RES MILITARIS
REVUE EUROPEENNE D ETUDES EUROPEAN JOURNAL OF MILITARY STUDIES
Social Science Journal

Product Design From Waste: Developing Sedge Plant Fiber Residues Into Novel, Value-Added, And Market-Oriented Products

By

Vuthipong Roadkasamsri (corresponding author)
Mahasarakham University, Thailand
Email: wut_ap@hotmail,com

Apiched Teekalee
Mahasarakham University, Thailand

Arnon Sungvondee
Mahasarakham University, Thailand

Yingfeng Li
Mahasarakham University, Thailand

Abstract

Thai research rarely mentions product design and development from waste, such as transforming sedge plant fiber wastes into new, market-oriented items. This study aims to reinvent product design from residues. This mixed-method study focused on community-based participatory research (CBPR) in a Thai village. This study provides an effective, simple, technological, and strategic approach to adding value to sedge plant fiber waste from reed mat production in simple steps (manufacturing raw materials, pulping method, sheet-forming process, experimenting with materials, investigating community reactions to manufacturing process, and product design). This study transfers market viability assessment of prototypes (bannock basket and berry basket) using a questionnaire survey and SWOT analysis. The findings of the study provide options beyond traditional tactics to tackle economic and environmental constraints of waste minimization and add value to waste. It redesigns the conceptual framework of product design and development from residues overlooked by current Thai research. Policy implications should promote marketability to general and ecologically conscientious customers, using 11,824 community-level "one town, one product" (OTOP) establishments nationally, and prepare for natural disasters, which can harm reed plants and decrease productivity.

Keywords: product design and development from waste, sedge plant fiber residues, community-based participatory research (CBPR), one town, one product (OTOP)

1. Introduction

Agricultural waste in a circular bioeconomy causes a wide range of environmental challenges, especially large CO2 emissions (Devendra & Thomas, 2002; Gattuso et al., 2015; Wang et al., 2021). Agricultural waste, leftovers, and combination products have created environmental and economic issues in an agriculturally dominant region. This has been studied extensively. Recent research on turning agricultural waste into valuable goods has focused on almond hulls (Najari et al., 2022), walnut shells (Goklani et al., 2022), recycled wood waste (Khodaei et al., 2022), rice husks (Jung et al., 2021), cocoa waste (de Arajo Veloso et al., 2020), and biogas for renewable energy (Cha (2022). For all countries, including developing ones, to become carbon neutral, they need to come up with a simple, recyclable way to use agricultural waste efficiently.

Thailand, a big agricultural nation, acknowledged the environmental and economic impacts. A policy for economic and social development based on the Bio-Circular-Green Economic Model (BCG) emphasizes the Bio Economy system and the growth of biotechnology in industry. The policy has been implemented using a circular economy, which reduces and reuses resources, and a green economy, which integrates economic, social, and environmental activities. These policies reduce environmental impact by increasing resource efficiency and adding value. Thailand's Department of Industrial Promotion (2021:10) is, therefore, adding value to unique industrial products. This encourages the use of leftovers from agricultural, industrial, service, and tourism product manufacturing, like local consumption waste and recycled materials, to make a product or service with more value through creativity, innovation, and design.

In response to the aforementioned policy, the objective of this research project is to offer a method for designing and developing items using sedge plant fibers, which are produced as a byproduct of reed mat manufacturing. This plant's study has been neglected despite its enormous influence. An enormous amount of reed waste is produced annually by one of Thailand's major production networks, which comprises more than 200 homes. This quantity represents 20% of the total reed utilized for production in the country. To meet the goal of the study, Ban Daeng was chosen on purpose as a case study.

The contents of this paper are divided into six sections. The first section outlines the study's rationale, the research gap, and its objectives. The second describes the literature review, relevant prior research, the theoretical framework of the study, and the research questions (RQs). The third focuses on the study's methodological approach. The fourth presents the study's findings. The final section summarizes the conclusion of research results, discussions, limitations, and implications of the study.

2. Agricultural Waste Design And Development Prior Research

In designing and developing value-added agricultural waste, two things must be considered: design and development influence and community-based participatory research (CBPR), a method used in this study.

2.1 Factors influencing agricultural waste design and development

Prior research (e.g., Hua et al., 2022; Mohite et al., 2022; Zheng et al., 2021) shows that recycling agricultural waste can yield valuable products that contribute to the circular economy, environment, and sustainability. Different ways to recycle garbage technological, strategic, and market viability determine plant recycling and product design (Awasthi et al., 2022). Each factor's details follow.

2.1.1 Technology for recycling

Multiple research studies show that technology can design and generate value-added agricultural waste. Rejeb et al. (2022) found that the IoT is efficient for designing and developing value-added agricultural waste. Hallioui et al. (2022) employed a systems-based approach to promote corporate sustainability in the context of Industry 4.0, the circular economy, competitiveness, and numerous stakeholders. According to De Bernardi et al., digital channels attract, motivate, and communicate with consumers. To connect with people's current state of mind, organizations should offer well-being-focused content.

2.1.2 Recycling of agricultural waste

Several researchers suggested recycling agricultural trash. Some models and strategies include value chain operations, such as two-stage supply chain management for waste elimination driven by circular economy (Sarkar et al., 2022), a closed-loop supply chain for agricultural plastic waste focusing on bale wrap waste recycling (Mayanti & Helo, 2022), and a customized multi-cycle model for determining the viability of circular paths in agri-food supply chains (Stillitano et al., 2022). Some concepts and tactics use knowledge dissemination to bring value to agricultural waste. Rejeb et al. (2022) studied circular economy (CE) knowledge transmission. Scholars can understand how the field has changed over time, spot new problems, and learn about CE's past, present, and future.

2.1.3 Farm residue marketing

New and waste items need marketing. Theoretical and practical strategies were offered. Awan et al. (2022) theorized effective marketing tactics. Business models must be aligned with value chain operations first. Second, value chain actors must engage with Industry 4.0 and the circular economy to internalize knowledge flows. Third, value chains and new business models are needed for sustainable global growth. Eliopoulos et al. (2022) used solid state fermentation to transform olive mill stone waste and oat bran. Solid state fermentation and agricultural byproducts improve nutritional value. Location-specific marketing tactics may be tied to social, institutional, and marketing aspects (Milford et al., 2021; Wanasinghe & Sachitra, 2022). Influencer marketing helps recycle agricultural waste in a changing world (Belanche et al., 2021). A cost-benefit analysis helps companies decide which methods of recycling agricultural waste to use (Hsu, 2021; Jie and Guanghua, 2022; Liu et al., 2021; Jamil et al., 2022).

These characteristics lead to success if the chosen approach is suitable for designing and producing value-added agricultural waste. CBPR is one of several successful methods. This study used collaborative inquiry to achieve real-world effects. This study aims to gain insights into a community enterprise with which the researchers partnered and developed novel items with additional value. CBPR, which involves rigorous study with enterprise members affected by trash to design and manufacture recycled products from leftovers, could engage members who were not skilled in research in meaningful collaboration. PR was optimal for this study because it may assist researchers by including stakeholders and communities, leading to relevant, actionable research findings.

2.2. Community-based participatory research for novel value-added and waste products

CBPR emphasizes local or community priorities and views (Cornwall & Jewkes, 1995), direct partnership with affected parties for action or change (Cargo & Mercer, 2008), co-constructing research with stakeholders, community people, and others with insider knowledge (Jagosh et al., 2012), and engaging people who are not trained in research but reflect the research's subjects' interests. CBPR collaborates with stakeholders, communities, constituents, and end-users. This strategy "contributes directly to human, community, and environmental flourishing" (Reason & Torbert, 2001, p. 6). Benefits include research that is relevant to real-world contexts, results that can be more effectively translated into community and non-academic settings, and improved research quality and rigor by integrating researchers' theoretical and methodological expertise with non-academic participants' real-world knowledge and experiences (Balazs & Morello-Frosch, 2013; Bush et al., 2009).

Product design and development from waste, notably converting sedge plant fiber leftovers into new, value-added and market-oriented products, is rarely mentioned in contemporary research papers. This topic is part of the redesigned product design and development conceptual framework.

2.2. A theoretical framework of the study and research questions

2.2.1 Theoretical framework of the study

The framework of the study could be photographically illustrated as follows.

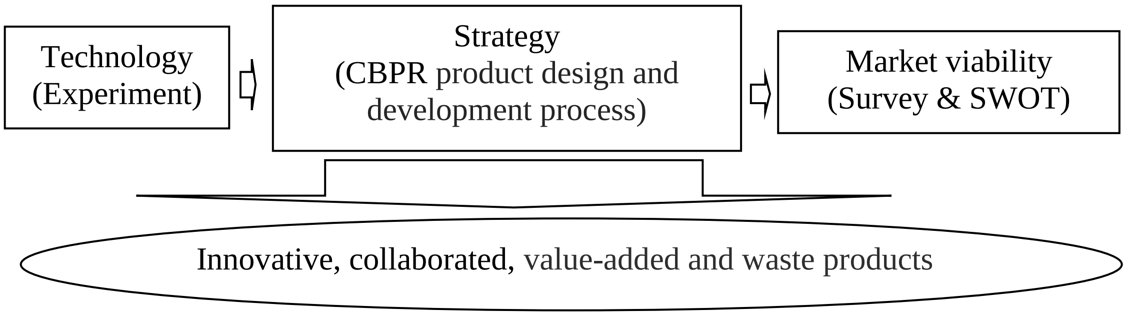

Figure 1 *The theoretical framework of the study*

Figure 1 shows the study's theoretical framework. In this product design and development method, researchers work directly with the community as partners to experiment with materials with simple technology and design prototypes. The goods were then evaluated for market viability and SWOT to determine if they met market demands. These techniques target novel, collaborative, value-added, and waste goods.

2.3 Research questions

In response to the study's theoretical framework, three RQs were constructed.

RQ 1: How should sedge waste from reed mat manufacture be valued?
RQ 2: Do newly created products match market demands?
RQ 3: What are products' strengths, limitations, opportunities, and threats?

3. Research Methods

3.1 Design

This mixed-method case study was conducted. CBPR guided this study. In this research approach, the researchers worked directly with the community based on input, information, and collaboration, in which the community made research decisions. All the CBPR participants were from Ban Daeng Noi, Ban Daeng Subdistrict, Trakan Phuetphon District, Ubonrachathani Province. As this study used a mixed-method methodology, quantitative data were gained from product market assessments. 140 Baby Boomers and generation Z customers, ages 20–50, frequented the community enterprise. The Krejcie and Morgan formula was used to calculate sample size. 103 consumers were sampled.

3.2 Instruments

Below are the data-collection instruments.

3.2.1 Site survey

The site study was part of a requirements analysis to determine the community's production potential, manufacturing processes, product distribution, and types and amounts of raw materials. This instrument sought to develop, build, assess, and maintain partnerships with enterprise community members.

3.2.2 Interviews

In-depth interviews were conducted to complement the site assessment and get insights into the community's design, manufacturing, and marketing potential and challenges, as well as target and potential customers.

3.2.3 Focus groups

The group discussions fell into three phases: before, during, and after the experiment. Before design and development, a group conversation was held to examine the community's needs, assets, and objectives and formulate research questions and a methodology. The community received research-related information. During design and development, additional group discussions were held to generate experiment ideas and obtain community input on the experiment and prototypes. After design and development, another panel discussed the data and questionnaire market assessments.

3.2.3 Experiment

This instrument emphasized experimentation and development. The use of reed residues as a raw material were developed using mulberry paper production technology and composite materials theory.

3.2.4 Recordkeeping

Observations were made on community members' product design, development, and testing. The community was informed using these records.

3.2.5 Questionnaire

New product marketing testing used a 5-level rating scale questionnaire. In the first part of the questionnaire, respondents were asked for personal information. In the second part, they were asked for feedback on product prototypes, including their exquisiteness, utility, material suitability, distinctiveness and attractiveness, competitive price, and commercial possibilities.

3.2.6 SWOT

This instrument analyzed strengths, weaknesses, opportunities, and threats to products, stakeholders, and the community/society.

3.3 Data collection

There were five phases of data collection. Phase 1 involved the site survey. The researchers collected data at the site to learn about the workplace environment, production potential, manufacturing procedures, product distribution, and raw material types and amounts. Phase 2 involved experimentation. Using the technology for making mulberry paper and the theory of composite materials, the community members found a way to use reed residues as a raw material. Phase 3 involved community distribution and training. The knowledge transfer included raw material development, production procedures, and community-specific guidelines for reed fiber goods. This phase also focused on community-made products. Phase 4 included product redesigns. The researchers created prototypes and solicited feedback to improve them. When the product's shape was decided, community members designed a prototype while researchers served as manufacturing consultants. Phase 5 introduced prototypes to test customer response.

3.4 Data analysis and validity check

3.4.1 Data analysis

Because this was a mixed-method study, all data was triangulated, interpreted, analyzed, and compared qualitative data from site surveys, interviews, experiments, record keeping, and SWOT analysis. Survey data was statistically examined. The study's conclusion was drawn from qualitative and quantitative data.

3.4.2 Check for reliability and validity

The questionnaire was reviewed by five scholars in this area and adjusted based on their advance. The Alpha Cronbach test was used to verify questionnaire reliability. 0.90 represents good, reliable values. The levels of the satisfaction of the questionnaire fell into 5 groups: the lowest (1.00-1.50), low (average 1.51-2.50), moderate (2.51-3.50), high (average 3.51-4.50), and highest questionnaire satisfaction scores (average 4.51-5.00).

4. Results Of The Study

The study results were presented in response to the research questions: (RQ 1) How should sedge waste from reed mat manufacture be valued? (RQ 2) Do newly created products match market demands? (RQ 3) What are products' strengths, limitations, opportunities, and threats? Below are the results of RQ 1.

4.1 Adding value to sedge mat waste fiber

4.1.1 Needs analysis

To understand the background of Ban Daeng reed mat weaving community enterprise, which was a case study in this research, the results of the site survey and interviews revealed that, before 2012, Ban Daeng residents' main occupation was weaving reed mats and their secondary occupation was farming, according to a site survey and interviews for this research. After 2012, the government backed OTOP products strongly, and Thailand has 11,824 community-level OTOP establishments. Raw materials include many varieties of plant fiber. Ban Daeng villagers realized that reed mats might supplement their rice agricultural income. They made things from reeds as shown in Figure 2.

Figure 2 *Ban Daeng's reed mat products*

Figure 2 shows the community enterprise's baskets, handbags, boxes, lights, roll mats, and folding mats.

In discussions with the community enterprise's head, sedge plant fiber waste and reed remnants made up about 20% of the waste. Recycling and adding value could turn leftovers into raw materials. Reed mats sell well and create constant money for the community enterprise, but they cannot reach new customers. Reed residues must become value-added goods. It is necessary to develop the reed residues to new value-added products.

4.1.2 Producing raw resources from waste

Focus group discussions between community enterprise members and researchers led to the development of value-added reed products. Key concerns (including a process of manufacturing experiment of residues, designs and productions of the products, job responsibilities, transfer of all production, process, and knowledge, and consumer marketing assessments) were discussed. All agree that reeds from the community's production should be explored in a materials and manufacturing process experiment. This experiment followed mulberry paper manufacturing process. These steps produced pulp and other commodities from waste reeds.

Step 1: Making raw materials

The leftover reed raw materials from making reed mats appear as a 20–30 cm long, spherical trunk to uniformly distribute pulp fibers. The reed stem must be chopped to 1 to 2 cm before pulping and not knotted until after sheet creation as shown in Figure 3.

Reed production-leftover raw material

Prepared reeds for the pulping procedure

Figure 3 *Reed qualities and pulping preparation*

Figure 3 shows the reed qualities and pulping preparation. There is reed production-leftover raw material (left) and prepared reeds for the pulping procedure (right) The prepared reeds were then brought into the pulping procedure as described in the next step.

Step 2: Pulping production

The pulping production could be shown in Figure 4.


Reed noodles boiled with sodium hydroxide


Utilizing high-pressure water to properly digest the fibers

Figure 4 *Fiber separation for pulp production*

Figure 4 shows fiber separation for pulp production. The reed noodles fibers were separated by high-pressure boiling water combined with sodium hydroxide or caustic flakes at a ratio of 10 g of caustic soda per 1 liter of water for two hours at 100 to 120 degrees Celsius in order to properly digest the fibers. Reeds and coarse fibers retain their original form if the fibers are not completely shattered. Due to the arrangement of coarse fibers, it is possible to create materials or items with a distinct appearance on the surface.

Nonetheless, if a workpiece with a finer surface is needed, it must be digested so that the fiber membrane can be broken down more finely, which, per the conventional technique, must be cooked to obtain a fine pulp. Utilizing high-pressure water jets, the researcher applied a mechanical method in this experiment as shown in Figure 5.


Fibrous pulp boiled in sodium hydroxide

Fibrous pulp boiled with sodium hydroxide and digested with high-pressure water

Figure 5 *Comparison of pulp before and after mechanical pulping*

Figure 5 shows a comparison of pulp before and after mechanical pulping. By bringing a high-pressure washer with a water pressure of 100 to 120 bar, the application will inject water through the water cannon's smallest adjustment head, allowing the water to be injected into a powerful water mass. The application will also help squeeze the pulp into smaller fibers and wash away the sodium hydroxide. After the process, fibrous pulp boiled in sodium hydroxide (left) resulted in Fibrous pulp boiled with sodium hydroxide and digested with high-pressure water (right).

Step 3: Sheet-forming process

Below is the sheet-forming process as shown in Figure 6.

1. Spread the reed pulp into the water
2. Spoon the pulp forming sheet
3. Spread the membrane spreads on the sieve
4. Dry the pulp

Figure 6 *The process of spooning the pulp to make sheets of material*

In a water bath, distribute 500 grams of reed pulp per 20 liters of water (1). Utilize a sieve with a frequency of 15 mesh (2). As the pulp is equally distributed across the sheet on the sieve, scoop the pulp into the body in this manner (3). Raise the grate vertically and let it dry in the sun before transferring it to a shady location to finish drying (3). Once the sheet has dried, gradually remove the sheet material from the sieve. The density of the reed pulp, on the other hand, will determine how thick the substance. The resulting products from the process above could be shown as seen in Figure 7.

Material fabricated from dried reeds

Sheet material made from fresh reeds

Figure 7 *Preliminary materials from the experiment*

Figure 7 displays experimentally determined preliminary material characteristics. The sheet material (left), consisting of fine fibers with strong adhesion, will be covered with a gray-cream sheet. The distribution of bark fibers across the surface of the sheet material seems to be brown and black. The surface is neither brittle nor easily ripped when stretched. The sheet material (right), consisting of finer fibers than the dry material, is remarkably stable. The coarse fibers and consequent pulp are of a creamy-white to yellow hue. The color is uniform throughout the sheet. The uneven surface will result from the random distribution of the sample throughout the sheet. The surface is neither brittle nor easily ripped when stretched. The sheet material was then experimented as shown in the next part.

4.1.3 Experimenting the materials

The experimenting process could be shown as seen in Figure 7.


1. Blending fibers as directed


2. Spreading the membrane until it adheres by compressing it with a thin towel


3. Peeling off the mixed membrane to remove it


4. Molding in the vessel


5. Using a composite membrane to cover the mold


6. Organizing the cleanliness of the workpiece

7. Sun-drying in the open air


8. The object resulting from the experiment

Figure 7 *Experimental process for material development*

Figure 7 shows the experimental process for material development. The process

consisted of seven steps: blending fibers as directed, spreading the membrane until it adheres by compressing it with a thin towel, peeling off the mixed membrane to remove it, molding in the vessel, using a composite membrane to cover the mold, organizing the cleanliness of the workpiece, and sun-drying in the open air, respectively. In this experiment utilizing the concept of composite materials, the fibrous pulp was created by boiling caustic soda served as the matrix phase, while 500 grams of twisted, wet reed pulp and 250 milliliters of latex glue made up the reinforced fiber phase. Knead the dough until it is homogenous and malleable, like clay. On a thin white fabric, the pulp is then pressed to a thickness of around 0.5 centimeters. According to the sketch, the workpiece will be made from a product that has been molded using a widely available plastic covering and then sun-dried.

Then, the quality of the materials was evaluated and specimens were obtained during the experiment and determining the outcomes. After this step, knowledge of the production process was then transferred to the community members as detailed in the next part.

4.1.4 Knowledge transfer of the production process

The knowledge transfer of the production process to the community members could be shown as seen in Figure 8.

Figure 8 *Knowledge transfer to the community*

Figure 8 shows the knowledge transfer to the community, focusing on conducting material production and product-forming trials. The community of Ban Daeng Noi acquired the transferred knowledge. This means giving group members the chance to try out different ways to make workpieces, like molding, forming, using molds, and patching sheet materials, through demonstrations and talks about making materials and products out of the waste reeds of the community.

At this stage, familiarity with the new material was being established until the community was self-sufficient. They were instructed on how to exploit the natural beauty of materials and given advice on how to create objects and prepare for product design and development, as shown in the next part.

4.1.5 Product design and development

Working with the community through brainstorming is essential. The determination of the form, proportion, use of materials, and production technique for new items depends on the community's potential when the conclusions are arrived at, as shown in Figure 9.

Figure 9 *Implementation by participants of product design and fabrication of prototypes*

Figure 9 demonstrates the participants' prototype design and construction. After receiving a revised product document, members divided duties and built prototypes. The research team acts as a consultant to provide recommendations, then discusses and analyzes the results to determine the workpiece's development standards. Combining a solid forming sheet with reed weave formed the items. The product's aesthetics stress the natural beauty of the material and use its inherent color and texture capabilities.

The two developed prototypes are presented as shown in Figure 10.

Prototype 1: *Bannock basket*

Prototype 2: *Berry basket*
Figure 10 *Prototypes*

Figure 10 shows developed basket prototypes. Both prototypes (the bannock and berry baskets) were produced from reed mat leftovers. By combining the natural color and texture of the materials with the qualities of knitted reed line, the products bring out the natural beauty of the materials.

As these products were developed for business purposes, market viability was assessed. The next part is the results of RQ 2.

4.2 Newly created prototype market viability

Table 1 shows the survey's marketing viability findings.

Table 1 *The prototypes' marketing viability results*

Items of evaluation	Mean	Level of satisfaction
Exquisiteness	4.57	Highly satisfied
Utility	4.60	Highly satisfied
Material suitability	4.83	Highly satisfied
Distinctiveness and attractiveness	4.75	Highly satisfied
Competitive price	4.63	Highly satisfied
Commercial possibilities	4.59	Highly satisfied
Total	4.66	Highly satisfied

Table 1 presents the results of the two prototypes' marketing viability assessment. The mean score for both prototypes was 4.66, and the respondents were highly satisfied with them. Material suitability ($\bar{x}$= 4.83) and distinctiveness and attractiveness ($\bar{x}$= 4.75) scored higher than the overall mean whilst competitive price ($\bar{x}$= 4.63), commercial potential ($\bar{x}$= 4.59), exquisiteness ($\bar{x}$= 4.57), and utility ($\bar{x}$= 4.61) scored lower than the overall mean. This suggests that the two prototypes satisfied market demand overall. The results of each product are provided in detail in tables 2 and 3.

In detail, the results of either product were presented in Tables 2 and 3.

Table 2 *The bannock basket's marketing viability results*

Items of evaluation	Mean	Level of satisfaction
Exquisiteness	4.54	Highly satisfied
Utility	4.56	Highly satisfied
Material suitability	4.82	Highly satisfied
Distinctiveness and attractiveness	4.73	Highly satisfied
Competitive price	4.68	Highly satisfied
Commercial possibilities	4.51	Highly satisfied
Total	4.64	Highly satisfied

Table 2 presents the results of the prototype bannock basket's marketing viability assessment. The overall mean score for this prototype was 4.64, and the respondents were satisfied with it. Material appropriateness ($\bar{x}$= 4.82), distinctiveness and appeal ($\bar{x}$= 4.73), and competitive price ($\bar{x}$= 4.68) scored higher than the overall mean, whilst utility ($\bar{x}$ = 4.56), exquisiteness ($\bar{x}$ = 4.54), and commercial prospects ($\bar{x}$ = 4.51) scored lower than the overall mean. This shows that this prototype satisfied market demand.

Table 3 *The berry basket's marketing viability results*

Items of evaluation	Mean	Level of satisfaction
Exquisiteness	4.60	Highly satisfied
Utility	4.64	Highly satisfied
Material suitability	4.85	Highly satisfied
Distinctiveness and attractiveness	4.78	Highly satisfied
Competitive price	4.58	Highly satisfied
Commercial possibilities	4.68	Highly satisfied
Total	4.69	Highly satisfied

Table 3 presents the results of the prototype berry basket's marketing viability assessment. The overall mean score for this prototype was 4.69, and the respondents were highly satisfied with it. Material appropriateness ($\bar{x}$= 4.85) and distinctiveness and attractiveness ($\bar{x}$= 4.78) scored higher than the overall mean, whilst commercial prospects ($\bar{x}$= 4.68), utility ($\bar{x}$ = 4.64), exquisiteness ($\bar{x}$ = 4.60), and competitive price ($\bar{x}$ = 4.58) scored lower than the overall mean. This shows that this prototype satisfied market demand.

4.3 Results of SWOT analysis

The results of SWOT analysis were drawn from all research instruments (namely, questionnaire, site survey, experiment, interviews, focus groups, and record keeping).

4.3.1 Strengths

The developed products possessed these strengths: raw materials, craftmanship, and quality of the developed products. On raw materials, there are abundant raw materials for local manufacture, which can save production costs. Numerous additional forms of plant fiber are employed as raw materials in the production of goods. In the production process, there is still a significant amount of waste materials that can be examined and utilized in other ways. On craftmanship, members have substantial skills and experience. They are receptive to learning and development and have high value of craftsmanship. On quality of the developed products, the developed products are genuine, durable, and of high-quality and meet the market viability and demands. The respondents were highly satisfied with them, especially material suitability, and distinctiveness and attractiveness. In detail, the bannock basket prototype possesses these strengths (namely material suitability, distinctiveness and attractiveness, and competitive price) while the berry basket prototype possesses these strengths (namely material suitability and distinctiveness and attractiveness). The products aesthetically emphasize the natural beauty of the materials and utilized the inherent color and textural properties of the materials combined with the collection of knitted reed line features.

However, the developed products possess some weaknesses. It is necessary to analyze the products' strengths, limitations, opportunities, and threats to answer RQ 3 as shown in the next part.

4.3 Results of the SWOT analysis

The results of the SWOT analysis were derived from all instruments of study (namely, questionnaires, site surveys, experiments, interviews, focus groups, and record keeping). Below are the details of each element.

4.3.1 Strengths

Raw materials, craftsmanship, and quality characterized the products. Local manufacturers have abundant raw materials on hand, which can reduce production costs. Raw materials include many varieties of plant fiber. There are still many production wastes that can be explored and used. Members have extensive craft knowledge. They value progress and craftsmanship. The developed items are authentic, long-lasting, and of outstanding quality so they meet market viability and demand. Respondents liked their compatibility, distinctiveness, and appeal. The bannock basket prototype has material compatibility, distinctiveness, attractiveness, and competitive pricing. The berry basket prototype has the same qualities (namely material suitability, distinctiveness, and attractiveness). The pieces highlight the natural color and texture of the materials with knitted reed line features. The products have flaws. However, the products have several flaws as shown in the next part.

4.3.2 Weaknesses

The bannock basket prototype lacks usefulness, elegance, and economic potential. Berry basket prototype flaws (namely, commercial possibilities, utility, exquisiteness, and competitive price). As new products, they face these issues (namely, competitive pricing, commercial possibilities, exquisiteness, and the inability to produce novel or inventive things in order to keep up with fashion trends). These issues need to be solved.

4.3.3 Opportunities

The created prototypes present potential opportunities and increase the community enterprise's competitive edge. There are a large number of community-level OTOP establishments in Thailand. Since 2012, the government has strongly pushed OTOP goods. Apart from the display and production location at Ban Daeng Noi, Ban Daeng Subdistrict, Trakan Phuetphon District, Ubon Rattana Province, there are 11,824 community-level OTOP establishments in Thailand that serve as distribution channels. As awareness of global warming, one of the most significant problems facing modern civilization, grows, the produced products provide value that justifies the use of natural resources to reduce carbon dioxide emissions from combustion. According to interviews with potential and target customers, most consumers who cared about the environment liked the products.

4.3.4 Threats

Natural catastrophes (such as droughts, flooding, and unanticipated calamities caused by global warming), which can cause harm to the reed plants and reduce their productivity, pose the greatest threat to the future mass selling of established products. Increasing material costs, labor shortages, and rising rivalry may all be prominent obstacles.

5. Conclusion Of The Study

This final section summarizes the conclusion of research results, discussions, limitations, and implications of the study.

5.1 Conclusion

Three conclusions were possible in answer to the RQs.

The value of sedge plant fiber waste from the production of reed mats can be increased by developing the waste and manufacturing raw materials, which involves a series of simple steps (manufacturing raw materials; pulping method, sheet-forming process; experimenting with the materials; investigating the community's reactions to the manufacturing process; and product design).

Also, the results of the market viability evaluation of the prototypes (the bannock basket and the berry baskets) showed that the two prototypes met market demand in terms of material suitability, uniqueness and attractiveness, competitive price, commercial possibilities, exquisiteness, and utility.

The results of the SWOT analysis revealed the following observations. The strengths of the created items are the abundance of raw materials, the workmanship of the locals, and the excellent quality of the products from the perspective of possible target clients. The designed bannock basket prototype has weaknesses in utility, exquisiteness, and commercial viability, while the berry basket prototype has weaknesses in commercial viability, utility, exquisiteness, and competitive price. In order to keep up with marketing trends, product challenges include competitive pricing, commercial potential, exquisiteness, and the inability to manufacture innovative or inventive things. In addition to the exhibition and production site in Ban Daeng Noi, Ban Daeng Subdistrict, Trakan Phuetphon District, Ubon Rattana Province, a large number of community-level OTOP establishments can serve as distribution channels for the developed items. The products can also attract buyers that are environmentally sensitive. On the other hand, natural disasters, which can cause harm to the reed plants and destroy productivity, can be potential threats to the developed products for mass marketing in the future.

5.2 Discussion

The findings of this study confirm prior research indicating that agricultural waste recycling can contribute to the circular economy, ecology, and sustainability if properly monitored and managed (e.g., Hua et al., 2022; Mohite et al., 2022; Zheng et al., 2021).

This study's conclusion is congruent with that of Awasthi et al. (2022) regarding the success factors for recycling agricultural waste, which include technology, strategy, and market viability. But the parts of this study were specific to the location and could be used to meet the technological, strategic, and market needs of the stakeholders.

The first significant factor is technology. Prior research (e.g., De Bernardi et al., 2022) uncovered that technology (e.g., digital channels) is a crucial aspect of this objective. But in this study, simple technology was chosen (based on how the raw materials were made, how the pulp was made, how the sheets were made, how the materials were tested, how the community reacted to the manufacturing process, and how the products were designed) because the participants or stakeholders are local farmers in a rural part of Thailand where agriculture is mostly based on simple technology.

Strategies are also a crucial issue. There are numerous methodologies and models, such as supply chain management and chain operations (Sarkar et al., 2022; Mayanti & Helo, 2022), for establishing the viability of circular pathways (Stillitano et al., 2022). This study adopted a CBPR strategy in which the researchers collaborated directly with the community, focusing on the real-world and location-specific challenges of the community members as stakeholders. Consistent with previous research, the findings of this study indicate that CBPR promotes local or community objectives and perspectives and direct engagement with affected parties for action or change (Cornwall & Jewkes, 1995) and emphasizes co-constructing research with stakeholders, community members, and those with insider knowledge (Jagosh et al., 2012). This study found, however, that CBPR is effective for information dissemination and training of knowledge transfer to the community (including raw material development of reed pulp products and manufacturing techniques, and community-specific guidelines for the fabrication of products made from reed fiber) so that the community can develop a strategy for the future production of new goods. This study confirms what previous studies (Cornwall & Jewkes, 1995; Cargo & Mercer, 2008; Jagosh et al., 2012; Balazs & Morello-Frosch, 2013; Bush et al., 2009) have found that CBPR focuses on local priorities and opinions, directs action with affected stakeholders, and co-constructs research with the insiders based on their real-world knowledge and experiences.

The final important component is marketing strategy. Effective marketing strategies must be location-specific and connected to social, institutional, and marketing aspects (Milford et al., 2021; Wanasinghe & Sachitra, 2022). Cost-benefit evaluations assist businesses in deciding whether and which agricultural waste recycling options to pursue based on new value and waste products. (Hsu, 2021; Jie and Guanghua, 2022; Liu et al., 2021; Jamil et al., 2022). In support of the researchers' consultancy, this study also assessed marketing viability suited to the caliber of the involved parties (namely a questionnaire survey of the potential customers and SWOT analysis). In this investigation, both prototypes demonstrated excellent market viability.

5.3 Limitation of the study

In this study, the effort to transform sedge plant fiber leftovers into innovative, value-added, and market-oriented goods in accordance with CBPR design and development was effective. However, just one case study was examined in this work. To use different plant fiber scraps, future research must be done that takes into account the limits of the location and the best technological, strategic, and market imperatives.

5.4 Implications of the study

This research has at least three significant implications.

First, from a pragmatic standpoint, this study offers alternatives beyond conventional tactics as an economically viable means of overcoming the current economic and environmental obstacles to waste minimization and adding value to waste.

Second, conceptually and methodologically, it offers a technique to rebuild the conceptual framework of product design and development from waste (i.e., turning sedge plant fiber remnants into new, value-added and market-oriented items), which is rarely mentioned in modern Thai research. This study is part of a paradigm shift in redesigned product design and development that is essential for economic and environmental sustainability.

Lastly, for policy implication for marketability, the government could increase the viability of stakeholders in new markets, thus boosting sales and market share. The government should also promote this potential marketability by establishing a large number of community-level OTOP establishments nationally to increase distribution channels in addition to the sale location in this case study. In addition, the government should prepare for natural disasters that might damage reed plants and reduce productivity, posing future dangers to mass marketing and international trade.

References

Awan, U., Sroufe, R., & Bozan, K. (2022). Designing Value Chains for Industry 4.0 and a Circular Economy: A Review of the Literature. *Sustainability*, *14*(12), 7084.

Awasthi, M. K., Sindhu, R., Sirohi, R., Kumar, V., Ahluwalia, V., Binod, P., ... & Taherzadeh, M. J. (2022). Agricultural waste biorefinery development towards circular bioeconomy. *Renewable and Sustainable Energy Reviews*, *158*, 112122.

Balazs, C. L., & Morello-Frosch, R. (2013). The three Rs: How community-based participatory research strengthens the rigor, relevance, and reach of science. *Environmental justice*, *6*(1), 9-16.

Cargo, M., & Mercer, S. L. (2008). The value and challenges of participatory research: strengthening its practice. *Annu. Rev. Public Health*, *29*, 325-350.

Chaianong, A., & Pharino, C. (2022). How to design an area-based prioritization of biogas production from organic municipal solid waste? Evidence from Thailand. *Waste Management*, *138*, 243-252.

Cornwall, A., & Jewkes, R. (1995). What is participatory research?. *Social science & medicine*, *41*(12), 1667-1676.

de Araújo Veloso, M. C. R., Pires, M. R., Villela, L. S., Scatolino, M. V., de Paula Protásio, T., Mendes, L. M., & Júnior, J. B. G. (2020). Potential destination of Brazilian cocoa agro-industrial wastes for production of materials with high added value. *Waste Management*, *118*, 36-44.

De Bernardi, P., Bertello, A., & Forliano, C. (2022). Circularity of food systems: a review and research agenda. *British Food Journal*, (ahead-of-print).

Department of Industrial Promotion of Thailand (International Industrial Economic Division of Thailand, 2021:10)

Devendra, C., & Thomas, D. (2002). Crop–animal interactions in mixed farming systems in

Asia. *Agricultural Systems*, *71*(1-2), 27-40.
Eliopoulos, C., Markou, G., Chorianopoulos, N., Haroutounian, S. A., & Arapoglou, D. (2022). Transformation of mixtures of olive mill stone waste and oat bran or Lathyrus clymenum pericarps into high added value products using solid state fermentation. *Waste Management*, *149*, 168-176.
Gattuso, J. P., Magnan, A., Billé, R., Cheung, W. W., Howes, E. L., Joos, F., ... & Turley, C. (2015). Contrasting futures for ocean and society from different anthropogenic CO^2 emissions scenarios. *Science*, *349*(6243), aac4722.
Goklani, B., Prapurna, P. N., & Srinath, S. (2022). Simulation of pyrolytic conversion of Walnut shell waste to value added products. *Materials Today: Proceedings*.
Hsu, E. (2021). Cost-benefit analysis for recycling of agricultural wastes in Taiwan. *Waste Management*, *120*, 424-432.
Hua, L. S., Chen, L. W., Geng, B. J., Kristak, L., Antov, P., Pędzik, M., ... & Pizzi, A. (2022). Particleboard from Agricultural Biomass and Recycled Wood Waste: A Review. *Journal of Materials Research and Technology*.
Hallioui, A., Herrou, B., Santos, R. S., Katina, P. F., & Egbue, O. (2022). Systems-based approach to contemporary business management: An enabler of business sustainability in a context of industry 4.0, circular economy, competitiveness and diverse stakeholders. *Journal of Cleaner Production*, 133819
International Industrial Economic Division. (2021). Meeting of Thailand-Japan Policy Dialogue on Promotion Circular Economy Cooperation in relation to the Ministry of Industry. Journal of Industrial Economics. Office of Industrial Economics. 17(65), 10. July 11, 2019. Retrieved December 25, 2021. https://www.the101.world/circular-economy/.
Jagosh, J., Macaulay, A. C., Pluye, P., Salsberg, J. O. N., Bush, P. L., Henderson, J. I. M., ... & Greenhalgh, T. (2012). Uncovering the benefits of participatory research: implications of a realist review for health research and practice. *The Milbank Quarterly*, *90*(2), 311-346.
Jamil, S. R., Wang, L., Tang, C., Khan, H. M. S., & Che, D. (2022). The role and impact of costing method in the decision-making of energy project: A comparative assessment between levelized cost of energy and benefit-to-cost ratio analysis. *International Journal of Energy Research*, *46*(4), 4754-4769.
Jie, P., & Guanghua, Q. (2022). Optimization of Solid Waste Resource Utilization Mode of Different-scale Dairy Farms from the Cost–Benefit Perspective. *The Journal of Solid Waste Technology and Management*, *48*(1), 137-146.
Jung, C. F., de Jesus Pacheco, D. A., Sporket, F., do Nascimento, C. A., & Ten Caten, C. S. (2021). Product design from waste: A novel eco-efficient pyramidal microwave absorber using rice husks and medium density fibreboard residues. *Waste Management*, *119*, 91-100.
Khodaei, H., Olson, C., Patino, D., Rico, J., Jin, Q., & Boateng, A. (2022). Multi-objective utilization of wood waste recycled from construction and demolition (C&D): Products and characterization. *Waste Management*, *149*, 228-238.
Liu, H., Qin, S., Sirohi, R., Ahluwalia, V., Zhou, Y., Sindhu, R., ... & Awasthi, M. K. (2021). Sustainable blueberry waste recycling towards biorefinery strategy and circular bioeconomy: A review. *Bioresource Technology*, *332*, 125181.
Mayanti, B., & Helo, P. (2022). Closed-loop supply chain potential of agricultural plastic waste: Economic and environmental assessment of bale wrap waste recycling in Finland. *International Journal of Production Economics*, *244*, 108347.
Milford, A. B., Lien, G., & Reed, M. (2021). Different sales channels for different farmers: Local and mainstream marketing of organic fruits and vegetables in Norway. *Journal*

of Rural Studies, *88*, 279-288.
Mohite, A. S., Jagtap, A. R., Avhad, M. S., & More, A. P. (2022). Recycling of major agriculture crop residues and its application in polymer industry: A Review in the context of waste to energy nexus. *Energy Nexus*, 100134.
Najari, Z., Khodaiyan, F., Yarmand, M. S., & Hosseini, S. S. (2022). Almond hulls waste valorization towards sustainable agricultural development: Production of pectin, phenolics, pullulan, and single cell protein. *Waste Management*, *141*, 208-219.
Reason, P., & Torbert, W. (2001). The action turn: Toward a transformational social science. *Concepts and transformation*, *6*(1), 1-37.
Rejeb, A., Rejeb, K., Zailani, S., Kayikci, Y., & Keogh, J. G. (2022). Examining knowledge diffusion in the circular economy domain: a main path analysis. *Circular Economy and Sustainability*, 1-42.
Rejeb, A., Suhaiza, Z., Rejeb, K., Seuring, S., & Treiblmaier, H. (2022). The Internet of Things and the circular economy: A systematic literature review and research agenda. *Journal of Cleaner Production*, 131439.
Wang, P., Casner, R. G., Nair, M. S., Wang, M., Yu, J., Cerutti, G., ... & Ho, D. D. (2021). Increased resistance of SARS-CoV-2 variant P. 1 to antibody neutralization. *Cell host & microbe*, *29*(5), 747-751.
Sarkar, B., Debnath, A., Chiu, A. S., & Ahmed, W. (2022). Circular economy-driven two-stage supply chain management for nullifying waste. *Journal of Cleaner Production*, *339*, 130513. (33 citations)
Stillitano, T., Falcone, G., Iofrida, N., Spada, E., Gulisano, G., & De Luca, A. I. (2022). A customized multi-cycle model for measuring the sustainability of circular pathways in agri-food supply chains. *Science of The Total Environment*, *844*, 157229.
Zheng, Y., Zhang, Q., Zhang, Z., Jing, Y., Hu, J., He, C., & Lu, C. (2021). A review on biological recycling in agricultural waste-based biohydrogen production: Recent developments. *Bioresource Technology*, 126595.