Design and Development of Dried Rabbitfish *(Siganidae)* Production Workstation for Calatagan, Batangas, Philippines

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ABSTRACT

The study aims to design and develop a workstation for dried rabbitfish production in order to avoid work-related musculoskeletal disorders and risk factors. Using different ergonomic assessment tools such as RULA, REBA and with direct observation and interview, it was found out that the traditional process of rabbitfish drying does not follow the requirements provided by the Ergonomic Standards. The workers were also not exposed in good working conditions. The study proposed three alternative designs considering the materials, components, and cost in guaranteeing the efficiency, cost-effectiveness, and assurance to lessen the risk factors. The three alternative designs were evaluated using trade-off analysis to identify the best design for fabrication. The fabricated design which is the L-shaped undergoes several trials to evaluate the effect of the proposed equipment in the job risk factors and measure the productivity of the workers. Time and motion studies as well as observations were done in determining the effectiveness of the proposed workstation. Productivity, ergonomic factors, and cost benefits were used in this study.

Keywords: Workstation, Dried rabbitfish, Trade-off analysis, Ergonomic factors

1. INTRODUCTION

The Philippines is one of the top fish producing countries in the world. The total volume of fisheries production in the Philippines in 2019 reached 4.42 million metric tons. Fish drying is the most common form of processing particularly the smaller size species caught by commercial trawlers. Smoked and salted fish are prepared in various forms for selected species like anchovies and rabbitfish.[1]. Rabbitfish is a favorite fish in Calatagan, Batangas, Philippines. This fish is locally known as *kuyog*, which is also called *danggit* in other parts of the country. This fish is usually served with fried garlic rice, an egg either sunny side up or scrambled, vinegar with red hot chili pepper as a dip, and a hot cup of coffee. Besides, the food can be found anywhere in the province due to the fact that the area has ample water, be it fresh or salt-water. The fish is not only popular among the said locals but among Filipinos all over the Philippines. Thus, preserving the fish has been a source of livelihood in the province of Batangas [2].

Ideally, productivity increase is combined with discomfort reduction. An essential part of an ergonomics program is designing a workstation for the task. Fo repetitive tasks, look for the characteristics of the user workstation interface that could lead to cumulative trauma disorder (CTDs). Significant issues are posture and contact stress. Important also in evaluating a workstation is the identification of safety hazards that could cause non-cumulative types of injuries – cuts, bruises, and fractures. A user's posture is greatly influenced by the design of the workstation's furniture and accessories and by the layout of the tools, piece parts, and other equipment.[3].

For those who work at a desk, in front of a computer, or on an assembly line, an organized workstation can save a worker from unnecessary pain, stress, and injury to the body. A workstation is any area where workers spend most of their time using tools and completing tasks with their hands. For office workers, it may mean using a keyboard, mouse, and monitor. For carpenters, it may mean standing at a workbench using various tools. Whatever the workstation may look like, it is important to maintain the proper posture while working so that the workers do not have to strain or add stress to their bodies while performing the job.

A properly organized workstation, that is ergonomically designed, is the key to correct posture and comfort ability and can prevent painful disorders that stem from poor posture. Taking a few minutes to get the workstation organized and to make the rest of the day less of a hassle may ultimately save one from pain in the long run. It is the science of adjusting the workstation and the tasks to the employee. It allows the employee to perform his job safely and efficiently. Ergonomics can affect several aspects of work such as computer workstations, manual handling, musculoskeletal disorders, and work schedules.

In today's world, everyone is aiming for the most efficient way on how to finish their work every day, but due to certain reasons, they are not able to do so. After the interview with rabbitfish production workers, it was found that they experienced body pain due to their work. Also noticeable were the improper postures of workers while working that may be due to improper workstation design. The workers just sit on a small stool with their stainless steel and plastic basins with kilos of rabbitfish to be processed in about four hours straight daily. These body pains

caused by improper posture affect not only the efficiency of the workers but also their health. The body pains that the workers commonly experience are in the lower back, neck, and strains on the thighs, arms, and forearms. With the lack of knowledge, these workers continue to acquire unnecessary body strains that led to less productivity. Due to the problems encountered by the workers, this study aimed to design and develop a workstation for dried rabbitfish production. It reduces the health risks that the workers are experiencing and helps improve their productivity.

Several studies about workstation and ergonomics were considered in the study. The research of Ericson C., and Heldmann J. [4] entitled "Lean Workstation Design Process" studied a company that is working towards becoming lean. The study created a standard structured process that puts the operator in focus as a crucial step on the journey. The study also emphasized the importance of having a standardized process when designing a new workstation. The study of Garbie I. [5] with a title "An Experimental Study on Assembly Workstation Considering Ergonomically Issues" applied ergonomics in designing a smart assembly workstation by providing fully adjustable ergonomically designed workstation. The adjustment done resulted in a higher productivity level. Three factors were considered in the experimental work, table and chair adjustments and the gender. The result of the study shows that the interaction between chair adjustment and gender is producing the highest value in production rate, thus it is recommended to hire female workers in the assembly workstation.

A study of Samson G. and Waiganjo M. [6] entitled "Effect of Workplace Environment on the Performance of Commercial Banks Employees in Nakuru Town" shows that the employee performance is the combined result of effort, ability and perception of tasks. The study found out that the physical workplace environment has a significant positive effect on employee performance in the commercial banks in Nakuru town. Thus, it shows that there is a significant relationship existing between the workplace environment and performance. Lastly, a study entitled [7] "Ergonomics Study for Injection Molding Section using RULA and REBA Techniques" by Kulkami S., and Kapali C. applied the ergonomic assessment tools REBA and RULA to reduce human stress at the existing working method of injection molding machine in a plastic industry. The study proposed an ergonomically designed workstation that will help reduce the musculoskeletal disorders (MSD's) that the workers in the injecting process are experiencing.

Objectives of the study

The main objective of the study is to design and develop a workstation for the dried rabbitfish industry, to maximize their efficiency and productivity and to reduce the health risks of the workers.

Specifically, it aimed:

1. To analyze the current production workstation for dried rabbitfish.

2. To identify the health risks and discomforts that the workers are experiencing using different Ergonomic Assessment Tools.

3. To design a workstation considering the following parameters:

    3.1. Process of dried rabbitfish production

    3.2. Ergonomic factors

    3.3. Cost

4. To conduct a trade-off analysis.

5. To develop the best alternative dried rabbitfish production workstation base on the following parameters:

    5.1. System components

    5.2 Material specifications

    5.3 Ergonomic Factors

6. To determine the effectiveness of workstation in relation to:

    6.1 Productivity

    6.2 Ergonomic Benefits

    6.3 Cost Benefits

2. MATERIALS AND METHODS

Research design

The study used the developmental research method. It is the systematic study of designing, developing, and evaluating instructional programs, processes, and products that must meet the criteria of internal consistency and effectiveness. The evaluation was done by means of observation and checklist on the processes involved in the dried rabbitfish production. The data collected were analyzed and used to identify the problems.

Rapid upper limb assessment (RULA)

The study used this assessment tool in assessing the upper and lower arm, wrist, neck, trunks, and legs of the workers. It was used in analysing the worker's postures and in identifying the actions to take. The result of the assessment shows that there is a need for a workstation.

Rapid entire body assessment (REBA)

The study used this assessment tool in evaluating both the upper and lower parts of the musculoskeletal system

for biomechanical and MSD risks associated with the job task being evaluated. The result shows that the workers are in medium risk and therefore need a workstation.

Trade-off analysis

It is a tool used to determine the effect of decreasing one or more key factors and simultaneously increasing one or more other key factors in a decision, design and project. In this study, it was used in selecting the best alternative design.

Subject of the study

The subjects of study were twelve (12) workers in the production of dried rabbitfish from Brgy. Poblacion 1, Calatagan, Batangas.

Data gathering instrument

The study used an interview guide questionnaire which consists of a series of questions concerning the health and safety of workers upon exposure to the existing workstation.

The study also used an ergonomic assessment worksheet and tools like a tape measure, digital camera, and stopwatch for the time and motion study on the current process.

Data gathering procedure

The study started in the assessment of the existing cleaning, gutting, and preserving process in the dried rabbitfish production at Calatagan, Batangas. Actual observations and semi-structured interviews were conducted at the workplace to gather information and evaluate the process. Literature reviews on dried fish industry workstation were also done. The next step is the designing of the workstation or the workplace based on the anthropometric measurements of the workers and the considerations of the cleaning process. Drawings and other presentation documents were then prepared in presenting the design concept and describing it in terms of ergonomics and structure systems. The selection of the materials used in the workstation was based on the research from the web and from the Municipality of Calatagan which holds the rabbitfish livelihood. After the preparation of the overall design of the workstation, the development stage took place.

3. RESULTS AND DISCUSSION

Analysis of current workstation of dried rabbitfish production

Before and excluding the actual fish drying, the dried rabbitfish production consists of four (4) main processes: fin removal, cleaning, gutting, and soaking in brine solution. Upon observing the existing workstation, it was found out that the workers are only using a tent that was laid flatly on the ground where the process of cutting, cleaning, and gutting occurs. The worker is doing the process in a squatting position where the upper body is bent forward.

Table 1. Process flow at the workstation of dried rabbitfish production.

Activity	Making of kuyog		Event	Present	
Date	October, 2018		Operation	5	
Operator	Analyst		Transport	3	
Circle the appropriate method and type			Delay	0	
Method (Present) Proposed			Inspection	0	
Type			Storage	0	
Material (Worker) Machine			Time (min)	22	
Remarks			Distance (m)	11	
			Cost		
Event distribution	Symbol		Time (sec)	Distance (m)	Remarks
Removing of fins			62		
Washing of fish			11		
Transferring to work area			5	3	
Cutting and gutting of fish			530		Curing and gutting time could vary with worker efficiency and fish size.
Transferring to water source			7	3	
Rinsing of fish			533		Cutting, gutting, and rinsing were rapid and sequential. Cut and gutted fish transferred to another worker for immediate rinsing.
Soaking in brine solution			180		
Transferring of fish to drying rack			9	5	
		Total	1337	11	

The process starts on removing the fins of the fish which took 62.33 seconds. After removing the fins, the fishes were being washed followed by the cutting and gutting of the fish which lasted for 530 seconds. The next step was the transferring to the water source, then rinsing, soaking in the brine solution and lastly transferring the fish to the drying rack. The overall process took 1,337 seconds.

Health risks and discomforts of the workers

Table 2 shows the work-related risk factors of the existing dried rabbitfish production workstation. The work-related risk factors are awkward posture, repetitive motion, and long period of sitting. Because of these factors, the workers suffered from back pain, neck pain, muscle pain, and musculoskeletal disorders such as wrist pain and other hand and arm pain.

Design of workstation alternatives

After the conduct of actual observations and interviews with the dried rabbitfish production workers in Calatagan, Batangas, three workstation designs were developed. These workstation designs are expected to reduce health risks and increase productivity.

Table 2. Work-related risk factors of the existing workstation.

Work-related risk factor	Description
Awkward posture	The worker experiences awkward posture because of the existing dried rabbitfish production workstation leading to back and body pain. All workers mostly clean 6-8 kilos of fishes per day. And that leads to them to experience awkward posture for about 2 hours per day.
Repetitive motion	The worker experiences repetitive motion in cleaning and gutting of fish resulting in musculoskeletal disorder such as wrist pain.
Extended period of squatting	The worker experiences an extended period of squatting in the dried rabbitfish production process that results in the worker experiencing back pain and leg pain.
Non-conducive work environment	The workers cannot work properly because there is no proper workplace to produce dried rabbitfish.

Design and process based on the design

The design was simple and flexible for the production of dried rabbitfish. The flat-lowered surface was designed for the rabbitfish cleaning and gutting process. An opening on the side of the working surface was placed so that the fish organs, the water, and blood can be easily swept off directly to the waste bin. The process is on a straight line from one end to another end

The design is an L-shaped workstation where it doesn't require moving from place to place. The worker will just turn their body to work on the other processes.

Ergonomic factors

Table 3 shows the results of the anthropometric measurements of some of the dried rabbitfish production workers at Brgy. Poblacion 1, Calatagan, Batangas. The study considered the percentage for the anthropometry of the workers in sitting position. It helps the study to comply the exact measurement to design the dried rabbitfish production workstation.

Development cost

The fabrication of the chosen alternative incurred the following costs shown at the table below. It includes all the materials needed in fabrication.

Table 4 shows the development cost for alternative design 1 of the dried rabbitfish workstation. It has a development cost of Php 19,010. Table 5 shows the development cost for alternative design 2 of the dried rabbitfish workstation. It has a development cost of Php 23, 760. Table 6 shows the development cost for alternative design 3 of the dried rabbitfish workstation. It has a development cost of Php 22, 615

Trade-off analysis

Table 7 shows the result of the trade-off analysis done from the dried rabbitfish production at the dried rabbitfish production at Brgy. Poblacion 1, Calatagan, Batangas, four out of four obtained that L-shaped

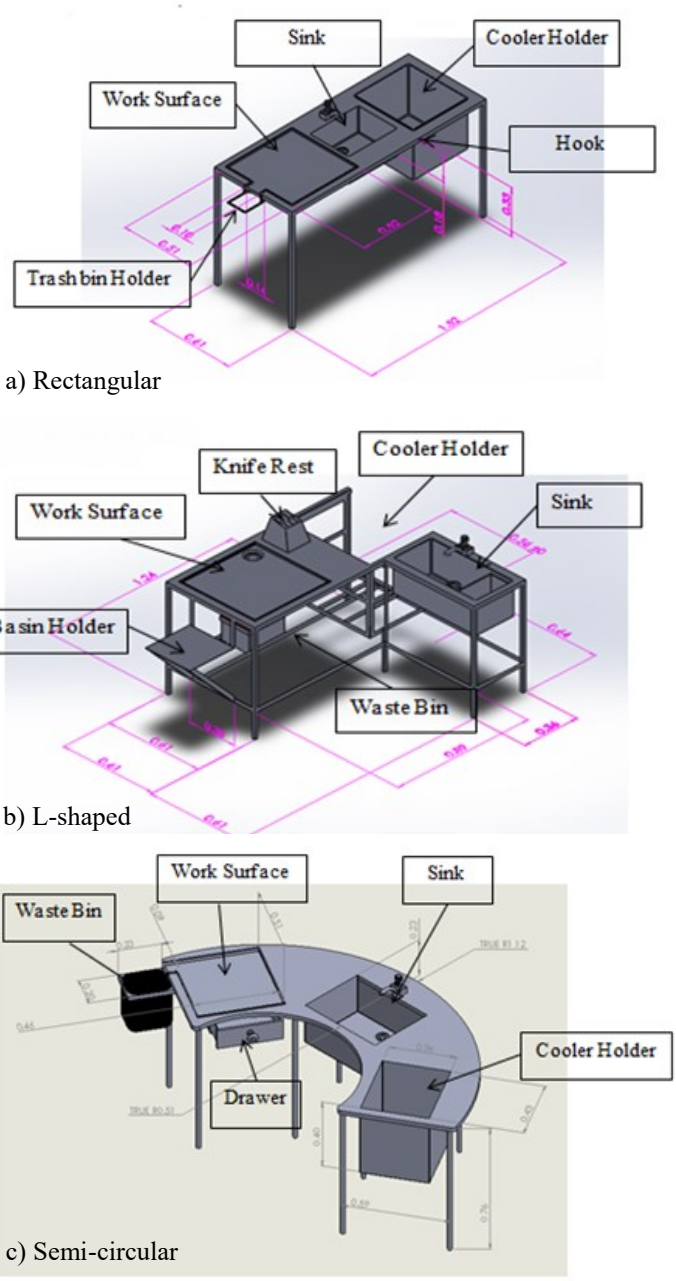

Figure 1. Comparison of the design of three proposed alternative workstations a) rectangular, b) L-shaped, and c) semi-circular.

workstation is the best design. L-shaped stainless steel design is the best design since it had the highest scores in all the four methods used.

Table 3. Some anthropomorphic considerations during dried rabbitfish production in a sitting position.

Parameters	Measurements (cm)	Percentage (%)
Sitting height	42.39	91.31
Shoulder to elbow	30.00	89.07
Elbow to tip	67.63	90.99
Arm reach	43.66	99.22
Upper leg length	44.13	96.56
Knee height	41.23	69.15

Table 4. Development cost for the first alternative dried rabbitfish workstation design (rectangular).

Materials	Quantity/Dimension	Amount (Php)
Stainless steel Plate	1 pc/4x8x1.5mm	7,000
Stainless steel tubular	3 pcs/1x1x1.5mm	1,600
Stainless steel tubular	2 pcs/0.75x0.75x1.5mm	980
Drain plug	2 pcs	140
Faucet set	1 set	280
Stainless flat bar	1 pc	860
Sand paper	1 pc	500
Rivet		100
Aluminum sink	1 pc.	550
Labor cost	9 days	7,000
Total		19, 010

Table 5. Development cost for the second alternative dried rabbitfish workstation design (L-shaped).

Materials	Quantity/Dimension	Amount (Php)
Stainless steel plate	1 pc/4x8x1.5mm	7,000
Stainless steel tubular	3 pcs/1x1x1.5mm	1,600
Stainless steel tubular	2 pcs/0.75x0.75x1.5mm	980
Knife rest	1 pc	280
Drain plug	2 pcs	140
Faucet set	1 set	280
Stainless flat bar	1 pc	860
Stainless rod	1 kilo	500
Stainless screen		200
Sanding flacks	1 pc	500
Rivet		100
Labor cost	9 days	7,000
Total		23, 760

Table 6. Development cost for the third alternative dried rabbitfish workstation design (semi-circular.

Materials	Quantity/Dimension	Amount (Php)
Stainless steel plate	1 ½ pc/4x8x1.5mm	10,500
Stainless steel tubular	4 pcs/1x1x1.5mm	1,600
Stainless steel tubular	2 pcs/0.75x0.75x1.5mm	980
Drain plug	2 pcs	140
Drawer knob	1 pc.	105
Faucet set	1 set	280
Stainless flat bar	1 pc	860
Sand paper	1 pc	500
Rivet		100
Aluminum sink	1 pc.	550
Labor cost	9 days	7,000
Total		22,615

Development of best alternative design of workstation for dried rabbitfish production

Table 7. Results of the best design using different method of trade-off analysis

Method	Rectangular	L-shaped	Semi-circular
Standard weighted sum method	17.56	19.16	16.8
Imprecise designer ranking table	0.68	0.74	0.65
Maximin (best of worst)	3.58	3.67	3.33
Analytical hierarchy	6.19	6.80	6.01

With the data from the trade-off analysis, evaluation, and survey, the study determined the L-shaped workstation as the best alternative design.

System components

Figure 2 shows the system components of the best alternative design which is the alternative design 2, the L-shaped workstation.

Material Specifications

In developing the best alternative design, the study used materials that were suitable for the workstation such as

stainless steel plate for the surface of the table, tubular stainless steel was used in the frame of the table, a faucet valve, a coupling socket for connecting the pipe or hose, a wooden knife rest, a drainage plug,

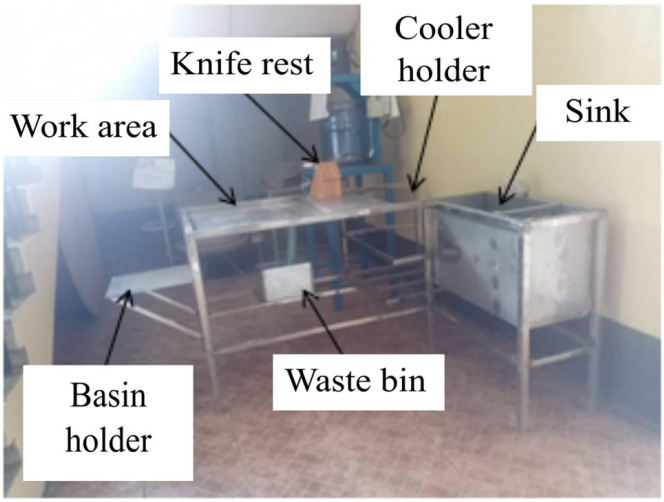

Figure 2. System components of the best alternative design

a rivet, and a screen wire.

Evaluation of effectiveness of the proposed dried rabbitfish workstation

To determine the effectiveness of the workstation in terms of productivity, ergonomic benefits, and usability, the study conducted trials using the proposed workstation and evaluated the results.

Productivity of the worker

Table 8 shows the results of the testing in the current and proposed workstation of the dried rabbitfish production process. The total average time of the three (3) trials is 1243.44 seconds for the existing workstation and 978.11 seconds for the three (3) trials in the proposed workstation.

Productivity of the existing and proposed workstation

Table 8. Cycle time for both existing and proposed workstation

Trial (day)	Number of kilo	Existing workstation's cycle time (sec)	Proposed workstation's cycle time (sec)
1	1	1338	1263.33
2	1	1337.33	841.84
3	1	1055	829.15
Average		1243.44	978.11

Using the average cycle time, the productivity on the existing workstation was 2.8952 kilos/hour while that on the existing workstation was 3.6806 kilos/hour.

Ergonomic benefits

Table 9 shows the work-related risk factors for the proposed dried rabbitfish production workstation. Since the workstation was based on the anthropometric measurements of the workers, work-related risk factors such as awkward posture and back and neck pain were eliminated. The proper design of the workstation also gave the worker a better workplace.

Table 9. Work-related risk factors for the proposed workstation.

Ergonomic Concepts	Yes	No	REMARKS
Awkward Posture		✓	The awkward posture that the worker has been experiencing was eliminated because of the proper height of the working space. The worker doesn't lower his head anymore to cut and gut the fish.
Repetitive motion	✓		The repetitive motion in cutting and gutting of fish wasn't eliminated.
Long period of squatting.		✓	Long period of squatting was not eliminated.
Inappropriate workplace		✓	The workers can work properly because there is a proper and more organized workplace for the production of dried rabbitfish.

Cost benefits

The cost benefit was computed to determine the benefit of the dried rabbitfish workstation as an investment. The study compared the benefits and cost of investments using net present value (NPV), which determines the annual cash flow based on the following formula.

$$Annual\ cash\ inflow = \frac{3.38\ kg}{day} \times \frac{30\ days}{1\ month} \times \frac{12\ months}{1\ year} \times \frac{Php\ 100}{1\ kg}$$

The estimated annual cash flow is Php 132,501.

4. CONCLUSIONS

From the results of the study , the following conclusions are drawn:

In the existing dried rabbitfish production, the worker was manually cleaning, gutting, and preserving the fish in an awkward position. The existing workstation was inappropriate because it causes too many health risks for the workers.

The existing workstation for dried rabbitfish production results in a work related risk factor for the workers particularly awkward posture and repetitive motion.

The design alternatives were designed based on the dried rabbitfish production process, ergonomic factors, and its development cost. The workstation was made to be fitted to the worker based on the worker's anthropometric measurements.

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