ERGONOMIC REDESIGN OF WORKING TOOLS INCREASES PERFORMANCE OF TRADITIONAL COCONUT OIL MAKERS IN THE DISTRICT OF DAWAN, KLUNGKUNG

I Made Gede Arimbawa
E-mail: arimbawa09@yahoo.com

ABSTRACT

The business of producing coconut oil in the district of Dawan, Klungkung is one example of small-scale home industries in the rural area. The level of working productivity of the oil makers can be categorized as relatively low, as viewed from the aspect of the following indicators: (a) level of working burden, (b) musculoskeletal complaints, (c) level of fatigue or tiredness, and (d) level of productivity. One factor that causes the low productivity is the fact that the working tools used in this industry are non-ergonomically designed such as: (1) tool for peeling off the coconut fibers, (2) tool for taking the coconut flesh, (3) tool for grating the coconut flesh, (4) tool for extracting milk from the water-mixed grated coconut, (5) stove for boiling the coconut milk. Based on the above problems background, it is necessary to make more ergonomic new design or redesign of the tools that are used by the coconut oil makers in the district of Dawan in order to increase their working performance or productivity.

This research was carried out using *treatment by subject design* by comparing before and after treatment involving 22 female subjects selected by simple random method from all female coconut oil makers in the studied area. Before treatment the research subjects were asked to make coconut oil as usual with their traditional tools. After an interval of *washing out period* was given, the subjects entered the treatment phase in which they were asked to make coconut oil by using the tools already redesigned ergonomically. The data obtained from the research were analyzed by *t-paired* test at a significance level of 5%.

Results of the analysis showed as follows: (1) average of working heart rate before treatment was 108.49 ± 0.95 pulse /minute and after treatment 91.92 ± 1.91 pulse /minute, indicating a decrease of workload from moderate to mild one (decrease of working heart rate of 16.59 pulse/minute or 14.69%); (2) average of musculoskeletal complaints before treatment was 51.73 ± 1.36 and after treatment 36.79 ± 0.83 (a decrease of 14.94 or 26.17%); (3) average of fatigue before treatment was 66.75 ± 3.60 and after treatment 49.50 ± 3.28 (a decrease of 17.19 or 25.83%); (4) average of working productivity before and after treatment was 35.86 ± 1.09 and 48.66 ± 1.10, respectively (an increase of 12.81 or 35.71%). Based on evaluation of investment yield, the NVP value in a five-year period Rp. 11.503.431,- > 0, PBP 9.22 months > 0, and RoI 32.54 > 13% (*rate of interest* commonly applied in 2008).

It is concluded that redesign of working tools to be more ergonomic has proven to be able to increase the working performance of coconut oil makers and hence worth investing. Novelty of this research is in the positive results related to ergonomic redesigning of the tools for making coconut oil in the district of Dawan, Klungkung by approaches to being systemic, holistic, interdisciplinary, participatory, and appropriate technology usage. Further studies on similar related working issue should focus on the aspects of working environment, especially on how to overcome smoke pollutant in the kitchen area, on more proper work station and working organization or on that related to production quality of the coconut oil by generating maximally all the potential already in existence among the local traditional coconut oil makers.

Keywords: redesign; working tools; ergonomic; working performance

INTRODUCTION

One of the efforts to increase performance of workers in the rural areas is optimizing the potential of human resources in the handling process of local primary plantation produces. One such effort is ergonomic redesigning of working tools used in the making process of coconut oil in the district of Dawan in Klungkung Regency, Bali.

The above effort seems to be worthdoing since traditionally producing coconut oil still exists as a prominent business of many inhabitants of the district of Dawan. According to a report by the Bali Provincial Department of Trade and Industries, in the district of Dawan alone there exist at least 45 coconut oil home industries with a total of 61 laborers being involved in the business.[1] This quite big number of home industries of coconut oil in Dawan area has been made possible by several supporting factors: (1) The existence of many fertile and productive coconut groves; about 49.36% of the district of Dawan consists of coconut groves [2]; (2) The local community remains willing to use coconut oil produced by these coconut oil home industries; (3) As such, the business of traditional coconut oil comprises one of the economic backbones of a large segment of the local inhabitants.

It is understandable that the business of coconut oil production in Dawan has resulted in the establishment of a number of small scaled home industries in which coconut oil is produced by a traditional mechanism. Most of the laborers in the industries are female workers between 24 – 50 years of aged. In the present time, the working performance of the female workers can still be categorized as relatively low. This relates with the mindset of the greater majority of the workers to think they would be ready to do anything for whatever amount of yield regardless of their own safety in the job. From the ergonomic point of view, therefore, such outlook and the related working condition and performance is far from being satisfactory.[3]

One important concern to the above problem is the fact the workers use non-ergonomic working tools in the several stages of the coconut oil making: (1) In the first stage of the oil making process, the workers must peel the coconut fibers off the outer shells by using a special tool for that purpose, called *pengesan*. The average height of this tool is 50 cm, about 20 cm lower than the average worker's elbow level, namely 62 cm, so to create an unnatural working position [4]. The worker's body position becomes a bending position at about 50^{o} from the erect position or more than a third of the possible maximal movement the upper part of the body can make [5]; (2) In the second stage, the workers must extract the coconut flesh off the inner part of the shells by use of a special tool called *penyeluhan* (the process called *nyeluh nyuh*). This particular tool has a handle of 1.2 cm in thickness, which is obviously not matching with the anthropometry of the workers' clinched hands[5.6], thus to cause pain in the palm, wrist and arm; (3) in the third stage, the workers must grate the coconut flesh (*ngikih nyuh*) using a grating

machine. The average height of the machine is less than 60 cm, not suitable for the average height of the workers' elbow level of 82,08 cm, to make the workers' bodies inclined forward and cause the muscles of the arm to stretch when reaching the feeder opening of the machine; (4) The fourth stage is making of coconut milk, where the workers have to squeeze the water-mixed grated coconut by using their hands; a procedure that tends to cause muscular stress of the shoulders, arms, hands and fingers; (5) In the fifth stage the workers boil the coconut milk (*ngelalab santen*) on a traditional stove or *jalikan.* The stove's entrance for feeding fire woods opposes the worker, so while working a worker is exposed to heat of the fire. Furthermore, the distance of the stove is about 65 cm, which is beyond the average 65 cm strech of the arm of a worker to reach the stove. This condition causes a worker to incline forward when working with the stove, with the arm being lifted about 90^{o}, beyond a third of the maximal distance a stretching arm can reach forward [5].

In our preliminary research done previously, of 10 workers who used traditional tools to make coconut oil, we encountered the following findings: (1) The average pulse rate of the workers was 113.7 ± 9.3 pulses/minute. Converted to the criteria of Grandjean [7], the work load can be classified as moderate; (2) Using the quaestionnaire of *Nordic Body Map*, the most prominent complaint of the workers was pain in the right arm in 65%, and the least complaints was pain around the heel in 45 %; and (3) Regarding fatigue or tiredness, the most prominent type was that of physical weakness in 40% [3]

The effort to redesign the working tools in this present research was made based on the principles of ergonomy through the approaches to being systemic, holistic, interdisciplinary and participatory. Then in the problem solving phase, usage of proper techonology was applied according to the following six criteria: (a) economical, (b) technical, (c) ergonomic, (d) socio-cultural, (e) energy saving; and (f) environment friendly [8.9]. With the above efforts, solutions of problems could be made effectively, efficiently and in accordance with the actual situation, so to create humane, competitive and continual working condition[10. 11.12. 13] Objective of this research was to assess the increase of the working performance of the traditional coconut oil makers in Dawan district, Klungkung by means of ergonomic redesigning of the working tools, based on the following indicators: (a) decrease of complaints related to work load, musculoskeletal complaints, and tiredness (b) increase of working productivity. [14]

MATERIALS AND METHODS

This research was an experimental research using *treatment by subject design,* involving 22 research subjects selected by simple random sampling [15.16] from existing female coconut oil makers in the district or Kecamatan Dawan Klungkung[17.18]. Before treatment was given, the

research subjects were asked to make coconut oil by using the old traditional working tools. Then an interval of three days was given as *washing out period*, and two days were given to adapt to using the new, more ergonomic redesigned tools. After this interval and adaptation, the same subjects were asked to make coconut oil by using the new redesigned tools. To determine any differences that might result between data before and after treatment, analysis was done on the average of difference using *t-paired* test at a significance level of 5%.

RESULTS

1. Characteristics of the Coconut Oil Makers

Characteristic data of the studied coconut oil makers were related to age, body weight, height, and blood pressure (Table 1).

Table 1
Average and Stardard Deviation of the Characteristics of Coconut Oil Makers (n=22) at District of Dawan, Klungkung

Characteristics	Average	SD
Age (years)	36.86	± 5.55
Body weight (kg)	56.70	± 4.45
Height (cm)	156.64	±10.60
Body Mass Index (BMI) (kg/m2)	23.41	± 2.86
Systolic Blood Pressure (mmHg)	101.73	± 9.15
Diatoslic Blood Pressure (mmHg)	71.55	± 6.64

2. Results of Research and Statistical Analysis

Data of the research results and the statistical analysis by *t-independent* test on the microclimate average before and after ergonomic redesigning of the working tools are compiled in Table 2. Data of the research results and statistical analysis on the averages of workload, musculoskeletal complaints, tiredness, and level of productivity are presented in Table 3.

Table 2
Data and Results of t- *Independent* Test on Average Microclimate of Working Places of Coconut Oil Makers (n=22) at District of Dawan, Klungkung

	Before Treatment		After Treatment		Average		
Variable	Average	SD	Average	SD	Difference	t	p
Wet bulb temp (^oC)	24.58	±0.31	24.56	±0.45	-0.02	0.19	0.85
Dry bulb temp (^oC)	27.16	±0.29	27.17	±0.31	0.01	0.15	0.88
Relative humidity (%)	80.49	±1.70	81.14	±3.28	0.65	0.83	0.41
Wind velocity (m/sec)	0.07	±0.02	0.08	±0.02	-0.01	-1.65	0.10

Table 3

Data and Results of *t-Paired* Test on Resting Heart Rate, Working Heart Rate, Musculoskeletal Complaints, Fatigue and Productivity of Coconut Oil Makers (n=22) at District of Dawan Klungkung

Variable	Before Treatment		After Treatment		Average Difference	t	p
	Average	SD	Average	SD			
Resting heart rate (pulse/min)	71.09	± 2.25	70.32	±1.86	0.77	1.75	0.09
Working heart rate (pulse/min)	108.49	± 0.95	91.90	±1.91	16.59	37.45	0,00
Musculoskeletal complaints	51.73	± 2.25	36.79	±0.83	14.94	59.53	0.00
Fatigue	65.55	±1.66	48.36	±1.65	17.19	42.60	0.00
Work productivity	35.86	±1.09	48.66	±1.10	12.81	54.35	0.00

DISCUSSION

Results of analysis of age, body weight, height, body mass index and blood pressure of the research subjects as shown in Table 1 indicate that the 22 coconut oil makers studied were in good health condition for the job of making coconut oil. One of the indicators of this evaluation was the average age of 15 - 60 years, which categorize as productive age [8.19.20]. Average of BMI was in the range of 10 – 25.00 kg/m^2, which indicate the female coconut oil makers had normal body parameters [20. 21.22]. Data of the blood pressure show normal blood pressure since the research subjects had systolic blood pressure of between 110.00 mmHg and 125.00 mmHg and distolic blood pressure of 60.00 mmHg – 70.00 mmHg[23].

The environment of the working areas of the coconut oil home industries based on micro climate analysis as shown in Table 2 indicate that wet bulb temperature, dry bulb temperature, relative humidity, and wind velocity before and after treatment in the form of ergonomic redesigning of the tools did not cause any significant differences ($p>0.05$). This finding means that the coconut oil makers during their work were exposed to similar microclimate before and after treatment, which could be controlled during the research period, hence it can be concluded that the working environment did not give any influence to the treatments given[24.25.26.]

Performance of a worker is influenced by both individual and situational factors. The individual variable consists of the physical characteristic. While the situational variable consists of physical and job variable, one of which relates to the working tools. Working performance relates with individual factor because performance is influenced by the degree of work-related complaints and level of productivity. As such, improvement of working performance of the coconut oil makers due to ergonomic redesigning of the working tools was evaluated based on some indicators, as follows: (1) working complaints such as those related to workload, musculoskeletal complaints, fatigue and (2) work productivity[13.14.27].

According to the analysis results of the average resting heart rate of the coconut oil makers before and after redesigning was made to the working tools as shown in Table 3, it proved that

there was no difference in the average pulse rate ($p>0.05$; $p = 0.09$). This finding indicates that physical conditions of the coconut oil makers before and after redesigning remained the same, as shown by their normal resting heart rate of 60 to 80 pulse/minute [28.29]. In relation with this fact, to know the work load the coconut oil makers had to take, evaluation was made based on the changes of working heart rates of the research subjects during work [30]. In Table 3 it is obvious that the average pulse rate during one cycle of coconut oil making process before and after redesigning of the working tools showed a significant difference ($p<0.05$; $p=0.00$). This latter finding indicates ergonomic redesigning of working tools in the making of coconut oil could reduce the degree of work load from moderate to mild [7] as shown by the reduction of average working heart rate of 16.59 pulse/minute or 14.69% as compared with that before redesigning. Reduction of the work load was due to reduction of the unnecessary additional burden in the form of muscle contraction such as that of the shoulders, upper joints of arms, muscles of arms, wrists, palms, hips, waists, and backs, so this indirectly caused reduction of working pulse rate [7]. Similarly, Surata has also shown reduction of workload in his research on the use of hand wheel with handle on the machines for pressing grated coconut flesh in traditional coconut oil home industries in the village of Ped on Nusa Penida Island, where he found a reduction of workload of 16.77%[31]. Also the research by Tandaju in which modification was made on *lewang* that was matching the athropometric bodily features of a group of workers whose job was to peel coconut fibers in the village of Lobu, District of Tombatu, Minahasa Regency, resulted in a reduction of average workload of 17.90 % [32].

Result of *t-paired* analysis, as presented in Table 3 showed a significant difference of the average score of musculoskeletal complaints in one cycle of coconut oil making before and after ergonomic redesigning of the working tools ($p<0.05$; $p=0.00$). The redesigning of the working tools resulted in reduction of musculoskeletal complaints score of 14.94 or 26.17% as compared with that before redesigning. This finding is similar to result of a research by Surata on the use of handled hand-operated wheels of machines for pressing grated coconut flesh in the village of Ped, Nusa Penida Island where he found a 29.52% reduction of musculoskelatal complaints [31]. The research by Tandaju in the village of Lobu, District of Tombatu, Minahasa Regency on the effect of modification made on *lewang* that matched the athropometric features of workers whose job was to peel coconut fibers showed a reduction of musculoskeletal complaints of 32.70%[32]. Reduction of musculoskeletal complaints shown in the above studies, including our present research, was due to the ergonomic redesigning made to the working tools, which resulted in avoidance of improper or unnatural body orientation that can cause static (*isometric*) muscular contraction on the shoulder, base of arms, arms, wrists, palms, hips, waist, and back [.33].

The *t-paired* analysis on the average of fatigue score of the coconut oil makers in the district of Dawan, Klungkung (Table 3) showed a significant difference before and after ergonomic redesigning of working tools ($p<0.05$, $p = 0.00$). As seen in Table 3, there was a reduction of the level of fatigue of 17.19 or 25.83%. Sucipta also noted similar reduction of fatigue of 48.91% in his research on the improvement of working environment or condition[34]. Similarly, Sarsono in his research on improvement of ergonomic working system found a reduction of fatigue level of 21.40%[35].

Increase of working productivity of the coconut oil makers could be assessed by comparing the amount of oil produced (*output*) with the number of coconuts needed (*input*) in one cycle of the oil making with consideration on the specific time (t) needed for the process of the coconut oil making [36.37].

Based on the *t-paired* analysis, there was a significant improvement of the working productivity of the coconut oil makers (Table 3) before and after rergonomic redesigning of working tools was made ($p<0.05$, $p=0.00$). There was increase of working productivity of 12.81 or 35.71% due to ergonomic redesigning of the working tools. Purnomo has found a similar result in his research on improvement of working system of pottery industries in Kasongan, Bantul, Central Java, where he noted an increase of working productivity of 59.49%[38]. Surata also encountered improvement of working productivity in his experimental research on the use of handled wheels of machines for squeezing coconut milk of grated coconut in traditional coconut oil industries in the village of Ped in Nusa Penida Island, where he noted a productivity increase of 30.23 %[31]. Improvement of productivity in these research was associated with reduction of the time needed for producing a certain amount of coconut oil as well as reduction of level of complaints reported by the workers.

From another viewpoint, ergonomic redesigning of working tools used in the coconut oil home industries in the district of Dawan, Klungkung, could be regarded as a form of investment, as there was a certain amount of capital needed for coconut oil production, with the hope to get a significant gain (*profitability*) after the improvement was made[39.40]

In relation to the above consideration, it is necessary to evaluate the degree of feasibility of the investment in association with the improvement made by ergonomic redesigning of the working tools. Our present research has indicated there are three methods that are normally used for assessing feasibility level of a certain improvement project: 1) *Net Present Value* (NPV), 2) *Payback Period* (PBP) and 3) *Return on Investment* (RoI)[41.42.43] Based on evaluation by the above three methods, it proved that ergonomic redesigning of working tools used in industries is significantly worth-investing. Ergonomic redesigning of working tools would give

an estimated profit or *Net Present Value* (NPV) in a five-year period of >0, namely for Rp.11.503.431,-. The *Payback Period* (PBP) was > 0, meaning in 0.77 year or 9.22 months and the value of contribution or *Return on Investment* (RoI) of the ergonomic redesigning effort of working tools against the investment made in a five-year period was 32.54% >13% (*rate of interest* of the year 2008).

CONCLUSIONS

1) Ergonomic redesigning of working tools could decrease work load of traditional coconut oil makers in the district or Kecamatan Dawan, Klungkung from the category of moderate to mild work load of 14.69%
2) Ergonomic redesigning of working tools could decrease musculoskeletal complaints of traditional coconut oil makers in the district or Kecamatan Dawan, Klungkung in 26.17% as compared to that before redesigning.
3) Ergonomic redesigning of working tools could reduce level of tiredness of coconut oil makers in the district or Kecamatan Dawan Klungkung in 25.84% as compared with that before redesigning.
4) Ergonomic redesigning of working tools could increase working productivity of coconut oil makers in the district or Kecamatan Dawan Klungkung in 35.71% from that before redesigning, and this effort has proved wort investing as it is estimated in five years duration benefit gains will be made by the coconut oil makers as high as Rp.11.503.431,- with a total investment reaching Rp 525.500.-.

RECOMMENDATIONS

1. As this present research has some limitation in relation with its being focused only on the aspect of ergonomic redesigning of working tools as the treatment, it is recommended that further studies be carried out more intensively and more in depth on the management of smoke pollutant in the kitchen areas, improvement of working organization and quality of products of the coconut oil makers at the district or Kecamatan Dawan, Klungkung.
2. As ergonomic redesigning of working tools has proved to be able to reduce work-releted complaints, hence to increase productivity of traditional coconut oil makers at the district or Kecamatan Dawan Klungkung, it is recommended that results of this research be adopted to similar industries other than coconut oil production in order to create efficient, comfortable, safe, healthy, and effective working conditions.

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