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Developing Environmentally Friendly Products from Rice Stumps for Community Economy

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Abstract

This research is a study and development of environmentally friendly products from rice stumps for community economy. The study was done by testing the coatings for heavy metals and volatile organic compounds to match with material choices with low environmental impacts. The author therefore chose 9 types of popular coatings which the community can easily obtain from the market. Testing was done in two parts: the first part was to find 7 heavy metals by using Thailand's green label standard and standard criteria set by the European Union while the second part was to test for volatile organic compounds (VOCs) and evaluate the environmental impacts in order to list materials and energy used by the products for their entire lifetime. Lastly, a survey was conducted using environmentally friendly products from rice stumps as models in order to investigate the perceptions in relation to manufacturing factors consistent with the manufacturers, the designers, as well as the perceptions of consumers. The study has found that rice stump coatings that passed the standard criteria are white shellac, gloss lacquer, wood preservatives, varnish and polyurethane respectively. It was found that manufacturers and designers had differing opinions in using low-impact materials and avoiding harmful materials while manufacturers, designers and consumers had statistically significant differing opinions in terms of the appropriate sizes and colors of products. In terms of product aesthetics, convenience of use, promotion of environmental friendliness, indication of natural manufacturing process and ease of elimination after the end of product lifetime, there were no differing opinions which were at a good level.

Keywords: environmentally friendly products, rice stumps, community economy

1. Introduction

1.1 Introduce the Problem

Rice is one of the world's important crops, especially for Asian countries where it is widely eaten daily more than any other region in the world. The production and consumption of rice is therefore concentrated in Asia. Most of the rice produced in Thailand is consumed domestically, with only 6% exported to overseas markets. Top rice exporters are Thailand, India, Vietnam, China, and Myanmar, respectively, with Thailand exporting approximately 8.5 million tons of rice annually (Office of Agricultural Economics, 2009).

Because Thailand has an agricultural area of 209.6 million hectares, there are approximately 35 million tons of waste in the form of rice stumps, corns and others annually, or at an average of nearly 300 kilograms of agricultural waste per 0.16 hectares. This agricultural waste is burned after harvest to simplify the plowing process. This practice causes the soil to lose organic matter which is deemed to play the most important role in soil improvement for sustainable agriculture. This results in degraded soil and increasing reliance on chemical fertilizers and chemical products. According to one estimate, the burning of rice stumps and rice straws alone caused the soil to lose major nutrients by as much as 90 million kilograms of nitrogen, 20 million kilograms of phosphorus and 260 million kilograms of potassium as well as minor nutrients such as calcium, magnesium and phosphorus by nearly 150 million kilograms per year at a value of nearly 5 billion baht, causing farmers to purchase chemical fertilizers to use in their fields to compensate for lost nutrients from burnt rice stumps and maintain crop yields. However, Thailand has implemented organic farming as a national agenda and campaigned for farmers to stop the practice of burning rice stumps as well as supported the implementation of the national agenda in accordance with government policies such as campaigning for the end of burning rice stumps, creating sustainable soil and restoring the environment. Farmers were encouraged to stop burning which was a problem in the agricultural sector because most farmers would burn rice stumps after harvest, causing widespread fires throughout the area, damaging the environment and causing global warming as well as altering weather patterns, with the problem likely to worsen every year. This was a concern for many agencies, prompting them to warn farmers to stop burning rice stumps or agricultural waste and put them to more use instead.

As a result, the world has now become interested in designing environmentally friendly products, which is a way to actively address various environmental issues. Naturally, "global warming" awareness should no longer be sensational news because environmental problems affect every life as can be seen in changing climates, increasing heat levels, or worsened diseases. These are all a result of both conscious and unconscious human actions (National Science and Technology Development Agency, 2012). Sustainable development has been accepted as an important idea for improving modern organizations' survival chances in the competing world (Bevilacqua et al., 2007). These organizations are forced to use this in their designs to preserve the environment and reduce energy usage. Sustainable organizations will reduce manufacturing costs and prevent environmental problems by maintaining cleanliness and the natural environment (Senthilkumaran et al., 2001). Sustainable development systems including the issue of product designs and manufacturing planning as well as quantity control, evaluation and management of waste flow to the environment according to the highest goals of reducing environmental impacts (Azzone & Noci, 1996). Industries committed to being environmentally friendly try to utilize resources efficiently to manufacture parts sustainably. Sustainability is an important factor such as in manufacturing, product designs and environmental concerns (Rusinko, 2007). Preventing environmental problems by trying to reduce overall operating costs of a product can be considered sustainable development (Kaebernick et al., 2002). This includes designing products and services to be environmentally friendly, which is important to every employment sector when adapting the principles to include various problems and solutions such as aiming to reduce waste, prolonging product lifetime and recycling. The concept of Life Cycle Thinking aims to avoid waste that follows for the entire lifetime of the product or service. Regulations, laws, or standards related to the environment are also introduced, especially the International Organization for Standardization (ISO), which introduced ISO14000 standards for environmental management that organizations can conform to. These standards aim to reduce environmental impacts starting from product designs by considering future environmental impacts during the lifetime of the products, helping to more effectively reduce environmental impacts. These international environmental standards have increasingly been used in the industrial sector of Thailand, especially for the export industry to customers in Europe, the US or Japan, for example. Therefore, the Thai industry should quickly adapt their businesses to conform to these various product standards which can help to maintain the export markets or conversely help to expand the markets for environmentally friendly products (Excellence Center for the Development of Environmentally friendly Products, 2010).

In the past decade, there was a need to recommend environmental requirements in the design and development of products. This became an important issue in terms of applying environmental criteria to product designs and the comparison of environmental requirements for original designs with an emphasis on significance (Brent & Labuschagne, 2004). Product design academics all agreed that the most effective way to reduce environmental impacts must start from the product design stage because even though the direct cost of designing a product is only 5-13% of the overall cost of product, the resulting design will determine 60-80% of the cost structure. For this reason, EcoDesign (Ecomonic & Ecological Design) has become an important part in the product manufacturing process by combining the economic and ecological concepts with the design process in order to develop an environmentally friendly product. This includes analyzing the environmental performance of the product, elimination of discarded products, and reduction of environmental impacts in every stage of the product's lifecycle along with the analysis of other factors such as costs, manufacturing process, quality control and marketing. Sustainable development is important not only as a guideline for reducing environmental impacts but it is also important to trade and exports because nowadays developed nations, such as the European Union, the US, and Japan are increasingly becoming interested in the environment as can be seen in trade regulations and requirements in relation to the environment (National Science and Technology Development Agency, 2012). Based on the origin and importance, as well as the nature of the problems, the author was inspired to develop environmentally friendly products from rice stumps for community economy. The project was expected to be very interesting to study for the benefits of using agricultural waste to create products as a source of income for the community as well as in order to support environmentally friendly product designs which designers and the industrial sector at the community level can directly use to increase their production capacity and market competitiveness where demands for environmentally friendly products are increasing. This would also help to increase the nation's capacity to develop environmentally friendly products.

2. Method

2.1 Population and Sample Group

For this study, the sample group was chosen from the results of study by Gifford, Hine, Muller-Clememm, Reynold, JR. and Shaw, which found that the visual perceptions of architects and ordinary people are completely different. It can therefore be surmised that backgrounds in art or designs are also part of the reason for this differing of visual perceptions, based on the study of design components so that components of art as its foundation as well as the utilization of designs (referenced from Krukaset, 2011). In this research, there are 3 sample groups as follows:

2.1.1 Manufacturers – The author chose 100 people from a community in Ang Thong Province, Thailand to represent this group. The author used quota sampling as the selection method in order to match the characteristics of the desired sample group. The accidental sampling method was then used to reach the target amount at the location of data collection.

2.1.2 Designers – The author chose 100 senior-year designer students studying product designs at the undergraduate level to represent this group. The author chose the simple random sampling method by choosing sample students majoring in product design and then using the random number table to reach the target amount.

2.1.3 Consumers – The author chose 100 ordinary consumers to represent this group by using the accidental sampling method.

2.2 Research Methodology

This research is a study of the development of environmentally friendly products from rice stumps in relation to the community economy and in accordance with consumer perceptions. This also supports environmentally friendly policies as well as serves as a strategy to change consumer behaviors to take part in environmental conservation. The study analyzed documents, books and related literature, conducted field studies and surveys in the following steps:

2.2.1 Step 1 – Gather preliminary data through reviews of literature, documents, ideas and theories for use as guidelines in creating the scope of study, variables, indicators as well as research methodology using ideas, theories and research related to this study.

2.2.2 Step 2 – Specify scope of study, including variables and indicators for using as guidelines in determining the research methodology.

2.2.3 Step 3 – Study the physical and special properties of rice stumps with the ability to be used as a material for manufacturing environmentally friendly products from rice stumps for community economy and investigate environmental products for using as a case study by determining design variables through the physical properties of the products and reviewing the literature, documents, ideas and theories from various kinds of documents as well as surveying the occupations and various product-making skills in the community.

2.2.4 Step 4 – Synthesize factors between designs and environmental conservation then link the results with design characteristics of environmentally friendly products to determine the topics for use as indicators in the evaluation of opinions regarding the styles of environmentally friendly products and to create testing tools.

2.2.5 Step 5 – Results from the study, interviews and surveys are used to design and create environmentally friendly products.

2.2.6 Step 6 – For this study, tools were created which can be grouped into 3 parts as follows:

Part 1: Testing the coatings for heavy metals and volatile organic compounds in accordance with the selection of materials with low environmental impacts.

Part 2: Environmental impact assessment by means of MET Matrix analysis.

Part 3: Use environmentally friendly products from rice stumps as models and questionnaires to determine the issue of perceptions of design factors in relation to manufacturers, designers and consumer perceptions as research tools and use scales as a guideline for data analysis and conclusion.

2.2.7 Step 7 – Use research tools which included environmentally friendly products from rice stumps to collect data from 3 sample groups which included manufacturers, designers and consumers while also using questionnaires.

2.2.8 Step 8 – Analyze data collected with questionnaires by processing with a statistical analysis program to summarize ideas related to the styles of environmentally friendly products from rice stumps.

2.2.9 Step 9 – Summarize development results of environmentally friendly products from rice stumps for community economy in terms of the selection of materials with low environmental impacts, maximum production and energy efficiency, designs to best reduce waste products and the ability to be produced at the community level.

2.3 Evaluation of Tools

In this study, the author has conducted a reliability analysis of research tools by using the Cronbach's Alpha Coefficient to determine the consistency within the same set and the stability and consistency of the questionnaire and found the Cronbach's Alpha Coefficient to be at 0.83 which was very close to 1. This means that each respondent gave a score consistent to each other.

3. Results

In developing environmentally friendly products from rice stumps for community economy, the author firstly reviewed relevant literature (secondary source) from ideas, theories, books and relevant studies to summarize into product development trends. The author then studied and linked various data to use as a basis for hypotheses and objectives of the study. The author then detailed the results for developing environmentally friendly products from rice stumps for community economy by taking three issues into consideration: 1) the issue of choosing materials with low environmental impacts to study and test the coatings with the least impacts to humans and the environment; 2) the issue of maximizing production and energy efficiency and designs to best reduce waste products, in order to find production methods that help to reduce environmental impacts and energy usage as well as efficient energy usage suitable for production in the community, minimize waste products in nature and design products for easy disposal after the end of their lifetime, and; 3) the issue of the ability to be produced in the community that corresponds to the production possibility and perception of consumers in order to summarize and suggest ways to design and create an economy for the community.

1. Rice stumps coated with gloss lacquer 2. Rice stumps coated with varnish 3. Rice stumps coated with wood preservatives 4. Rice stumps coated with polyurethane 5. Rice stumps coated with white shellac

6. Rice stumps coated with spray paint 7. Rice stumps coated with oil paint 8. Rice stumps coated with natural dye 9. Rice stumps coated with artificial dye

Figure 1. Rice stumps with 9 coatings

3.1 Results of Study on Choosing Materials with Low Environmental Impacts

The development of environmentally friendly products from rice stumps for community economy which uses rice stumps as a primary material without using glue as a linking material due to urea-formaldehyde was to conform with the idea of using materials with low environmental impacts as well as reducing heavy metals and volatile organic compounds which can move the ozone from high in the atmosphere nearer to the earth's surface. This ozone is a danger to humans and also damages buildings and reduces crop yields. However, because rice stumps are natural materials that can easily decompose, a coating is needed to increase durability and attractiveness. The author therefore chose 9 popular coatings that a community can easily obtain from the market which included gloss lacquer, varnish, wood preservatives, polyurethane, white shellac, spray paints, oil paints, natural dyes, and artificial dyes by testing for 7 heavy metals including lead, cadmium, chromium, cobalt, tin, arsenic and mercury as well as volatile organic compounds (VOCs) by analyzing/testing at the Analytical Chemistry Laboratory, Testing and Metrology Center, Thailand Institute of Scientific and Technological Research (TISTR). The results are shown in Table 1 and Table 2.

Table 1. Testing results for heavy metals Unit: milligram per kilogram

List	Rice Stumps Coated with								
	Gloss lacquer	Varnish	Wood preser vative	Poly-urethane	White shellac	Spray paint	Oil paint	Natural dye	Artificial dye
1. Lead	7.03	4.24	6.54	3.55	9.48	13.56	90.83	17.89	0.30
2. Cadmium	0.10	0.10	0.07	0.05	0.11	0.08	0.62	0.09	0.07
3. Chromium	13.94	4.53	20.00	21.79	24.49	1,500.00	16.67	41.99	102.08
4. Cobalt	1.75	81.13	6.64	1.58	3.08	2.12	268.76	8.41	1.59
5. Tin	2.00	2.50	3.00	2.55	4.50	1.05	2.50	3.01	2.50
6. Arsenic	13.27	8.51	18.17	6.51	10.58	6.72	0.28	9.36	3.18
7. Mercury	0.034	0.023	0.027	0.017	0.020	0.015	0.008	0.030	0.017

Note Union. Value exceeded Thailand's green label standard

Value exceeded standards determined by the European Union

Value exceeded Thailand's green label standard and standards determined by the European Union

In these tests for heavy metals, the author compared the results with domestic and international standards. However, because there were no direct standards or requirements for products from rice stumps, domestic and international standards or requirements with the most similarities were studied. The standards with the most similarities chosen by the author are Thailand's green label standard for regulations on Panels for the Building, Decorating and Furniture Industry and European Standards according to relevant regulations as shown in document 2009/894/EC: Commission Decision of 30 November 2009 on establishing the ecological criteria for the award of the Community eco-label for wooden furniture (notified under document C (2009) 9522).

Test results for heavy metals by percentage to weight with values not exceeding Thailand's green label standard and standards determined by the European Union are rice stumps coated with gloss lacquer, rice stumps coated with varnish, rice stumps coated with wood preservatives, rice stumps coated with polyurethane, and rice stumps coated with white shellac. Coatings that passed Thailand's green label standard but exceeded standards determined by the European Union are rice stumps coated with natural dye which had a chromium value of 41.99 mg/kg but the standards determined by the European Union was set at 25 mg/kg. The result may be partly due to the flowers used to extract natural dye were obtained from ordinary markets which may contain residual chemicals or pesticides.

Coatings with values exceeding Thailand's green label standard and European Union standard are rice stumps coated with spray paint containing chromium at 1,500 mg/kg and rice stumps coated with artificial dye containing chromium at 102.08 mg/kg but Thailand's green label standard set the value at 60 mg/kg while the European Union set the value at 25 mg/kg. As for rice stumps coated with oil paint, the lead value was at 90.83 mg/kg but Thailand's green label standard and the European Union standard both set the value at 90 mg/kg while the values for cobalt and tin were neither set by Thailand's green label standard nor European Union standard.

Table 2. Test results for volatile organic compounds (VOCs)

List	Rice stumps coated with								
	Gloss lacquer	Varnish	Wood preser vatives	Polyure thane	White shellac	Spray paint	Oil paint	Natural dye	Artificial dye
VOCs Contents**	0.19	2.02	0.74	5.15	<0.05	<0.05	3.73	<0.05	<0.05
Dichloromethane (DCM)*	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Trichloroethane (TCE)*	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
n-Hexane*	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Ethylacetate*	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
o-Xylene*	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
p-Xylene*	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
m-Xylene*	<0.0005	<0.0005	<0.0005	0.0495	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Benzene*	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Toluene*	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cyclohexanone	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Unidentified * Compounds	0.0019	0.0202	0.0074	0.0515	<0.0005	<0.0005	0.0023	<0.0005	<0.0005

Table 2 shows that for coatings that were tested for volatile organic compounds (VOCs), rice stumps coated with white shellac, spray paint, natural dye and artificial dye had the smallest values at less than 0.5 followed by rice stumps coated with gloss lacquer, wood preservatives, varnish, oil paint and polyurethane, respectively.

3.2 Results of Study on Maximizing Production and Energy Efficiency and Designs That Minimize Waste

Environmental impact assessment in this study cannot be carried out using software as a tool to create LCA simulations or product assessment simulations because material database and processes lacked data on rice stumps or similar materials. For this reason, lifecycle assessment using MET Matrix was conducted by forming products primarily in two ways including compressing into slats and weaving or retaining the shape of the material.

Analysis was carried by comparing only the production processes due to their differences as well as other processes such as the storage/digging of rice stumps, cleaning, sun-drying, coloring/coating of the surface, transportation, usage and burying all have the same processes. General indicators for impact assessment were used such as energy usage, waste reduction amounts as well as waste and chemical emissions. Assessment results are shown in Table 3.

Table 3. Slat production and weaving assessments

	Energy usage	Amount of waste	Waste and chemical emissions
Slat compression	Uses a lot of electricity, mostly for machinery	Little amount of waste in slat compression process but medium amount of waste in product manufacturing process	- Urea-formaldehyde - Volatile organic compounds (VOCs) - Heavy metals
Weaving or retaining material shape	Uses little electricity, human labor primarily used	Little amount of waste but undamaged straws of rice stumps must be used	- Volatile organic compounds (VOCs) - Heavy metals

Weaving or retaining material shape were chosen as they required little electricity, produced similar amounts of waste, reduced urea-formaldehyde and could be employed for community-level production, unlike slat compression which was appropriate for industrial production.

MET Matrix analysis for listing materials and energy usage of a product during its entire lifecycle and chemicals released in various stages is shown in Figure 2.

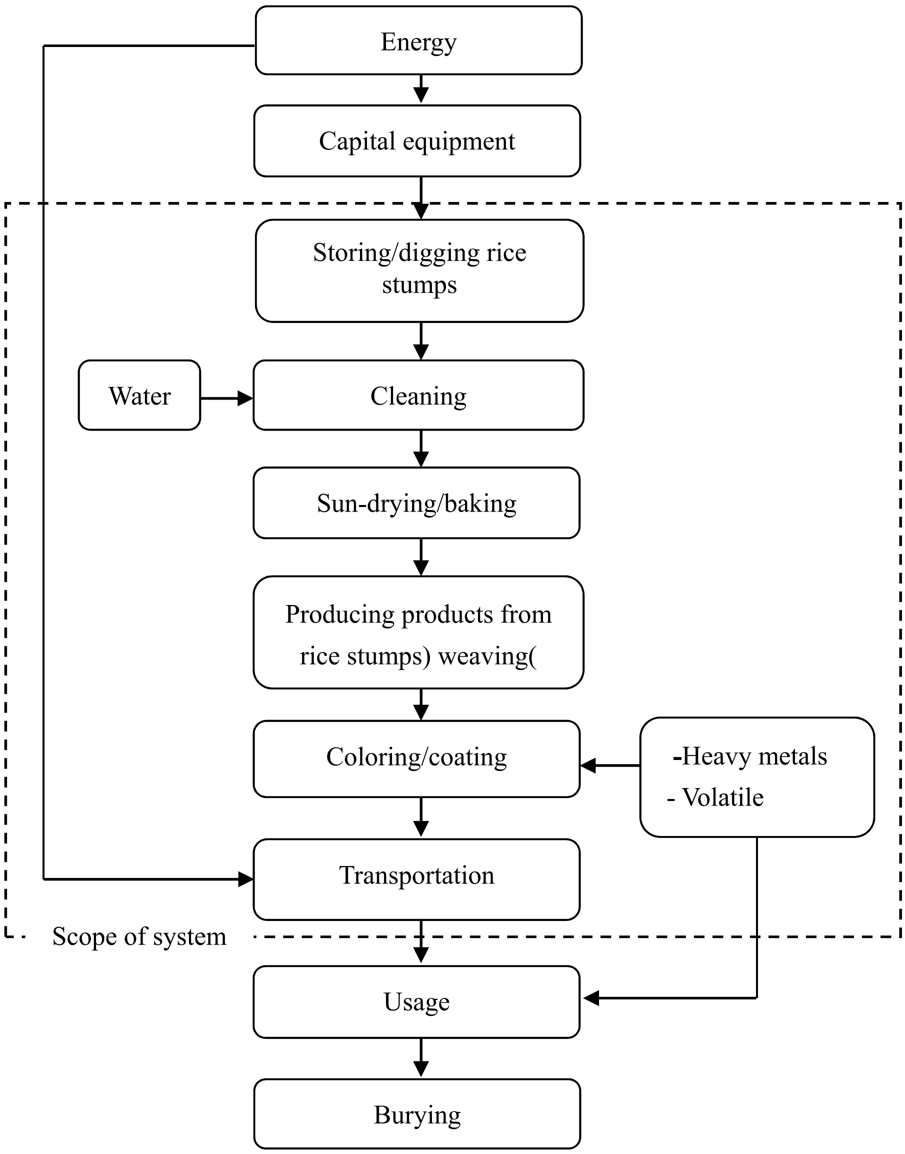

Figure 2. Product system from lifecycle point of view

3.3 Results of Study on Community-Level Production

In terms of production factors for environmentally friendly products from rice stumps for community economy, there are a total of 3 related groups which are manufacturers, designers and consumers. In order to survey opinions on 3 model environmentally friendly products from rice stumps which included lamps, serving trays and women's handbags, the author analyzed questionnaire data from the three sample groups as follows:

Figure 3. Samples of environmentally friendly product designs from rice stumps for community economy

Table 4. Average values of scores and comparisons between manufacturers and designers

Topic	Manufacturers	Designers	Independent Samples Test	
	M(*SD*)	*M*(*SD*)	t	*p*
.1Use low-impact materials	3.81(0.58)	4.15(0.61)	-4.04	0.00*
.2Avoid harmful materials	3.87(0.39)	4.22(0.58)	-5.00	0.00*
.3Efficient energy usage	4.07(0.59)	4.19(0.60)	-1.43	0.16
.4Minimize impacts of waste disposal	4.06(0.51)	4.12(0.66)	-0.72	0.47
.5Promote community products	4.09(0.68)	4.26(0.68)	-1.77	0.78
.6Promote community sustainability	3.98(0.55)	4.09(0.55)	-1.41	0.16
.7Production viability	4.10(0.61)	4.19(0.54)	-1.10	0.27
.8Commercial viability	4.05(0.58)	4.20(0.59)	-1.83	0.07

*p<.05 is the level of significance

As shown in Table 4, data analysis found that in terms of opinions on types of environmentally friendly products from rice stumps for community economy, there are 2 topics with statistically significant differences at 0.05 which are the use of low-impact materials and avoiding harmful materials with values at good levels because most manufacturers wished to use familiar low-cost materials that can be obtained easily. This differed from designers who would primarily use environmentally friendly materials to make products.

As for the remaining 6 topics, the manufacturers and designers had opinions at good levels with no differences because their viewpoints in terms of production and revenue creation for community were in the same direction.

Table 5. Average scores and comparisons between designers and consumers

Topic	Designers	Consumers	Independent Samples Test	
	M(*SD*)	*M*(*SD*)	t	*p*
1. Product is attractive	4.04(0.53)	4.02(0.47)	0.26	0.79
2. Product signifies degradable materials	4.15(0.67)	4.05(0.67)	1.05	0.29
3. Product signifies reusable materials	4.03(0.63)	3.92(0.72)	1.15	0.25
4. Product signifies environmentally friendly materials	4.18(0.57)	4.17(0.47)	0.13	0.89
5. Product signifies environmental safety	4.20(0.68)	4.12(0.56)	0.91	0.36

*p<.05 is the level of significance

As shown in Table 5, data analysis found that the opinions of designers and consumers are in the same direction on every topic and opinions at a good level.

Table 6. Average scores and comparisons between manufacturers and consumers

Topic	Manufacturers	Designers	Consumers	One-Way ANOVA	
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	F	*p*
1. Product is attractive	3.94(0.53)	4.06(0.49)	4.01(0.56)	1.31	0.27
2. Product has appropriate sizes	3.92(0.49)	4.18(0.48)	4.12(0.55)	7.17	0.00*
3. Product's colors are attractive	3.80(0.53)	4.08(0.58)	4.01(0.56)	6.83	0.00*
4. Product is easy to use	4.05(0.52)	4.11(0.71)	4.18(0.67)	1.04	0.36
5. Product promotes conservation of environment	4.21(0.69)	4.24(0.65)	4.12(0.54)	0.99	0.37
6. Product signifies natural manufacturing process	4.36(0.58)	4.44(0.52)	4.29(0.57)	1.81	0.17
7. Product can be easily eliminated after end of lifetime	4.17(0.55)	4.24(0.57)	4.12(0.41)	1.37	0.26
Total	4.03(0.58)	4.17(0.61)	4.09(0.58)	8.71	0.00*

*p<.05 is the level of significance

As shown in Table 6, the data analysis found that manufacturers, designers and consumers had the same opinions at a statistically significant level of 0.05 on 5 topics, which are; product is attractive, product is easy to use, product promotes conservation of environment, product signifies natural manufacturing process, and product can be easily eliminated after end of lifetime. Overall, opinions in every topic are at good levels and with each individual group at a good level. The designers group had the highest average values, followed by the consumers and manufacturers group with average values at 4.17, 4.09 and 4.03 respectively. Opinions in the other two topics, product has appropriate sizes and product's colors are attractive, differed at a statistically significant level of 0.05 but it was still unclear which groups differed from each other. The author therefore performed an analysis to see which of the pairs had differing opinions as shown in Table 7.

Table 7. Determining Post Hoc LSD

Product has appropriate sizes	*M*	Manufacturers	Designers	Consumers
Manufacturers	3.92	-	0.000*	0.006*
Designers	4.18		-	0.404
Consumers	4.12			-
Product's colors are attractive				
Manufacturers	3.80	-	0.000*	0.008*
Designers	4.08		-	0.375
Consumers	4.01			-

*p<.05 is the level of significance

As shown in Table 7, Post Hoc LSD (Least Significant Difference) analysis shows that on the topic of product has appropriate sizes, opinions of manufacturers differed from those of designers and consumers at a statistically significant level of 0.05 and on the topic of product's colors are attractive, the opinions of manufacturers differed from those of designers at a statistically significant level of 0.05 because manufacturers were still used to original-style products and favored the use of colors which differed from the idea of product development from nature as shown in Table 1 and Table 2 for coatings analysis. Designers also understood consumer behaviors on natural product perceptions more than manufacturers.

4. Discussion

4.1 Conclusion of Study Results on Choosing Materials with Low Environmental Impacts

Other than the fact that rice stumps are natural agricultural leftover materials, coating is another material that must have a low environmental impact and pose as little harm to users as possible. Popular coatings that can be easily obtained from the market with heavy metal contents within Thailand's green label standard and the European Union standards as well as containing volatile organic compounds (VOCs) in ascending order for a total of 5 items are, white shellac, gloss lacquer, wood preservatives, varnish, and polyurethane. There are a total of 4 coatings with values exceeding both standards including spray paint which contained chromium exceeding both standards, some of which also contained CFCs (Chlorofluorocarbons) which are substances that can damage the earth's atmosphere and cause holes in the ozone layer; artificial dye with chromium exceeding both standards; natural dye with chromium within Thailand's green label standard but exceeding European Union standards which, under European Union and European Commission regulations, manufacturers using hazardous materials in the form of lead, mercury, cadmium and chromium must cease using such materials (Lewis et al., 2006). Because most chromium compounds are toxic and if the body contains excessive levels of chromium, symptoms may occur such as dizziness, severe thirst, vomiting, loss of consciousness and death due to kidney failure and urine toxicity, and; oil paint with lead exceeding both standards which can negatively affect the environment by means of biological accumulation and/or toxic contamination. Lead can enter into the respiratory system and absorb through the skin which affect humans by causing tiredness, loss of appetite, headache, and anemia. In high concentrations, it can cause paralysis of the limbs, abnormal brain functions, delirium, convulsion and then loss of consciousness.

4.2 Conclusion of Study Results on Maximizing Manufacturing and Energy Efficiency and Designs for Minimizing Waste Products

After testing for chemicals in rice stump coatings, the rice stump materials are used to design products with a primary focus on the community using sample groups from Ang Thong Province. Product lifecycle started from collecting/digging rice stumps within Ang Thong Province to reduce the burning and plowing of rice stumps as a way to utilize agricultural waste products, with manufacturing and sales in the province. Weaving was chosen as a primary method as it produced little waste, reduced the use of urea-formaldehyde and primarily used human labor as Ang Thong Province workers are proficient while impacts on method of work is minimized. This also helped to reduce energy and transportation usage as well as manufacturing costs, energy and resources while also resulting in few materials for recycling or elimination (Lewis et al., 2006). Examples of products designed are lamps, serving trays and women's handbags.

4.3 Conclusion of Study Results on Manufacturing at the Community Level

As for the test for differences in average population, the factors for 2 independent population samples are the groups of manufacturers and designers with questionnaires focusing only on the use of materials, manufacturing and product promotion for the community while questionnaires for the groups of designers and consumers focused only on attracting attention and natural materials without involving manufacturing. For this test, the author hypothesized that the average value for perceptions of environmental products from rice stumps for community economy of manufacturers would differ from that of designers and designers would differ from consumers. Based on the investigation of environmental products from rice stumps for community economy of the groups of manufacturers and designers, it was found that the opinions differed in terms of using materials with low environmental impacts and avoiding harmful materials while there were no differences in the opinions of designers and consumers. For the test for differences in average population for three groups which are manufacturers, designers and consumers, the questionnaires focused on opinions related to all 3 groups to find average values for perceptions of environmentally friendly products from rice stumps for community economy in each group that differed. In this test, the author hypothesized that the average values for perceptions of environmentally friendly products from rice stumps for community economy in each group would not differ. However, the results contradicted the hypothesis as there was at least one group with an average value for perceptions of environmentally friendly products from rice stumps for community economy that differed from those of other groups at a statistically significant level with details as follows:

The questionnaire results on environmentally friendly products from rice stumps for community economy showed that the opinions of manufacturers differed from those of designers and consumers in terms of appropriate sizes of products and whether the products have beautiful colors. As for whether the products are beautiful, the products are easy to use, the products promote environmental conservation, the products signify natural manufacturing, and the products can be easily eliminated after the end of lifetime, there were no differing opinions which were at a good level.

Based on the results of the study above, it can be concluded that differences in individual characteristics have an impact on the perceptions of environmentally friendly products from rice stumps for community economy. It can be said that cultural backgrounds, experience and motivation of each person will result in different perceptions. Therefore, the development of environmentally friendly products from rice stumps for community economy that can be linked to a better image of community business is directly related to the unique characteristics of consumers. In order for target consumers to become customers through perception, creating positive knowledge and affection of the products and community that ultimately results in a purchase, a way to convey meaningful messages that can stimulate consumer perceptions through stimuli is needed. Stimulants should be effective for consumers through unique product characteristics of environmental conservation as well as product designs with the environment in mind which must be done at the product development process. This is done by applying environmental requirements to each stage of product development toward sustainable development of the manufacturing paradigm (Conteras et al., 2009). And determining new environmental characteristics of the product with the potential to improve overall product quality in order to increase market performance and profits (Soriano & Kaebernick, 2000).

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