CHANGING BODY POSTURE AND WORKING SYSTEM IMPROVES WOKERS PERFORMANCE AND PRODUCT QUALITY

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ABSTRACT

Seaweed is one of the nation's potential marine commodities that may contribute to the national revenue and a new source of income for the local community, as the cultivation of seaweed is much easier and cheaper than paddy crop, because neither pesticides nor fertilizer would be required. Other advantages of cultivating seaweed are the fact that it can be carried out throughout the year, and its relatively shorter duration to reach the harvesting time. Local practice of drying the seaweed is by spreading it over a plastic sheet on the ground and exposing it to the sun. Unfortunately, such traditional practice of drying seaweed has led to increased risk of contamination of seaweed by dust and sand particles and other impurities. The quality of seaweed is influenced by the type of seedlings, harvesting age, and the crucial process of drying. The local traditional working posture during drying is squatting and stooping to flatten and spread evenly the seaweed. Our preliminary study has shown that the farmers have had considerable musculoskeletal complaints and fatigue with the seaweed quality being still relatively low.

This study was conducted to examine the effects of changing the workers' working posture and limiting lift weight at 23 kg and introduced a 5-minute break after an-hour work with the aim to improve both workers' performance and seaweed quality and productivity. This is an experimental study using a two-period cross-over design on 20 farmers of seaweed cultivation in the Ped Village of Nusa Penida.

The results of our study showed that redesigning and changing the workers' working posture and working system improved the performance of seaweed farmers as revealed by the decrease of musculoskeletal complaints to 56.15% ($p < 0.05$); by decrease in general fatigue to 50.84% ($p < 0.05$); by the increase in productivity to 37.93% ($p < 0.05$), and by the increase in income to 41.62% ($p < 0.05$). The quality of the dried seaweed was also improved as could be seen from the decrease in water content to 29.24% ($p < 0.05$) and decrease in impurities to 33.33% ($p < 0.05$).

From our data it could be inferred that changing the workers' working body posture and working system significantly improved both their performance and the quality of their product.

Key words: redesign and change, working body posture, working system, seaweed quality

INTRODUCTION

Seaweed is one of the nation's potential marine commodities that may contribute to the national revenue and a new source of income for the local community. The villages in the district of Nusa Penida which have a beach such as Lembongan, Jungut Batu, Toya Pakeh, and Ped has been successfully to develop seaweed cultivation. One of the villages that have quite large seaweed farming area is Ped village. The area is about 21.150 km^2 with population of 3,658 inhabitants[1]. While the seaweed farming area around 32 hectares, with number of family that involved for the cultivation is around 325 families[2].

There are 2 types of seaweed that suitable to be cultivated in Nusa Penida, namely euchema spinosum and euchema cottonii. Seaweed cultivation nowadays is a major job for the coastal community, due to the demand of seaweed to meet the export market is considerable high. Nusa Penida seaweed productions for the last two years are as follows: (1) in 2007 production 105,015 tons, the value more than Rp. 42 billion[3]; and (2) in 2008 production of 101,210 tons with a value of Rp. 85 billion[4]. Dried seaweed is sent to Surabaya, and then exported to the countries of destination such as Japan, China, Australia, USA, UK, and other countries.

Seaweed is widely used for food and medicine. Seaweed extract which is a hydrocolloid such as gelatin, carrageenan, and alginates are also much needed in various industries. Alginate is used in food, beverage, paint, graphic photo paper, textiles, and pharmaceuticals[5,6].

The cultivation of seaweed is much easier and cheaper than paddy crop, because neither pesticides nor fertilizer would be required. Other advantages of cultivating seaweed are the fact that it can be carried out throughout the year, and its relatively shorter duration to reach the harvesting time. Seaweed cultivation activities consist of several steps[5,7] starting from (1) preparation of farming area, (2) preparation and selection of seedlings, (3) maintenance periods (4) harvesting at ages between 6 to 8 weeks after planting, (5) drying for 2-3 days, and ended with (6) packaging and storage.

The drying process is necessary to get attention, despite of the products is good, but if the postharvest handling is poor it will reduce the quality of seaweed[5,8]. The quality of seaweed is influenced by the type of seedlings, harvesting age, and the crucial process of drying. Seaweed is stated in dried condition if the water content between 31-35 % for euchema[5,9].

Local practice of drying the seaweed is by spreading it over a plastic sheet on the ground and exposing it to the sun. Unfortunately, such traditional practice of drying seaweed has led to increased risk of contamination of seaweed by dust and sand particles and other impurities. The local traditional working posture during drying is squatting and stooping to flatten and spread evenly the seaweed. Stooping work posture is not physiological posture that will cause a reaction in the form of musculoskeletal complaints and fatigue[10,11,12]. More even this method produces low quality of seaweed that is indicated by high content of water and impurities such as dust, sand, and stone[6,7]. During activity the workers exposed to direct sun, without regular rest, and excessive lifting load. Such working conditions are not physiological, and the workers have fatigue and musculoskeletal complaints[12,13,14].

Some exporter companies complaint about the quality of seaweed that is sold by farmers. The main complaint is concerning the water content and impurities that exceeds standard quality for export[15]. The price of seaweed slumped because it still dirty, sandy and contain others impurities, that occurs because the drying process still using a plastic sheet, even directly on the floor[16].

Drying methods for handling agricultural products by utilizing solar energy have been performed traditionally for a long time. Solar energy is categorized as renewable energy that is suitable to be developed in rural areas where the people lack of education, low skill, and lack of economic capability. Based on these conditions, appropriate technology will be suitable to be developed and used in rural areas. There are many types of solar dryers such as tents, crates, racks, and houses[17,18]. Solar dryer is designed based on application of appropriate technology that meet the following criteria[19] (1) technically to simplify and to speed up the work; (2) economically, efficient in natural resources and affordable in cost; (3) ergonomically to improve physical and mental heath, prevent illness and injury that caused by work; (4) socio-cultural considering towards work organization, work habits, norms, values, and trust of workers; (5) saving energy; and (6) environmentally friendly.

This study is conducted to examine the effects of changing the workers' working posture and limiting lift weight at 23 kg and introduced a 5-minute break after an-hour work with the aim to improve both workers' performance and seaweed quality. Workers' performance consists of (1) reduction of musculoskeletal complaints, (2) decrease in fatigue, (3) increase on productivity, and (4) increase in income. Seaweed quality consists of (1) decrease in water content, (2) decrease impurities level in dried seaweed.

MATERIALS AND METHODS

This was an experimental study using a two-period cross-over design. The advantages of this design were biological variability inter-subject can be controlled, and the number of samples only half of the parallel design[20,21,22]. In cross over design, interval between treatments was given a washing out period, to eliminate the residual effect of treatment that have been implemented. Subject involved in this study 20 farmers of seaweed cultivation in the Ped Village of Nusa Penida.

Research variables consisted of (1) independent variable were redesign of dryer and working system; (2) independent variables were performance and seaweed quality; (3) control variables were human aspects and environmental. Performance assessed from musculoskeletal complaints, fatigue, productivity, and income. Quality of seaweed assessed from water content, impurities level. Environmental aspects included temperature, humidity, wind velocity, sun intensity.

Before redesign, drying was carried out by putting the seaweed on plastic sheet on the ground, the working posture during drying was squatting and stooping, as shown in Figure 1. Excessive lifting weight of seaweed, and without short breaks, except for lunch breaks. After redesign, drying was carried out by using dryer as height as elbow in standing position, as shown in Figure 2. Limitation of lifting weight by 23 kg; provided 5 minutes breaks every hour worked, and availability of drinking water.

Figure 1 Drying Seaweed by Using Plastic Sheet

Figure 2 Drying Seaweed by Using Dryer as Height as Elbow

The tools used in this study include anthropometer, anemometer, luxmeter, stopwatch, digital camera, sling thermometer, globe thermometer, psychrometric chart, Nordic Body Map questionnaires, and 30 items of fatigue questionnaires. Data obtained from this study were processed by SPSS software. Treatment effects were analyzed by using t-paired test for a normal distribution, while Wilcoxon test were used for those that not normally distributed, at significant level α = 0,05.

RESULTS

The characteristics of seaweed dryers were presented in the Table 1. The mean temperature on the drying surface was no significant difference ($p > 0.05$), however the wind velocity on the drying surface was significant difference ($p < 0.05$).

Table 1 Characteristics of Seaweed Dryer

Variable	n	Average		p
		Terpal	*Bedeg*	
Temperature (^{o}C)	9	34.46±2.17	32.65±1.71	0.067
Wind velocity (m/s)	9	0.38±0.19	1.73±0.66	0.000

The daily temperatures and wind velocity were measured from 8.00 to 16.00 for 8 days. The mean value of temperature profile was shown in Figure 3. It showed that the temperature on *terpal* surface (plastic sheet) was higher than on *bedeg* surface (bamboo woven). On the other hand, the mean wind velocity on the *terpal* surface was lower than on *bedeg* surface as depicted in Figure 4.

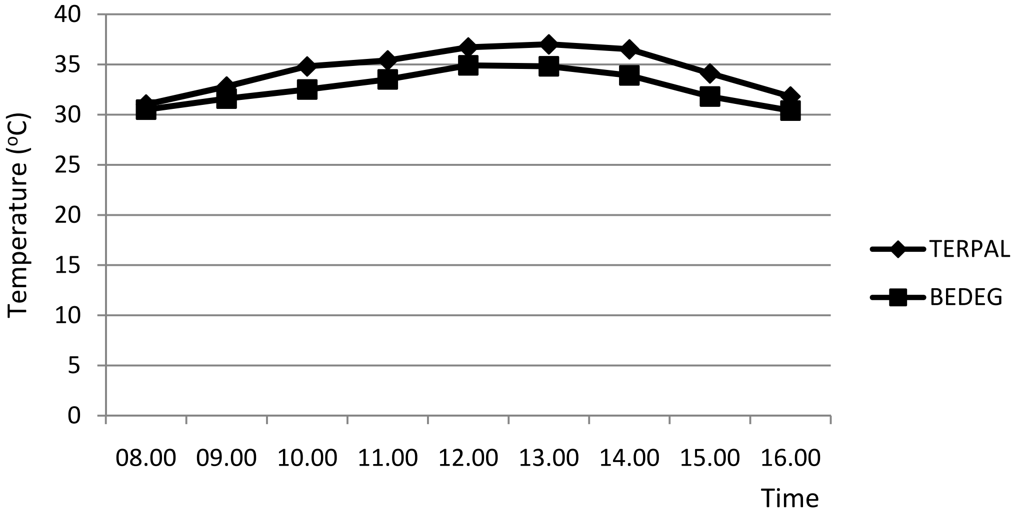

Figure 3 Temperature Profile on Drying Surface

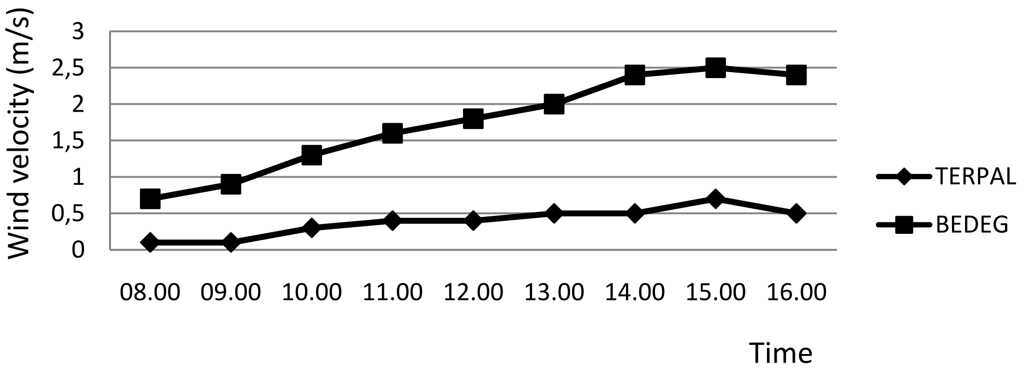

Figure 4 Wind Velocity on Drying Surface

The farmer performances and seaweed quality were described in the Table 2. There were no significant differences of musculoskeletal, general fatigue, and heart rate before start working ($p > 0.05$). However, after finish working there were significant differences of musculoskeletal complaints, general fatigue, heart rate, productivity, and the income ($p < 0.05$). The quality of dried seaweed that presented by water content and impurities level were significant differences ($p < 0.05$). Wind velocity on *bedeg* surface was higher than at the surface of the *terpal* or plastic sheet, air circulation took place either from above or from below of the *bedeg* surface, that impact on the drying rate faster.

Table 2 Mean Difference of Work Performance and Seaweed Quality

Variable	n	Average		p
		Before improvement	After improvement	
Musculoskeletal Disorders (MSDs)				
MSDs-score before working	20	29.38±0.79	29.15±0.81	0.119
MSDs-score after working	20	50.97±1.81	38.62±1.21	0.000
Difference	20	21.60±1.72	9.47±1.29	0.000
General Fatigue (GF)				
GF-score before working	20	31.05±0.84	30.80±0.70	0.128
GF-score after working	20	51.15±1.87	40.67±1.26	0.000
Difference	20	20.10±1.63	9.87±1.36	0.000
Heart Rate (HR)				
HR before working (pulses/min)	20	76.10±3.58	75.85±4.00	0.411
HR after working (pulses/min)	20	96.01±4.81	91.06±4.51	0.000
Workload (pulses/min)	20	19.90±2.66	15.21±2.02	0.000
CVL (%)	20	33.11±3.93	25.30±2.88	0.000
Productivity				
Drying rate (kg/h)	20	17.00±0.66	17.98±0.43	0.000
Work productivity	20	0.87±0.12	1.20±0.17	0.000
Income				
Farmers income (Rp)	20	215,775±24,075	240,750±20,581	0.000
Seaweed Quality				
Water content (%)	20	41.82±4.86	29.59±8.1	0.000
Impurities level (%)	20	5.25±0.78	3.50±0.68	0.000

DISCUSSION

Seaweed Dryer

The average temperature on the surface of the plastic sheet was about 34.46 ± 2.17 ^{o}C, and on the surface of *bedeg* 32.65 ± 1.71 ^{o}C. The temperature on the surface of the plastic sheet is higher because the brown color has a coefficient of absorption higher than *bedeg* surface that made from bamboo woven[23]. However, the results showed that there was no significant difference (p> 0.05) between the temperature at the plastic sheet and the temperature at the *bedeg* surface. Thus the difference in surface temperature does not affect the drying rate. This drying temperature was match with the results of solar dryer[24] for drying silk, with drying temperature ranged between 31-39 ^{o}C.

The wind blows from the southeast direction with average velocity on the surface of the plastic sheet is 0.38 ± 0.19 m/s, and on the surface of *bedeg* 1.73 ± 0.66 m/s. Difference test showed a significant difference ($p < 0.05$) between wind velocity at the plastic sheet and at the *bedeg* surface. This difference was caused by the plastic sheet was on the soil surface (0 cm height), so the wind blocked by bushes, and buildings in surrounding. While the surface of *bedeg* located 93 cm above the ground, and not blocked by the bushes. The higher wind velocity affect on more rapid air circulation. On the surface of *bedeg* circulation occurred from above and below of the surface. The results of this study approached the report of *Balai Besar Meteorologi dan Geofisika Wilayah III Denpasar*, for the period of June 2008, with wind velocity ranging from 1.94 - 8.33 m/s from southeast direction.

Musculoskeletal Complaints

The average score of musculoskeletal complaints before working with condition before redesign about 29.38 ± 0.79, and conditions after redesign of 29.15 ± 0.81. The results showed that the score of musculoskeletal complaints was not significantly different ($p > 0.05$). Thereby it can be assumed that the decrease in musculoskeletal complaints due to the redesign of dryer and working system.

The different test results showed a score of musculoskeletal complaints after working was significantly different ($p < 0.05$), with a score of 50.97 ± 1.81 for condition before redesign, and 38.62 ± 1.21 for the condition after redesign. These results indicated a decline of musculoskeletal score complaints by 24.22%.

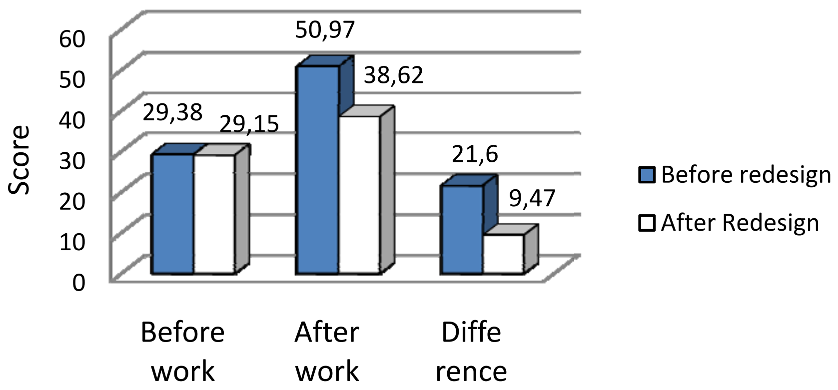

Figure 5 Score of Musculoskeletal Complaints

The differences of musculoskeletal complaints before and after working for both treatments were compared, and the results were significantly different ($p < 0.05$). The mean difference score of musculoskeletal complaints of workers before redesign 21.60 ± 1.72, and after redesign of 9.47 ± 1.29, a decrease of 56.15%, as shown in Figure 5.

Musculoskeletal complaints in the process of drying seaweed caused by squatting and stooping work posture when drying used a plastic sheet, and excessive lifting weight. Musculoskeletal complaints can occur in almost type of work, with light category, moderate, heavy, especially very heavy[25]. Musculoskeletal complaints caused by many factors[26] such as psychosocial, individual, workplace, and work organization. In the process of drying seaweed workplace factor and work organization have been improved, resulting in a decrease in musculoskeletal complaints.

The decrease in musculoskeletal complaints on seaweed drying process caused by redesign of seaweed dryer with elevation in accordance with the elbow high of the workers in standing position. To ensure that the subject could reach the surface of the dryer, the high set at the 5 percentile elbow height or 93 cm. Redesign of dryer has caused a change of posture from the squatting to standing position.

Standing work posture produced a low level of activation of muscles in the lumbar erector spinae, the intra-discal pressure was low, and known as an efficient position[10]. Dynamic standing posture was better than static standing posture[27]. Drying seaweed done with dynamic standing posture, where the subject moves around the dryer to flatten the seaweed, which means the blood circulation more smoothly so that the fulfillment of O_2 and the wastes of metabolic transport more smoothly.

An improvement of work station on Balinese gamelan craftsmen from sitting on the floor changed using the table and sat in the chair was proven to reduce the work load and musculoskeletal complaints[28]. To improve working conditions, for instance, improvement of work stations, improvements in material handling, and improved work organization can improve productivity, generate higher product quality, save time, reduce accidents and fatigue[29]. An improvement on a small industrial by redesign layout of work station, redesign of lift equipment, design table with the appropriate height, job rotation, giving a break and snack, can reduce workload, reduce muscle work, and increase productivity[30].

Fatigue

The average score of general fatigue before working with condition before redesign 31.05 ± 0.84, and condition after redesign 30.80 ± 0.70. The fatigue score before working occurred in the category of physical fatigue, which felt stiff in the shoulder, and pain in the back. The results showed no significant difference ($p > 0.05$), so the decrease in fatigue is assumed to be caused by the redesign of dryer and working system.

The average score of general fatigue after working with condition before redesign 51.15 ± 1.87, and condition after redesign 40.68 ± 1.26. The results showed significant difference ($p < 0.05$), with a decrease in fatigue scores by 20.46%.

The difference of fatigue between before and after working compared, and the results there were significant differences ($p < 0.05$). The differences of fatigue score before redesign about 20.10 ± 1.63, and after redesign 9.87 ± 1.36, a decline in fatigue score of 50.84%, as shown in Figure 6. Then the difference was analyzed by category, it was obtained weakening in activity score decreased from 8.75 to 3.70, or reduced by 57.71%, decrease in motivation scores from 4.60 to 2.30, or reduced by 50%, and reduced physical fatigue from score of 6.75 to 3.95, or down 41.48%.

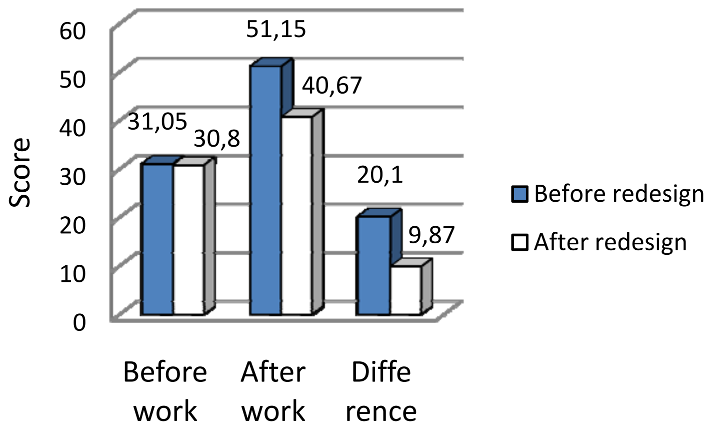

Figure 6 Fatigue Score of the Subjects

The decrease of fatigue was caused by redesign of seaweed dryer with elevation in accordance with elbow height of the workers in standing position, the high set at the 5 percentile elbow height or 93 cm, so that the working posture change from squatting to standing. Dynamic standing posture was better than static standing posture, which means the blood circulation more smoothly so that the fulfillment of O_2 and the transport of waste metabolic more smoothly[27]. Drying seaweed done with dynamic standing posture, where the subject moved around the dryer to flatten the seaweed. Lifting weight and transport was limited by 23 kg in accordance with the recommendations of NIOSH caused muscle work was lighter, workers can do the job during work time 8 hours per day. Giving a short break 5-minute every hour worked, quickly able to restore energy as before, because the subject has not experienced excessive fatigue.

Workload

The mean heart rate before working for two groups were not significantly different ($p > 0.05$), with a mean value of 76.10 ± 3.58 ppm for the working condition before redesign, and 75.85 ± 4.00 ppm for the working condition after redesign. These data including the category of light workload that was in the range 75-100 ppm[11,31]. Thus it can be assumed that the decrease of workload caused by the redesign of dryer and working system.

Statistical analysis of heart rate after working for two groups were significantly different ($p < 0.05$), with average of 96.01 ± 4.81 ppm for working condition before redesign, and 91.06 ± 4.51 ppm for working condition after redesign. Both of working heart rate was still including the categories of light work load that was in the range 75-100 ppm[11,31,32]. The results also showed increased heart rate of working conditions before redesign of 26.15%, and group after redesign of 20.05% from the initial conditions. The increasing resting heart rate to the working heart rate allowable 35 ppm for men, so that work can performed 8 hours continuously[11]. Based on these limits in both groups were under the required conditions, so it can carry out the work 8 hours continuously. The average working heart rate did not exceed 112 ppm for the work using foot or leg tasks, and 99 ppm for the work using hand or arm tasks[33]. The heart rate of the subject study was under required, so it can perform 8 hours continuously.

Similarly, the results of workload analysis show the average workload was significantly different ($p < 0.05$), with average of 19.90 ± 2.66 ppm for the working condition before redesign and 15.21 ± 2.02 ppm for working condition after redesign. There was a decrease of 4.69 ppm workload or 23.56%, as shown in Figure 7. The decrease of workload was caused by the redesign of seaweed dryer in accordance with the 5 percentile of elbow height in standing position or 93 cm, so that the work posture change from squatting to standing.

Drying seaweed was done with dynamic standing posture, where the subject moves around the dryer to flatten the seaweed. Lifting weight was limited 23 kg as recommended by NIOSH, and lifted freely (free style), causing the muscle work was lighter, and the subject can do during work time 8 hours per day. The freestyle posture was the best posture for lifting loads with the smallest fatigue[33]. Giving a short 5-minute break every hour worked, and the availability of drinking water, the worker can quickly perform the recovery, so that fatigue was reduced[34].

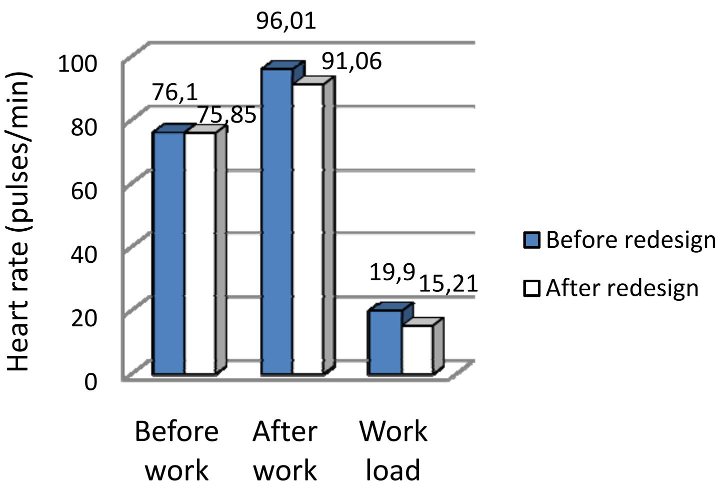

Figure 7 Heart Rate of the Subject

By providing 5-minute break at lifting and lowering goods that lasted 9 minutes will occurred recovery time and can prevent muscle fatigue[35]. Working with new working tools and systems which refers to aspects of anthropometry was also shown to reduce cardiovascular load (CVL) significantly ($p < 0.05$). This is evident from the decrease in % CVL, before redesign the average about 33.11 ± 3.93% and after redesign the average 25.30 ± 2.88%. Working conditions before redesign is categorized as moderate workload, which requires 75% work and 25% of rest for every hour. After redesign a decline % CVL and change the work conditions into categories of light work, so that workers can perform 8 hours of continuous activity.

Productivity

Analysis of drying rate on both groups showed significant difference ($p < 0.05$), with average of 17.00 ± 0.66 kg/hour for the use plastic sheet and 17.98 ± 0.43 kg/hour for the using *bedeg*, or an increase of 5.76%. It meant that the drying process was faster on dryer as high as 93 cm, with *bedeg* surface that has slope. The success of drying was determined by three factors: the heat to remove water vapor, dry air to absorb the water vapor, and circulation to carry the water vapor[36]. Based on this formula, the decline in water content was caused by a higher evaporation rate on *bedeg* surface, due to higher wind velocity. Drying process was found faster, needed only 2 days when the weather in sunny conditions. While drying by using plastic sheet needed at least 3 days.

Productivity analysis on both groups showed significant difference ($p < 0.05$), with average value of 0.87 ± 0.12 kg/ (hour.ppm) for working conditions before redesign and 1.20 ± 0.17 kg/(hour.ppm) for working conditions after redesign or increase productivity by 37.93%. The increasing of productivity was due to an increase in drying rate and decreasing workload.

Income

Income analysis on two groups showed significant differences ($p < 0.05$), with average value of Rp. 215,775 ± 24,075 for working conditions before redesign and Rp. 240,750 ± 20,581 for working condition after redesign. Thus an increase in income within 2 days of Rp. 24,975, - or Rp. 12,487.50 per day. According to Widiastuti (2009) and based on preliminary study, the average income of farmers cultivating seaweed around Rp. 30.000, - per day, thus an increase in income of 41.62%.

Quality of Dried Seaweed

Water content analysis of dried seaweed for two groups showed significant differences ($p < 0.05$), with a mean value of 41.82 ± 4.86% for the use plastic sheet (tarpaulin), and 29.59 ± 8.10% for the use *bedeg*, or a decrease of 29.24%. It meant that the drying process faster. Dryer as high as 93 cm, with *bedeg* surface that has slope produce maximum temperature, because the sunlight hit the surface perpendicular *bedeg* surface, so that the drying process faster. Wind velocity on *bedeg* surface was higher than at the surface of the plastic sheet, air circulation took place either from above or from below of the *bedeg* surface, that impact on the drying process faster. Seaweed already dried within 2 days, with water content 29.59% and met the Indonesian National Standard[37].

The average analysis of impurities level showed significant difference ($p < 0.05$), with average value of 5.25 ± 0.78% for the use plastic sheet, and 3.5 ± 0.68% for the use *bedeg*, or a decrease of 33.33%. It meant that the use of dryer with elevation 93 cm can reduce the impurities level in dried seaweed. This happened because during the drying process sand and dirt in the form of salt crystals that attached on seaweed fell due to friction with the wavy surface of *bedeg* and holes.

Dried seaweed that produced by this way has bright color and clean with impurities level of 3.5%, and already met Indonesian National Standard[37].

NOVELTY

The study found new model of seaweed dryer which is designed according to the anthropometry of workers through SHIP and appropriate technology approaches, and limitation of lifting weight, so that workers become more comfortable when working, the drying rate faster, and better product quality.

CONCLUSION

Based on the analysis and discussion that obtained in this study, it can be concluded the following results.

1. Changing body posture and working system decreased musculoskeletal complaints to 56.15%.
2. Changing body posture and working system decreased general fatigue to 50.84%, followed by an increase in activity by 57.71%, increased motivation by 50%, and reduced physical fatigue by 41.48%.
3. Changing body posture and working system increased productivity to 37.93%.
4. Changing body posture and working system increased income to 41.62%.
5. Changing body posture and working system decreased water content to 29.24%.
6. Changing body posture and working system decreased impurities level to 33.33%.

SUGGESTION

The redesign of seaweed dryer and limitation of lifting load, and giving a short breaks should begin to be implemented due to dryer and working system have been proven to reduce musculoskeletal complaints, reduce fatigue, improved productivity and income.

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