Ergo-innovative design of cow slaughter tool

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Abstract. Rough handling in the slaughtering operation can cause animal’s stress resulting in the poor quality of meat because of the depleting muscle reserves to the lowest level. This condition will reduce the muscle lactic acid and increase the potential hydrogen on the meat above the normal level allowing a higher possibility for bacterial growth. Moreover, the rough slaughtering operation using the conventional technique may lead to slaughterer’s accident because of the cow’s mutiny. Thus, it is crucial to use the slaughtering tool that is safer and more comfortable to operate. This study aims to design the innovative slaughtering tool ergonomically and satisfying the user requirement. A survey was conducted to identify user criteria of the design. Theory of Inventive Problem Solving (TRIZ) was implemented as a fundamental basis to determine the inventive principle of the design, and the Quality Function Deployment was applied to develop the design specification. Non-parametric statistical analysis was done to test the hypothesis. This study reveals some identified inventive principles including dynamic quality, parameter changes, combination, and equipotentiality. Thus, the proposed design is valid to satisfy user need at 5% of significance level as it is proven to be safer, stronger, more practical, and more durable.

1. Introduction

The currently widespread animal’s slaughtering technique, including the one for cows, is the manual slaughtering by tying the cow’ body parts and legs before being knocked over by force. This commonplace method may harm the cows and result in many negative impacts. According to [1] rough handling in the slaughtering operation can cause animal’s stress and result in the poor quality of meat. [2] and [3] confirm that the stressful animals before slaughtering will adversely affect the carcass quality i.e. slackening the supply of muscle glycogen, widely known as “Dark Firm Dry (DFD)”. As a result, the DFD condition will reduce the content of lactic acid on the muscle and raise the potential hydrogen (pH) grade on the meat above the normal level resulting in higher possibility for bacterial growth [4]. Such condition is indicated by the darker color of the meat, stiffer and drier. This characteristic shows that the meat is not fresh and unhealthy.

On the other side, such conventional methods can also harm the slaughterers and may lead to an accident because the tie is usually not strong enough and may endanger the slaughterers during the tying process especially when the cow is frenzied. Such incident may also occur both in the slaughterhouse and during outdoor slaughtering, especially on the preparation process.

Another notable technique or method in the slaughtering process is known as stunning. This method is done with low shooting on the head of the cow to faint it [5]. However, this technique may still lead to harmful incident as the conventional method and may even kill the cow forbidding us from consuming
its meat (haram) as indicated by [6] and [7]. Therefore, it is necessary to create a novel facility for safer slaughtering process to ensure that the quality of meat is fresh, healthy, and "halal".

On this basis, the objective of this study is to design the ergonomic and innovative slaughtering tools to satisfy the user requirement for safer and more comfortable cows’ slaughtering process.

2. Research Method

2.1. Survey
The paper-based survey was conducted by distributing questionnaires to 30 respondents in an age range of 14 to 60 years old. The aim of this survey is to identify some attributes of the Assistance Appliance design for Slaughtering the Cow that the user is looking for.

2.2. Theory of Inventive Problem Solving (TRIZ)
TRIZ is a systematic method that provides a logical approach to develop creativity for innovation and inventive problem solving. This method produces an innovative solution of technical problems in the product development process [8]. This method will be used to find the inventive principle for design based on some contradictions identified between worsening features and improving features [9].

Figure 1. TRIZ problem solving steps [10]

Figure 1 explains the stages of TRIZ in finding the specific solution by referring to the inventive principle identified. These stages started from identification and analysis of the specific problems. Then it was done by determining contradiction between improving features and worsening features. The last stage was finding the solution according to the 40 principles [10].

2.3. Quality Function Deployment (QFD)
The method was used to plan and develop a structured product that allows the development team to clearly define the needs of consumers [11]. In the design process and/or product development, QFD was used for determining the specification of product concepts. House of Quality (HOQ) is a tool utilized to convert from what the customer wants into how to achieve it [12]. Subsequently [12] explains that this house encompasses six blocks. They are customer needs, competitive evaluation, technical requirement, relationship matrix between what and how, technical correlation matrix, and target specification. The relationship among them was determined by mapping process, which started from identifying customer requirements and transforming them to the technical requirements. This transformation describes the
level of correlation: strong, moderate, and weak. The target specification was developed from the identified technical requirement as attribute of design. More details are presented in Figure 2.

2.4. Apparatus
The following tools were used to support this study consist of Questionnaire. This questionnaire is to identify the attributes of the design, to determine the important rating, and to validate the proposed design. And IBM SPSS version 25 software is used to process some statistical data. As for Solidwork Software 2016 version to develop a virtual prototype of the proposed design.

2.5. Statistical Analysis
Non-parametric statistical analysis was conducted by using the Marginal Homogeneity method and the Wilcoxon method. The first method was applied to test a hypothesis with the specification of the developed design that satisfied the customer requirement. The second method was done to validate the hypothesis with the safer proposed design, more practical, more reliable and more durable than the existing design. 5% of significance level was used in these test [13].

3. Result and Discussion

3.1. Survey Result
Table 1 presents the four valid attributes of the design that consumers need. The attributes identified are strong, safe, practical, and durable. The strong attribute describes the ability of the slaughtering tool to withstand the motion of cow. It aims to calm the cow and avoid the state of mutiny for easy slaughter. The safe attribute of the design is required in order that the slaughtering operation does not endanger the slaughterers. In the common manual slaughtering process, the slaughterers may be harmed because the cow is not tied properly resulting in an uncontrollable motion. Meanwhile, the practical attribute of the tool is meant to ease the user in the slaughtering process. In addition, the durable attribute is required by the user because the tool can be used frequently and is not easy to damage.

| Attribute   |
|-------------|
| Safe        |
| Strong      |
| Practical   |
| Durable     |

3.2. Functional Analysis
Functional analysis is described in Figure 3. This explains on the level of correlation between one variable to another in the slaughtering process. Such correlation covers normal (no risk), insufficient, and harmful attributes. Figure 3 shows that the roping operation on leg, head, and body by using rope is not rather sturdy since it risks the slaughterer because the binding is easy to loose and may expose the slaughterer to the reflex movements and kicks of the cow. Moreover, the process of cutting with a sharp knife does not have a significant risk on cow and slaughterer so that it is called the normal correlation.
Meanwhile, the means to restrain cow movement using the hollow box has a high risk because the leg of a cow can come out of the box and cause injury on the cow. The fall down process has a high risk because the head and body of the cow can hit the floor, causing injury and stress. Moreover, the water used to clean the floor also has a high risk, which results in the slippery floor so that both the cow and the slaughterer can slip and fall down.

3.3. Cause & Effect Chain Analysis
Figure 4 describes the Cause & Effect Chain Analysis. It is meant for identifying a root cause of the effect that is occurred in the pre-slaughtering process. It reveals five root causes namely are rough handling, hollow box, the roping process, the unmovable tool, and the easily damaged rope. Rough handling and the use of cow retaining hollow box can injure the cow and endanger the slaughterers. It is because the leg of the cow may come out of the box harming the slaughterers from being kicked. Meanwhile, the roping method used causes less practical operation of slaughtering because the slaughterers are required to tie many body parts of the cow causing complicated operation. Another drawback of the manual method is the tool used to fall the cow down that cannot be moved easily. Meanwhile, the rope cannot be used frequently because it is not forceful.
attribute, it has an inventive dynamic principle and equipotentiality. The dynamic principle recommends adding the element of motion on the tool in order to drop the cow slowly and make the operation safer for the cow and the slaughterer. However, this method must require extra energy. An alternative to solve the problem is to install the double acting hydraulic system with single ended cylinder that has the maximum capacity of 600 kg with the system that can fall down the cow slowly and automatically (change dropping technique). While the equipotentiality principle recommends alignment in accordance with the use so it will be safe and practical. Thus, the improvement of the appliance from the hollow box is to provide two rooms; open space with the width of 63 cm for the clamp system and closed space with the width of 62 cm for the cow where the closed space is to avoid the cow’s foot from slippage out of the box (modifying the box). In addition, the inventive principle for practical and strong attributes is parameters changes which recommends change on the objects to increase an effective use. Thus, to improve the appliance, it is necessary to change the roping technique with a clamp system with a length of 153cm, width of 30 cm, and height of 146 cm to withstand the movement of the cow firmly and practically (changing the roping technique). Meanwhile, the combination of inventive principle recommends combining two or more objects for two or more functions by installing 7-inch trolley wheel for mobility and a lock system for restraining the tool. Therefore, the slaughter process cannot endanger the cow and slaughterers (the movable tool design). In order to satisfy durable and strong attributes, it is necessary to have the parameter changes principle, which recommends replacing the rope with double acting hydraulic system with single ended cylinder that has a capacity of 600 kg for the process of dropping the cow and with a capacity of 200 kg for clamping, as well as a capacity of 50 kg for the cow head restraint system (change the roping tool). More details can be seen in Figure 5.

**Table 2. TRIZ results**

| Attribute       | Root of the Problem     | Improving feature       | Worsening feature                      | Inventive Principles       |
|-----------------|-------------------------|-------------------------|----------------------------------------|---------------------------|
| Safe            | Rough handling          | Force -10               | Los of energy -22                      | Dynamic – 15              |
| Safe and practical | Hollow box               | Easy to roping          | The cow's foot slips out of the box     | Equipotentiality – 12      |
| Practical and strong | Too many roping processes | Quantity of substance-26 | Strength – 14                        | Parameter changes -35     |
| Practical and safe | The box cannot be moved | Reliability - 27       | Object generated harmful factor – 31   | Combination -5            |
| Durable and Strong | The rope is easily damaged | To hold back the movement | Easy to damage                        | Parameter change – 35     |
3.6. Conceptual Design

Figure 6 is a visual design of assistance appliance for slaughtering the cow based on the identification of consumer desires.

![Figure 6. Design of assistance appliance for slaughtering](image)

3.7. Statistical Analysis

3.7.1. Conformity Test

The conformity test is to identify the proposed design of the attributes of consumer desires. By using a significance level of 5%, the results of the conformity test are shown in Table 3 as follows:

| Attribute | Asymp Sig. (2-tailed) |
|-----------|-----------------------|
| Safe      | 0.371                 |
| Practical | 0.109                 |
| Strong    | 0.139                 |
| Durable   | 0.637                 |

The hypothesis at this conformity test is when the value of Asymp. Sig. (2-tailed)> 0.05, there is no significant differences between consumer need with the proposed design and vice versa. This can be seen in the results of the conformity test of the Asymp section. Sig. (2-tailed) the four attributes have Sig. > 0.05, which means that the proposed design is in accordance with the consumer need.
3.7.2. Different Test

Table 4 presents the result of different-test used to identify differences between the proposed product with the existing products. This test uses a significance level of 5%, and has the hypothesis if Asymp. Sig. (2-tailed) <0.05, which means there are significant differences between these two tools.

| Attribute | Asymp Sig. (2-tailed) |
|-----------|-----------------------|
| Safe      | 0.000                 |
| Practical | 0.000                 |
| Strong    | 0.000                 |
| Durable   | 0.000                 |

The test result indicates of the four attributes having Asymp values. Sig. (2-tailed) <0.05. It can be said that the proposed tool has significant differences with the existing tools.

4. Conclusion

Based on the analysis of Ergo-Innovative Design of Cow Slaughter Tool, stated that consumer attribute identified of the design developed encompasses strong, safe, practical, and durable attributes. For the appropriate inventive principles to design the assistance appliance of slaughtering are dynamic, parameter changes, combination, and equipotentiality. Then the design parameters of the design are as follow: double acting hydraulic (single ended cylinder) capacity of 600 kg for slaughtering process assistance, box with the length of 153 cm, width of 125 cm, and height of 146 cm, dimensions of cow head restraint with the length of 55 cm, jaw width of 31 cm, muzzle width of 15 cm, jaw height of 8 cm, and muzzle height of 4 cm, wheel type: trolley wheel with the brake system, 4 pieces (7 inches), clamp system with the length of 153 cm, width of 61 cm, height of 146 cm. Added with a matte rubber coated roll system, the wireless remote control system, alloy steel material, roping with a hydraulic system double acting (single ended cylinder) 100 kg capacity. Therefore, the developed assistance appliance design for slaughtering a cow is valid to conform the costumer requirement at 5% of significance level. This design is also valid to be better than the existing design.

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