Use of Solar Energy Hybrid Dryer with Techno-Ergonomic Application to Increase Productivity of Dodol Workers in Buleleng, Bali

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Abstract. Penglatan Village is one of dodol industrial centres in Buleleng Regency, Bali. Dodol is a balinese traditional snack that usually used for religion ceremonies offering or “sesajen”. Dodol’s making processes had several layer of stages, from making dough, stirring dough, packaging and drying dodol. Because the drying process is done with traditional work tools, this process cause several ergonomic problems. Based on preliminary research, the complaints that felt by dodol workers are pain in the neck, shoulders, back, waist, head, and hands. Therefore, productivity of workers are decreasing. This problem solved by designing a hybrid solar drying tools with the application of techno-ergonomic, appropriate technology concept (TTG) and from ergonomic science with the application of SHIP concept (systemic, holistic, interdisciplinary, participatory). This research use 20 people as sample. The sample performance is observed while working traditionally and using techno-ergonomic hybrid solar dryer tools. The measurements conducted three times which are First Period (PI), Second Period (PII), and Third Period (PIII) with interspersed time for rest. WOP (washing out period) is intended to eliminate residual effects. The data were analyzed with SPSS program with significance level of 0.05. Hopefully, with this solution will improve worker productivity.

1. Introduction
Penglatan village is one of the villages in Buleleng, Bali, located approximately five kilometers from the Singaraja city, with an area of 186.193 hectares and population which is 3,582 peoples. There are various potential at Penglatan village from agriculture (rice plants), livestock (various livestock: cows, chickens, ducks), field crafts (woven bamboo, carved face, weaving, “songket”), and traditional snacks in example dodol. Penglatan village is one of dodol industry centre in Buleleng, with the number of its makers has reached 44 groups, and each group consist of 6-8 workers. Dodol is already sold to various regions in the province of Bali and has sold well in the modern markets and souvenir centers in Bali. Dodol is one of the traditional snack that is used for religious ceremonies, especially in Bali. Along with the development, this traditional Balinese food is very popular among the tourists, both domestic and foreign, that are sold in various places and used as traditional souvenirs of Bali. Balinese dodol or also known as dodol Buleleng has a unique sweet sticky taste and fragrant. Each dodol wrapped in dried corn leaves called “klobot” in balinese with a slightly elongated shape and both sides being tied up with rope. The aroma of dried corn leaves as a wrapper give the impression of fragrance when enjoying it [1]. Another uniqueness, Balinese dodol is not packed in boxes or plastic. This dodol strung (Bahasa Bali: direnceng) tied together, become one and it is consists of 10 pieces. Dodol’s making processes had several layer of stages, from making dough, stirring dough, packaging and
drying dodol. Drying process is done with natural methods that are drying and using a traditional tools [2]. The dodol spread over woven bamboo and then dried over the sunlight. When the water content in the dodol ranged between 20.05% -26.61%, dodol can only last for ± 2 weeks. By applying controlled heating at a temperature of 80 – 85°C, good sanitation and improving package design, it is able to last more than 8 weeks. Lack of heating, as well as the packaging is not good enough, causing the dodol that found on the market has been damaged (rancidity) due to mold contamination, by a species which is Syncephalastrum racemosum. If the dodol already old, this kind of mold will reproduce and make a form colonies of white and gray colour. This fungus is avoided because it can damage the sensory quality of the dodol product, based on it required an effort to inhibit fungal contamination that consumers are not harmed [3]. In order to said that product in good quality, the product must be in accordance with established standards (SNI 01-2986-1992) [4]. The process of drying the dodol in the sunlight requires a large area, so the roof of the house also used as a drying space. This process lasted from 8:00 to 16:00 WITA. At 08:00 to 09:30 WITA, workers prepare the drying tools, continue with spreading the dodol, and until it begin to dry. At 9:30 to 12:00 WITA dried dodol checked by the workers to prevent and protect it from animals such as chickens, cats and flies while occasionally take shelter. 12:00 to 13:30 WITA is time to flip over the dodol. The process of flip over the dodol is done to get the drying evenly. At 13:30 to 15:00 WITA dried dodol checked again by the workers. 15.00-16.00 WITA workers carried the result of drying and this process is repeated two consecutive days in good weather conditions until the water content of dodol in the range ± 15%. This drying process inflicted the workers working under the sunlight. Warm work environment can cause workers to suffer heat stress that requires extra effort on a limb to maintain heat balance. Physiological responses will be evident to workers with a warm working environment such as an increase in blood pressure and pulse. To control the effect of heat stress exposure of the workers in need to correction of work, the sources of environmental heat, work activities are carried out, and reducing the workload factor with mechanization. Ergonomic problems in the drying process Balinese dodol in the Penglatan village can be solved by the application of ergonomics through changing the equipment that used by the workers, thus improving working attitude, work time, reduced muscle disease, fatigue and the risk of exposure to the sun's heat that has implications for energy savings [5]. Using equipment ergonomically will create working attitude and how workers become more effective, convenient, safe, healthy, and efficient. Ergonomic equipment can improve the comfort and reduce injuries that can be caused by workers [6], [7]. Ergonomic principles used to designed the equipment of drying process, through the implementation of the Techno-Ergonomics with the concept of appropriate technology (TTG) and ergonomics application of SHIP (systemic, holistic, interdisciplinary, participatory) TTG and SHIP are done by consistently and continuous [7], [8]. The application of appropriate technology (TTG) were studied comprehensively through six criteria: (1) technical; (2) economic; (3) socio-cultural; (4) ergonomics; (5) energy saving; (6) the effect to environmental. In the application of TTG, process that approach analyzed by SHIP (systemic, holistic, interdisciplinary and participatory). Systemic, is an analysis carried out in one unified system. Holistic means a thorough analysis that performed by the synergy between the system with other systems. Interdisciplinary done by analyzing the existing problems from the perspective of various disciplines related. Participatory done by involving all stakeholders ranging from identifying problems to the selection of the solution. Drying equipment was designed based on input from the workers to the system or dodol drying process has been done, such as constraints and the desired improvement. By incorporating the principles of ergonomics and the desire of the dodol makers, then resulted a hybrid solar dryer techno ergonomics. The hybrid solar dryer techno ergonomics is a dryer that can use with two or more energy sources and can be replace each other so as to overlap each other's weaknesses and designed based on anthropometric data of workers. In this case, the hybrid solar dryer consist of a thermal solar dryers which use solar collectors with solar energy resources, as well as biomass dryer that uses heat exchanger with coconut husk for biomass energy sources. Solar energy is an abundant source of energy and renewable forms of energy. In tropical countries like Indonesia preservation by means of drying the product is a common method to do. The same was done by dodol wokers in the Penglatan village trough the drying process is done
by direct drying in the sunlight. Temperature drying by direct drying in the sunlight is still low ± 33.43°C, because it only utilizes ambient temperature. The effectiveness use of sunlight can be improved by using a solar collectors. Solar collector is a major tool in the solar thermal system which serves to collect and absorb solar radiation and then convert it into heat energy [9]. Solar collector is used because of its simple, easy to obtain the materials, and cheap [10]. Solar thermal dryer is used when the weather is sunny, while when the weather is cloudy or rainy use the biomass dryer. Utilization of biomass through combustion in furnaces and hot air generated streamed using the heat exchanger. Biomass used the coconut husks, because it is easily obtained and widely found in the environment around the dwelling workers. Biomass is organic material derived from part of living things, both animals and plants such as leaves, grass, twigs, weeds, agricultural waste, livestock waste, and turf. Hybrid solar dryer in the drying process of dodol uses the principle of heat and mass transfer. Mass transfer include mass reduction due to loss of water that evaporates due to the heat transfer process due to temperature differences between dodol with hot air flowing from the solar collectors and heat exchangers. This temperature difference caused by the flow of hot air over the surface of the material to be dried which has a lower temperature. The flow of hot air is the fluid process for the drying of this system. Based on these descriptions, it is necessary to conduct a research on hybrid solar dryer as techno-ergonomic work tool to improve the process of drying dodol with ergonomic intervention through SHIP approach in the application of TTG. This needs to be done to determine the effect of ergonomic hybrid solar dryer to the drying temperature, the drying time, the drying rate and dodol quality.

2. Physical Description
Hybrid solar energy dryer consist of 3 components, that are the drying chamber, the components of solar collectors and heat exchangers. Solar collectors are used when the weather is sunny, while when the weather is cloudy or rainy recommended to use biomass dryer. Utilization of biomass through combustion in furnaces and hot air generated streamed using the heat exchanger. Biomass that used is coconut husks, because it is easily obtained and widely found in the environment around the dwelling workers. Hybrid solar dryer in the dodol drying process uses the principle of heat and mass transfer. Mass transfer happened because there is mass reduction due to loss of water that evaporates due to the heat transfer process due to temperature differences between dodol with hot air flowing from the solar collectors and heat exchangers. This temperature difference caused by the flow of hot air over the surface of the material to be dried which has a lower temperature. The flow of hot air is the fluid process for the drying of this system.

![Figure 1. Hybrid solar energy dryer](image)

3. Experimental and Method
This research is an experimental research with the same design subject and observation method. Observation and measurement of the drying process is done at 20 dodol factories in Buleleng, Bali, which is viewed from the economic aspect with 3 periods. Each period will be analyzed significance (p <0.05) and compared from each period with interspersed time. WOP (washing out period) is given to remove residual effects.
4. Result and Discussion

Work productivity is a comparison between output and input. Work productivity in this research is reviewed based on economic aspect and analyzed from production amount and price of dodol as output and operational cost covering raw material and wage as input. Results of analysis based on output and input ratio. Normality test with Shapiro-Wilk test (n <50) work productivity data from Economic aspect of Period I, Period II, and Period III are shown in Table 1. Normality test results illustrate, data in the three periods are not normally distributed (p <0.05). Because the data is not normally distributed, significance analysis uses the Friedman test.

| Work Productivity in terms of Economic Aspect Period I, Period II, and Period III (n = 20) |
|-----------------------------------------------|-----------------|---------------|-----------------|---------------|
| Economic Aspect Period I                      | Work Productivity Period I | Median (minimum-maximum) | Mean±SB          | p             | p*            |
|                                              | 0,91 (0,87-0,94)  | 0,91±0,02      | 0,103           | 0,001         |
|                                              | 1,41 (1,36-1,48)  | 1,41±0,04      | 0,014           |
|                                              | 1,38 (1,33-1,48)  | 1,39±0,04      | 0,048           |

Description: SB = standard intersection, p = Significance for normality, p * = Significance for comparability

Significance analysis of work productivity data in terms of economic aspects with Friedman test showed p * = 0.001. This suggests that there is a difference in work productivity in terms of economic aspects that are meaningful at least in two periods (p <0.05). To know the difference, its done by applying post hoc Wilcoxon test analysis which is comparing work productivity data between periods as shown in Table 2.

| Comparison of Work Productivity Viewed from Economic Aspects between Period I, Period II, and Period III (n = 20) |
|---------------------------------------------------------------|-----------------|---------------|
| Description p       | Work Productivity with Economic Aspects PI-PII 0,001 |
| Period I            | PI-PIII 0,001   |
| Peroid II           | PI-IIII 0,355   |

Description: PI = Period I, PII = Period II, PIII = Period III, p = Significance for comparability

The result of post hoc Wilcoxon work productivity analysis in terms of economic aspect shows p <0.05 in comparison Period I with Period II and Period I with Period III, and p> 0.05 in comparison Period II with Period III. It states that work productivity in Period I is different from Period II and work productivity in Period I is different from Period III, and work productivity in Period II is not different from Period III. This means that there is an increase in work productivity in terms of economic aspects after using ergonomic hybrid solar dryers. Working productivity in Period II is the same as Period III, because in Period II and Period III using ergonomic dryers.
Conclusions

The drying process using ergonomic hybrid solar dryers increases the productivity of dodol crafters in the Penglataan Village of Buleleng Bali. Increased productivity of dodol crafters in terms of economic aspects of 54.95% on the use of solar energy and 51.65% on the use of biomass (economic aspects).

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