Minute)	(Kkal/8 Hours)	(Pulse/ Minute)
Too Heavy	>12,5	>6000	>175
Very heavy	10,0-12, 5	4800-6000	150-175
Heavy	7,5-10,0	3600-4800	125-150
Currently	5,0-7,5	2400-3600	100-125
Light	2,5-5,0	1200-2400	60-100
Very Light	<2,5	<1200	<60

Measuring pulse or heart rate is a measure of objectively measuring the level of physical activity, determining the physical condition or fitness of humans, and measuring the level of fatigue in humans (Silalahi, R.L, R et al., 2018). This measurement method is widely used because it is easy to observe and measure, and can indirectly measure energy consumption (Sitohang, DR, et al., 2010). There are several types of pulse-based estimates of physical workload indicators (Simanjuntak, R. A., 2011), namely:

a. Resting pulse is the average pulse before starting work
b. Working pulse is the average pulse during the working period
c. Working pulse is the difference between resting heart rate and working heart rate.

Heart Rate Reverse (HRR) or reserve heart rate is the difference between maximum (peak) heart rate and resting heart rate. The addition of a human pulse plays an important role in increasing heart rate from rest to maximum work (Tarwaka, 2010). Classify workload by adding the resting pulse potential to the maximum workload as measured by pulse reserve (Sari, A. D., et al., 2016). Determining the classification of workload based on increased heart rate is very important to increase cardiac output from rest to maximum work (Manuaba 1992). Classification of workload is based on the increase in heart rate at work compared to the maximum heart rate due to cardiovascular load (% CVL), calculated as follows (Hidayat 2020). The results of the %CVL assessment were then carried out using a classification comparison (Mutia 2014).

Table 2. Classification %CVL

%CVL	Information
X≤30%	No signs of fatigue
30%≤ X ≤60%	Need to be repaired
60%≤ X ≤80%	Work in no time
80%≤ X ≤100%	Urgent action is required
X> 100%	No movement allowed

2. Method

The data needed includes quantitative data which is data obtained from UD. The coder in the form of numbers includes:

a. Number of production employees
b. Age of workers
c. Production results
d. Resting pulse (DNI)
e. Working pulse (DNK)

The steps in this study can be seen in Figure 2 below.

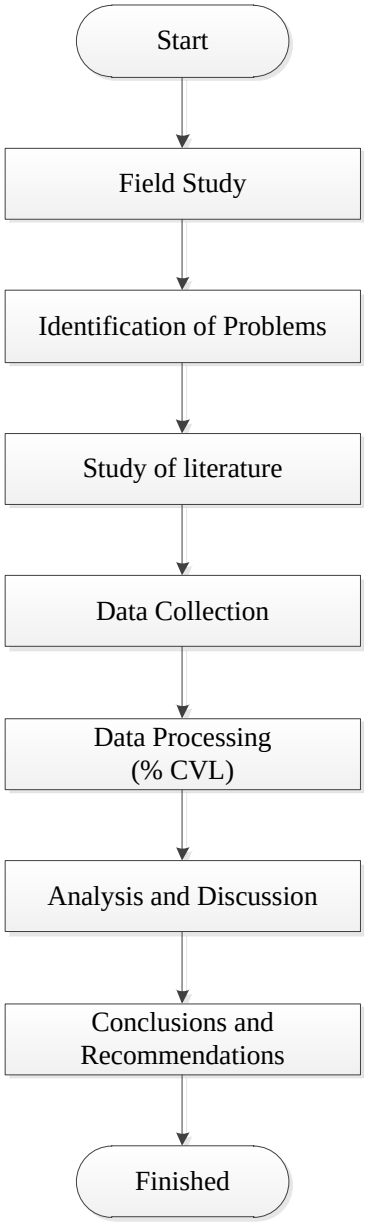


Figure 2. Research Flowchart

Data processing in this study was carried out through the following steps:

a. Each worker's pulse is measured
b. Then do the calculation of the Resting Pulse Rate (DNI)
c. After that, calculate the Pulse of Work (DNK) calculated in formula number
d. The next step is to calculate the Maximum Pulse Rate (DNK Max)
   DNK Max For Men = 220 – Age
   DNK Max For Women = 200 - Age
e. Calculation of Work Pulse (NK) by (DNK - DNI)
f. Furthermore, the calculation of HRR

$$\%HR\ reverse = \frac{(DNK-DNI)}{DNKmax-DNI} x100 \quad (1)$$

Information:
DNK : Working pulse, average pulse at work
DNI : Resting pulse, the average pulse is not yet working
DNKmax : Maximum heart rate

g. Calculation of Cardiovasculair strain (%CVL)

$$\%\ CVL = \frac{100x(DNK-DNI)}{DNmax-DNI} \quad (2)$$

h. Comparison of the results of the calculation of %CVL with the classification of %CVL
i. Calculation of Energy Consumption

$$Y = 1{,}80411 - 0{,}0229038\ X + 4{,}71733 \times 10^{-4} X^2 \quad (3)$$

Information:
Y = Kcal/minute energy expenditure
X = Heart rate/minute

j. Perform physical workload assessment recapitulation
k. Performing energy recovery at rest using the physiological approach method

$$R = \frac{T(W-S)}{W-1.5} \quad (4)$$

Information:
R = Required rest time (minutes)
T = Total shift time (minutes)
W = Average energy expenditure (kcal/minute)
S = Level of energy expended while working (kcal/minute)
(4 Kcal/minute for women and 5 Kcal/minute for men)
1.5 = Energy needed at rest (kcal/minute)

3. Result and Discussion

The research was carried out specifically in the tofu production section, namely by collecting data starting with taking blood pressure and measuring the worker's pulse using a digital tensimeter at rest (DNI) and while working (DNK). The pulse data is collected from all tofu production workers. Work pulse measurement is carried out for each worker. The results of work measurements can be seen in Table 3.

Table 3. Pulse Rate Worker Data at UD. Koder

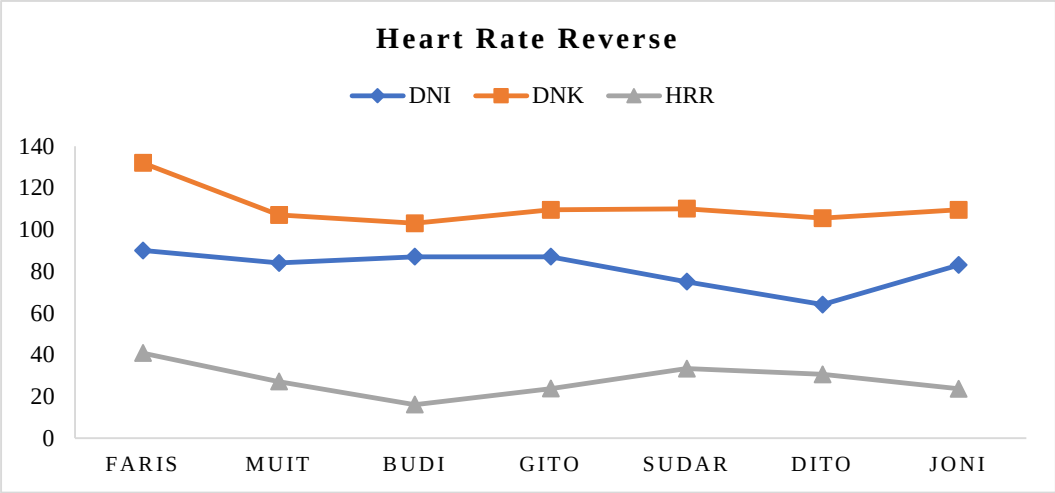
Worker Name	Age (Year)	DNI (Minute)	DNK (Minute)		Average
			11:00	15:00	DNK
Faris	27	90	114	150	132
Muit	51	84	95	119	107
Budi	33	87	92	114	103
Gito	38	87	93	126	109.5
Sudar	40	75	100	120	110
Dito	20	64	104	107	105.5
Joni	25	83	108	111	109.5

Then the data is processed into maximum heart rate data for each worker. The recapitulation of workers' maximum heart rate data can be seen in Table 4.

Table 4. Recapitulation of Worker's Pulse

Worker Name	DNI	DNK	DNK Maks	NK
Faris	90	132	193	42
Muit	84	107	169	23
Budi	87	103	187	16
Gito	87	109.5	182	22.5
Sudar	75	110	180	35
Dito	64	105.5	200	41.5
Joni	83	109.5	195	26.5
Average	81,43	110.93	186,57	29.5

From this data, then calculate the HRR. In Figure 3, you can see a graph of the HRR value of each worker.



Source: Data Processing

Figure 3. Chart of HRR Values

Furthermore, the calculation of cardiovascular strain (% CVL) was performed. Calculation of %CVL and action criteria for each worker can be seen in Table 5.

Table 5. % CVL & Action Criteria for Each Worker

Worker Name	DNI	DNK	DNK Maks	%CVL	Information
Faris	90	132	193	40.78	Needs repair
Muit	84	107	169	27.06	Fatigue does not occur
Budi	87	103	187	16	Fatigue does not occur
Gito	87	109.5	182	23.68	Fatigue does not occur
Sudar	75	110	180	33.33	Needs repair
Dito	64	105.5	200	30.51	Needs repair
Joni	83	109.5	195	23.66	Fatigue does not occur

From Table 4, it is produced by UD workers. The coder is at a moderate level which requires improvement so that fatigue does not occur. The energy consumption used and the physiological reactions of each worker can be seen in Table 6.

Table 6. Classification and Physiological Reactions

Worker Name	Energy Expenditure		Pulse (Pulse/Minute)	Work Category
	(Kkal/Minute)	(Pulse/Minute)		
Faris	7.0	3.360	132	Heavy
Muit	4.7	2.282	107	Light
Budi	4.4	2.136	103	Light
Gito	4.9	2.352	109.5	Light
Sudar	5.0	2.396	110	Currently
Dito	4.6	2.202	105.5	Light

Worker Name	Energy Expenditure (Kkal/Minute)	Energy Expenditure (Pulse/Minute)	Pulse (Pulse/Minute)	Work Category
Joni	4.9	2.352	109.5	Light
Average	5.1	2.436	110,92	Currently

4. Conclusion

Based on the calculations that have been done, the energy consumption of each worker is Faris (7.0 Kcal/minute), Muit (4.7 Kcal/minute), Budi (4.4 Kcal/minute), Gito (4.9 Kcal/minute), Sudar (5.0 Kcal/minute), Dito (4.6 Kcal/minute), Joni (4.9 Kcal/minute). The average energy consumption of all workers is (5.1 Kcal/minute). The results of these calculations also show that the physiological burden of CV. Coder in medium category. The optimal rest time for workers in one production process is 1 minute 27 seconds.

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