Design of Table and Chairs for Packaging Tempe Chips Work Station for Reducing the Risk of Occupational Diseases in Putra Tunggal Home Industry Wonosobo

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Abstract

Home Industry Putra Tunggal Wonosobo is a tempeh chip industry whose production process is manual, so it can have a negative impact on worker ergonomics. Preliminary research was conducted by interviewing pain complaints and assessing work posture using the OWAS method. The tempeh chips packaging workstation was the workstation that had the most pain complaints at 67.86% (19 of 28 body parts) and the highest OWAS score at 4, so this was at high risk of experiencing musculoskeletal disorders. The next study used the NBM questionnaire to analyze the level of pain due to work and RULA for work posture. CATIA software was used to design tables and chairs, as well as assess the posture of the design results using the RULA method. Worker performance will be compared before and after using tables and chairs based on the level of body pain due to work (NBM) and work posture (RULA). The research results showed a decrease in the risk of work-related diseases by 80 and 78 to 40 and 44 (from high to low-risk levels) as well as a decrease in the RULA score from 7 (dangerous posture) to 2 (good posture).

Keywords: *NBM, OWAS, posture, RULA.*

1. INTRODUCTION

The production process of most Home Industries in Indonesia still applies a labor-intensive system with minimal skills (Thorbecke, 2018) and is carried out manually (Manual Material Handling). This can result in workers being 62% more at risk of developing work-related musculoskeletal disorders (WMSDs) (Calzavara et al., 2017). Moving goods that are not supported by good facilities causes unhealthy body posture (Zhang et al., 2018). Therefore, it is necessary to apply knowledge of the design of work facilities that pay attention to human aspects as users, which is often called ergonomics.

Ergonomic work facility design requires anthropometric aspects. Anthropometry is the science of measurement that determines the physical geometry, mass properties, and strength capabilities of the human body and plays an important role in the design of household and industrial environments (Sutalaksana and Widyanti, 2016). The aim of designing ergonomic work facilities is to reduce complaints of pain during work and after work. The methods that can be used to assess working posture are the OWAS (Ovako Working Posture Analysis System) method as a preliminary assessment method and the RULA (Rapid Upper Limb Assessment) method as a follow-up assessment method. The use of the RULA method is due to the packaging workstation being static (not requiring whole-body movement). The NBM (Nordic Body Map) questionnaire is a questionnaire used to determine workers' complaints before and after work (Wahyudi et al., 2015).

Ergonomics research like this is very necessary in all industries, especially in MSME-based industries. This is because the average MSME production process is still manual with minimal work facilities (without paying attention to ergonomics). For example, research conducted by Zulkifli (2010) related to "Analysis of Cracker Making Workstations Based on the OWAS Method [Case Study: *Dua Saudara* Home Industry]". The results of the research show that of all the workstations there is a workstation that is the most uncomfortable, one of which is mixing workstation 1 with an OWAS score of 3 because the mixing process is still on the floor with a bucket tool. (back bent, both arms straight at the shoulders, and both legs bent). Therefore, at workstation 1 a table is provided to make the kneading process more comfortable and safe by improving the position of the back straighter, both arms under the shoulders, and both legs straight.

Putra Tunggal Home Industry is one of the home industries with a superior product in the form of tempe chips which is located in Wonosobo. The production process is carried out by 8 workers

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consisting of 5 workstations, namely workstations for slicing tempeh, making flour and spice dough, frying tempeh chips, packaging tempeh chips, and sealing packaging for tempeh chips. However, the production process is carried out manually with work facilities that are unergonomic, one of which is at the tempeh chips packaging workstation. This can be proven in preliminary research with the results of assessing the percentage of worker complaints based on NBM and the results of the OWAS assessment at other workstations such as the tempeh slicing workstation with an NBM value of 39.28% (11 out of 28 body parts) and a final OWAS value of 1 (normal work); a workstation for making chip dough with an NBM of 21.43% (6 out of 28 body parts) and a final OWAS score of 2 (rather heavy work); a chip frying workstation with an NBM value of 28.57% (8 out of 28 body parts) and a final OWAS score of 2 (rather heavy work); as well as the packaging sealing workstation with an NBM value of 7.14% (2 out of 28 body parts) and a final OWAS value of 1 (normal work), while the tempeh chips packaging workstation had an NBM value of 67.86% (19 out of 28 body parts) and a final OWAS value of 4 (very heavy work) which indicates that the musculoskeletal system has a very fatal risk (high risk) and requires improvement. Therefore, improvements are needed in the ergonomic aspects of the tempe chips packaging workstation. This aims to obtain a work facility design in the form of ergonomic tables and chairs at the tempeh chips packaging workstation which can reduce WMSDs in the form of pain after work.

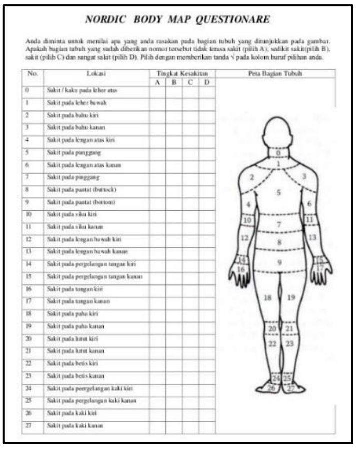
2. MATERIAL & METHODS

2.1. Material

The materials used in this research were tempeh chips and there were 8 workers (2 people slicing tempeh, 1 person making chip dough, 2 people frying chips, 2 people packing chips, and 1 person at the sealing workstation), the NBM questionnaire as a medium for assessing work-related pain, the OWAS questionnaire as a medium for assessing preliminary work posture, the RULA questionnaire as a medium for assessing advanced working posture, a notebook, smartphones as a medium for taking photos, and writing tools. Other materials used are the CATIA (Dassault Systemes, French) application as a design and simulation maker as well as wood and tools as the main materials for making table and chair work facilities.

2.2. Methods

The research method uses the Ovako Working Posture Analysis System (OWAS) method which is a method used to analyze and evaluate uncomfortable working postures and result in musculoskeletal injuries (Karhu et al., 1977). The parts of OWAS posture that are assessed are the back, arms, legs, and weight of the load when working (loads/use of force). Assessment of the level of work-related pain using the Nordic Body Map (NBM) method is a method that uses a questionnaire to determine the level of fatigue which is measured before and after carrying out work at each workstation, and is usually characterized by the appearance of disorders or complaints in the muscles and bones that occur. often called musculoskeletal disorders (Sutari et al., 2015). The questionnaire can be seen in Fig 1.


NORDIC BODY MAP QUESTIONARE

Anda diminta untuk menilai apa yang anda rasakan pada bagian tubuh yang ditunjukkan pada gambar. Apakah bagian tubuh yang sudah diberikan nomor tersebut tidak terasa sakit (pilih A), sedikit sakit(pilih B), sakit (pilih C) dan sangat sakit (pilih D). Pilih dengan memberikan tanda √ pada kolom huruf pilihan anda.

No.	Lokasi	Tingkat Kesakitan				Peta Bagian Tubuh
		A	B	C	D	
0	Sakit / kaku pada leher atas					
1	Sakit pada leher bawah					
2	Sakit pada bahu kiri					
3	Sakit pada bahu kanan					
4	Sakit pada lengan atas kiri					
5	Sakit pada punggung					
6	Sakit pada lengan atas kanan					
7	Sakit pada pinggang					
8	Sakit pada pantat (buttock)					
9	Sakit pada pantat (bottom)					
10	Sakit pada siku kiri					
11	Sakit pada siku kanan					
12	Sakit pada lengan bawah kiri					
13	Sakit pada lengan bawah kanan					
14	Sakit pada pergelangan tangan kiri					
15	Sakit pada pergelangan tangan kanan					
16	Sakit pada tangan kiri					
17	Sakit pada tangan kanan					
18	Sakit pada paha kiri					
19	Sakit pada paha kanan					
20	Sakit pada lutut kiri					
21	Sakit pada lutut kanan					
22	Sakit pada betis kiri					
23	Sakit pada betis kanan					
24	Sakit pada pergelangan kaki kiri					
25	Sakit pada pergelangan kaki kanan					
26	Sakit pada kaki kiri					
27	Sakit pada kaki kanan					

Figure 1. Nordic Body Map Questionnaire
(Source: Dewi, 2020)

Based on Fig 1, the NBM questionnaire can be calculated by adding up the parts of the body that feel uncomfortable working multiplied by their respective scores (A for score 1, B for score 2, C for score 3, and D for score 4), then added together overall for all parts of the body. According to Dewi (2020), after the total score is obtained, it is then matched with the respective total scores, where a score of 28-49 has a low level of risk (no improvement has been made, a score of 50-70 has a medium level of risk (it is possible to make improvements at a later date, a score of 71-91 has a high-risk level (immediate action is required), and a score of 92-112 has a very high-risk level (repair is needed as soon as possible).

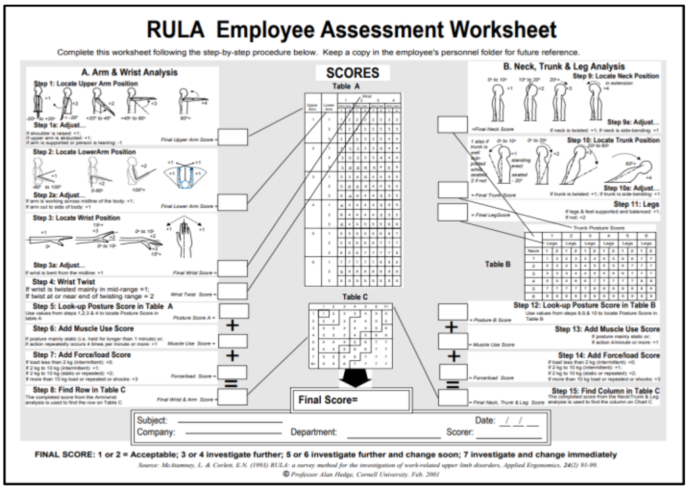


Figure 2. RULA Assessment Questionnaire *(Source: McAtamney dan Corlett, 1993)*

Rapid Upper Limb Assessment (RULA) is a method of ergonomic analysis and assessment of body posture when working with the use of the upper body (Tiogana and Hartono, 2020). Based on Fig 2, the final score obtained from table A and table B in the questionnaire, a final score can be obtained in table C which can be linked to risks and corrective actions. According to McAtamney and Corlett (1993), a score of 1-2 is still acceptable, a score of 3-4 may be corrected at a later date, a score of 5-6 can be corrected, and a score of 7 must be corrected as soon as possible. The advantages of the RULA method are the most accurate and specific analysis of upper body posture, easy calculations, and does not require special equipment to carry out.

Anthropometry is the science of measurement that determines the physical geometry, mass properties, and strength capabilities of the human body, and plays an important role in the design of household and industrial environments (Sutalaksana and Widyanti, 2016). This anthropometric measurement can be carried out using four dimensions of body part groups, namely anthropometry of the head, body, hands and feet. Anthropometric calculations can be adjusted to the percentile requirements, where the percentiles commonly used in this calculation are the 5^{th}, 50^{th} and 95^{th} percentiles. The determination of this percentile formula can be seen in Table 1.

Table 1. Normal Distribution and Calculation of Anthropometric Percentiles

Percentiles	**Calculation**
1	$\underline{X} - 2.325\ \sigma_x$
2.5	$\underline{X} - 1.960\ \sigma_x$
5	$\underline{X} - 1.645\ \sigma_x$
10	$\underline{X} - 1.280\ \sigma_x$
50	$\underline{X}$
90	$\underline{X} + 1.280\ \sigma_x$
95	$\underline{X} + 1.645\ \sigma_x$
97.5	$\underline{X} + 1.960\ \sigma_x$
99	$\underline{X} + 2.325\ \sigma_x$

(Source: Wignjosoebroto, 2000)

Based on Table 1, the percentiles that will be used are 5, 50, and 95. However, the 50th percentile is not used in this study because the results of the design can only be used comfortably for adults who have average body dimensions (people who have extreme bodies will feel uncomfortable) (Purnomo, 2013). The 5th percentile is used in the design because it can accommodate the type of work for the smallest people in the population who can use the design, while the 95th percentile is used to accommodate the type of work for the tallest and fattest user population. The use of these two percentiles can be applied to the design of tables and chairs as in Table 2.

Table 2. Specifications for the use of anthropometric data in making tables and chairs

Specifications	**Body Limb Size**	**Percentiles**
Table Width	Distance between the hand grip to the back (horizontal hand position)	5
Table Length	Shoulder Width (bideltoid) + 2 thigh thickness (allowance)	5
Table Height	Knee Crease Height (popliteal) + Elbow height in sitting position	95
Chair Width	Distance from the knee (popliteal) to the buttocks	95
Chair Length	Pelvic Width	95
Chair Height	Knee Fold Height (popliteal)	5

3. RESULTS AND DISCUSSION

3.1. OWAS and NBM


Work element 1


Work element 2


Work element 3

Figure 3. Initial Conditions of the Tempe Chips Packaging Workstation

Based on Fig 3, the OWAS assessment was used during preliminary research only because observation techniques are compatible with occupational health care, practical to use, oriented towards corrective action (not just problem identification), and proven to function as a safety tool at work in a company (Karhu et al, 1981). The results obtained at the tempe chips packaging workstation had a value of 4 which was categorized as very heavy work. This is because work element 1 of putting tempeh chips into 0.5 kg plastic packaging has a score of 4 (code 4 1 4 1), work element 2 of weighing packaged tempeh chips (0.5 kg) has a score of 4 (code 4 1 4 1), as well as work element 3 of placing and tidying up the packaged tempeh chips that will be sealed with a score of 4 (code 4 2 4 1). Packaging of tempe chips is done by sitting on a dingklik chair with dimensions of 30x25x20 cm and without a supporting base for the basin holding the frying tempe chips which causes the worker's back to bend (forward and to the side) and the knees to be too bent. This result makes the tempe chips packaging workstation have the highest OWAS score compared to other workstations, so improvements are needed as soon as possible.

The NBM questionnaire was used to assess chip packaging employees before and after work. However, the results that will be compared are the NBM value of workers after work because the NBM value before work is 28 which shows that the whole body is still normal. The results that will be compared are before using the table and chairs (initial conditions) and when using the table and chairs as in Table 3.

Table 3. NBM assessment results in initial conditions and using tables and chairs

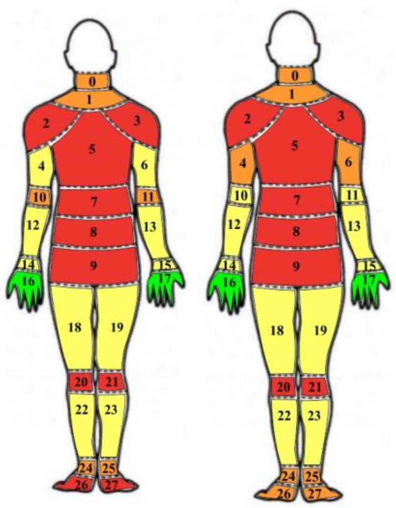
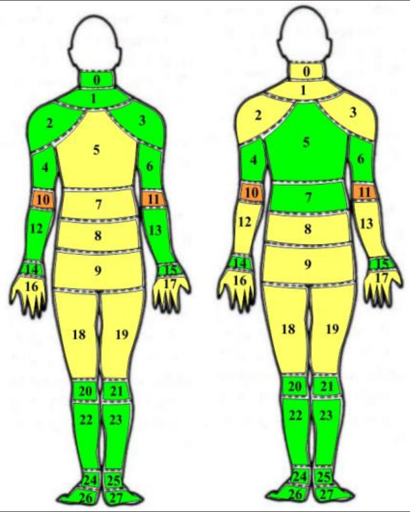
Initial Condition	Using a table and chair
	
Score of worker 1 (left)= 80 Score of worker 2 (right)= 78	Score of worker 1 (left)= 40 Score of worker 2 (right)= 44

Table 3 explains that when using packaging tables and chairs there is a decrease in work-related pain based on the NBM value for both workers. In the initial conditions, worker 1 and worker 2 respectively had NBM scores of 80 and 78, where this result indicates that the chip packaging workstation has a high level of risk so immediate corrective action is needed. However, when using packaging tables and chairs, there was a decrease in the NBM score. Worker 1 and worker 2 respectively had NBM scores of 40 and 44, where this result indicates that the chip packaging workstation has a low risk level so no corrective action has been found. These results indicate that the improvements made in the form of creating work facilities such as tables and chairs can reduce the level of risk of work-related illness from high risk to low risk.

3.2. RULA

The initial conditions of the tempeh chips packaging workstation with minimal facilities can be seen in Figure 4 and the results of the RULA assessment can be seen in Table 4.

Worker 1 Worker 2

Figure 4. Worker's position in initial conditions and the elevation angle

Table 4. RULA assessment in initial conditions

Assessment Indicators	RULA Score		Information
	Worker 1	Worker 2	
Group A			
Upper arm	4	4	Worker 1 experiences flexion at an angle of 70°, while worker 2 experiences flexion at an angle of 75°, and the upper arm is raised away from the body
Forearm	1	1	Worker 1 experiences flexion at an angle of 80°, while worker 2 experiences excessive flexion at an angle of 65°
Wrist	3	3	Worker 1 experiences extension at an angle of 31°, while worker 2 experiences extension at an angle of 25°
Wrist twist	1	1	Wrist rotation is within a rotation range of no more than 90°
Muscle Use Score	1	1	This posture is repeated more than 4 times in 1 minute
Load Score	0	0	Load < 2 kg
Group A Score	5	5	-
Group B			
Neck	3	3	Worker 1 experiences flexion at an angle of 20.5°, while worker 2 experiences flexion at an angle of 21°
Back	4	4	Worker 1 experiences flexion at an angle of 21°, while worker 2 experiences flexion at an angle of 32°, and his back tends to tilt to the side.
Legs	2	2	Legs are not balanced by bending the knees due to limited facilities (stool)
Muscle Use Score	1	1	This posture is repeated more than 4 times in 1 minute
Load Score	0	0	Load < 2 kg
Group B Score	7	7	-
Final Score	7	7	The work posture is less than natural so investigation and correction are needed as soon as possible

Based on Fig 4 and Table 4, the results of the RULA assessment at this packaging workstation received a score of 7 (less common work posture). This final score shows that this packaging workstation really has an unnatural working posture so investigation and repair are needed as soon as possible. It can be seen that the upper arm is flexed more than 45°, the lower arm is flexed more than 100° or less than 60°, the neck is flexed more than 20° or extended, the back is flexed more than 20°, and legs are similar to a squatting position. This is because the facility only uses seating mats in the form of chairs measuring 30x25x20 cm and there is no support for the basin holding the tempe chips frying which causes the upper and lower arms to be raised for long periods of time, the neck bends, the worker's back bends and the knees (feet) too bent. The RULA assessment results after using the packaging table and chair facilities have different RULA scores. This can be seen in Figure 5 for the working posture and Table 5 for the RULA assessment results.

Worker 1

Worker 2

Figure 5. The position of the worker using the table and chair and the elevation angle

Table 5. RULA assessment when using tables and chairs

Assessment Indicators	RULA Score		Information
	Worker 1	Worker 2	
Group A			
Upper arm	1	1	Worker 1 experiences flexion with an elevation angle of 40°, while worker 2 experiences flexion with an elevation angle of 40.5°, and his arm can rest on the table.
Forearm	1	1	Worker 1 experiences flexion with an elevation angle of 87°, while worker 2 experiences flexion with an elevation angle of 95°
Wrist	1	1	Worker 1 and worker 2 do not experience extension or flexion because both elevation angles are 0°.
Wrist twist	1	1	Wrist rotation is within a rotation range of no more than 90°
Muscle Use Score	1	1	This posture is repeated more than 4 times in 1 minute
Load Score	0	0	Load < 2 kg
Group A Score	2	2	-
Group B			
Neck	1	1	Worker 1 experiences flexion with an elevation angle of 8°, while worker 2 experiences flexion with an elevation angle of 9°
Back	1	1	Worker 1 and worker 2 do not experience flexion or extension because the elevation angle formed is 0°.
Legs	1	1	Leg posture is balanced with the help of a chair that suits the anthropometry (ergonomics)
Muscle Use Score	1	1	This posture is repeated more than 4 times in 1 minute
Load Score	0	0	Load < 2 kg
Group B Score	2	2	-
Final Score	2	2	The working posture is acceptable

Based on Table 5, the final RULA score before the repairs took place was from 7 (requires investigation and repair as soon as possible) to 2 (acceptable work posture). This can be seen in the upper arm which is not too raised because it can be leaned on the table (flexed less than 45°), the lower arm which can be leaned on the table, the wrist which is straight (not too bent/extended), the neck which is no longer bent forward (flexed less than 10°), the back is straighter (not flexed), and the legs are not too bent and can be easily moved forward or backward. These results indicate that using these work facilities can create conditions for good working posture naturally and can minimize the danger of WMSDs in packaging workers.

3.3. Design of Table and Chair

The design of the table and chairs is closely related to the anthropometric data of the two tempe chips packaging workers. This stage requires carrying out anthropometric calculations using the 5th, 50th, and 95th percentiles, but the percentiles that will be applied are the 5th and 95th percentiles. The 5th percentile is used as a representation of the range of dimensions that accommodates the type of work for the smallest people in the population. Meanwhile, the 95th percentile represents a spatial dimension that can accommodate types of work for a large population (Purnomo, 2013). The basic requirements that need to be used to make tables and chairs include the length, height, and width of each facility which are adjusted to the anthropometric data used as in Table 6.

Table 6. Measurement and Calculation of Anthropometric Data

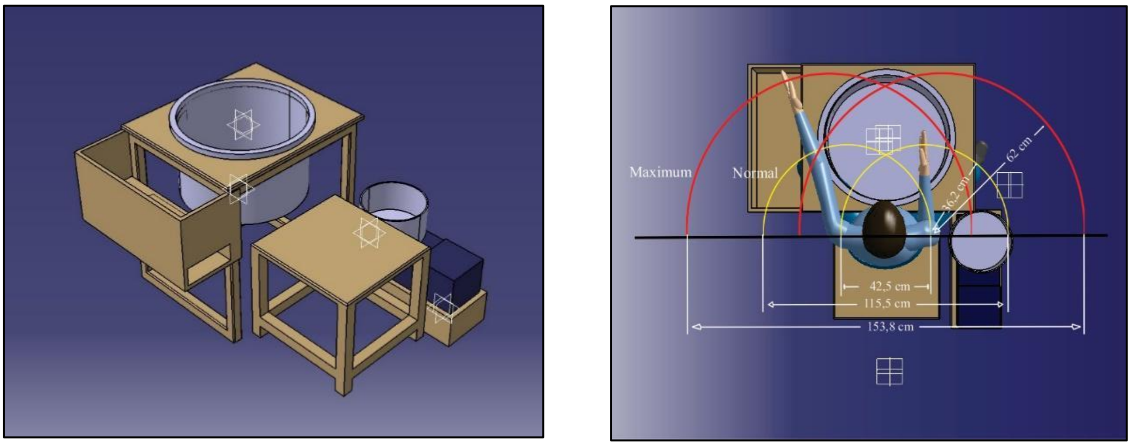
Specific Needs	**Part of Body**	**Dimensi of Worker**		**Percentile**	**Size Specifications**
		1	**2**		
Table Width	The distance between the hand (grip) to the back (horizontal hand position)	55	59	5	55.5
Table Length	Shoulder width (bideltoid) + 2 thigh thickness (allowance)	65.4	66	5	65
Table Height	Knee height (popliteal) + elbow height in sitting position	55	59.5	95	62.5
Chair Width	The distance from the knee (popliteal) to the buttocks	42.5	40	95	44.5
Chair Length	Pelvic width	38	32	95	42
Chair Height	Knee height (popliteal)	37	37.5	5	37

Table 6 explains that the percentiles used are adjusted to the dimensions, where table width, table length, and chair height use the 5th percentile (distance dimension) while table height, chair width, and chair length use the 95th percentile (space dimension) (Purnomo, 2013). This stage is rounded up to the nearest one with the aim of making the error smaller. This stage also requires modifications to suit existing tools such as basins, scales, and the size of the packaged chips. The specifications for these modifications are as in Table 7.

Table 7. Specifications of Modifications Made

Specific Needs	Parts Required	Sizes	Specifications Used	Remarks
Table Hole Diameter	Inner basin diameter	47	47	No handle on the basin
Length of Scale place	Length of Scale	46	50	Plus 2 cm for the 2 sides of the fence
Width of Scales place	Width of Scales	17	21	Plus 2 cm for 2 sides for the fence
Height of Scales place	Height of chairs - height of scales (total)	7	12	Plus allowance for 5 cm of scale to fit into place
Plastic Container Length	Plastic length	40	40	-
Width of Plastic Container	Plastic width	18	21	Plus 1.5 cm for the 2 sides of the fence
Height of Plastic Container	Height of Plastic Stack 2 pack	5	7	Plus 1.5 cm for the base
Shelf Length	Table width	55.5	52.5	Minus 1.5 cm for the 2 sides of the fence and a total distance of 1 cm from the edge of the tabletop
Shelf Width	Width of Packed Chips	18	21.5	Plus 1.5 cm for 1 fence and 2 cm allowance
Shelf height	It is half the length of the packaged chips	20	20	-
Shelf Height From Ground	Table Height-(Shelf Height+Plastic Container Height)	35.5	35.5	-
Distance between weighing place and chair	-	5	5	To the right of the chair
Distance between Shelf and Table	-	0	0	To the right of the table
Distance of Plastic Container to Table	-	0	0	To the right of the table

Based on the specifications for making packaging tables and chairs in Table 6 and Table 7, a design can be created using CATIA along with the work area as in Figure 6.



(a) Model Design (SE Isometric)

(b) Normal (Yellow) and Maximum (Red) Work Area

Figure 6. Table and Chair Design and Work Area

Fig 6 explains the design position of the packaging table and chair facilities, such as the position of the frying basin in the middle of the table with a hole, the scale to the right of the chair, and the temporary chip placement rack and its plastic packaging container to the left of the table. This placement is done to create more effective working habits. Figure 6 also explains the normal work area with a distance of 36.2 cm which makes it easier and easier for the work to be done, while the maximum work area is with a distance of 62 cm which makes the work done difficult and burdensome. The design in Figure 6 is then carried out with a work posture assessment (RULA) using the CATIA application as in Figure 7.

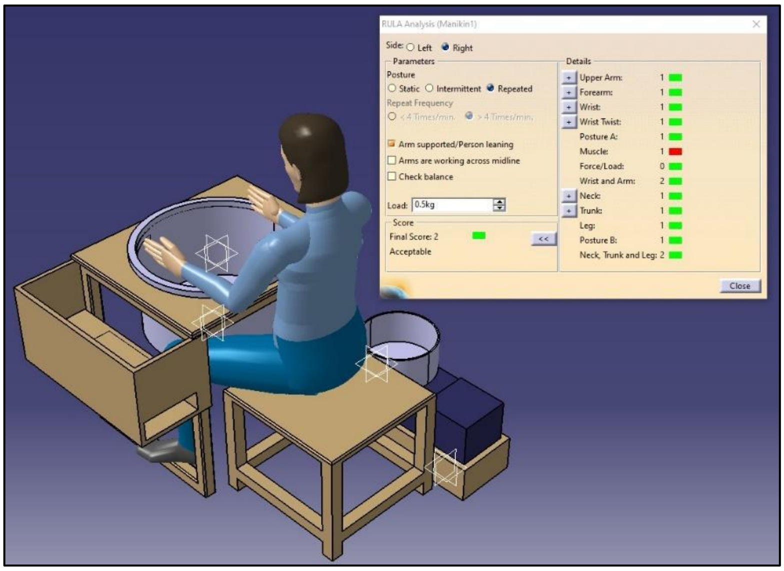


Figure 7. RULA Posture Assessment in the CATIA application

Based on Figure 7, explains that with a tempe chips load of 0.5 kg (score 0), the RULA score for the upper arm, forearm, wrist, wrist rotation, and muscle use is 1 so the RULA score for the upper limb is 2, while the RULA score for the neck, back and legs is 1 so the RULA score for the lower limbs is 2. Both of these body parts results can be obtained with a final RULA score of 2 on CATIA which indicates that the working posture is more comfortable and acceptable, so this design will be directly created as in Figure 8.

Desk and chair facilities from behind the side

Figure 8. Packaging table and chair facilities

Based on Fig 8, it can be seen that the work facilities for packaging tempe chips in the form of tables and chairs are made from sengon wood, totaling 4 wooden planks measuring 2 meters and 4 wooden poles measuring 3 meters. This work facility has been used by employees of the tempe chips packaging department during the 3-day trial period for data to be collected.

This research needs to increase the flexibility of the working facilities of tables and chairs for packaging tempeh chips so that these facilities can be used by anyone apart from the two packaging worker respondents with different anthropometric measurements. Increased flexibility by using table and chair heights that can be adjusted according to needs, for example by using a hydraulic system to raise and lower height levels.

4. CONCLUSION

This table and chair facility can reduce the level of risk of work-related illnesses (NBM score) from 80 and 78 to 40 and 44 (high risk to low risk) and also minimize mismatches in a working posture with RULA score of 7 to 2, so that working posture is better. Overall, the packaging table and chair facilities make workers work more safely and comfortably.

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