VOL. 13, NO. 5, MARCH 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

IMPROVE OF WORKER PERFORMANCE AND QUALITY OF ANCHOVY WITH ERGONOMIC HYBRID SOLAR DRYER

I. Gede Bawa Susana
Department of Mechanical Engineering, Mataram University, Jl. Majapahit no. 62, Mataram, NTB, Indonesia
E-Mail: bawa.mech@yahoo.co.id

ABSTRACT

The process of drying of anchovy has traditionally caused work posture to squat, squat while shifting, bending, and exposed to heat pressure and drying result not yet optimal. This results in low worker performance and the quality of anchovy. To improve the worker's performance and the quality of the anchovy is done the design of the dryer with ergonomics intervention. The experimental research through treatment by subject design with a sample of 20 people. Sample performance is observed when working traditionally and intervention of ergonomics used the ergonomic hybrid solar dryer. Ergonomic hybrid solar dryer consist of solar thermal dryers, biomass dryer, and work desk. Data were analyzed with a significance level of 0.05. The results showed that the ergonomic hybrid solar dryer increase the drying temperature 31.94% and decrease workload 14.57%, musculoskeletal complaints 27.02%, fatigue 30.43%. Laboratory test results showed an increase anchovy quality corresponding of national standards. It was concluded that the ergonomic hybrid solar dryer improve performance of workers and income, as well as quality of anchovy.

Keywords: ergonomic hybrid solar dryer, biomass, performance, anchovy.

INTRODUCTION

The anchovy drying process is traditionally, namely the direct drying under the sun and placed in the yard, the edge of the village street, the roof of the house. This is certainly less attention to ergonomic principles. Ergonomic problems experienced by workers are (a) the moderate workload, (b) musculoskeletal complaints arising in the neck, shoulders, arms, hands, waist, thighs, legs, (c) the onset of fatigue, and (d) drying time is not efficient. This is the cause of the poor performance of workers.

Range of both physical and psychological complaints will certainly degrade performance or work performance, which in turn will reduce work productivity [1]. Ergonomics problem are caused by a hot working environment, where workers are exposed to solar heat. Ergonomics problem are caused by a heat working environment, where workers are exposed to solar heat. In addition, the work equipment used is very simple and the worker's posture is not natural as shown in Figure-1. Activities drying dominated by squat position while transitioning to the side, bending and wisting, repetitive and monotonous nature in the process of sowing, managing and reversing anchovy.

Figure-1. Posture worker drying anchovies.

Work posture bent is a working posture not physiological of that causes reactions such as musculoskeletal complaints [2]. Estimated 30% of skeletal muscle injury caused by manner of lifting which requires working posture bending and twisting, thus spine of rotating [3, 4]. Work posture as opposed to the natural posture of the body will cause fatigue and risk of injury to the muscles, where the unnatural posture will cause muscle movements that are not supposed to happen and waste of energy [5]. While a hot work environment can cause additional strain on the blood circulation. Physiological responses would seem obvious to workers working with hot climates such as an increase in blood pressure and pulse [6]. Control effect of exposure to heat stress of worker is required corrections a workplace, environmental heat sources and work activities are carried out [7].

Ergonomic problems faced by workers in the process of anchovy drying can be solved through repair of appliance dryer. With improved ergonomics-based tool will affect work posture and work time that will improve the performance of the workers. To address the ergonomic issues that need to be fixed are work posture, work tools, work environment, working time, work systems and human-machine interaction [8, 9]. Standpoint of ergonomics, the demands of the task with a working capacity must always be in balance to achieve high work performance [10]. Performance can be fulfilled when the equipment or work facilities, work station, work products and procedures can be designed and customized with the approach and the principles of ergonomics [11].

Performance of workers the maker of anchovy dried can be increased by decreases the workload, musculoskeletal complaints, fatigue and increase drying temperature. For it is done with design of dryer based on ergonomics intervention through SHIP approach (systemic, holistic, interdisciplinary, participatory) within application of appropriate technology based on the seven

criteria of assessment (technical, economical, social cultural, ergonomic, energy efficient, environmentally friendly and trends). Ergonomics approach can prevent employment problems often experienced by humans such as eyestrain, headaches and musculoskeletal complaints [11]. Total Ergonomics approach is one form of ergonomics interventions that aim to get a working system that is humane, competitive and sustainable, which consists of a ergonomic intervention through approaches SHIP within application of appropriate technologies [12].

Based on these descriptions, the conducted research on ergonomic hybrid solar dryer for improved work tool of anchovy drying process with ergonomics interventions through SHIP approach in the application of appropriate technologies. This needs to be done to determine the effect of ergonomic hybrid solar dryer about drying temperature, workload, musculoskeletal complaints, fatigue, and quality of anchovy.

MATERIAL AND METHODS

This research is an experimental research using subject design with sample of 20 women people. Sample performance is observed when working traditionally (Period I), ergonomics intervention used the ergonomic hybrid solar dryer consist of solar thermal dryers and work desks (Period II), as well as biomass dryer and work desk (Period III). Measurements in period I, II and III was performed on the drying temperature, drying time, resting pulse rate, work pulse rate, musculoskeletal complaints, fatigue, productivity, and product quality. Data were analyzed with a significance level of 0.05.

RESULTS AND DISCUSSIONS

Results

a. Characteristics of Subjects

Subject characteristics research the women workers of special of anchovy at Banyubiru village Jembrana shown in Table-1.

Table-1. Subject characteristics.

Variable	Mean±SD	Range
Age (th)	29.80±9.81	20.00 – 55.00
Height (cm)	152.16±5.53	142.00 – 160.50
Weight (kg)	51.30±6.45	44.50 – 67.00
Work experience (th)	8.85±7.21	1.00 – 30.00
Body mass index	22.16±2.93	18.63 – 29.78

b. Environmental conditions

Measurements the environmental conditions carried when workers perform the drying process anchovy, comprise dry temperature, relative humidity and wet temperature as in Table-2.

Table-2. Environmental conditions.

Variable		Mean±SD	Median (minimum-maximum)	p
Dry temperature (°C)	Period I	34.75±0.58		0.997
	Period II	34.75±0.58		
	Period III	34.76±0.56		
Relative Humidity (%)	Period I	57.69±2.99		0.930
	Period II	57.72±3.01		
	Period III	57.45±2.81		
Wet temperature (°C)	Period I	27.45±0.22	27.49 (26.74-27.73)	0.387
	Period II	27.45±0.22	27.46 (26.77-27.77)	
	Period III	27.40±0.21	27.38 (26.79-27.77)	

c. Anthropometric of subject

Anthropometric measurements for the purpose redesigning chamber of dryer and workbench as shown in Table-3.

Table-3. Anthropometric data women workers for design the space of dryer chamber and work desk.

Anthropometry	5 percentile (cm)	Design
High of hands grasping	67.01	Height of shelf under
High of eye standing	123.20	Maximum height the top shelf
High the reach above	170.24	Maximum height of air chimney
High of elbow standing	85.28	Workbench height

d. Work pulse rate, musculoskeletal compalints, and fatigue

Work pulse rate, musculoskeletal complaints and fatigue used to determine the performance of workers are shown in Table-4 and Table-5.

Table-4. Mean of work pulse rate, musculoskeletal complaints, fatigue (n = 20).

Variable		Mean±SD	p
Work pulse rate (bpm)	Period I	104.84±1.76	0,001
	Period II	91.22±1.06	
	Period III	89.57±0.77	
Musculoskeletal complaints	Period I	52.25±1.03	0.001
	Period II	38.30±1.30	
	Period III	38.13±1.18	
Fatigue	Period I	54.65±0.93	0.001
	Period II	42.05±1.38	
	Period III	38.02±1.06	

ARPN Journal of Engineering and Applied Sciences

Table-5. Comparison mean of work pulse rate, musculoskeletal complaints, fatigue (n = 20).

Variable		Mean difference (95%)	p
Work pulse rate (bpm)	PI - PII	13.62 (12.90-14.34)	0.001
	PI - PIII	15.27 (14.33-16.20)	0.001
	PII - PIII	1.65 (1.01-2.29)	0.001
Musculoskeletal complaints	PI - PII	13.95 (13.53-14.37)	0.001
	PI - PIII	14.12 (13.65-14.58)	0.001
	PII - PIII	0.165 (0.06-0.39)	0.138
Fatigue	PI - PII	12.60 (11.86-13.34)	0.001
	PI - PIII	16.63 (16.03-17.24)	0.001
	PII - PIII	4.03 (3.22-4.85)	0.001

e. Drying temperature

Table-6. Drying temperature.

Variable		Median (minimum-maximum)	Mean±SD	p
Drying temperature (°C)	Period I	34.82 (33.44-35.51)	34.75±0.58	0.001
	Period II	45.94 (45.04-47.13)	46.10±0.58	
	Period III	41.32 (41.17-41.35)	41.30±0.05	

f. Product quality

Analysis of the quality of dried anchovy through testing at UPT-Analytical Laboratory, University of Udayana. The results are as shown in Table-7.

Table-7. Comparison of quality of dried anchovy with requirements PDII-LIPI and BSN.

Parameter	PDII-LIPI, BSN	Control (%)	Treatment 1 (%)	Treatment 2 (%)
Water content	Max. 20%	26.19	18.27	19.12
Ash content	Max. 0,3%	0.4	0.21	0.24
Protein	33.4%	22.09	32.87	34.01
Fat	3%	4.83	2.56	2.75
Carbohydrate	0	1.53	1.46	1.11

DISCUSSIONS

The research subject is women worker of anchovy dried at Banyubiru village of Jembrana who had a mean age of 29.80±9.81 years. The range of working age are used as subjects classified productive. This is in accordance with the benchmark average age of employees of private pensions in force in Indonesia under the provisions of the social security, that the pensions for private sector workers or employees are age 55.00 years [13]. The mean height was 152.16±5.53 with a range of 142.00 to 160.50 cm. The mean weight was 51.30±6.45 with a range of 44.50 to 67.00 kg. Weight and height of body used for the determine body mass index (BMI). The mean body mass index was 22.16±2.93 subject kg.m^{-2}. This is in accordance with the provisions of the Department of Health that a normal body mass index category and good nutritional status for women is 17.00-23.00 kg.m^{-2} [14]. The mean of work experience was 8.85±7.21 with a range of 1.00 to 30.00 years. Based on the work experience, subject of research has expertise and experience in the process of drying fish.

Environmental conditions in the drying process anchovy measured by dry temperature, relative humidity, and wet temperature between the three periods are comparable (p>0.05). Dry temperature 34.75±0.58°C at natural drying process is not optimal. Optimal drying temperature of fish is 40-50°C [15]. By this means the working environment temperature 34.75±0.58°C in the drying process of anchovy at Banyubiru village including heat category. If the ambient temperature is higher than normal body temperature, hence resulting in an increase in body temperature due to the body receiving heat from the environment.

Ergonomic hybrid solar dryer is a dryer that designed based on the participation of workers as a user of the tool and anthropometric data of workers. This dryer is one of the appliance of energy conversion with solar collectors to convert solar energy into thermal and the heat exchangers to transfer the heat of combustion of biomass. This dryer is the result of a synergy between the fields of mechanical engineering and ergonomics. Product of ergonomics is an disciplines of science interdisciplinary related to understanding the interaction between humans and other elements of the system and the user has a central role in the product development process [16].

Anchovy drying process can be done in any weather due to the drying process is done in a drying chamber and a work desk serves to facilitate and organize the workers when spread the product before input into the drying chamber. Dryers and work desk can be moved because the dryer is composed of several parts that can be removed such as space of dryer, solar collectors, heat exchangers and furnaces (Figure-2). As for the work table is made of lightweight material. When the weather is sunny enough using a drying chamber with solar collectors and wears solar energy sources. This is done because the collectors optimize energy source of the sun and the drying temperature in the drying chamber is sufficient for the drying process anchovy. Solar collector absorbs solar energy and used for several applications such as heating and ventilation, drying operations, refrigeration, etc [17].

Figure-2. Ergonomic hybrid solar dryer.

During the rainy season or when there is no sunlight used a dryer with biomass energy sources. Biomass energy (wood, briquette, etc.) is an energy source that is suitable for drying because it is easily available and relatively cheaper [18]. Similarly, rice husk biomass can be used as an alternative energy source for the process of drying food through heat exchange mechanisms providing a high enough temperature [19]. Biomass is an energy source that has tremendous potential as a raw material for production of various biochemical compounds of high value or production of bioenergy and Indonesia is one of the potential to develop biomass [20]. This study uses coconut husk biomass, because it is easy to find at area workers of dryer anchovy and be economically very beneficial. The calorific value biomass of the coconut fiber is high enough with 16,700 $kJ.kg^{-1}$, equivalent to the calorific value of wood waste 8,400-17,000 $kJ.kg^{-1}$ [21].

Use of the solar thermal dryer, increase drying temperature 32.66% compared with the natural drying is a from temperature of drying 34.82 (33.44-35.51)^{o}C into 45.94 (45.04-47.13)°C. In the drying process by using biomass dryer, drying temperature increased by 18.85% compared with the natural drying is a from temperature of drying 34.82 (33.44-35.51)^{o}C into 41.32 (41.17-41.35)°C. Temperature of drying in this study accordance with Abdullah which suggested that the drying temperature to 40°C-50°C fish, because the temperature exceeds 50°C led to the outside of the product to dry, but the inside is still wet [15].

The decrease in workload Period II was 12.99% and 14.57% for the third period due to the posture of the workers work more naturally than Period I. The decrease in workload in this study occurred after ergonomics intervention through the dryer for drying anchovy. The use of ergonomic hybrid solar dryer can be change the work posture of static into a more dynamic working posture and muscle exertion is only used to enter the fish into the drying chamber.

The decrease of musculoskeletal complaints from Period I to Period II and Period III are 26.70% and 27.02%, respectively. The decrease of musculoskeletal complaints is due to ergonomics interventions through design dryer appliance for the drying process anchovy. These results are in line with Singh and Arora who said that to prevent and reduce musculoskeletal disorders is done by designing tools and equipment by taking into account the characteristics of ergonomics [22]. It is also found in the study Adnyana, that the application of synergy ergo-mechanical system can reduce musculoskeletal complaints amounted to 15.10% on women workers in the industry makers Banten in Blahbatuh of Gianyar [23] .

Fatigue that occurs in the drying process by sunning in this study due to the use to traditional work tools and monotonous work. Fatigue on workers include headaches, stiffness in the shoulders, back pain, dizziness and etc. This is in line with the opinion of Gang and Lei stating that on worker occurs of physiological fatigue due to the manual operation and psychological fatigue (mental fatigue) due to poor working environment and the work monotonous [24]. After ergonomics interventions through designing appliance of dryer decreases fatigue in worker. The decrease of fatigue from the Period I into Period II and III respectively 23.06% and 30.43%. Results the same obtained Surata that the appliance redesigning of seaweed sunning in the form workbench that is designed based on anthropometric data can reduce worker fatigue 20.46% [25]. Furthermore Adnyana found a decrease of fatigue 22.23% after the application of synergy ergo-mechanical system at the female workers of maker industry banten in Blahbatuh of Gianyar [23]. Based on the OSHA, workplace of who ergonomics can reduce worker fatigue, improve employee morale, improve worker safety, worker comfort, product quality and productivity by making the work easier and convenient for workers [26].

Decreases at workload, fatigue and musculoskeletal complaints in this study due to the ergonomics intervention at drying process through design the dryer appliance. Posture of work before the ergonomics intervention is bending, squatting while shifting, squat stand, exposure to sunlight a longer during the process of managing and reversing fish, workers perform repetitive movements or static. After ergonomics intervention posture of worker is standing, setting anchovy done on the workbench and sunlight exposure time is shorter because it is not necessary to reverse fish and process of drying in the chamber closed, so the repetitive movements or static can be minimized. These results are appropriate exposure Bosch which stating that the monotonous work in a short period of time can support the relaxation of the network, this is due to good ergonomics, which in turn creates a good economy [27].

The application of ergonomics through design the dryer increase a drying temperature in the process of drying anchovy, decrease workload, musculoskeletal complaints and fatigue, resulting in increased quality of life and product quality. These results are corresponding with Sutjana which stating that the application of ergonomics will be able to improve the health and safety of workers as well improving work productivity [28]. The same was conveyed Shinde and Jadhav stating that application of ergonomics in the design of work stations showed better interaction between human-machine systems [29]. The application of ergonomics in the redesign of appliance drying creating methods of work a more effective and efficient and to improve work ability, work motivation that will lead to progress and increase performance while maintaining the health and comfort of workers. The same is conveyed Wignjosoebroto that the ergonomics is applied to improve the effectiveness of labor man-machine systems and maintain the safety, health and comfort of human labor [30].

The use of ergonomic hybrid solar dryer can negate interference flies, dust and other impurities during the drying process compared to open natural drying. During the rainy season by using ergonomic hybrid solar dryer, rain water will not fall the product and does not require transference of the dryer appliance. Based on this, ergonomic hybrid solar dryer contributed immensely in improving product quality. From the results of laboratory

tests, after ergonomics intervention through designing hybrid solar dryer, then obtained a decrease in the percentage of moisture content, ash content, fat and carbohydrates as well as an increase in the protein. Improving the quality of dried anchovy is evidenced by the results of laboratory testing and corresponding of national standardization.

CONCLUSIONS

Ergonomic hybrid solar dryers proved to improve the women workers performance and the quality of the anchovy. Performance in terms of existence an increase in drying temperature of 32.66% and 18.85%; decrease in workload by 12.99% and 14.57%, decrease in musculoskeletal complaints 26.70% and 27.02%, decrease in fatigue 23.06% and 30.43%. Improving the quality of dried anchovy or already meet the requirements of the national standardization.

REFERENCES

[1] Tarwaka. 2011. Ergonomi Industri: Dasar-dasar Pengetahuan Ergonomi dan Aplikasi di Tempat Kerja, Surakarta: Harapan Press.

[2] Kroemer K.H.E. and Grandjean E. 2000. Fitting the Task to the Human. A Textbook of Occupational Ergonomics, 5th edition, Philadelphia: Taylor & Francis.

[3] Pheasant S. and Haslegrave C.M. 2006. Bodyspace, Antropometry, Ergonomics and the Design of Work, London: Taylor & Francis.

[4] Bridger R.S. 2003. Introduction to Ergonomics, 2nd Edition, London and New York: Taylor & Francis.

[5] Adiputra N. 2004. Ergonomi. Disampaikan dalam Pelatihan Upaya Kesehatan Kerja Tenaga Kesehatan Kabupaten/Kota dan Puskesmas Propinsi Bali. Denpasar 23-27 Maret dan 29 Maret-2 April.

[6] Santoso. 2004. Manajemen Keselamatan & Kesehatan Kerja, Jakarta: Prestasi Pustaka.

[7] Darlis Suharyo W. and Sigit S. 2010. Kajian Stressor Operator Ruang Kendali Utama Untai Uji Thermohidrolika Reaktor, Prosiding Seminar Nasional ke-16 Teknologi dan Keselamatan PLTN Serta Fasilitas Nuklir. pp. 369-375.

[8] Barbini N. and Squadroni R. 2003. Aging of Health Workers and Multiple Musculoskeletal Complaint. G Ital Med Lav Ergon, April-Juni. 25(2): 68-72.

[9] Chung M.K., Lee I. and Kee D. 2003. Assessment of Postural Load for Lower Limb Postures Based on Perceived Discomfort. International Journal of Industrial Ergonomics. 31(1): 17-32.

[10] Manuaba A. Ergonomi, Kesehatan dan Keselamatan Kerja. Prosiding Seminar Nasional Ergonomi, Surabaya: Guna Wijaya. (2000) 1-4.

[11] Wignjosoebroto S. 2011. Ergonomi Industri dalam Pendidikan Terintegrasi: Pendekatan Ergonomi Menjawab Problematika Industri. Disampaikan dalam Acara Semiloka Linearitas Ergonomi, Universitas Udayana: Fakultas Kedokteran, Denpasar 21 April.

[12] Manuaba A. 2005. Total Ergonomic Enhancing Productivity, Product Quality and Customer Satisfaction. Disampaikan pada Seminar Nasional II Peningkatan Kualitas Sistem Manufaktur dan Jasa, Yogyakarta: Forum Komunikasi Teknik Industri.

[13] Jamsostek PT. 2013. Usia Program Pensiun Pekerja Swasta.

[14] Depkes RI. 2003. Survey Indeks Massa Tubuh (IMT) Pengumpulan Status Gizi Orang Dewasa Berdasarkan IMT, Direktorat Bina Gizi Masyarakat.

[15] Abdullah K. 2003. Fish Drying Using Solar Energy, Lectures and Workshop Exercises on Drying of Agricultural and Marine Products. Regional Workshops on Drying Technology. pp. 159-191.

[16] Fain N., Moes N. and Duhovnik J. 2010. The Role of the User and the Society in New Product Development. Strojniški vestnik-Journal of Mechanical Engineering. 56(7-8): 521-530.

[17] Mohseni L., Taherian H., Mosoodi R. and Reisel J.R. 2009. An Exergy and Heat Study of A Solar Thermal Air Collector. Thermal Science. 13: 205-216.

[18] Mukaminega D. 2008. Hybrid Dryer (Solar and Biomass Furnace) To Address The Problem of Post Harvest Losses of Tomatoes in Rwanda, Netherland: Van Hall Larenstein, Wageningen. pp. 1-57.

[19] Susana I G.B., Yudhyadi I G.N.K., Alit I.B., Mirmanto and Okariawan I D.K. 2017. Effect of Hole Spacing and Number of Pipe on Dryer Box Temperature. International Journal of Mechanical Engineering and Technology. 8(11): 1029-1035.

[20] BPPT. 2012. BPPT Gandeng Industri Jepang Kembangkan Teknologi Pemanfaatan Biomassa.

[21] Febijanto I. 2007. Potensi Biomassa Indonesia sebagai Bahan Bakar Pengganti Energi Fosil. Jurnal Sains dan Teknologi Indonesia. 9(2): 65-75.

[22] Singh S. and Arora R. 2010. Ergonomic Intervention for Preventing Musculoskeletal Disorders Among Farm Women. J Agri Sci. 1(2): 61-71.

[23] Adnyana I W. B. 2013. Aplikasi Synergy Ergo-Mechanical System Meningkatkan Kapasitas Kerja Para Pekerja Wanita dan Efisiensi Energi Bahan Bakar Alat Pengering pada Industri Sarana Banten di Blahbatuh Gianyar Bali (disertasi), Denpasar: Universitas Udayana.

[24] Gang Z.J., Lei and Wu. 2013. Research on the Factors of Fatigue of Coal Mine Workers and Its Control Measures. Research Journal of Applied Sciences, Engineering and Technology. 6(8): 1508-1512.

[25] Surata I W. 2011. Redesain Alat Pengering dan Sistem Kerja Meningkatkan Kinerja Petani dan Mutu Rumput Laut di Desa Ped Nusa Penida (disertasi), Denpasar: Universitas Udayana.

[26] OSHA. 2000. Ergonomic: The Study of Work. U.S. Department of Labor, Occupational Safety and Health Administration.

[27] Bosch T. 2011. Fatigue and Performance in Repetitive Industrial Work (dissertation), Amsterdam: Vrije Universiteit.

[28] Sutjana I D.P. 2006. Hambatan dalam Penerapan K3 dan Ergonomi di Perusahaan. Disampaikan pada Seminar Ergonomi dan K3, Surabaya 29 Juli.

[29] Shinde Gurunath V. and Jadhav V.S. 2012. Ergonomic Analysis of an Assembly Workstation to Identify Time Consuming and Fatigue Causing Factors Using Application of Motion Study. International Journal of Engineering and Technology. 4(4): 220-227.

[30] Wignjosoebroto S. 2009. Penerapan Ergo-Safety untuk Meningkatkan Produktivitas Kerja Industri Nasional. Disampaikan sebagai makalah kunci dalam Seminar Nasional Aplikasi Program Keselamatan & Kesehatan Kerja dan Ergonomi di Tempat Kerja, Universitas Sumatera Utara, Medan 7 Pebruari.