DEVELOPING GOAT FARM WASTE MANAGEMENT TOOL TO PRODUCE ORGANIC FERTILIZER

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ABSTRACT

In agriculture, the 'organic fertilizer' or popularly known by its trade name, 'Black Gold' is the result of livestock faeces that are processed or recycled as manure. This project aimed to develop a specific product for collecting goat manure while cleaning the pen. The clean-and-collect criteria of this product was created to complement the farm worker's task in working efficiently. The major target of this project was to identify existing cleaning products that can be enhanced for clean-and-collect purpose in the animal pen. Both primary and secondary research data were used in this study. The primary data were collected by interviewing the farm worker and farm officer; both shared information, experiences, and problems during the process of cleaning the goat pen. Data were also collected from observation of the cleaning tools used in the pen. The secondary data were collected from literature review and patents from previous studies including articles, journal, websites, and other documented sources. These data were described and analysed qualitatively in this research. The cleaning process in the pen will become easier with the clean-and-collect product that has been explored in this study. The time spent to clean the pen will be improved as well. In conclusion, the product will clean the pen effectively by collecting goat faeces efficiently. It is therefore feasible to be developed as a waste management tool that can aid in the production of organic fertilizer. Subsequently, this product is also beneficial in terms of income and labour requirements in the farm.

Keywords: *: Product design, cleaning tools, animal pen, farm management, manure*

1. INTRODUCTION

Manure-based compost is a source of side-income that can be generated in a goat farm. The organic fertilizer, also popularly known by its trade name, Black Gold, is produced from plant or animal sources that do not have any chemicals or hormones compound. With only 50 goats, farmers can already cultivate the organic fertilizer and thus increase revenues to replace the original main source of income. (Anem, 2012).

The easiest and cheapest method of composting is the process of incubation using EM (Effective microorganisms), where the bacteria will accelerate the elaboration process of faeces to fertilizer composition that is organic and not harmful. This can help the natural composition of soil fertility in the long term. Other available mixture is a fruit palm rest, which is buffeted palm branches and PKC (Palm Kernel Cake) that can be easily obtained. In terms of the law on the use of goat droppings as fertilizer, mainly as fertilizer for vegetables, the Malaysian Standard clause 5.6.4.2.3 states that nutrients and fertility products shall be applied in a way that does not harm soil, water, and biodiversity. Indeed, the direct use of goat manure without its elaboration process is not allowed, as stated in clause 5.6.4.2.6, where the mineral fertilizers shall only be used in a programme addressing long-term fertility, and together with other techniques such as organic matter additions, green manures, crop rotations, and nitrogen fixation by plants. Their use shall be justified by appropriate soil and leaf analysis or diagnosed by an independent expert (Department of Standard Malaysia, 2015). However, the animal stool or faeces that have been fully resolved through the proper process is required because it is good for soil fertility and safe to be used as fertilizer.

As the secondary product in the farm, manure composted from the goat faeces can serve as another source of income for the farmer.

2. LITERATURE REVIEW

The literature review is based on previous studies that relate to cleaning tools. In addition, this literature review also investigates the factors and effects of organic farming.

2.1 Books/Journal/Articles

a) Farmyard Manure (FYM)

Referring to the relation between soil organic matter and yield levels of non-legume crops in organic and conventional farming systems, (Migliorini et al., 2014) farmyard manure is the decomposed mixture of excreta (dung) and urine of farm animals like cow, horse, goat, and sheep, along with leftover hay and fodder. They are ready-made manures and contain nitrogen, phosphorus, and potassium. Farmyard manure that is collected in the field and stored in an exposed condition over a long period shows a considerable loss of ammonia, which signifies a loss of fertilizing value. To prevent this loss, the dung is stored in pits which are about a metre deep. When the pits are filled to the top, the surface is sealed with mud slurry. The manure is ready for use in about 4-5 months. Microbes play an important role in decomposing the dung and converting it into manure.

Figure 1: Farmyard Manure
Source: (AgriFarming, n.d.)

b) Effects of organic farming or organic fertilization on soils

Soils displayed higher microbial biomass (Cmic), with lower metabolic quotient (qCO2 = CO2: Cmic); (Reinhardt et al., 1996); (Fließbach, Oberholzer, Gunst, & Ma, 2007), as well as lower soil bulk density (Dominici et al., 2006). There were higher root colonization with arbuscular mycorrhiza fungi (AMF) and higher AMF spore density in the soil (Becskei et al., 2008); (Katzenberger et al., 2006). However, other trials showed unclear results or no difference with AMF (Bedini, Turrini, Rigo, Argese, & Giovannetti, 2010); (Vienna, Freyer, & Vienna, n.d. 2014). Under organic cultivation (and favourable weather conditions) soils have a high potential for short-term nutrient delivery. Organic farming is the best technology for poor site conditions.

c) Malaysian Standard

According to the Malaysian Standard, clause 5.6.4.2 material of microbial, plant, or animal origin shall form the basis of the fertility program. Maintenance of fertility may not rely solely on off-farm.

d) Patent research

Besides literature search, a patent search for similar products also needed to be done. It is because patents are very important to be identified to prevent similar products having claim in patent. Moreover, existing similar products cannot be used as the new product. Patent claims can occur in various aspects such as:

i) the design
ii) the function
iii) the technology

This research also explored on patent search where a lot of claims has been identified for a product. This patent documentation helps to identify which claims have been used. Thus, it will guide the research on which claims should be applied to the final product.

Furthermore, there is a lot of information on existing stool cleaning technology products and how the technology has been applied to collect animal faeces. Seven similar products have been identified to be patented so far.

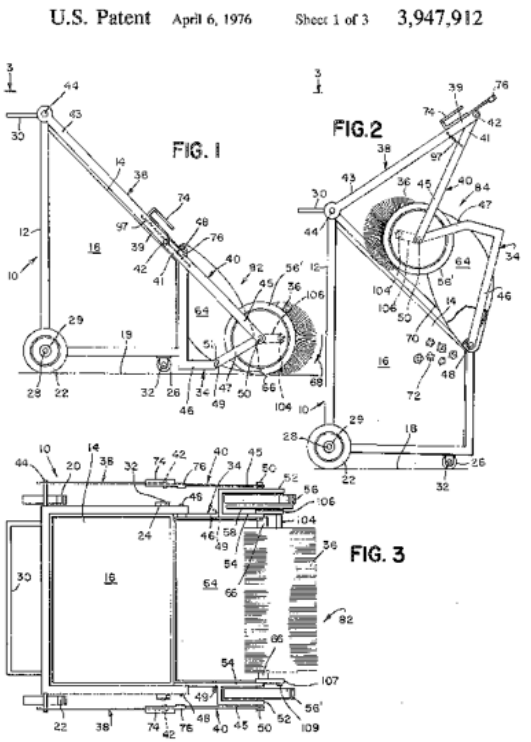

Figure 2: Existing patent products
Source: (Abraham Micheals, 638 Spruce St., Philadelphia, 1976)

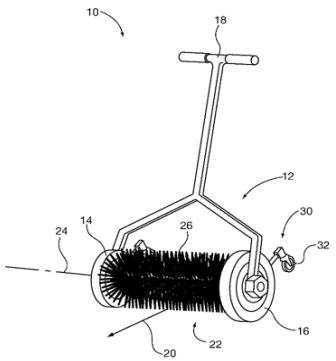

Figure 3: Existing patent products
Source: (Brian Rose, Sanford, 2012)

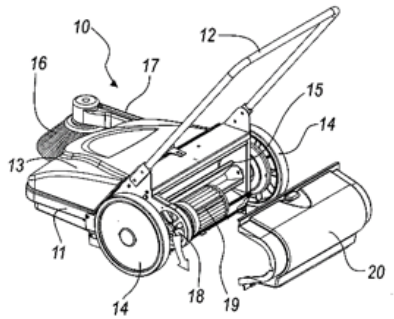

Figure 4: Existing patent products
Source: (Renato Scremin, Tezze Sul Brenta (IT): Gianfranco Lago, 2006)

Figure 5: Product used at Ladang 16 UPM

3. METHODOLOGY

Data collection for this research employs both primary and secondary research data. Primary data collection in the research have been conducted by interviews and observation. Meanwhile, the secondary data were collected from literature review and patents from previous studies such as articles, journal, websites, and other documented sources.

3.1 Conceptual Framework

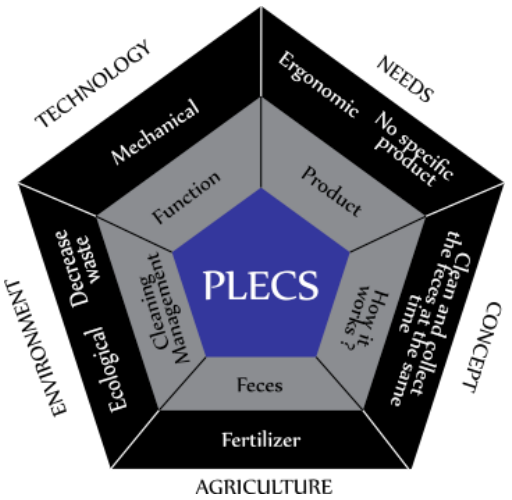

Figure 6: Research Process

Figure 6 shows a conceptual framework that follows three problem statements. All keywords are in the purposed group of the conceptual framework. Five factors have been indicated as the gaps for the conceptual framework. The gaps come from relevant issues and existing products.

a) Environment

One problem based on relevant issues is the effects of cleaning the pen from the waste, that can cause harm to the environment. Usually, a lot of water is used during pen cleaning, which could affect the environment and increase the expenses of water consumption. Moreover, the workers would use self-modified tools that are ineffective. Product incompatibility has been identified as the gap for this issue. This is because not many suitable products are readily and commercially available to clean a goat pen. Therefore, the target product should have a combination of clean-and-collect purposes to solve the problems of the target users.

b) Needs

The problem statement is the appearances of existing products which have low appeal in design. From the observation, most of the existing products are not for cleaning purposes. The farm workers usually use farming tools like a scoop and a wheel barrow to clean the pen. Furthermore, the design of existing products is not attractive. Thus, the design specification of dual functional cleaning tools must be guided by style to attract potential users.

c) Technology

The concepts of simplicity and feasibility have become the guide to develop the target product. The product will be designed based on specifications, criteria, and functions that adhere to both concepts. The product must be easy to use, portable, and compact. Most of the design specifications and criteria of existing tools make them difficult to use, due to lack of any storage compartment, leaving farm workers without access to a specific product for the intended task.

3.2 Summary

The conceptual study has been narrowed to the factors that influence goat breeders, farmers, and farm workers, as target users. All the information lead to the identification of appropriate design specifications, criteria, and concept for a cleaning tool in a goat pen. The combination of the ability to clean the pen while collecting the faeces will benefit the target users.

3.3 Primary Data

a) Interview

The interview was conducted at Ladang 16 UPM in three sessions with a farm worker, a farm officer, and a postgraduate student. Each respondent was interviewed separately, and a lot of information were obtained from the separate interview sessions. The respondents shared their experience and relevant information throughout the interview. Data were analysed qualitatively. The result of the survey will further be discussed in Section 4.

b) Questionnaires

A set of questionnaires was prepared and answered by 15 farm workers as the target respondents in this research. The aim of this questionnaires is to investigate their basic knowledge and experience in using farming tools to clean the goat pen. These are the list of question scopes that were asked:

i. their experience
ii. the frequency of cleaning the goat pen
iii. actions done to the goat manures after the cleaning process
iv. the main problem during the cleaning
v. the function of tools
vi. the product commonly used to clean goat faeces
vii. opinion on existing products

c) Observation

From the observation, it was clear that the farm workers have been struggling to clean the goat pen. Therefore, a good cleaning tool is needed to help them work efficiently. The observation result will be discussed in the next section. These are the main situations that had been observed:

i. how existing products are used
ii. the problems that may occur during and after the cleaning process
iii. the effects after the cleaning process has been completed

3.4 Secondary data

a) Journal

Secondary data was obtained from articles, journals, and books. The journals and articles were derived from various sources such as websites from the Internet, and library indices. More details of the journals will be further discussed in the next section. These are the information collected:

i. general information on organic farming
ii. amendments and updates in organic farming
iii. existing products relating to organic farming

4. DATA ANALYSIS AND FINDINGS

The results of this research will be discussed in this section. The results are separated based on primary data and secondary data. The primary data includes observation, questionnaires, and responses from the interview sessions, whereas the secondary data includes findings from journals, internet websites, and a video. The findings from Section 3 will be discussed and summarized in this section.

4.1 Data Analysis

a) Interview

The first session of the interview had been conducted for about an hour with a farm worker known as Mr. Yono, and these are the responses from the interview:

Mr. Yono said that he encountered many problems during the cleaning process. He said that the use of the self-modified product was not effective because it did not clean the pen properly. The factor of this problem was attributed to the fact that the product was not specifically designed for cleaning.

The second session of the interview was held with Mr. Abdul Rahman, the farm officer at Ladang 16 UPM. The findings from the interview are as follows:

Mr. Abdul Rahman said that they had no specific product for cleaning and collecting faeces. They need a product that can simplify the cleaning process, so that they can minimize the time spent to clean the pen. He suggested a conveyer to be put below the pen, so the faeces can be transferred into sacks. Furthermore, he suggested the observation of the machine being used to clean chicken coop as an idea for the development of the target product in this present study.

The third session of the interview was made with Mr. Abdul Mu'in Hassan Basri. He is a postgraduate student of Animal Science in UPM and is currently conducting a research in Ladang 16 UPM. Other problems have also been discovered during the interview session with him.

He said that goats or sheep can easily fall ill if there are kept in a dirty environment. The pen must be cleaned at least once a day and the water for drinking must be changed daily.

b) Summary of the interview

From the interview, the respondents already possess knowledge on organic farming. They seemed dissatisfied with the management of organic farming in Malaysia and they need proper tools that can help them to work efficiently. Since they have no specific tool to clean the pen, the respondents have been suffering back pains, which could be harmful for their well-being in the long run. Moreover, due to inappropriate tools and insufficient time, faeces cannot be processed into manure and fertilizer. Instead, the faeces were treated as waste product to be thrown away or burnt.

c) Questionnaires

i. Survey - Basic knowledge and experience of cleaning the goat pen from faeces

In this section, there is only one correct answer for each question. The aim of this survey is to test the respondents' basic knowledge and experience of cleaning the goat pen.

Question No. 1, "Have you ever cleaned the goat pen?"; the correct answer is:
A. Yes
From 15 respondents, 100% have experienced cleaning the goat pen (shown in Table 7).

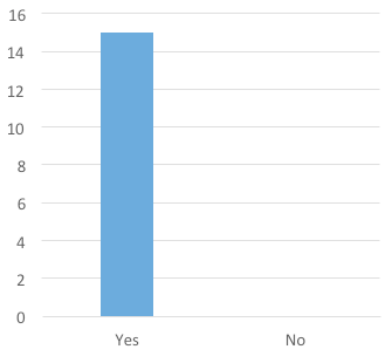

Figure 7: Experience of cleaning the goat pen from faeces

Question No. 2, "How often do you clean the goat pen?"; The correct answer is:

A. Very often

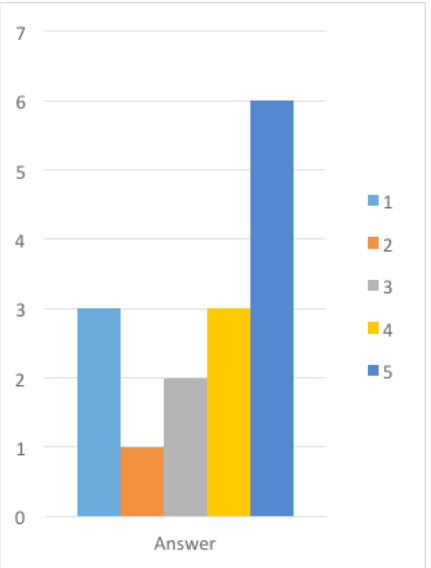

Figure 8: Answers of Question No.2: "How often do you clean the goat pen?"

All the respondents are farm workers, so most of them clean the goat pen on a regular basis (illustrated in Figure 8).

Table 1: Data analysis for the frequency of cleaning the goat pen

Correct answer (%)	Mean	Variance	Standard Deviation
40	3.53	2.55	1.60

From Table 1, 40% of the respondents cleaned the goat pen very often and only 20% did the job very rarely.

Question No. 3, "After the cleaning process, what is done to the goat faeces?"; The correct answer is:

B. Most of them are thrown away, which may harm the environment.

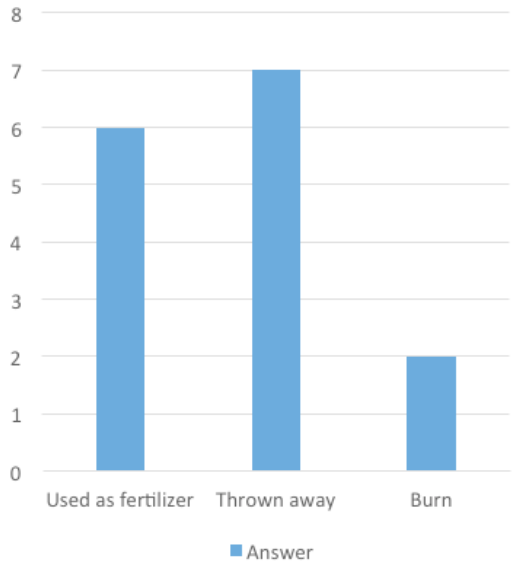

Figure 9: Answers to Question No.3: "What is done to the goat faeces?"

Table 2: Data analysis for what is done to the goat faeces after the cleaning process

Correct answer (%)	Mean	Variance	Standard Deviation
40	1.73	0.50	0.70

The percentage of the correct response for this question is 40%, which is to be "used as fertilizer," but most faeces were thrown away and burnt, which may harm the environment. The mean from this question is 1.73, and the variance of this result is 0.50.

Question No. 4, "What is the main problem during the cleaning process?"; The correct answer is:

A. Too much waste, such as water, time, energy, etc.

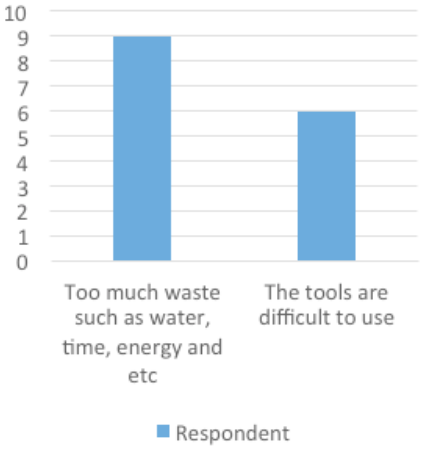

Figure 10: What is the main problem during the cleaning process?

Table 3: Data analysis for the main problem encountered during the cleaning process

Correct answer (%)	Mean	Variance	Standard Deviation
60	1.4	0.26	0.51

60% agreed that there were so much waste during the cleaning process. Most respondents chose different answers.

Section II: Design and function

For the design and function, all respondents had used cleaning tools to clean the goat faeces.

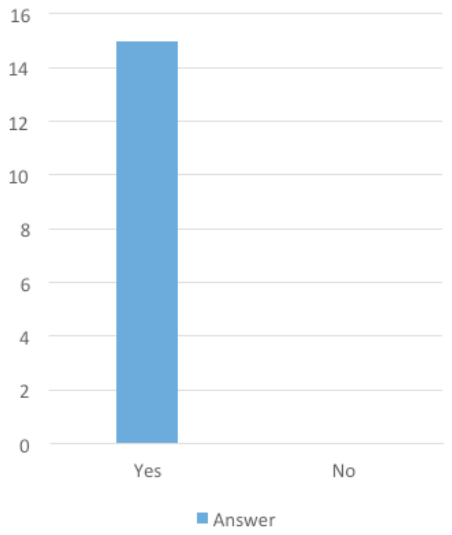

Figure 11: Answers to Question No.5: "Do you use any machine/tool to clean the goat pen?"

In Figure 11, 100% of respondents had used cleaning tools to clean the goat pen.

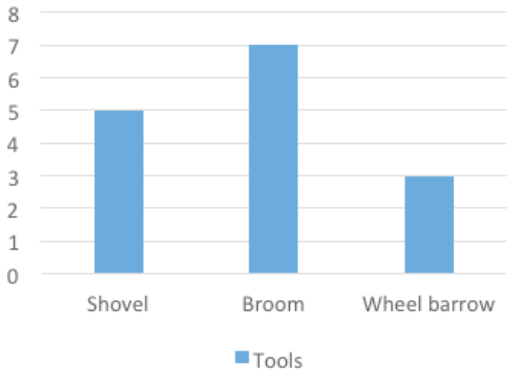

Figure 12: Tools that are normally used for cleaning the goat pen

Table 4: Data analysis of products that are normally used for cleaning the goat pen

Items	Frequency	Percentage (%)	Mean	Standard Deviation
Shovel	5	33.30	1.87	0.74
Broom	7	46.70		
Wheelbarrow	3	20.00		

The tools commonly used by the respondents to clean the goat pen are broom (46.70%), followed by shovel (33.30%), and wheelbarrow (20%).

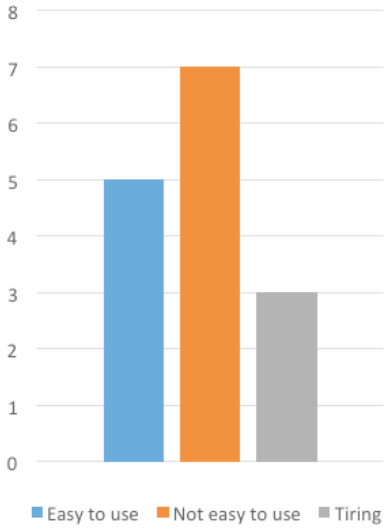

Figure 13: Opinion on existing products

Table 5: Opinion on existing products

Tools	Frequency	Percentage (%)	Mean	Standard Deviation
Easy to use	5	33.3	1.87	0.74
Not easy to use	7	46.7		
Tiring	3	20		

Most of the respondents said that existing products are difficult to use (46.70%). However, 33.30% of the respondents felt that existing cleaning tools are easy to use.

From the observation, it clearly seems that the respondents encountered many problems during the cleaning process. At the farm, they have been using too much water and the goat faeces are thrown away even though the manure can be processed into fertilizer. The respondents also complained about back pains during and after the cleaning process. The existing cleaning tools could be harmful to the respondents' well-being in the long term if they are continuously used.

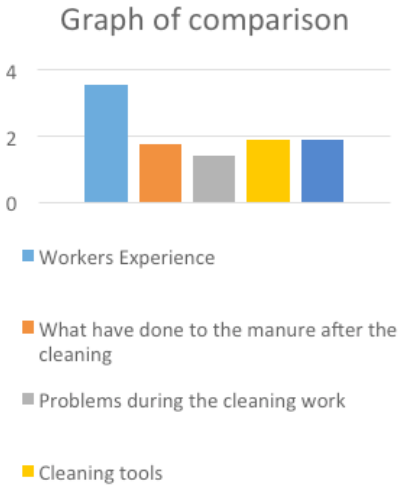

Figure 14: Graph of comparison among all the question scopes

4.2 Summary

The information obtained during data collection was used to design a product based on the guideline of product design specification (PDS). The idea development of the product will be discussed in the next section.

5. PRODUCT DESIGN DEVELOPMENT

In this section, the shape and the design of the farming tool will be shown. The product must undergo several phases before reaching the final design, for instance the design concept, idea sketches, mock-ups, idea development, and sampling/modelling.

5.1 Product Design Specifications

Product design and development involves several processes to increase the chances of success once in the market. To do this, the process of product design is initiated with the creation of a product design specification (PDS). PDS for farming tool includes location, appearance, ergonomics, size, materials, packaging, and safety.

This farming tool is specially designed to clean the goat pen while simultaneously collecting goat faeces. This farming tool must be built according to the location that it will be used. In this study, the goat pen must be built to the standard height of six feet (two metres) from the ground for easy collection of goat faeces. Furthermore, the ground must be a smooth cemented surface because the cleaning process will be difficult should the ground is naturally grassy or sandy or has a rough surface.

The appearance of the product is one of the important aspects in the cleaning process. The product must be hardy, easy to handle, and have a robust look. Thus, strong materials like steel or iron and hard plastic with a sturdy look and aesthetic design must be used to build this product. The tool should have a handle bar for easy handling.

For ergonomics considerations, a machine must be easy to operate, handled, adjusted, maintained, and so on. The height, posture, and strength among target users must also be considered considering the above criteria. This farming tool should have a compartment to store the faeces, which should be separately designed and moulded. This compartment must be well designed for easy and quick accessibility of contents.

The size of the machine must be suitable with human size and ergonomics; the size of the compartment must be enough to store 5kg of goat faeces.

5.2 Design brief

The design concept of this product is to "Clean-and-Collect."

This product is designed for farm workers to make their job much easier. It will benefit them in terms of minimizing time to clean the pen, as well as preventing serious injury on the spine. Besides, time, energy, and water consumption can be spent wisely. Fertilizer made from goat faeces can be a source of side-income for the farm as well.

The farming tool has several parts including a frame as the structure, compartment to store the faeces, and a duct for the faeces to enter the compartment. The tool was designed to be operated manually, so it must have wheels and mechanical components.

The design of this farming tool for cleaning goat faeces was inspired by the 'suckermouth catfish'. Green was the colour of choice for this tool as this colour dominates the agriculture industry's logos. Popular pairing colours include black, white, and blue (99designs, n.d.).

5.3 Idea development

The sketches below show the idea development of the cleaning tool scope.

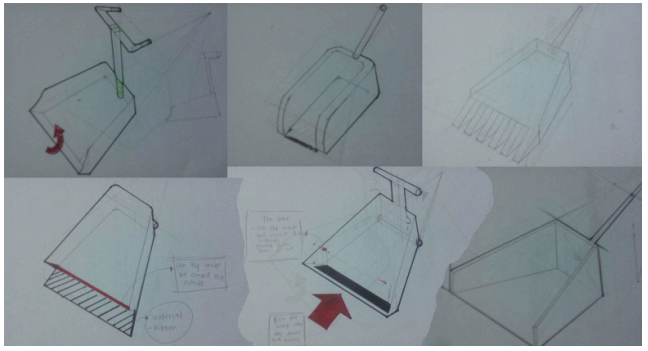

Figure 15: Idea Developments 1

Figure 15 shows this project's first idea development, which was also the first concept to design a tool to clean the goat pen and collect goat faeces at the same time. The targeted faeces collection must be aimed at the scoop. The faeces are collected as the scope is pushed forward.

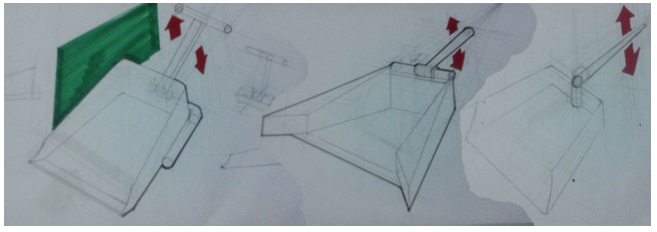

Figure 16: Idea Development 2

Figure 16 shows that the handle was adjustable and supported by bearings for easier handling and smoother movement.

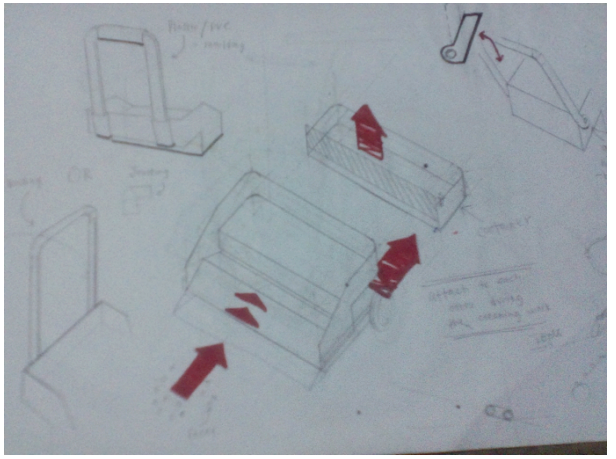

Figure 17: Idea Development 3

Figure 17 shows a new design of the cleaning tool, which had an additional compartment. The function of the compartment is to store the faeces to be processed into manure, that can be commercialized as organic fertilizer. However, the design was still not suitable.

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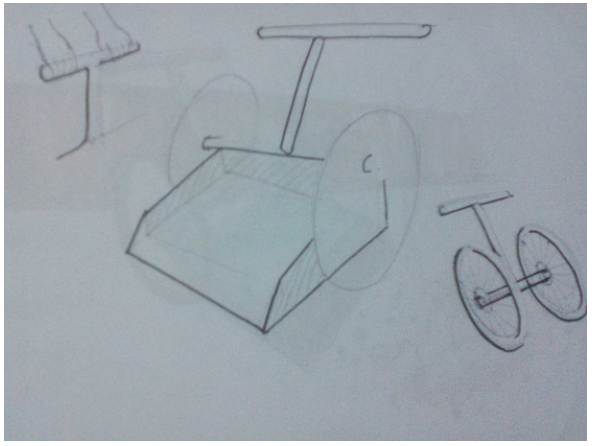

Figure 18: Idea Developments 4

Figure 19: Idea Developments 5

Figure 18 and Figure 19 show the idea development design of the tool for cleaning goat faeces. This design has wheels for easy handling. This concept has come from a wheelchair. It also has an adjustable handle, as well as a compartment to store the collected faeces. It works manually, employing chain and sprocket mechanism.

5.4 Visual proposed design

Figure 20 shows the final design of the tool for cleaning goat faeces, with actual colour and materials.

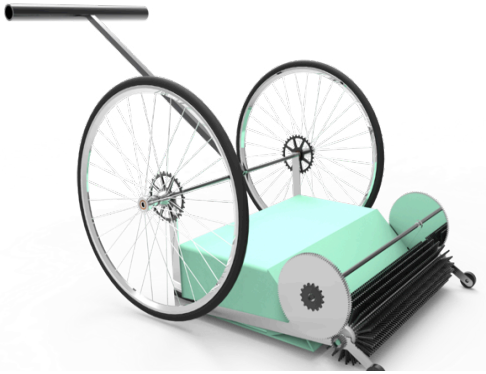

Figure 20: The final design of the tool for cleaning goat faeces

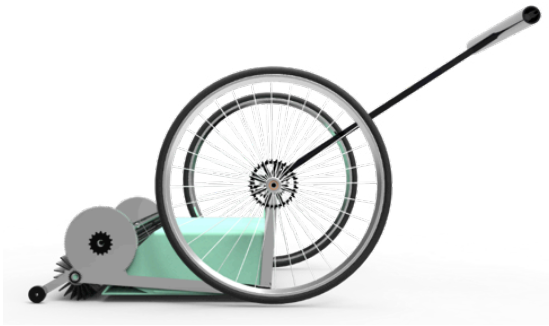

Figure 21: The side view of the tool for cleaning goat faeces

5.5 Validation

In this section, validation of the actual product is discussed, as obtained from the rendering form. The main questions include:

a) How does it work?
b) How much faeces can be stored in the compartment?
c) Why is the colour chosen as such?

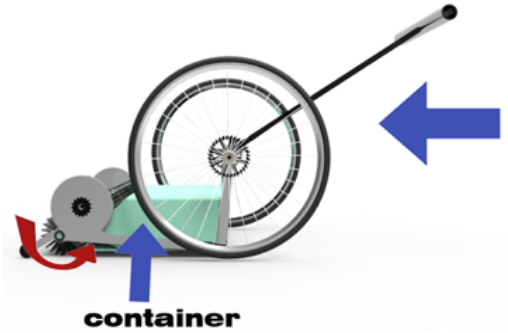

Figure 22: How the tool works in cleaning goat faeces

Figure 22 shows how the tool works in response to Question No. 1. The tool will be pushed forward and the broom roller will sweep the faeces through the duct and then into the compartment.

The compartment can store about 5kg of faeces at one time, answering Question No. 2. The compartment can be replaced with another compartment when the previous one is full.

As for the choice of colour from Question No. 3, it has been researched by MH Design that although most farmers have their own colour preferences, 64% choose green for an agriculture product.

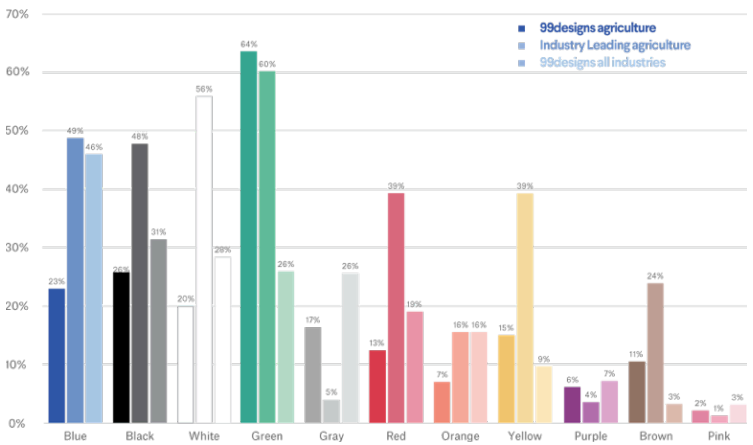

Figure 23: All data visualizations designed by MH Designs. Source: (99designs, n.d.)

Figure 24 illustrates the results obtained from an online questionnaire, where 40 took part.

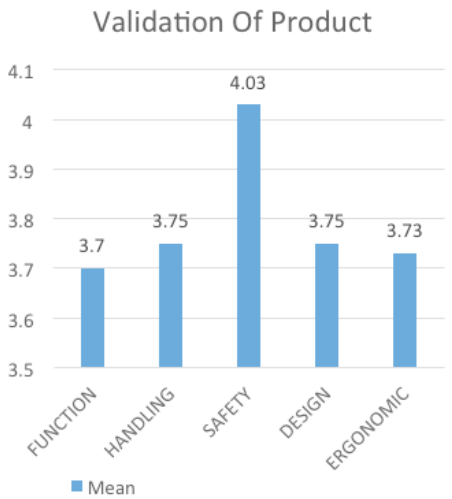

Figure 24: The Means of the Plecs

Figure 24 shows that the aspect of safety has the highest mean (4.03). It is followed by the aspects of handling and design (3.75), ergonomics (3.73) and function.

5.6 Intellectual Property

The intellectual property form has been submitted for registration. It can also detect whether the design has been patented before. This approach will protect the design idea from being stolen by outsiders. The list of intellectual property claims of the design Plecs is as follows:

i. The design of the product includes its shape, dimension, and features.
ii. It is made of steel, with a sturdy appearance.
iii. The tool for cleaning goat faeces is suitable for farm work.
iv. It does not easily break, and it is heavy duty.
v. It is manually operated using chain and sprocket mechanism, so there is no issue with power source.

5.7 Summary

In conclusion, from the idea development to the validation, there are numerous factors to obtain the best tool design for cleaning and collecting goat faeces, such as functionality, safety, ergonomics, design, and handling capability. Respondents' experiences and opinions were recorded and summarized for this design, which reflect the current and future needs in agriculture, particularly in the prospect of livestock farming industry in Malaysia.

6. CONCLUSION

The answers to the research questions will be explained in this section. In addition, contribution of the knowledge regarding the product from end users, and recommendations for future research will be discussed in this section to improve the product's design and function.

6.1 Discussion

The research questions are shown below:

I. What are the specifications of the farming tool that can be used to clean the goat pen and collect goat faeces?

From the research and product design specification, a farming tool that features a compartment and a roller broom is convenient and easy to be used for goat pen cleaning. The roller broom will sweep the goat faeces into the compartment and pass them through the duct. Besides, the goat pen must be designed according to the standard height of six feet (two metres) from the ground for an easier collection of goat faeces, as well as to prevent back pains among the tool's operators during the cleaning process. As for the preference amongst farm workers, some of them may be afraid to use this new tool because they have already adapted comfortability with other existing tools. Furthermore, some of them may not want to change the operation system during the cleaning work. Hence, the appearance of this farming tool should also appear suitable for the cleaning purpose and should appear easy to be handled.

II. What are the criteria that the clean-and-collect product can be used for among farm workers?

From the research, most of the high positions at the farm needed new tools for the cleaning job. Not all of the farm workers wanted to try the new tool because they have already been accustomed to existing tools they have been using daily. Thus, presumably it will be quite a challenge to convince farm workers to use this new farming tool.

Therefore, a clear instruction regarding the tool and its system of operation must be provided to solve this reluctance. The tool is multi-functional; to collect-and-clean. Hence, farm workers can complete two tasks at once. Furthermore, the tool is made of steel, which makes it long lasting and durable. Additionally, the collected faeces in the compartment can be readily processed into organic fertilizer.

6.2 Contribution of knowledge

This research concerns organic farming in Malaysia. As organic products are highly rated, organic farming provides many benefits such as the contribution to economic growth. Moreover, it provides a healthier lifestyle because organic food does not have added chemical substances. The product/tool developed in this study has met the need to produce organic fertilizer in the farming industry.

6.3 Future research

There are some limitations in this study, thus future research is needed to enhance the application of technology and materials used for the farming tool. The main materials can be replaced by other new materials, if they have more suitable properties to the product in the future.

6.4 Summary

In conclusion, with the clean-and-collect tool developed in this research, goat or sheep faeces can now be the source of side-income in farms, which previously depended solely on primary products such as meat and milk. Moreover, the environmental pollution caused by animal waste can be reduced, if not prevented, as the waste can be collected at ease to be processed into organic fertilizer. Furthermore, with this new tool, ergonomic hazards such as back pains among workers due to repetitive usage of inappropriate cleaning tools can be reduced drastically, if not entirely avoided.

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