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Development of a Semi-Automatic Banana Chip Slicing Machine for Reducing Musculoskeletal Disorders in Workers

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ABSTRACT

This research aims to improve the banana chip-slicing process at Aneka Keripik Clarissa'N UMKM. Currently, the slicing is done manually, leading to workers' discomfort and Musculoskeletal Disorders (MSDs). To address this, we are designing a new machine based on the Nordic Body Map (NBM) questionnaire results. This machine, tailored using workers' anthropometric data, aims to be ergonomic, reducing fatigue and enhancing comfort and efficiency in the slicing process. The goal is to simplify and speed up production while ensuring maximum worker well-being.

Keywords: *Anthropometrics, MSDS, Nordic Body Map, Tool Design*

Introduction

As technology develops and human thinking becomes increasingly sophisticated, product designs have been created to make it easier for human workers to produce more effective and efficient products for companies running micro, small, and medium enterprises on a national scale. [1]. Good product design pays attention to comfort using anthropometric and ergonomic methods [2]. One of the micro, small, and medium enterprises, Aneka Keripik Clarissa'N, currently, the production process for slicing banana chips that are used is still inefficient because it uses a simple banana chip slicer, which is done directly on a large frying pan. As a result of these process conditions, the slicing of raw banana fruit is uneven and takes quite a long time and makes the body and hands sore over time musculoskeletal disorders (MSDs) [3].

The author designed a semi-automatic banana chip-slicing machine design that is ergonomic and comfortable for workers to reduce musculoskeletal disorders (MSDs) in workers [4]. Musculoskeletal disorders (MSDs) are conditions that occur in the human musculoskeletal system and are caused by severe imbalances in muscle and bone performance. [5]–[10].

Therefore, this author will design a semi-automatic banana chip-slicing machine using anthropometric methods [11]. Anthropometric is a branch of ergonomics that is concerned with measuring the dimensions of the human body and can be used to design ergonomic facilities. [12] . The design size of the semi-automatic banana chip-slicing machine will be designed using measurements from the anthropometric data of workers produced by slicing bananas. The data will be selected using the percentile concept, and for the visual design, the author uses a 3D design application, namely AutoCAD [13].

The Nordic Body Map is used to identify the causes of musculoskeletal problems[14]–[17]. Using the Nordic Body Map can find out where symptoms appear in the muscles, depending on the severity, ranging from discomfort (slight pain) to very painful. It can estimate the type and severity of musculoskeletal problems experienced by a worker[18].

Research Methods

Data processing: the collected data is then processed using various methods, including [19]–[23]:

Data Sufficiency Test

This data processing is intended to check whether the data collected is complete or not. If the amount of data is still insufficient, additional observation data will be generated. Data adequacy is calculated using the formula, namely: [24]

$$N' = \left[\frac{k/s\sqrt{N\Sigma x^2 - (\Sigma x)^2}}{\Sigma x}\right]^2 \quad (1)$$

Where:
N = number of actual observation data
N' = theoretical amount of data
S = degree of accuracy
k = level of confidence

Data Uniformity Test

The data uniformity test is carried out to obtain uniform data. The data used is anthropometric data obtained from direct physical measurements of Aneka Keripik Clarissa'N employees. If data is available in BKA and BKB then the data is considered uniform. The formula is [25]:
Upper Control Limit (BKA) = X + k.σ
Lower Control Limit (BKB) = X – k.σ
Before determining BKA and BKB, first determine the standard deviation using the following formula[26]:

$$\sigma x = \sqrt{\frac{N.\Sigma(xi^2) - (\Sigma xi)^2}{N(N-1)}} \quad (2)$$

Where:
σx = Standard deviation of the population
N = Number of data
X = Average
k = Trust level index coefficient, namely:
Confidence level 0% - 68% price k is 1.
Confidence level 68% - 95% price k is 2.
Confidence level 96% - 100% price k is 3.

Percentile

The purpose of processing this data is to measure products based on the 5th, 50th, or 95th percentiles. The research object is workers. The formula for percentiles is [27]:

$P^5 = \bar{X}$ +Ki x S
$P^{50} = \bar{X}$
$P^{95} = \bar{X}$ +Ki x S

Research Flow

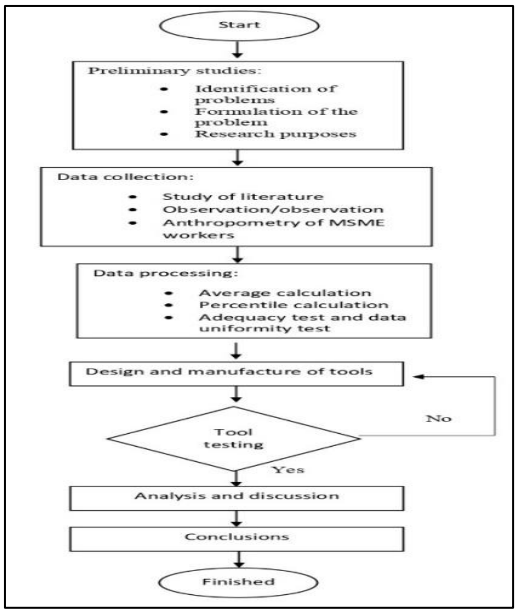

Figure 1. Research Method Flow

Results and Discussion

Nordic Body Map Questionnaire Results

Nordic Body Map questionnaire data processing was carried out to identify workers' muscle complaints.

Table 1. Questionnaire Data Results

No	Type of Complaint	P	QS	S	Vi
0	Pain above the neck	0	0	7	6
1	Pain under the neck	0	0	8	5
2	Pain in left shoulder	0	0	7	6
3	Pain in right shoulder	0	0	8	5
4	Pain in upper left arm	0	0	10	3
5	Back pain	0	0	5	8
6	Pain in right upper arm	0	0	4	9
7	Pain in the waist	0	0	4	9
8	Pain in the buttocks	0	0	4	9
9	Pain in lower buttocks	0	0	2	11
10	Pain in left elbow	0	0	8	5
11	Pain in right elbow	0	0	5	8
12	Pain in left forearm	0	0	6	7
13	Pain in right forearm	0	0	7	6
14	Pain in left wrist	0	0	7	6
15	Pain in right wrist	0	0	8	5
16	Pain in left hand	0	0	10	3
17	Pain in right hand	0	0	8	5
18	Pain in left thigh	0	0	9	4
19	Pain in right thigh	0	0	8	5
20	Pain in left knee	0	0	6	7
21	Pain in right knee	0	0	8	5
22	Pain in left calf	0	0	7	6
23	Pain in right calf	0	0	5	8
24	Pain in left ankle	0	0	8	5
25	Pain in right ankle	0	0	8	5
26	Pain in left leg	0	0	9	4
27	Pain in right leg	0	0	9	4
	Total	**0**	**0**	**195**	**169**

Information:
Painless = P
Quite Sick = QS
Sick = S
Very ill = Vi

From the questionnaire results data on the level of worker complaints, it produces the level of complaints experienced Sick (S) and Very ill (Vi), Therefore, as a basis for determining machine design using anthropometric data, it includes: Hip Height (HH), Hand Reach (HR), and Shoulder Width (SW), The results obtained from anthropometric calculations are to produce an ergonomic semi-automatic banana chip slicing machine design to reduce worker fatigue.

Anthropometric Data

The subjects measured to obtain anthropometric data were workers at the UMKM Aneka Keripik Clarissa'N in Semarang City, Central Java, with a sample of 13 workers. From this data, data processing is carried out.

Table 2. Data from Anthropometric Measurements

Name	Gender (L/P)	HH	HR	SW
Ponidah	P	89	71	41

Amin	P	88	70	44
Siti Darita	P	85	66	48
Ngasih	P	72	62	41
Mila	P	90	70	44
Dyo	L	92	71	43
Sabrina	P	89	70	44
Tara	P	82	68	43
Hajar	P	86	69	45
Rio	L	89	70	42
Maryati	P	70	65	39
Jumini	P	88	70	42
Maidah	P	71	63	41

Data Sufficiency Test

Table 3. Data Sufficiency Test Results

Anthropometric Dimensions	N	N'	Conclusion
Hip Height (HH)	13	3.1669	N'<N, enough data
Hand Reach (HR)	13	0.7497	N'<N, enough data
Shoulder Width (SW)	13	1.0340	N'<N, enough data

Data Uniformity Test

Table 4. Data Uniformity Test Results

Anthropometric Dimensions	Standard Deviation	BKA	BKB
Hip Height (HH)	7.77	99.46	68.38
Hand Reach (HR)	3.07	74.22	61.94
Shoulder Width (SW)	2.27	47.39	38.31

Percentile

Table 5. Percentile Results

Anthropometric Dimensions	$P5$	$P50$	$P95$
Hip Height (HH)	71.14	83.92	96.70
Hand Reach (HR)	63.03	68.08	73.13
Shoulder Width (SW)	39.11	42.84	46.57

Tool Design and Model

After the data has been collected and processed, the next step is to determine the size that will be used as the size for making a semi-automatic banana chip-slicing machine. Size determination is based on processed anthropometric data and several related tool sizes, as shown in the following table.

Table 6. Determining Design Sizes

Anthropometric Data	Design Size	Size	Reason
Hip Height (HH)	Machine Height	50th percentile	Workers who are short and tall can use the tools made.
Hand Reach (HR)	Machine Length	Percentile 5	So that the machine is not too long so that it limits workers' movement space.
Shoulder Width (SW)	Machine Width	95th percentile	In the process of carrying out the chip process, the space is large enough so that workers do not experience difficulties because the space is not large enough.

Table 7. Design Size of Semi-Automatic Banana Chip Slicing Machine

Part Name	Size
Machine Height	83.92 cm
Machine Length	63.03 cm
Machine Width	46.57 m

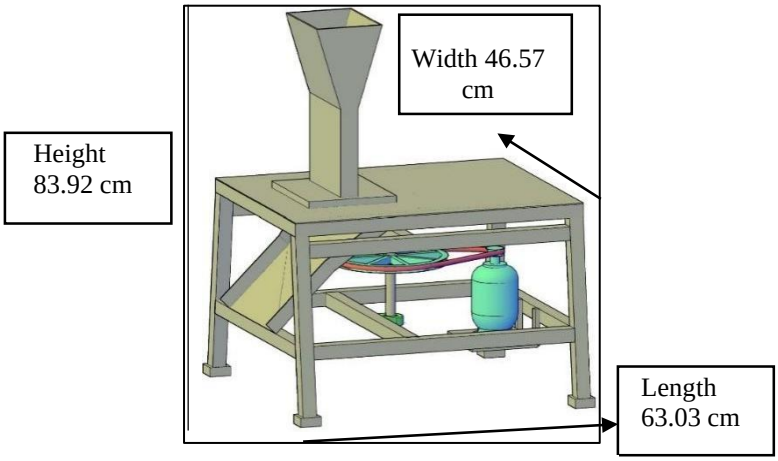

Figure 2. Final Design of Semi-Automatic Banana Chip Slicing Machine

Conclusion

The design of this machine using the Anthropometric method produces an ergonomic design aimed at making things easier, smoother, more comfortable, and can reduce MSDS fatigue on the body and hands of workers during the production process of slicing banana chips at the Aneka Keripik Clarissa'N UMKM and is expected to produce a maximum banana slices. By carrying out this research, a semi-automatic banana chip slicing machine design was obtained with specifications for machine height 83.92 cm, machine length 63.03 cm, machine width 46.57 cm.

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