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Using Traditional Wisdom and Goat Dung in Sustainable Textile Fabric Dyeing for Consumer Home Products

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Abstract

Goats are widely recognized as the most common domestic species globally, and have been shown to play a crucial economic role in many developing countries. Moreover, amongst the many resources derived from goats, natural cloth dye is often produced from their dung. Therefore, the research set out to investigate the process of fiber dyeing using goat dung and the subsequent design of consumer home products using the resulting dye. After reviewing natural fibers, cotton was selected as the main fiber for the goat dye experiments. A mixed-methods approach was used to study the traditional wisdom of goat farming and dyeing communities in central Thailand. The findings revealed that cotton fibers have good dye affinity, are cost-effective, and readily available in the country. The dye was produced using goat dung, and the experiment varied five control factors, including water temperature, amount, goat dung type, boiling time, and fiber properties. The results showed that fresh goat manure produced stronger color compared to fermented manure. In the second phase, expert evaluations determined the best design to be a ladybug pattern, rated as suitable, usable, beautiful, and unique (mean = 4.18, SD = 0.81). This study contributes to the Bio/Circular/Green (BCG) economy literature and expands on traditional Thai knowledge and wisdom.

Keywords: BCG economy, cloth dyeing process, goat dung dyeing, sustainability, Thailand, traditional wisdom.

Introduction

Goats are widely recognized as the most common domestic species globally, and have been shown to play a crucial economic role in many developing countries (Adriana et al., 2010). They are valuable assets for rural economies as they can thrive in challenging environments, are low-maintenance, and provide various benefits to families (Seilsuth et al., 2016).

In Thailand, animal husbandry is a significant aspect of agriculture, with a large population of farm animals such as cows, goats, and pigs. This sector provides essential products like meat, milk, and eggs, which are key sources of

nutrition in Thailand, while also providing employment opportunities to rural communities. Additionally, animal husbandry has environmental benefits, as farms can act as natural carbon sinks, storing carbon dioxide from the atmosphere (Subramaniyan et al., 2017). This helps to reduce greenhouse gas emissions and is an important part of Thailand's efforts to address climate change.

For centuries, goat dung has been used as a cloth dye in Southeast Asia. It has been a traditional and eco-friendly method of producing vibrant colors for clothing and other products (Bhattarai & Praditpornsilpa, 2018). Goat dung is processed by boiling it in water and then applying it to the fabric. The properties of the dung, which contain high amounts of potassium, nitrogen, and phosphorus, help to bind color molecules of the dye to the cloth (Aarti et al., 2017). The color stability due to the binding process is much greater than if the color were applied using other traditional dying processes (Bureekhampun & Maneepun, 2021).

The traditional method of applying dung as a dye requires manual labor, as the stained cloth must be hung out to dry and then repeatedly pounded with a stone pestle to set the color in (Bureekhampun & Maneepun, 2021). The resulting fabric is durable and resistant to washing and fading.

Goat dung is a renewable and sustainable resource, making it very attractive for producing cloth dye products in Southeast Asia. It is readily available from local farming communities, and no harmful chemicals are involved in the dying process (Bureekhampun & Maneepun, 2021). This process makes goat dung an environmentally-friendly option for producing vibrant colors.

The use of goat dung as a dye has expanded beyond Southeast Asia and is also used in parts of Europe, Africa, and the Middle East. The cloth dyeing process produces an intense, deep color that is highly sought-after. In some areas, it is even used to produce biodegradable plastics and other materials.

Designing products from goat dung aligns with Thailand's vision for a BCG (Bio/Circular/Green) Economy, a new economic model proposed by the government. The BCG Economy focuses on three main areas: the Bio-Economy, the Circular Economy, and the Green Economy (Thai Embassy, 2021; Thailand Textile Institute, 2020). The Bio-Economy aims to promote sustainable production of food, medicine, and other bioproducts, the Circular Economy focuses on sustainability and resource efficiency through reuse and recycling (Sandin & Peters, 2018), and the Green Economy supports renewable energy, low-carbon transportation, and other environmentally-friendly initiatives.

The purpose of the BCG Economy is to create a more sustainable, equitable, and prosperous economy in Thailand (Thai Embassy, 2021; Thailand Textile Institute, 2020). It seeks to reduce the country's ecological footprint by supporting sustainable production, reducing waste, and promoting green technologies. This will lead to an increase in employment opportunities and economic growth in Thailand. Additionally, the BCG Economy will benefit Thai citizens by helping reduce air pollution, improve access to clean water, and promote sustainable lifestyles. The BCG Economy is an ambitious plan, but one that has the potential to have a significant impact on Thailand's future (Thai Embassy, 2021; Thailand Textile Institute, 2020). It could transform Thailand's economy into more efficient, equitable, and environmentally friendly one. It will require cooperation between governments, businesses, and individuals, but if implemented, it could lead to a better future for Thailand and its citizens. The BCG Strategic Plan will focus on four sectors, including 1) food and agriculture, 2) medical and wellness, 3) bioenergy, biomaterial and biochemical, and 4) tourism and creative economy. It will also emphasize using biodiversity and cultural diversity as a foundation for developing the Kingdom and improving each individual's quality of life (National Science and Technology Development Agency (NSTDA), 2021).

Furthermore, goat farming is an excellent example of a typical farm animal that can fulfill most rural households' supplemental income objectives. It is also popular as an economic

activity in Thailand due to farmers' ability to sell their meat, milk, skin, and fur. Goats are also particularly popular in the rural southern border provinces of Thailand, where most are Thai Muslims who use goats for religious ceremonies and household consumption (Chairat, 2020). Rearing goats also fits nicely into Thailand's BCG goals (Chairat, 2020; Thai Embassy, 2021).

Goats are also easy and inexpensive to raise as they can eat leaves and grass and resist all weather conditions. They are robust, do not easily get sick like pigs or chickens, and yield meat and milk. Goat meat also has more digestible protein than beef, pork, and chicken. Goat meat also has lower fat levels than other meats. It has a high nutritional value similar to cow or buffalo milk, with smaller fat molecules that make it easier to digest and absorb in the digestive tract. It can be consumed as a better substitute for human milk than cows and buffalo.

In addition to meat and milk, goat hair and hides can be used in many ways. Typical products include bags, mats, carpets, and ropes, while goat dung is used to make fertilizer. The horns and hooves can also be made ornaments, and the blood and bones can be processed into animal feed (Chairat, 2020). These properties make goats an essential part of the economy in Thailand. They provide a valuable source of nutrition for people and are used for a wide variety of products, from fertilizer to animal feed to clothing and other fabric items. Goats are also highly resilient and require low costs to raise, which makes them a viable option for small-scale farmers in the country. Moreover, goats are essential to Thai culture and provide spiritual and practical benefits.

Goats are an essential part of the global agricultural landscape, as well. They are raised in many countries worldwide and can be found in tropical and temperate climates. They provide a sustainable source of meat, milk, and other products that can be produced in an ethical and environmentally-friendly way. Additionally, they help reduce greenhouse gas emissions while providing economic benefits as they can be raised in small-scale farming operations.

For all these reasons, goats have become an increasingly important part of the agricultural industry in Thailand and elsewhere. As more people recognize their many benefits, goats will always play an important role in the global economy. Goats are widely recognized as having a positive environmental impact. For example, they do not require large amounts of land and can be raised in small-scale operations, helping to reduce pressure on deforestation (Mohan et al., 2018).

Additionally, they can convert grasses and other plants into food, thereby improving soil fertility (Chinniah et al., 2016). Moreover, grazing animals like goats help to capture and store carbon from the atmosphere, trapping and storing it in soil and vegetation (Subramaniyan et al., 2017). Additionally, intensive grazing by goats can increase soil organic content, which helps the soil to retain more carbon. The study found this particularly true in areas with limited feeding opportunities and poorer soils.

The development of innovation plays a vital role in Thailand's circular economy. Innovation can minimize waste by implementing eco-design practices, which involve designing products and production processes to eliminate or reduce waste. Additionally, innovation can promote the reuse and sharing of materials, goods, and services, creating a more sustainable business model. Finally, innovation can support the management of waste from production and consumption, helping to reduce the environmental impacts of the circular economy.

By investing in innovation, Thailand can move closer to a truly circular economy. This can involve investing in research, developing new technologies and processes, and supporting existing technologies that can reduce waste (Akkalatham & Taghipour, 2021). Additionally, businesses can focus on developing new solutions for managing and utilizing waste, such as waste-to-energy plants, composting systems, and pre-consumer recycling systems. Innovation can also encourage the reuse of goods and services through product leasing, sharing, and upcycling systems. Finally, innovation can be used to develop new materials and products that are more sustainable, such as those made from recycled materials and bioplastics (Sandin &

Peters, 2018).

Innovation development is critical to success in Thailand's circular economy (Wannapiron & Pimdee, 2022). Investing in R&D, as well as in existing technologies, allows Thailand to create more sustainable production and consumption models. Thailand can then move to a circular economy by minimizing waste, promoting reuse, and managing waste.

Given these grand and sustainable objectives, the study's research team developed a good relationship with two farmer groups in the outlying farming rural areas near Bangkok at Minburi and Khlong Sam Wa (Na Ayutthaya, 2020). Although these two areas are more recognized for rice farming, numerous families are involved with developing consumer products from goats to supplement their farming incomes from rice or their other primary occupation (Na Ayutthaya, 2020).

From interviews with the village farming leaders of Min Buri and Khlong Sam Wa, information was obtained about their processes of raising goats to supplement their family incomes. One method was the use of goat dung's use to make fertilizer for growing vegetables to boost income for nearby schools (Usman, 2015). In addition, it was learned that goat dung could be used as fish food or a fuel source. Goat manure is also rich in nitrogen, phosphorus, and potassium (Office of the Secretary Department of Livestock Development, 2017).

As previously discussed, Thailand is pushing ahead with identifying and supporting the push for environmentally friendly products that are sustainable (Insorn et al., 2015). This results in finding natural raw materials for commercial product processing, including natural fibers and natural dyes (Department of Science Service (DSS), 2017; Thyavihalli Girijappa et al., 2019). This then reduces imports from abroad, creates added product value, and increases the competitiveness of the textile industry and other related industries (Office of Environmental and Pollution Control 13 (Chonburi), 2018).

Finally, exploring and documenting how goat farming is used retains a generation of traditional wisdom as younger villagers give up traditional farming occupations and leave for the excitement and glitter of urban life. Therefore, traditional wisdom must be studied, recorded, and embraced, as this knowledge is the cumulative result of decades, if not centuries, of experiences and experimentation (Bureekhampun & Maneepun, 2021). Wisdom strengthens local communities and offers people a stable life in a highly turbulent world (Egwutvongsa, 2023).

However, many have found that urban life can be complicated, and the wages could be better. Thus, many young people today are returning to their hometown villages to learn the wisdom of the elders, bringing with them their digital and social media knowledge. They are also aware that today that in response to consumer demands, products must be environmentally friendly (Guha, 2019; Suparna & Rinsey-Antony, 2016), consistent in quality, and have an affordable price (Cooper & Claxton, 2022; Repon et al., 2018).

Therefore, understanding the importance of traditional farming and associated handicrafts and their importance to Thailand's national economic goals, the researchers undertook a mixed-methods study developed in two phases (Cooper & Claxton, 2022). The first phase was determining which natural fibers were most appropriate for home consumer cloth products in Southeast Asia's hot and tropical climates. Two groups of Thai farmers were used for the study, one from Minburi and one from Khlong Sam Wa. As part of Phase 1, experiments were conducted using these farmers' traditional wisdom to determine which natural processes were best for the final cloth products.

In Phase 2, the goat dung-dyed cloth was used in designing multiple home/kitchen products, which were then evaluated by a panel of experts.

Natural Fibers Literature Review

From a review of numerous natural fiber studies, interviews with experts, and discussions with farmer handicraft groups, the following natural fiber materials were identified for possible inclusion and evaluation in the natural dye study:

Cotton cloth advantages and disadvantages

A report from the World Wildlife Fund (2020) details the many benefits of cotton as a natural

fiber with many advantages for making cloth. Some of these include being lightweight, breathable, resistant to wrinkles, and hypoallergenic (Sufian et al., 2016). Additionally, it requires fewer resources and energy than synthetics (Karimah et al., 2021). Furthermore, cotton is biodegradable, decomposing quickly, reducing the strain on landfills (Dhaliwal, 2019).

The disadvantages of cotton are that it can be expensive, prone to shrinking or stretching, and less durable than some other fabrics (Winnaar Garment, Natural fiber and synthetic fibers, 2020). Additionally, it requires more care during washing and drying, as it is not colorfast and can shrink significantly when washed (Repon et al., 2918).

Therefore, it is crucial to consider the advantages and disadvantages of cotton when deciding what fabric to use for your clothing.

In order to ensure a truly sustainable and eco-friendly product, it is essential to consider the environmental sustainability of cotton production, such as water usage and chemical inputs. Furthermore, supporting small-scale farmers is key to promoting sustainable cotton production.

Linin fiber advantages and disadvantages

The advantages of linen are that it is light, breathable, strong, absorbs moisture quickly, and is resistant to wrinkles (Ravandi & Valizadeh, 2011). Additionally, linen is hypoallergenic and eco-friendly, making it an excellent choice for sustainable fashion (Hammash, 2023).

The disadvantages of linen are that it can be expensive, prone to shrinkage, easily damaged, and requires more care during washing and drying. It is also not as stretchy as other fabrics, such as cotton or polyester.

Jute fibers advantages and disadvantages

The advantages of jute are that it is biodegradable, a natural fiber, relatively inexpensive, and has excellent moisture-absorbent properties. Additionally, jute is hypoallergenic, biodegradable, eco-friendly, and durable, making it an excellent choice for sustainable fashion (Suparno, 2020). It is relatively inexpensive, has excellent moisture-absorbent properties, and is durable.

However, it can be uncomfortable as it is not as soft as other fabrics, such as cotton or silk. Additionally, jute is prone to wrinkling and requires more care during washing and drying, as it is not colorfast and can shrink significantly when washed (Bhardwaj & Juneja, 2012).

Pineapple fibers advantages and disadvantages

The advantages of using pineapple fibers for cloth are that it is a natural, eco-friendly, and sustainable alternative to traditional synthetic fabrics (Jain & Sinha, 2021; Karimah et al., 2021; Pandit et al., 2020)). Additionally, it is lightweight, breathable, and resistant to wrinkles (Radoor et al., 2020). Pineapple fiber is also biodegradable and hypoallergenic, making it an excellent choice for individuals with sensitive skin (Tamta & Mahajan, 2020).

Pineapple fibers' disadvantages are that they can be expensive, prone to pilling, and not as durable as some other fabrics. It is also less soft than other fabrics, such as cotton or silk, and requires more care during washing and drying.

Kapok fiber advantages and disadvantages

The advantages of using kapok fibers for cloth are that it is a natural, eco-friendly, and sustainable alternative to traditional synthetic fabrics. Additionally, it is lightweight, breathable, and resistant to wrinkles. Kapok fibers are biodegradable, hypoallergenic, and have excellent moisture-absorbent properties (Christopher et al., 2012; Zheng et al., 2015). The disadvantages of kapok fibers are that they can be more expensive than other natural fibers, prone to shedding, and less durable than some other fabrics. It is also less soft than other fabrics, such as cotton or silk, and requires more care during washing and drying. Therefore, it is essential to consider the advantages and disadvantages of kapok fibers when deciding what fabric to use for your clothing (Liu & Wang, 2011).

Sisal fiber advantages and disadvantages

Sisal has been identified as a strong and durable natural fiber with many advantages for making

cloth (World Wildlife Fund, 2020). Some include being lightweight, breathable, resistant to wrinkles, and hypoallergenic. Additionally, sisal requires fewer resources and energy to produce compared to synthetics. Furthermore, sisal is biodegradable, decomposing quickly and reducing landfills' strain. The disadvantages of sisal are that it can be expensive, prone to shrinking or stretching, and not as soft as some other fabrics.

Additionally, it requires more care during washing and drying, as it is not colorfast and can shrink significantly when washed (Chandramohan & Marimuthu, 2011). Therefore, it is vital to consider the advantages and disadvantages of sisal when deciding what fabric to use for your clothing (Dunne et al., 2016). In order to ensure a truly sustainable and eco-friendly product, it is vital to consider the environmental sustainability of sisal production, such as water usage and chemical inputs. Furthermore, supporting small-scale farmers is key to promoting sustainable sisal production.

Coir fiber advantages and disadvantages

Coir fibers are obtained from the outer husk of the coconut fruit, and they have several advantages when used for cloth. These include its strength and durability. It is lightweight, breathable, resistant to wrinkles, hypoallergenic, and requires fewer resources and energy to produce compared to synthetics (Pillai & Vasudev, 2001). Furthermore, coir is biodegradable, decomposing quickly, reducing landfills' strain. (Varma et al., 1984).

The disadvantages of coir are that it can be expensive, not as soft as some other fabrics such as cotton or silk, and prone to shrinking or stretching (Oksman et al., 2016; Suparno, 2020). Additionally, it requires more care during washing and drying, as it is not colorfast and can shrink significantly when washed. Therefore, it is essential to consider the advantages and disadvantages of coir when deciding what fabric to use for your clothing. In order to ensure a truly sustainable and eco-friendly product, it is crucial to consider the environmental sustainability of coir production, such as water usage and chemical inputs.

Silk fiber advantages and disadvantages

Silk is a luxurious natural fiber that has many advantages for making cloth (Yukimatsu et al., 2008). It is lightweight, breathable, resistant to wrinkles, and hypoallergenic. Additionally, it requires fewer resources and energy to produce compared to synthetics. Furthermore, silk is biodegradable, decomposing quickly, reducing the strain on landfills (Suparno, 2020).

The disadvantages of silk are that it can be expensive, not as durable as some other fabrics, prone to pilling and stretching, and requires more care during washing and drying. Therefore, it is essential to consider the advantages and disadvantages of silk when deciding what fabric to use for your clothing (Patichol et al., 2014). Furthermore, it is essential to consider the environmental sustainability of silk production, such as water usage and chemical inputs. Supporting small-scale farmers is key to promoting sustainable silk production (Patichol et al, 2014).

Wool fiber advantages and disadvantages

In a World Wildlife Fund (2020) report, wool was stated to be a natural fiber with many advantages for making cloth. It is lightweight, breathable, resistant to wrinkles, hypoallergenic, and requires fewer resources and energy to produce compared to synthetics. Furthermore, wool is biodegradable, decomposing quickly, reducing the strain on landfills (Suparno, 2020).

The disadvantages of wool are that it can be expensive, not as durable as some other fabrics, prone to shedding and shrinking and requires more care during washing and drying (Troynikov & Wardiningsih, 2011).

Natural fiber selection summary

Table 1 provides an overview of the advantages and disadvantages of the nine natural fibers reviewed for possible inclusion in the study's experiments and potential use for consumer cloth in PHASE 2 (Winnaar Garment, Natural fiber and synthetic fibers, 2020) [35] It can be concluded from Table 1 that the most commonly used natural fibers are plant fibers, followed by animal fibers. This is because plant fibers are

cheap, easy to find, and more abundant than animal fibers. In this research, the researchers chose to use cotton fiber due to its good natural dye properties, affordability, availability, and variety of local Thai raw materials (Rathore, 2022; Repon et al., 2918; World Wildlife Fund, 2020).

Methods

Research objectives

1. To study the dyeing process for cloth dyed from goat dung (Phase 1).

2. To design cloth products from goat dung cloth dyeing (Phase 2).

Research objective 1 (Phase 1)

The research objective of Phase 1 was to examine the dyeing process from goat dung with the aim of using it in the design of promotional products for Minburi and Khlong Sam Wa agricultural groups (Na Ayutthaya, 2020). The conceptual framework for the study was partially based on the reports from Thailand's Department of Science Service (2017), which covered various aspects of natural dyeing processes, including cleaning of silk/cotton threads, dye preparation, and preparation of the dyeing agent or fixative. The study also considered the color extraction process from goat dung herbs to reduce odors and enhance color differences.

The sample for this phase was selected using a purposive selection method and included three members from the Goat-Sheep Shepherd Club in Minburi and Khlong Sam Wa who had at least five years of experience raising goats and creating dye from their dung. The researchers used a semi-structured interview form to collect data from the informants, which included questions based on the research framework and an open-ended section for additional insights. The data collected through the interviews was analyzed using qualitative analysis techniques and included notes, photographs, and videos.

Research objective 2 (Phase 2)

In Phase 2 of the study, the aim was to design consumer home products made from the dye produced from goat dung. The study used eco-friendly product design concepts from Maccioni et al. (2019) and a bio/circular/green economy model based on Thailand's BCG Economy (Thailand Textile Institute, 2020). A sample of three textile design experts with over 10 years of experience was selected through purposive sampling. The research tools included product sketch designs and an evaluation form to gather the experts' opinions on the product designs.

Other data were collected through notes, photos, videos, and an open-ended suggestion form.

Results

Research objective 1 (Phase 1) Results

The results of the first phase of the study on the dyeing process from goat dung were obtained from secondary data. The researchers emphasized the significance of the dyeing process, as it could serve as a foundation for preserving traditional knowledge and promoting goat farming, while utilizing goat dung effectively and supporting the community's weaving industry with natural raw materials.

Research objective 1 (Phase 1) results from experiment 1

Experiment 1: The extraction of dye from microbial-fermented goat dung involved placing 1.5 kg of fresh goat manure in a bucket and adding 8 liters of water and microorganisms to initiate the fermentation process. The mixture was then covered with a lid and left for seven days. Afterward, the fermented goat manure was filtered to obtain the colored water, which was boiled and mixed with pandan and citronella leaves to reduce its odor and enhance its color (Figure 1).

Figure 1

Fresh Goat Dung, Fermentation Process, and Colored Water Filtration Process

Research objective 1 (Phase 1) results from Experiment 2

Experiment 2's objective was to extract a new goat dung dye, with the process being a continuation of the research from Phase 1. One kilogram of fresh goat dung was used, which was then ground and mixed with 8 liters of clean water in a boiling solution with finely ground pandan leaves and citronella to deodorize the solution (Figure 2). After 20 minutes, the solution was filtered to obtain only the colored water, which was now odorless (Bureekhampun

& Maneepun, 2021). The results of Experiment 2 aimed to provide a new source of natural dye for future product design and development in the promotion of the goat farming industry and the community's weaving industry using natural raw materials. After the results of the extraction of color from goat dung were obtained, the researchers used the dye extracted from goat dung to dye the prepared cotton fibers. This solution was created using goat dung mixed with salt for 40 minutes and washed with clean water before drying in the sun for weaving in the next step (Figure 3).

Figure 2

Fresh Goat Dung is Mixed with Pandan Leaves and Citronella to Filter Only the Colored Water

Figure 3

Method for Dyeing Cotton Fibers with Goat Dung Mixed With Salt

Research objective 1 (Phase 1) results from experiment 3

Experiment 3: The third experiment in the study focused on using ashes from burned goat dung as a dye (Figure 4). The process involved burning dried goat dung in a charcoal oven until it turned into ashes, which were then finely ground and mixed with water to create a boiling solution. Cotton fibers were immersed in this solution and left for a specified time before being cleaned and dried in the sun for weaving into cloth. The results showed that the dye created in the third experiment was lighter than the one created in the second experiment, but still had a similar tone. The researchers used both colors to create the final product designs.

Figure 4

Staining from Goat Dung Ash

From the three experiments, it was determined that staining with goat manure water mixed with salt better adhered to the cloth over other methods. However, other methods were shown to be the most effective. These included staining the cloth with goat dung mixed with tamarind juice and salt, with the other three methods having quite similar staining characteristics.

Research objective 2 (Phase 2) results from the product designs

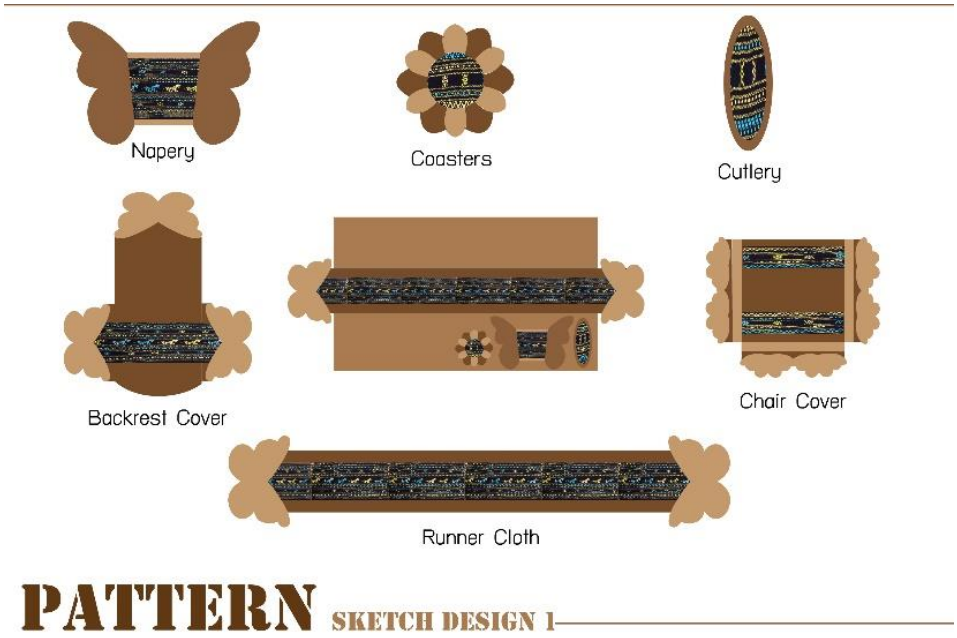
results from the study of secondary data concerning home furnishings and trends led to the design of three prototype home furnishing arrangements and designs. Three experts in design evaluated each. These were:

Sketch Design 1 (SD1): The design of a dining table decoration in SD1 was created using a

butterfly and its life cycle (Figure 5). The three experts' evaluation of the *butterfly* design was judged to be at an overall high level (mean = 4.14, SD = 0.74). The design's production element was judged as the highest (mean = 4.67), followed by function, safety, and ergonomics (mean = 4.33).

Figure 5

Sketch Design 1-Butterfly



Sketch Design 2 (SD2): The design of a dining table decoration in SD1 was created using a *ladybug* and its life cycle (Figure 6). The three experts' evaluation of the *ladybug* design was judged to be at an overall high level (mean = 4.18, SD = 0.81). The design's production element was judged equally as highest (mean = 4.33) with function, safety, and ergonomics (mean = 4.33).

Sketch Design 3 (SD3): The design of a dining table decoration in SD1 was created using a *bee* and its life cycle (Figure 7). The three experts' evaluation of the *bee* design was judged to be at an overall high level (mean = 3.94, SD = 0.60). Regarding safety, ergonomics, and production methods, experts have evaluated the product design at a good level, with an average mean = 4.17.

Figure 6

Sketch Design 2-Ladybug

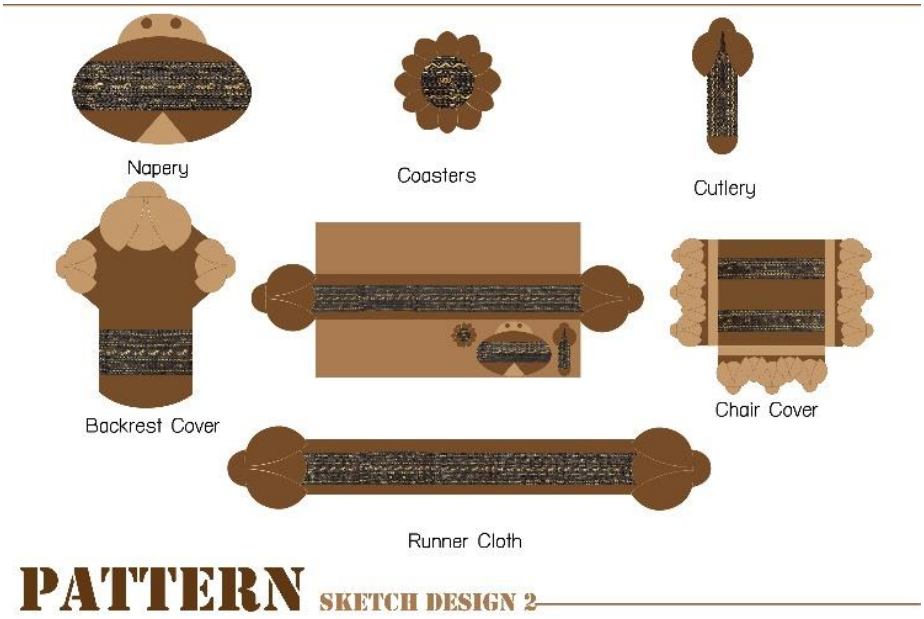
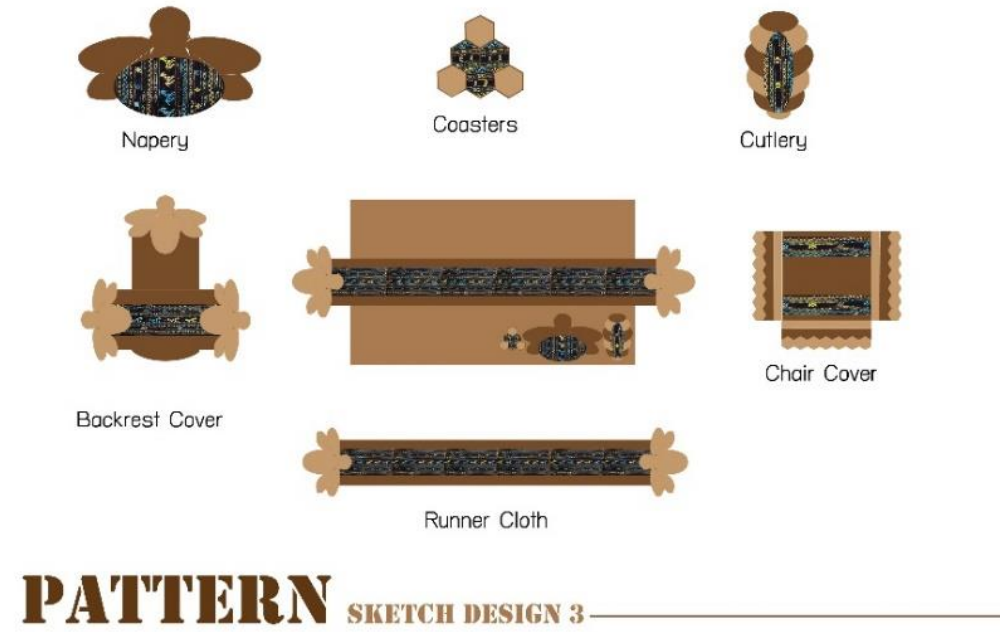


Figure 7

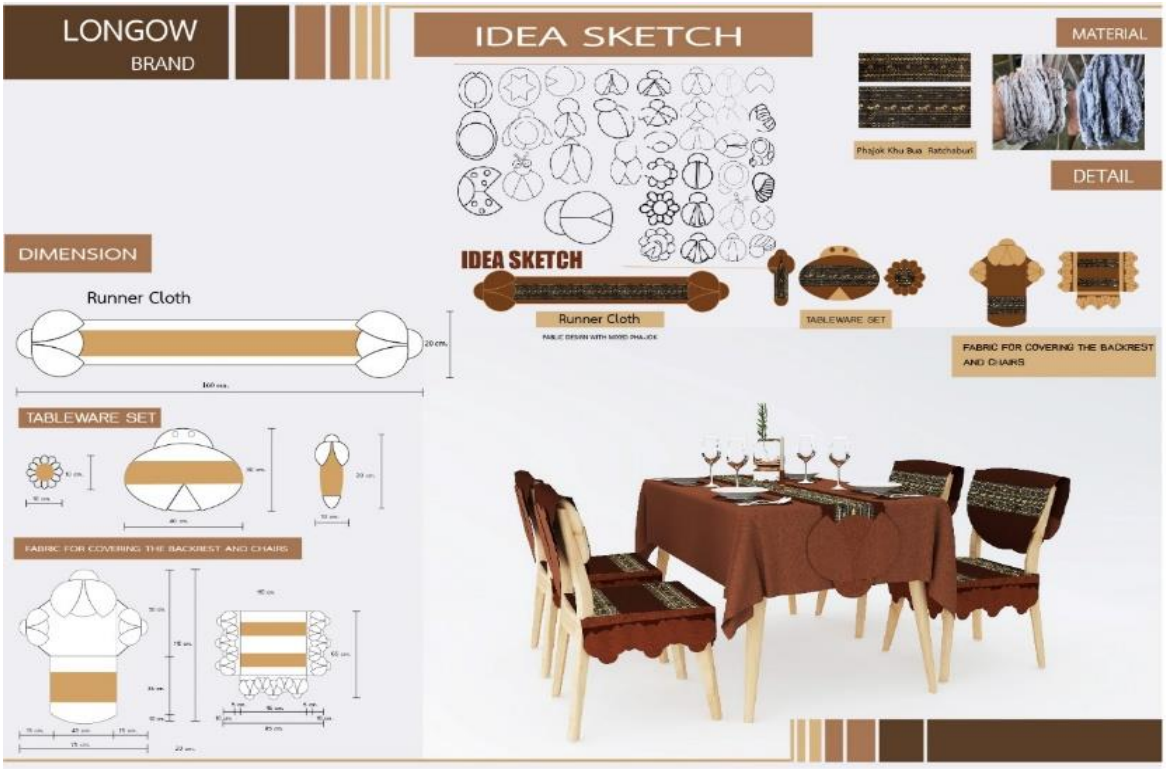
Sketch Design 3-Bee



Based on the results of the analysis and the suggestions from the textile design experts, the researchers improved the design of SD2 to create a small and large ladybug set with a more balanced pattern and color of the fabric (Figure 8). The design also included additional thread colors for pattern details, and attention was given to the packaging of the set. The improvements were made based on the feedback from the experts who had an average evaluation of the design at a high level (mean = 4.18, SD= 0.81). The final design was deemed suitable for actual production.

Figure 8

Final Design-FD



Discussion and Conclusions

The goat dung dyeing process results in a vibrant and durable material. Natural plant materials mixed with fermented goat dung create a natural dye that can color natural fibers like cotton, wool, linen, and hemp. This process is environmentally friendly as it uses renewable, biodegradable natural fibers and doesn't require synthetic dyes. It is also beneficial for small-scale farmers and supports the use of sustainable materials. Natural fibers like cotton in Thailand are affordable, comfortable, breathable, and resist wrinkling and shrinking better than synthetic alternatives. This dyeing process is a sustainable and economically advantageous way to produce beautiful materials. The use of natural fibers for dyeing supports small-scale farmers and promotes sustainability. Kerdtip and Angkulwattanakit (2023) has noted that involvement in self-direct learning (SDL) in a team-based environment is a highly effective method in learners their own goals and needs. Using this information, a flexible learning path is created, allowing each learner to choose their learning components based on their interests and needs.

Natural fibers are biodegradable, decompose quickly, and have a lower environmental impact compared to synthetic fibers. For example, cotton

requires less energy to produce than synthetic alternatives. Additionally, natural fibers provide sustainable livelihoods for local communities who rely on their growth. Hence, using natural fibers for dyeing is important for reducing the strain on landfills, supporting small farmers, and creating a more sustainable textile industry. For example, cotton only requires 0.2 megajoules of energy per kilogram, while its synthetic alternatives require 2.3 megajoules. Therefore, it is essential to consider using natural fibers for dyeing to support small farmers, reduce our environmental impact, and create more sustainable textile products (Suresh & Taheraly, n/d).

Additionally, synthetics often require fewer resources and energy than natural fibers. Furthermore, natural fibers are more biodegradable, as they decompose quickly, reducing the strain on landfills. Finally, choosing natural fibers for dyeing helps to support small-scale farmers who rely on the growth of these fibers, providing sustainable livelihoods for local communities.

The color of the cloth dyed using goat dung

From the knowledge gained from the interviews with the village goat herders, it was determined that there were five control variables needed for the proposed experiments. These variables included the water's temperature, amount of water, characteristics of goat manure, boiling time, and fabric characteristics.

Dyeing cloth using goat dung

In Experiment 2, it was found that using fresh goat manure that was ground had more staining capability than that fermented goat manure in microorganisms (Experiment 1) and using natural colorants. Quite interestingly, the results from the three experiments revealed that the best technique for achieving the richest colors was when salt was added to dried goat dung after being burnt into ashes and ground.

Experiment 3 was similarly colored but different from Experiment 2, as the dyeing technique that gave the fibers the most consistent beautiful color was the second and third experiments in which cotton fibers were boiled with fresh ground goat dung and burned goat dung. Both techniques created consistent and beautiful colors, but they were different shades. Also, it was noted that boiled ground goat dung is light brown, while burnt goat dung is dark brown. Therefore, the color obtained from dyeing goat dung is unique and valuable because it is a natural tone compatible with almost every color and pleasing to the eyes.

The goat dung dye has been recognized as having superior aesthetic quality, appealing to many who see it (Tripathi *et al.*, 2015). It was also revealed that some local weaving and knitting machines use natural dyes such as goat dye which is unique to the product. This is consistent with studies that have pointed out that these methods are natural and non-toxic in production (Guha, 2019; Agrawal, 2015).

Summary of the product design results

Evaluation results from the three experts indicated that SD2 (*ladybugs*) was the most inspiring and brought out the nature of the ladybug and its various characteristics. SD2 also made a reasonable effort to use all-natural materials in the design, promoted nature, and helped the community.

The use of cotton fabric dyed with goat dung and designed according to the *ladybug* concept was found to be suitable, functional, beautiful, and unique and received the highest evaluation scores from the three experts (mean = 4.18, SD = 0.81).

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