



BSAC

Eco-innovation from Reishi Mushroom Residue at the First Royal Factory, Fang, Chiang Mai

**Sponsored by
Doi Kham Food products Co., Ltd.**

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Abstract

Due to the unavoidable by-product of manufacturing process of producing concentrated reishi mushroom juice at Doi Kham Food Products Co., Ltd., the expensive mushroom cannot be fully utilized, and the residues are without any value. The goal of our project is to develop the most suitable plan for turning the reishi mushroom residue into a valuable product. Based on our evaluation of Doi Kham's expectations and needs of the Ban Yang community, we proposed 3 plans. Firstly, the Center of Analysis for Product Quality (CAPQ) will determine the chemical components from the residue. Secondly, the input reishi mushroom can be cut into small pieces to increase the surface area to obtain more concentrated juice. Lastly, the remaining mushroom after grinding will be turned into two new products namely noodle and paper. This paper can be reuse as packaging material.

Executive Summary

The Problem, Goal and Objectives

Reishi mushroom is an important Chinese herb that has a long history of over 2,000 years. It is well-known as a ‘mushroom of immortality’ and used for improving life expectancy. Moreover, the benefits of reishi mushroom have been proven in several researches, especially on boosting the immune system and having antitumor property. Doi Kham Food Products Co., Ltd. produces goods that contain high nutrients and reasonable price. These include reishi mushroom products, one of which is concentrated reishi mushroom extract with honey and lime. However, in the manufacturing process, after extracting the medical properties from the reishi mushroom, there are residues that are discarded without reusing. Due to the fairly high price of the reishi mushroom, Doi Kham company would like to fully utilize the reishi mushroom residues. Therefore, the reishi mushroom residues was used to turn into a valuable resource.

The goal of this project is to develop the most suitable and feasible plan for turning the reishi mushroom residue from the mushroom concentrated juice production process into a valuable product. To achieve this, five objectives were established.

1. To **study** the relationship between Doi Kham and Ban Yang residents.
2. To **explore** the production process of concentrated reishi mushroom juice
3. To **identify** the most effective technique to discover possible benefits in the reishi mushroom extracted residue
4. To **develop** plans to fully utilize the by-product of concentrated reishi mushroom juice production process.
5. To **produce and test** a prototype that utilizes the reishi mushroom extracted residue.

To achieve these objectives, we explored possible products from the reishi mushroom residue and identified the most suitable product for Doi Kham and local community. We also created a prototype to test its manufacturing process. Moreover, we took into consideration a suitable packaging which would help in the sale of the product and reduce the waste from the production line.

Methodology

To achieve the five objectives, our method consisted of three main steps which are: observation, development of plan for utilizing the reishi mushroom residue and creation of a prototype.

Firstly, to gain a better understanding about the reishi mushroom and to determine the components that are left in the reishi mushroom residues, we gathered the information from online databases. Next, during our field trip, we observe the manufacturing processes and the characteristics of the reishi mushroom. We also surveyed Ban Yang community, Doi Kham, their products, as well as the relationship between the community and Doi Kham to decide on a suitable solution for all parties involved. For this a semi-structured interview was conducted because this method can gather more thorough information on the direct experience of the interviewees. Our interviewees group are the sponsors, staff of the company and local people around the First Royal Factory in Fang.

Secondly, a development plan was created by first collecting data from both the aforementioned observers and interviewees. Then, the both sources of data were analyzed to find the most appropriate product for Doi Kham and the local community.

Lastly, a prototype was created according to the results of the first two steps. A pilot test was conducted to gather the information from the general public to find out people's opinions on the prototype and confirm the possibility of producing prototypes.

Key Findings

According to our study of Doi Kham and the local community, we have categorized our findings into five main topics according to our five objectives.

1. The relationship between Doi Kham and the local community.

The relationship between Doi Kham and local community can be considered as good, especially with establishment of the First Royal Factory Museum. We observed that the museum was attracting tourists to the Ban Yang community. At the museum, there is also have a Doi Kham shop which sells products from Doi Kham Company as well as products form the local people. However, we found also that there seems to be a conflict on the pricing of agricultural products. While Doi Kham believed that they bought agricultural products from local at the reasonable price, the local people think that the price is rather low. Also, there are many conditions when negotiating deals with Doi Kham. Furthermore, we found that although the local people are interested in creating new products from the reishi mushroom residue with Doi Kham, there are concerns regarding distribution channels and marketing. Thus, cooperation among local people in the community should be encouraged. People in the community have different styles of conducting business. Furthermore, only a few local enterprises have their own specialty food products. The main ingredient in the local food products is wheat flour. Previously, there used to be a group project that aimed to create jobs and sustainable living; however, the project was not successful due to conflicts among the local people.

2. The production process and residue of concentrated reishi mushroom extract.

Our project team visited the First Royal Factory and observed the production process of reishi mushroom extract with honey and lime. The temperature during the boiling process is approximately 95-98 degrees Celsius for 3 hours. The reishi mushroom tends to absorb water while boiling. At the end of the manufacturing process, the reishi mushroom residue of approximately 20 kg is left per month and would be transferred to a landfill. When the residue dries up, the mushroom however does not look any differently from how it looked like before extraction. The color is the same. The texture remains very hard and tough.

3. The most effective technique to determine the possible benefits in the reishi mushroom residue.

After we had obtained the information about the relationship between Doi Kham and Ban Yang community and also the production process of the reishi mushroom extract, the next step was to find out the components of the reishi mushroom residue. The most suitable techniques were selected using literature research, small-scale experiments, and interviews with university professors. We found two techniques from the literature research. These two techniques consisted of High Performance Liquid Chromatography and UV-spectroscopy. Secondly, we consulted with Associate Professor Noppamas Soonthornchareonnon who is an expert in this field at Mahidol University. We followed her suggestion to use the UV-spectroscopy technique to investigate the remaining polysaccharide in the reishi mushroom residue by sending a sample to the Center of Analysis Product Quality (CAPQ). Due to the

limited time CAPQ had, to ascertain our prediction we conducted our own test using a boiling technique. Our test consisted of re-boiling the residue to see whether the bio-active ingredients which has a bitter taste will appear. The result showed that after re-boiling, the bitter taste still remains. According to the results, the experiment indicates that there are bio-active components left in the residue.

4. The plan to fully utilize the waste produced from manufacturing concentrated reishi mushroom juice.

After gathering the information using both observation and interview, there are 7 possible products which are: animal feed, wooden board, tincture, tea, reishi noodle, reishi paper and extraction of chitosan as shown in **Table 1**. There are 2 main criteria to determine the suitability of each product. These criteria are time and technique. Regarding the time, the time required to produce each product must be suitable. As for the technique, we need to select the machine and the process to create products including terms of investment cost. Aside from these two main criteria, there are also other factors that will affect which product will be most appropriate.

Table 1: The summary of suitability of 7 possible products by using 2 main criteria: time and technique.

Products	Time	Technique	Remarks
Animal feed	✓	✓	The profit is low.
Wooden board	✓	✗	The amount of the reishi mushroom residue is too small.
Tincture	✗	✗	A high concentration of alcohol is required.
Tea	✓	✓	It cannot compete with other reishi mushroom tea product in the market.
Chitosan	✗	✗	The amount of the reishi mushroom residue is too small.
Reishi mushroom noodle	✓	✓	-
Reishi mushroom paper	✓	✓	-

5. The product prototypes and prototypes testing.

To come up with two possible products, we produced and tested the prototypes. The two prototypes were reishi noodle and reishi paper. First, we made homemade pasta with different concentrations of the reishi mushroom powder: 0%, 1% and 3%. Pasta noodle was selected because of its similarity to Yunnan noodle which is a traditional noodle made by the locals in the community. The powder that we added to the wheat flour is fine powder. In the pilot test, most people prefer 3% of the reishi mushroom powder mixed in the noodle due to its appearance that is similar to a whole wheat product but at the same time unique.

As for production of the reishi paper, we used the 90% rough powder which is left from the blender. For this product, we aimed to use 100% recycled raw material. By doing so, the paper can be fully degradable and environmental friendly. The reishi paper is light brown in color and the texture is similar to fibrous paper but stronger.

Recommendations

Firstly, to determine the possible benefits from the remaining residue, we recommend that Doi Kham should send the reishi mushroom residue to CAPQ to be tested.

Secondly, according to previous study, we suggest the dried reishi mushroom be cut into small pieces to increase the surface area of the reishi mushroom. This would help to extract polysaccharide from the residue more easily which could save the amount of time, labor and energy spent in the extracting process.

Lastly, after the reishi mushroom is grinded, 10 percent of the powder can be used in noodle making and the other 90 percent can be used for other products such as reishi paper. This will mean the company can move towards being a zero-waste company. The company can become an important role model for other waste manufacturing companies.

In trying to significantly increase the value of the production waste to produce reishi noodle, Doi Kham Company and the local people have to work together closely. Thus, this collaborative effort in the recycling the wasted mushroom residue will bring both parties closer furthermore strengthening the good relationship.

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Chapter 1: Introduction

The reishi mushroom has over 2,000-years-old history as a traditional Chinese medicine. In Chinese, the reishi mushroom is commonly called as ‘the mushroom of immortality’ and also considered as a superior herb for health. The history of the reishi mushroom is ambiguous. However, the first document to record about the reishi mushroom appeared in the Qin dynasty (221 B.C.-207 B.C.) when it was used as the medicine for an emperor and it was believed to be a medicine of immortality. After that reishi mushroom also appeared in ‘Compendium of Materia Medical’ (Li Shi Zhen, 1578) which is an important Chinese herbology book. In this book, reishi mushroom is mentioned as the herb that enhances the energy of life. It is beneficial for the heart and can gives its users a healthy life if taken routinely. In the year 2000, reishi mushroom was recorded in Pharmacopoeia of the People’s Republic of China 2000 that it can relieve coughing, dizziness, and heart palpitation. Furthermore, it is cancer-curing, anti-tumor, antioxidant (Bishop et al., 2015), anti-inflammatory and immunomodulatory (Liu et al., 2016).

Thailand has been growing reishi mushroom for commercial purposes for more than 20 years. The mushroom species was brought over from Japan as a gift, which is an expert cultivator of reishi mushroom (Department of agricultural, 1985). Reishi mushroom can be found in every part of Thailand, known by different traditional names, such as ‘Hed Kra Dank’. Because of its benefits and soaring prices, many people have tried to develop products from it. For instance, reishi tea, reishi coffee, dried reishi mushroom and many more.

Doi Kham Food Company Ltd., our project sponsor, mainly produces and develops food products. Their list of products concentrates on food, especially health-related ones. Doi Kham first started in 1964 after H.M. King Bhumibol visited Chiang Mai and noticed the problems facing the rural villagers in hilly regions. H.M. The King thus, introduced royal projects to create an alternative source of income for the villagers who were then relying heavily on opium production. After his visit, the First Royal Factory was established to solve the middleman problems for the villagers.

Furthermore, Doi Kham company has a product line especially based on the reishi mushroom such as Ganoderma concentrated drink. A major production site for this was set up at the First Royal Factory Fang, Chiang Mai. During the manufacturing process, the medical properties of the reishi mushroom was extracted by boiling in water to produce Doi Kham drinking products. The production process, however, generates a small amount of reishi mushroom waste. Even though the price of reishi mushroom is very high, the reishi mushroom residue is normally disposed in a landfill. Generally, it does not affect the community nearby because the landfill is situated far away from the community. However, some previous studies conducted by Doi Kham’s internship programs indicated a possibility that the reishi mushroom residue may still have some nutrients left (Supamongkol P., 2015). This suggests therefore an opportunity to fully utilize the leftover residue and study its financial benefit.

The goal of this project aims to develop the most suitable and feasible plan for repurposing reishi mushroom residue that remains after the production of concentrated juice, into a valuable or as a product resource. To achieve the goal, five objectives were established: the first objective is to study the relationship between Doi Kham and Ban Yang residents. Secondly, to search for the most effective technique to determine the benefits left in the reishi mushroom residue and thirdly, to explore the manufacturing process of producing concentrated reishi mushroom extract. Fourthly, our team was developed a plan to fully utilize the residues. Finally, the prototype was created, and a final test was made a sample population to learn of their opinions and preferences.

Chapter 2: Background

2.1 What is Reishi Mushroom?

Reishi mushroom (*G. lucidum*) is a plant in the family of Ganodermataceae. It is a large mushroom with a cap of liver shape or fan shape. The cap is dark to brown in color and has a glossy appearance and a wooden texture as shown in **figure 1**. The reishi mushroom is usually ten to twelve centimeters in diameter. Under the cap, there are many small holes that contains spores. It can be found in nature and generally grows on wood such as oak wood or maple (Lingzhi: From Mystery to Science, 2009). However, studies have found that most of the reishi mushroom in natural surroundings are not perfectly formed because of unfavorable environmental conditions. Nowadays, most of the reishi mushroom used for medical purposes are grown in closed farms system that imitate the natural conditions with strict control. There are six different types of the reishi mushroom according to their colors consisting of red, purple, green, white, yellow and black (American Herbal Pharmacopoeia Reishi mushroom, 2006). The most well-known and most often used for medical treatment worldwide is the red reishi mushroom.



Figure 1: Reishi mushroom

Source: <http://holistichealthmastery.com/the-most-important-herb-in-the-world/>

2.1.1 The components of the reishi mushroom

There are several components in the reishi mushroom: the mushroom contains 1.8% ash, 26–28% carbohydrate, 3–5% crude fat, 59% crude fiber, and 7–8% crude protein (Mau, Lin, and Chen, 2001). In addition, there are also a wide variety of other bioactive molecules which are the main contributors to the health value. Example of these bioactive molecules and their benefit are shown in **Table 2**

Table 2: Benefits of some components of reishi mushroom

Component	Benefits
Polysaccharide	Boost the immune system, anti-inflammatory, hypoglycemic, antiulcer, antitumorigenic and immunostimulating effects
Triterpenes	Anti-inflammatory, antitumorigenic, hypolipidemic activity, protect liver and reduce blood pressure, relieve allergies
Peptidoglycan	Control blood glucose level in the body
Nucleotide	Relieve pain and prevention paresis
Germanium	Immunopotentiating, antitumor, antioxidant and antimutagenic activities

Polysaccharide is one of the main bioactive components in reishi mushroom. Fungal mycelia cultured in fermenters is responsible for wide variety of polysaccharide in the reishi mushroom. These polysaccharides have glucose as their major sugar component with some modification in their side group (Lee, Lee, and Lee 1999; Bao et al. 2002). Polysaccharides are reported to exhibit a broad range of bioactivities, including anti-inflammatory, hypoglycemic, antiulcer, antitumorigenic, and immunostimulating effects (Miyazaki and Nishijima 1981; Hikino et al. 1985; Tomoda et al. 1986; Bao et al. 2001; Wachtel-Galor, Buswell et al. 2004). Reishi mushroom also consists of a matrix of the polysaccharide chitin which is indigestible by human body and responsible for its hardness (Upton 2000).

Another main bioactive ingredient in reishi mushroom is Triterpenes. Triterpenes is a subclass of terpenes and have a basic skeleton of C₃₀. In reishi mushroom, triterpenes structure is based on lanostane. Reishi mushroom is shown to be rich in triterpenes which gives it a bitter taste and health benefits, such as lipid-lowering and antioxidant effects.

Moreover, the crude fiber in reishi mushroom is in the form of chitin which can be extracted by different types of procedures. During extraction, chitin goes through a chemical reaction and is converted into its derivative known as chitosan. Chitosan has wide range of applications in agricultural use and as drug delivery substance.

2.1.2 The reishi mushroom and its residue in Doi Kham factory

Doi Kham uses the red reishi mushroom as the main component of its concentrated reishi mushroom juice. The reishi mushroom is extracted by a process called water-soluble extraction. This is a common technique to obtain active components from reishi mushroom. However, this manufacturing process also produce waste output when compared with the amount of input.

The mushroom residues produced by the First Royal Factory of Fang are bio-agricultural waste from the manufacturing process which takes place on average once a month. Dried and sliced reishi mushrooms are used for the juice production. The texture of the reishi mushroom residues are similar to the dried reishi mushroom before

extraction. After extraction, the reishi mushroom residue is disposed directly in a landfill.

2.2 The Local community

Aside from turning the leftover reishi mushroom into a valuable resource, this project also aims to create products which provides benefits to the local community. Although, there has never been any negative reports about the mushroom residue effects on nearby communities, still the reishi mushroom residue may have more use and the company would like to transform it into products which can enhance the quality of life for the local people. To achieve the latter, the local community needs to be studied as well.

The First Royal Factory is surrounded by a small village called Ban Yang. This village population is mostly made up of Chinese immigrants who came to Thailand during the year 1953 as a result of political issues in China. This village is well-known for being a Thai-Yunnan community as shown in **Figure 2**. Due to this background, people in this village has brought with them a variety of different cultural heritages such as languages, religions and cuisines. Most of the villagers are bilingual and work in the tourism industry or go abroad to work in Chinese-speaking countries such as Taiwan. This give advantages and opportunities for villagers to find jobs outside the village. However, this it is true of working-age people only. The remaining villagers are therefore mostly children and the elderly. With the uniqueness of Thai-Yunnan culture, the village produces many different kinds of products which reflect their ancestry or have been inspired by them. As a result, there are several local enterprises which mainly produced food and are selling their products all over Thailand or even import them to China. One of the famous products from this community is Yunnan style noodle.



Figure 2: Ban Yang community

2.3 Project Challenges

According to the information gathered from Doi Kham Company, the challenges can be separated into 2 main categories: one is the lack of technologies and the other cost of investment.

2.3.1 Technologies

At present, Doi Kham Food Product, Co. Ltd has 3 factories in Thailand which produce a lot of products daily. Each factory employs a different production method using different types of machineries. One of the requirements of Doi Kham is to create a new product whose production process will make use the existing machineries in its different factories. Doing so will help reduce cost and increase the profit for the company. In addition, the components of the residues that are obtained after the extraction and which are believed to have beneficial components need to be determined. So advance machinery may be necessary to produce detailed and accurate results. Without sufficient knowledge about the componential make-up of the residues, we cannot proceed successfully with our project.

2.3.2 Investment cost

The cost of investment is another main concern. Doi Kham's budget and the cost effectiveness or financial feasibility of the project need to be carefully considered. There have been different creative new products, and each time the financial factor has to be taken into account. The production cost of a new product should match the cost and budget of the company. There will be a cost for a specialist whose expertise in reishi mushroom will help us investigate the leftover nutrients. Most business companies focus on financial profits from a product because monetary gains are often regarded as the main purpose of conducting a business. Our sponsor expectation is to create a new product or turn the waste into a valuable resource. The new product should also be a food product because the existing machines in Doi Kham factories are for food production. To branch out into non-food products would mean investing in new technologies and new machineries which means overreaching the company's budget.

Chapter 3: Methodology

The goal of this project is to develop the most suitable and feasible plan for repurposing the reishi mushroom residue leftover from the company's production of concentrated juice, into more valuable or product resource. In order to accomplish our goal, we had set up five objectives as follows:

1. To **study** the relationship between Doi Kham and Ban Yang residents.
2. To **explore** the manufacturing process of producing concentrated reishi mushroom juice.
3. To **identify** the most effective technique to determine the possible benefits in the reishi mushroom residue.
4. To **develop a** plan to fully utilize the wastes produced from manufacturing concentrated reishi mushroom juice
5. To **produce and test** the prototypes that utilize reishi mushroom residue

The methods to achieve these five objectives can be summarized as shown in **Table 2**

Table 3: A summary of the methods to achieve in our five objectives

Objective	Method(s)
Objective 1: To study the relationship between Doi Kham and Ban Yang residents	- Semi-structured interview involving Ban Yang residents and Doi Kham factory's staff
Objective 2: To explore the manufacturing process of producing concentrated reishi juice	- Participant observation - Semi-structured interview
Objective 3: To identify the most effective technique to determine the benefits in the reishi mushroom residue	- Literature research - Data analysis
Objective 4: To develop a plan to fully utilize the waste produced from manufacturing concentrated reishi mushroom juice	- Data analysis
Objective 5: To produce and test the prototype that utilize reishi mushroom residue	- Prototyping - Pilot testing

1. To study the relationship between Doi Kham and Ban Yang residents

In order to design products that would benefit both Doi Kham and Ban Yang community, the relationship between Doi Kham and the community is one key factor that must be taken into consideration when proposing the ideas of utilizing the reishi mushroom residue. A semi-structured interview was used with both Doi Kham workers and Ban Yang residents to obtain opinions from both sides.

A semi-structured interview has an open framework that allows an interviewer to create questions during the interview. It is a less formal way of interview which perfectly

suits the local people in Ban Yang community. Using this method, we would gain insight knowledge from and about our target population.

First, we aimed to interview Doi Kham staff whose main responsibility is to work with the local community in order to obtain: the company point of view about the relationship between themselves and the local residents and the problem that they are facing. Then, we interviewed the residents who live near the factory who may be most affected by the factory as shown in **Figure 3**. We interviewed at least 10 households and villagers aged from 30 to 60 years old. The interview consisted of questions that would clarify the major problems that were being caused by the factory, how the factory affected their living conditions and what changes or solutions the villagers would like from the company. The questions and responses of these interviews can be found in **Appendix B**



Figure 3: An interview with a resident of Ban Yang community

2. To explore the manufacturing process of concentrated reishi mushroom juice

The manufacturing process of the reishi mushroom juice with 1% concentration was studied during the first field trip at the First royal factory in Fang, Chiang Mai using participant observation method. Participant observation is one of the commonly used data collection method in qualitative research. It is widely used because it is better to gain direct first-hand experience from the research location. The characteristics of the reishi mushroom residue were also observed, such as: texture, smell, and color. Once the characteristics of the reishi mushroom residue were recorded, we were able to decide the next step in handling these reishi mushroom residue. In other words, we were then able to decide on how to utilize the reishi mushroom residue and turn it into a resource. And consequently, we would be better able to determine the type of products which may be produce from these reishi mushroom residue. To gather more information, we conducted semi-structured interview with some members of staff from the Department of Manufacturing in the first Royal Factory (Fang).

3. To identify the most effective technique to determine the benefits of reishi mushroom residue

For this objective, literature research was required to identify available and suitable techniques to determine the leftover components.

The results obtained from the literature research were studied and used to determine each method's effectiveness according to separate categories such as time, cost and others. After that the results were used to reach a decision on what products would best suit the expectations of Doi Kham company.

4. To develop a plan to fully utilize the residue produced from manufacturing concentrated reishi mushroom juice

In order to develop a plan that would enable us to utilize the residue produced from reishi mushroom juice extraction, relevant data must be gathered. To gather such data, we studied the residue from the extracted reishi mushroom and interviewed people who live in Ban Yang community. Studying the reishi mushroom residue gave us first-hand information that we could use for an analysis and evaluation of the characteristics of the residue. Interviewing the local people provided us with more information from people who actually have direct contact with the waste in a greater amount of time and so have closer and more detailed knowledge. The information we received helped us to decide which products may be produced from the waste and which products are not practical in view of Doi Kham Company's requirements. Once the relevant information was obtained and evaluated, we would try to utilize this information and turn the residue into a resource which may lead to a new product. This product then will be presented to Doi Kham Company.

5. To produce and test the prototype that utilize reishi mushroom residue

In producing prototypes that utilize reishi mushroom residue, the product that we design have to be suitable for Ban Yang residents. After the prototypes are created, a pilot test will be carried out.

In order to test the prototypes, pilot testing was used to collect the data. Close-ended questions about the preference of the consumer were used. The results will indicate the potential of the new product in the market.

Chapter 4: Findings and Results

The results in this chapter are based on the aforementioned 5 objectives: the relationship between Doi Kham and Ban Yang residents, the manufacturing process of concentrated reishi juice, the technique to determine the benefits in reishi mushroom residues, the development of a plan to fully utilize the mushroom waste, and the pilot test of the prototypes utilized from reishi residue.

4.1 The relationship between Doi Kham and local community

In this section, data was obtained by interviewing and observing both Doi Kham Company and Ban Yang community. The data gave us working ideas and we reached a decision about an eco-innovation using the reishi residue.

Finding 1: The relationship between Doi Kham and Local community is considered to be good.

Doi Kham company is a social business company that originated from the Royal Project. Therefore, the relationship between Doi Kham and the local community is considered an important factor. We found that the problems of local people are under the care of Corporate Social Responsibility (CSR). In the past, Doi Kham Company had set up projects that developed traditional products from the local community with the main focus on adding more value to the local products. For example, the traditional soft cake flour 'Kao Soi Tad' (**Figure 4**). A local development program of Doi Kham introduced a new strawberry flavor for the soft cake. However, the flavor is not as popular as the traditional one.



Figure 4: The original 'Kao Soi Tad'

During a field trip, it was found that the First Royal Factory is an important local landmark of Ban Yang for tourists. The factory has created jobs for the local people. 90% of the workers in factory is a Ban Yang resident except the staff who came directly from Doi Kham Head Office. Additionally, there is the living museum located in Doi Kham Factory grounds. The museum exhibits the history of Doi Kham Company, the origin of factory as well as the traditional culture of Ban Yang community. This museum has attracted more tourists to the village than in the past. It also has workshops at weekends for tourists to learn how to make homemade jams. Some tourists especially come to learn the jam recipe in order build their own small business. There is also a Doi Kham shop which sells product from Doi Kham and the villagers. The relationship among Doi Kham and the local community can consider to be good -the living museum playing a major role in creating constant and mutual help between the two.

However, there are some conflicts between Doi Kham and local community. Most residents in Ban Yang community are farmers. Doi Kham buys agricultural products from local farmer in the amount that is needed in the manufacturing process. This accounts for a rather small amount when compared to a huge number of agricultural products that are produced by the villagers. This has led to some friction between Doi Kham and the local people. There was an instance when the production line had to suddenly stop after a remonstrance by the villagers. Moreover, some locals think Doi Kham offers too low of a price for their produce compared with other buyers. The relationship between the local people and Doi Kham is an important factor. They both depend on each other. While Doi Kham creates a job for the local people, Doi Kham also uses the resources that produced by local people.

Finding 2: Expectations of Doi Kham and the community are different.

The interview results showed that the expectations of Doi Kham and the local people differ. From Doi Kham's point of view, its main focus is to study of nutritional value in the reishi residue and to utilize the residue using Doi Kham's production line. For example, if the second extraction of reishi mushroom residue has the concentration of more than 0.3%, it is possible to be re-extract and use for their ready-to-drink product. Or it can be anything that could create opportunities or be useful for the local community. The limitation of the project is that Doi Kham products are mainly food products that must also be healthy.

On the other hand, the data gathered from interviews of Ban Yang residents, showed that the villagers are interested in a project that could turn the reishi mushroom waste into an eco-innovation. So, this raises concerns are about distribution channel and marketing. The local people are good at producing creative goods, but there is lack of good marketing, communication and distribution which can promote and deliver them to target consumers. Additionally, the agreement and conditions of consignment among them cannot be matched.

Finding 3: Cooperation among the local community should be enhanced

Ban Yang community is a Thai-Yunnan community that consists of various religions. Most villagers produce food products as a second source of income. However, as mentioned before, there is a lack of teenagers and working-age human resources. Most have moved to work in the tourism industry. Thus, only children and elderly people are left behind in the village. The results of the semi-structured interview with local people indicates that a cooperation among the residents in this community should be enhanced. Most have independent lifestyle. Moreover, only a few local enterprises have their own special products. However, almost all local people have enough income and live a self-sufficient life. For example, the owner of Kao

Soi restaurant reported that she produces 5 kg of noodle a day, and after the 5 kg are sold, she closes her shop. She does not produce more than 5 kg. She does not wish to expand her restaurant or produce more noodle although there is actually a higher demand than 5 kg a day. Furthermore, from the preliminary interview of Ban Yang's Headman, Mr. Krittipong Yawut, it is difficult for the villagers to work as a group. Since the past, there has been attempts to conduct group projects to create more jobs. However, these attempts fell through due to conflict among the villagers themselves.

A Summary on the relationship between Doi Kham and Ban Yang people

According to **Findings 1 to 3**, the relationship between Doi Kham and the local community is good. However, a better cooperation among local people themselves could help the whole community. We also suggest finding a compromise which gives equal benefits for Doi Kham and the local community. We observed that most local enterprise including Yunnan noodle makers (**figure 5**) who currently use wheat flour as the main ingredient, are interested to create the new products from the reishi mushroom residue if there is a commercial potential. Due to factors namely time limits, the sponsor's expectation and the nature of the local community, our team decided to focus on the specific local enterprises that are interested in products from the reishi residue and has a potential business-wise. If successful, the enterprise and the product will set an example for others and even develop their own products further. With achievement, the relationship between Doi Kham and local people will become even better. The project will also create more sustainable jobs for residents in Ban Yang community as well as add more value to their products.



Figure 5: Yunnan traditional noodle

4.2 The manufacturing process of the concentrated reishi mushroom extract

Through observation during a visit to the First Royal Factory at Fang, we obtained information about the manufacturing process. Also, we gained more knowledge on the characteristics and quantity of reishi residue.

Finding 4: The reishi mushroom was extracted by boiling in water and the waste after the production process was put into a landfill.

During the first visit of the First Royal factory, we studied the production line of concentrated reishi mushroom extract with honey and lime which contains the reishi mushroom as the main ingredient. The process is quite simple and common which mostly consisted of human worker. Video recording of the production line was not allowed but photographing of the machineries was allowed. Photos and notes were taken during the study visit.



Figure 6: The reishi mushroom was being boiled in the water

First, dried reishi mushrooms are obtained from the supplier. Then, the mushroom was put into the big filtered bag and boiled in the water for 3 hours at 95 to 98 degrees Celsius (**Figure 6**). After it had been boiled for 3 hours, it is mixed it with honey and a stabilizer to prevent the precipitation. Then, lime is added, and the mixture is left to cool down before being transferred into the glass bottles. Finally, a quality control is conducted by factory staff to check for any defect.

After the manufacturing process of reishi mushroom extract with honey and lime, the residue is treated by disposing it the company's own landfill. This landfill is located outside the local community. Incidentally, the same procedure also applies to another residue such as roselle.

Finding 5: The appearance of the mushroom waste was similar to the mushroom before the production process.

Reishi has a tendency to absorb water while boiling, so the weight of the reishi mushroom increased from 3.5 kilograms to 14 kilograms and it becomes darker in color shown in **Figure 7**. In order to prevent reishi residue from molding, the residue must be dried. So, Miss Angcana Malasam, Supervisor of reishi mushroom extract production process oversees the drying of the wet residue in an infrared oven which takes 3 hours. The dried residue is then stored in a dry and clean place. The dried residue is shown in **Figure 7 and 8**.



Figure 7: Reishi mushroom waste



Figure 8: The residue of the reishi mushroom after having been dried using an infrared oven

Dried reishi mushroom residues are hard and tough, hard to break and grind into powder. The texture is similar to wood with small pores under the fruity body. These characteristics are very similar to regular dried reishi mushroom. These similarities can create difficulty in separating the two.

Due to the fixed nature of the production process, the reishi mushroom residue from the manufacturing line cannot be reduced. The manufacturing process has been in use for a long time. Changing the process might increase the production cost. Moreover, the internship student's report suggests that the reishi mushroom extraction process can be given more time and done with higher temperature to get more polysaccharide from the reishi mushroom. Adding more time and higher temperature naturally increase the production cost, plus it requires more factory workers.

A Summary on the manufacturing process of the reishi mushroom extract

Data obtained from Findings 4 to 5 indicate that the Doi Kham factory cannot extract all the nutrients out from the reishi mushroom. The company chose to use the method that best suits its existing factory process. The literature method of extraction does not fit with its process even though it can extract higher concentration of the reishi mushroom extract. Moreover, there are some nutrients left in the reishi mushroom residue, but the factory cannot reprocess the residue. Therefore, recycling the residue rather than extracting more beneficial nutrients can be another solution to reduce manufacturing cost.

4.3 The most effective technique to determine the benefits left in reishi residue.

The most effective techniques were determined using literature research, small-scale experiments, and interviews with university professors.

Finding 6: There are several methods that can be used to determine the leftover components in the reishi residue.

The method used by the First Royal Factory is from the method found in scientific research. The factory boiled the sliced reishi mushroom in hot water for only 3 hours, but scientific research boil reishi mushroom powder for approximately 6 to 8 hours. According to the research, it is suggested that there are nutrients leftover in the reishi mushroom residue.

Another evidence regarding whether or not there are nutrients left in the residue comes from an experiment conducted by internship students of Doi Kham company which studied study about the amount of polysaccharide left in the residue. The amount of polysaccharide remaining was determined by boiling with ultrasonic heat at 60 and 95-degree Celsius for a different length of time. The amount of polysaccharide left in the residue was measured after extracting from the hot water. (Supamongkol P., 2015). According to this research, it also suggested that the reishi mushroom that was extracted with hot water, might have polysaccharide leftovers.

For more advance chemical structure, further research is required. High performance liquid chromatography (HPLC) is one method that can be used, but for specialists to interpret the results would take time and only a small number of researchers are capable to conduct a research in this matter.

Our group had a great opportunity to interview Associate Professor Noppamas Soonthornchareonnon who is a reishi mushroom expert at the Faculty of Pharmacy, Mahidol University. During our discussion, she suggested a UV-spectroscopy to investigate the remaining polysaccharide in the residue by reacting the sample to integrate chromophore compound into a sample. Moreover, the faculty that has full access to equipment and a specialist ready to conduct an identification. It normally takes a minimum of 15 working days and costs 3000 baht per sample when determine at the Center of Analysis for Product Quality (CAPQ) of Mahidol university.

A small-scale experiment was further conducted to determine whether the bioactive compound of the reishi mushroom residue can be extracted using ordinary household method which involves simple hot water extraction. The main active ingredients of reishi are polysaccharide and triterpenoid. However, only triterpenoid can be distinguished due to its bitter taste. While, the amount of polysaccharide can be determined only with more complicated scientific method. Our experiment started with separating the reishi mushroom into 2 portions, 10 grams each. For the first portion, the reishi residue was cut into small pieces. For another portion, the reishi residue was grinded into powder. After that, these two portions were boiled in 600 ml of hot water for 30 minutes and the liquid was tasted for bitterness. Boiling the residue for 30 minutes complies with the most common household method. The result of the experiment shows that the powder form of the reishi residue gave bitter taste while the small pieces of reishi mushroom did not give any taste. This bitter taste results from the triterpenoids that was extracted. In conclusion, using normal household method of boiling the reishi residue powder, one can gain triterpenoids. Nonetheless, the amount of the triterpenoids cannot be measured by this experiment.

4.4 The plan to fully utilize the waste produced from manufacturing concentrated reishi mushroom juice.

A plan is drawn up after analyzing all the data from the previous findings to determine the suitable way to for utilize the residue of the production line.

Finding 7: Due to the small amount of waste, the project should focus on the solution in small scale.

According to previous findings, three main factors indicated that a small-scale solution is the most suitable for turning the reishi mushroom residue into a valuable resource. The first factor is that the amount of the residue produced by the factory is quite small - only 20 kilograms per month. After manufacturing process, the residue is soaked in water. Due to its ability absorb water easily, the residue can become moldy. Thus, the residue should be treated as soon as possible or dried immediately and stored in completely dry place. Secondly, the high location of the factory. Transporting the residue waste involves high cost, is inconvenient and consumes a lot of resources. Using or converting the residue in the nearby community is more reasonable. Thirdly, the residue itself does not cause any significant negative effect on the factory or Ban Yang community. In conclusion, spending a large amount of resource - labor and money- to create new products in faraway places is not worthwhile. Thus, a small-scale operation appears to be the best plan due to these factors.

Finding 8: From gathered information, a number of possible products can be identified.

After analyzing data obtained through different methods, ideas were generated in order to determine the most suitable plan for using the reishi residue. Two criteria are used to determine the suitability of each product. The criteria are time and technique.

The time used for each product must be suitable for the duration of this project. Secondly, the technique or the machine required to produce each product has to be worth the investment. We were also aware that there could be other significant factors that will affect the suitability of the product.

The first idea is animal feed. For this, Doi Kham company does not have to invest in new equipment or machineries. The residue can be directly sold to animal feed producers or to farmers. However, only a small amount of income can be generated this way.

Reishi wooden or cardboard is another idea. Reishi residue is similar to wood and sawdust after blending. However, the reishi mushroom is extremely hard and tough, it requires a special blender to reduce its size into small pieces which Doi Kham company does not have. As a result, it will mean more investment for Doi Kham. In addition, the small amount of residue means it is not worthwhile sending the residue to elsewhere to be recycled or made into cardboards.

The idea of reishi mushroom tincture was generated from the manufacturing process which use only hot water to extract concentrated reishi mushroom juice. According to **Finding 6**, from our experiment, the possibility of having triterpenoid as a remaining component of the residue is high. The triterpenoid is one of the components which can be extracted by using high concentration alcohol and hot water (Chen et al. 1999; Su et al. 2001). This compound is well-known for detoxification, improving liver function and especially helpful for people who have liver cirrhosis. Therefore, adding reishi mushroom extract to alcoholic beverage can be one way to utilize triterpenoid left in the reishi mushroom residue. However, creating a prototype of this alcoholic beverage would involve brewing which is not suitable for this project since it requires a long period of time and high concentration alcohol.

Using the reishi mushroom as a raw material for chitin extraction is another idea generated during literature research. The reishi mushroom contains chitin as its main support structure. Chitin can be turned into chitosan which has a wide variety of health benefits. However, Doi Kham does not have enough information and technical support to convert chitin

to chitosan. Currently, there is no company that provides such support in Thailand. To explore and develop chitosan, it would require more research into this topic, and certainly very high investment cost.

After the residue is grinded into rough powder, two products are possible. The first is tea which can be made from the powder. Powder increases the surface area of the reishi mushroom. Thus, it is easier to extract its benefit when boiled with hot water. However, the reishi mushroom was already extracted in the manufacturing process, the remaining benefit is less than other reishi mushroom tea products which are currently sold in the market. Moreover, the resulting benefit is not certain when using ordinary household method to make tea.

Paper is another possible product and was thought to be suitable due to the hard and tough characteristic of the residue. We found that turning reishi residue into paper is not very complicated and the time required for paper production is within the limit required by Doi Kham. Furthermore, the paper that is created from reishi is 100% degradable and is produced entirely from organic waste. It will create less negative impact on the environment. This paper used as packaging would lead to a sustainable cycle and will benefit Doi Kham in long term.

Grinding does not only produce rough powder, it can also produce fine powder. This fine powder can be added to noodle flour. Our team observed that noodle is widely consumed among villagers in Ban Yang community and is produced by many households. Some noodle business actually offers different flavors including original, black sesame, dragon fruit, rice berry and egg. Of these flavors, rice berry and black sesame are the most similar to the reishi mushroom residue powder in terms of texture. Thus, ingredients used for these latter two flavors were selected and a cost comparison was made against reishi powder (**Table 4**). **Table 4** shows that the cost of these three ingredients are not significantly different. This small difference in their prices supports the possibility of adding reishi powder to introduce a new noodle flavor. The local enterprise which produces this noodle is interested working with this trial project. A prototype of the reishi noodle was then created.

Table 4: Comparison of the cost of three ingredients

Ingredients	Cost per 1 gram (Baht)
1. Sesame powder	0.2*
2. Riceberry	0.058**
3. Reishi powder	0.0377***

***Source:** <http://www.phoomtai.com>

****Source:** <http://www.dit.go.th/>

*****Appendix E**

To conclude, two products were found to be suitable. Both require grinding. Fine powder is used for reishi noodle which can be used in the local business. Rough powder is used for making paper to be used as raw material for paper packaging.

4.5 Product prototypes and prototypes testing.

After we came up with two suitable products: reishi noodle and reishi paper, we made the prototypes and tested them.

Finding 9: The prototypes of both the noodle powder and the paper were successfully created.

We focused on Yunnan noodle since it receives welcome support by the local business. Reishi residue is a biodegradable waste. The product that we test must be able to last for a period of time. Therefore, we made the pasta noodle which is similar to Yunnan noodle. The prototype consists of 3 different types of homemade pasta noodle. Each prototype has different content of powder: 0, 1 and 3 grams respectively. All prototypes contain the same amount of whole wheat flour of 100 grams. The steps of making the prototype can be found in **Appendix C**.

The results show that noodles that have 1 grams of the reishi powder content (**Figure 9b**) has smooth and still elastic dough which can set like to the regular dough without the reishi mushroom powder (**Figure 9a**). The noodle has an appearance like whole wheat pasta except there is small amount of reishi powder on the surface and no flagrant. After the pasta was cooked, no difference in taste, texture and fragrance was detected.

The noodle with 3 grams of the reishi mushroom powder content (**Figure 9c**), showed darker color. It also is a dough with less elasticity which make it hard to roll into pasta sheets. The cooked pasta still has little to no taste and smell of the reishi mushroom, but the texture is significantly different. The higher content of the reishi powder creates the powdery texture inside the noodle.

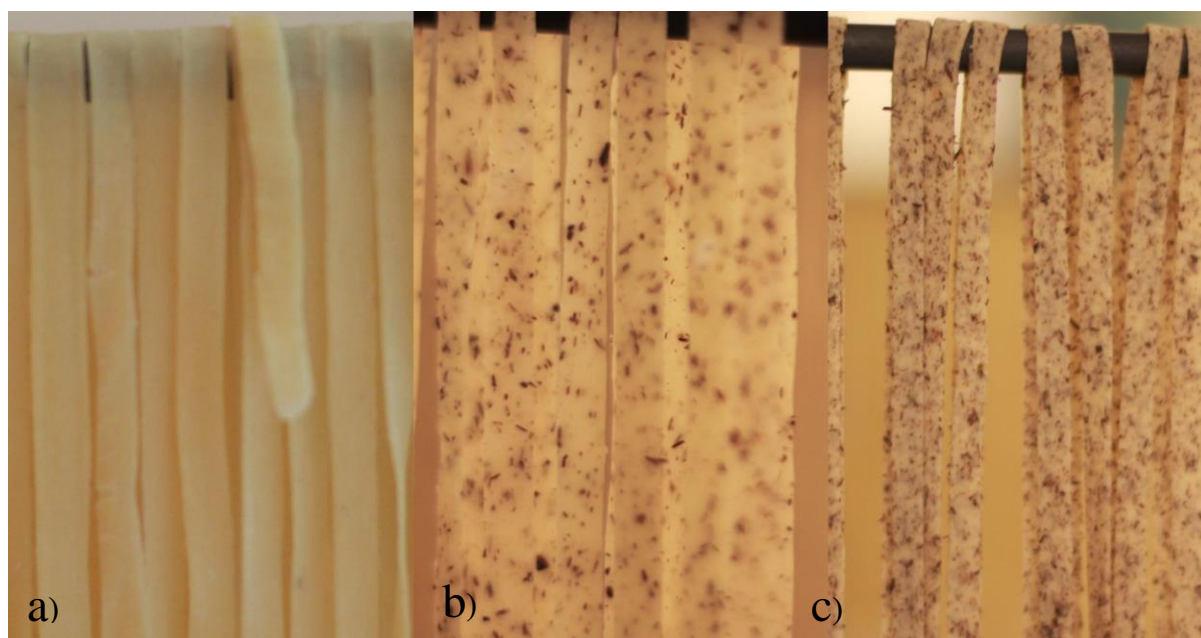


Figure 9: A comparison of the texture of the different types of noodle mixed with different amount of reishi powder (a) 0%, (b) 1% and (c) 3% by weight respectively.

After our team created the pasta prototype, there was rough powder left of around 90 percent. The blender could not to grind all the reishi waste into fine powder. So, we decide to make paper from the reishi waste by mixing in water and caustic soda. From that, after the mixture has been left to dry for 2 days, we obtained the reishi mushroom paper. The paper was dark brown in color on the front and has a rough surface as shown in **Figure 10a**. On the other hand, light brown color appeared on the back and it had a smooth surface since on one side it was

pressed on plastic sheets placed on the ground as shown in **Figure 10b**. Overall, the texture was hard. Furthermore, there was still the smell of the mushroom.

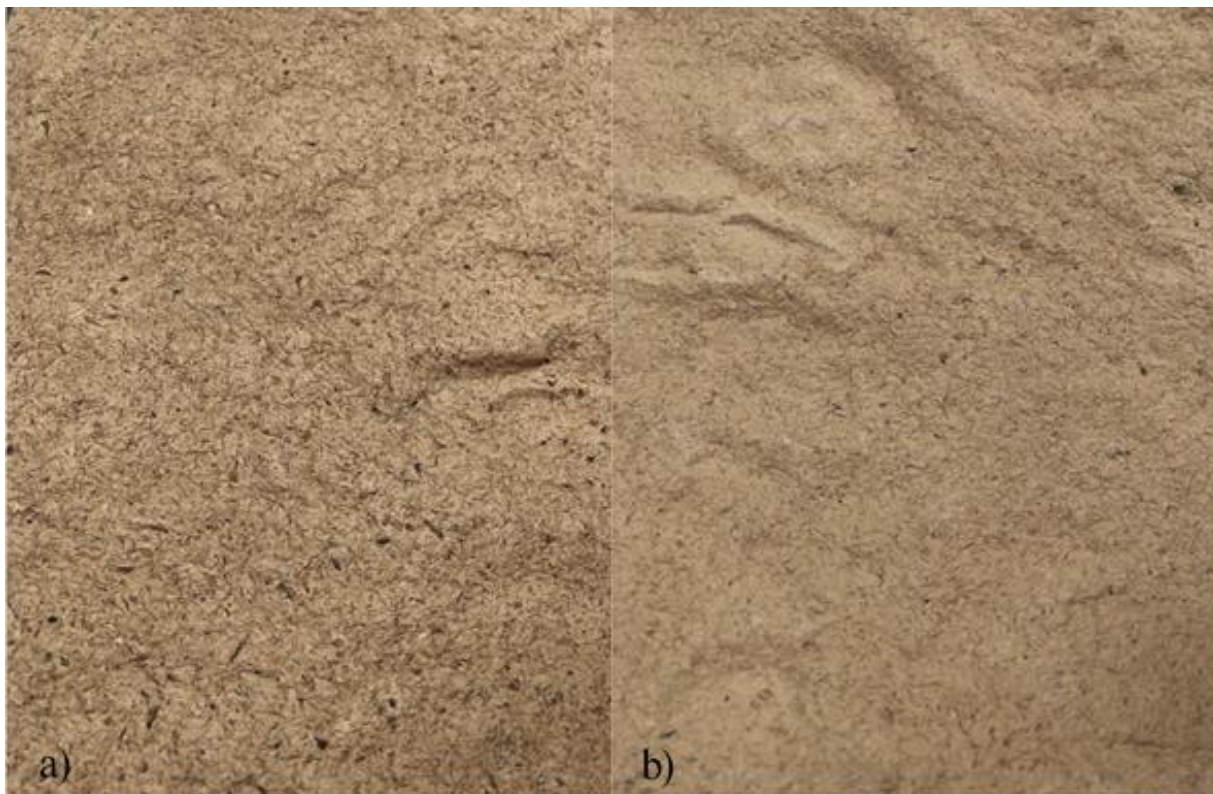


Figure 10: Two side of the prototype paper (a) the front side with rough surface (b) another side with the smooth surface

Finding 10: The participants who tasted our pasta preferred the noodle with 3% mushroom powder.

After the prototypes were produced, a small-scale pilot testing conducted to receive feedback from a group of people. This pilot testing was done to confirm that the noodle was edible and investigate the taste preference of the consumers. The respondents consisted of 30 people aged 18-24 years old who like rice or noodles. However, the respondents that we focused on are the noodle-lovers to eliminate negative bias that could come from rice-lovers. For the first question, we divided people in two groups to check whether the respondent prefer noodle or rice to eliminate this bias. This step lead to 5 rice-lover respondents being eliminated. Then, the team continued asking 25 noodle lovers another 4 questions to obtain feedback about the best noodle. These respondents were asked to the prototype according to: appearance, texture, smell-and-taste and overall satisfaction. The full set of questions can be found in **Appendix C**.

The result obtained showed that noodles with 1 grams of the reishi mushroom content is the most preferred one in terms of smell and taste even though most of the respondents said there was not any significantly difference between the three (**figure 11**). However, in term of appearance and texture, the majority of respondents prefer the noodle with 3 grams of the reishi mushroom with 48 percent of the respondents (**Figure 12 and 13**). It coincides with the overall satisfaction which shows a preference for noodles with 3 grams of the reishi powder (**Figure 14**).

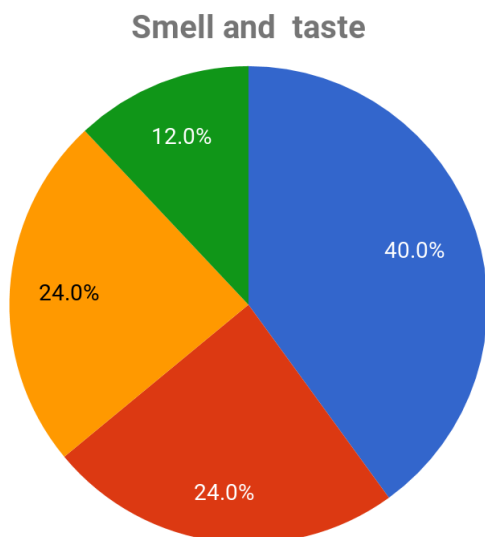


Figure 11: Smell and taste preference

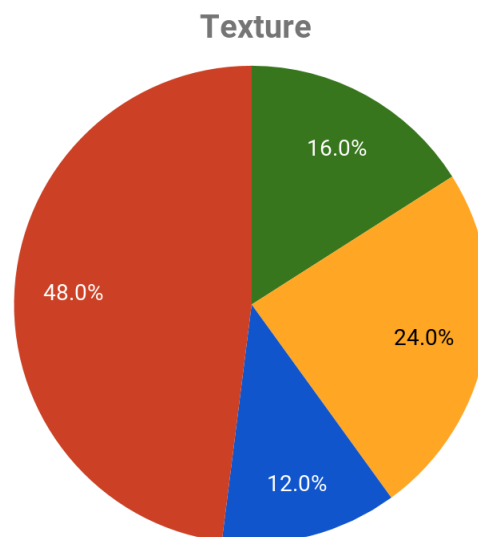


Figure 12: Texture preference

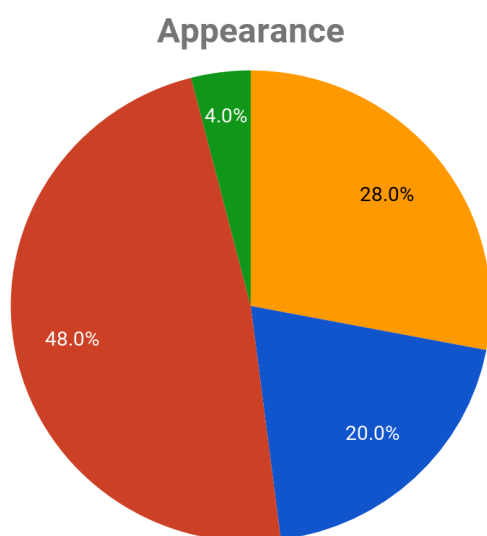


Figure 13: Appearance preference

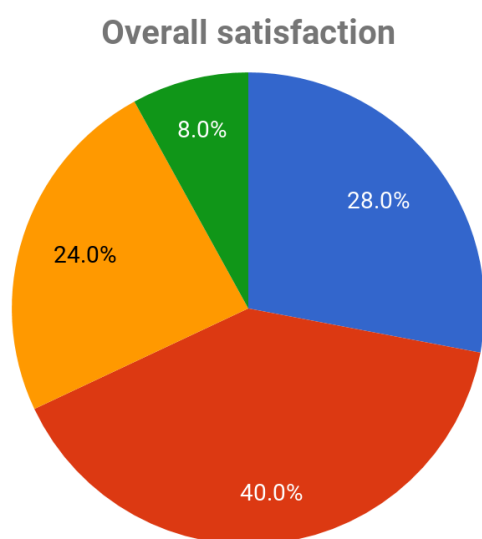
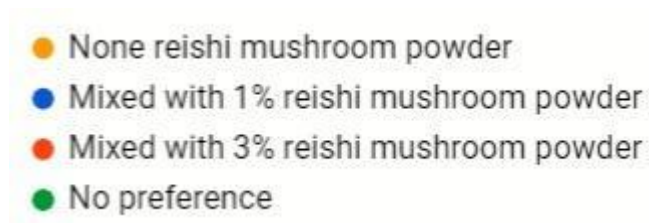


Figure 14: Overall satisfaction preference



In summary, out of the 3 types, the pasta with 3 grams of the reishi powder has the best appearance and texture. These characteristics of the pasta seemed to affect the overall satisfaction of our respondents even though the noodle with 3 grams of powder might not be the most preferred in terms of taste and smell.

Chapter 5: Recommendation

From our findings, our team has determined possible plans that suitable for the sponsor's expectation while maintaining the good relationship between Doi Kham and Ban yang community. There are 4 recommendations that we would show and suggest to Doi Kham. This chapter begins with the recommendation for determining the component that left in the reishi mushroom residue. Also, the effective process to second extract the reishi mushroom. Then, our team recommends the possible products from the reishi mushroom residue that suit both Doi Kham and the local.

5.1 The reishi mushroom residue can be sent to the Center of Analysis for Product Quality (CAPQ)

Previous researches on reishi mushroom components and manufacturing process found that polysaccharide is the main component of the reishi mushroom. The polysaccharide in reishi residue can be determined by the Center of Analysis for Product Quality (CAPQ) of Mahidol University. This analysis center was established for determining and analyzing product's qualities, especially herbal and medical products. To test the reishi mushroom residue, Doi Kham has to prepare two different samples of reishi mushroom extract: (1) approximately 10 grams of mushroom residue and (2) 10 milliliters of juice extract of 0.3 wt.%. The Center will conduct a comparison test. The analysis costs approximately 3,000 baht per sample and takes 15 working days. However, due to the large number of samples waiting to be tested, the center will be available in August 2018*.

5.2 Adaptation of some manufacturing processes can lead to higher concentration of polysaccharide from the reishi mushroom extraction.

According to **Finding 4** in **chapter 4**, we found that the reishi mushroom extract manufacturing process at Doi Kham uses hot water extraction method to produce. During the extraction process, the mushroom is boiled at 95-98 degrees Celsius for 3 hours. A large amount of water is needed to extract 1wt% of concentrated juice. However, from a previous study by Cheng P. G., in 2013, the concentrated juice was extracted by hot water extraction at 100 degrees Celsius. The extraction takes 6-8 hours. The method's aimed to extract the polysaccharides as much as possible. The mushroom was grinded into a powder form before the hot water extraction stage. In Doi Kham's case, it is possible therefore that there would be some polysaccharide left in the residue. To extract more polysaccharide from the residue, we recommend that Doi Kham cut the mushroom into the small pieces. This will increase the surface area which will come into contact with water and increase the amount of polysaccharide extracted.

* For further details, interested person may contact Center of Analysis for Product Quality (CAPQ), 447 Sri-Ayuthaya Rd. Rajathevi Bangkok Thailand 10400, Miss Monreudee, at Tel. number +668-6008-9979.

5.3 An eco-innovation product that involves local people's participation would benefit Doi Kham, the local community and at the same time is environmental friendly.

Following Doi Kham Company's main object to transform the reishi mushroom residue into more valuable resources, many possible products have been explored as seen in **Finding 8**. However, there are only 2 products that is suitable for Doi Kham which are the reishi mushroom noodle and paper. To create these 2 products, the residue needs to grind into powder form. After grinding, the powder will be separated into 2 types: one with 10% of fine powder and the other with 90% of rough powder.

The fine powder can be sold to the local community who can adapt it to use with their existing products and create kinds of noodle with new flavor and texture. According to **Findings 9 and 10**, it was found that the powder mixes well with wheat flour.

Apart from noodle making, the reishi mushroom powder can be adapted to create other products. Ban Yang village has many products that are made from wheat flour. These products can use reishi powder as a new ingredient such as in Kao Soi Tad, dumplings and samosas. To achieve this, Doi Kham and the noodle making businesses will work together. Both parties will then become role models for the Ban Yang community as a whole on how to fully utilize leftovers from other kinds of manufacturing processes as well.

Beside food products, the residue can be turned into other materials such as paper. In the grinding process, a large amount of reishi mushroom residue cannot be fully grinded into fine powder. We suggest that this rough powder can be reused to produce the reishi mushroom paper which can be used in product packaging. Interestingly due to its special textural property, the residue can also be used as protective wrapping material.

These are suggestions which will utilize the residue efficiently where no waste will be generated. This way Doi Kham will shift towards a 'zero waste' manufacturing line. This reishi mushroom paper can be presented as a role model of a concerted effort to reduce and reuse organic waste. This project can be implemented in other manufacturing lines. For example, at the First Royal Factory, there are other residues containing cellulose such as roselle and passion fruit. These residues can be reused as raw materials for producing paper. Thus, the company can further reduce waste from manufacturing process by conducting a project on how to fully utilize the waste.

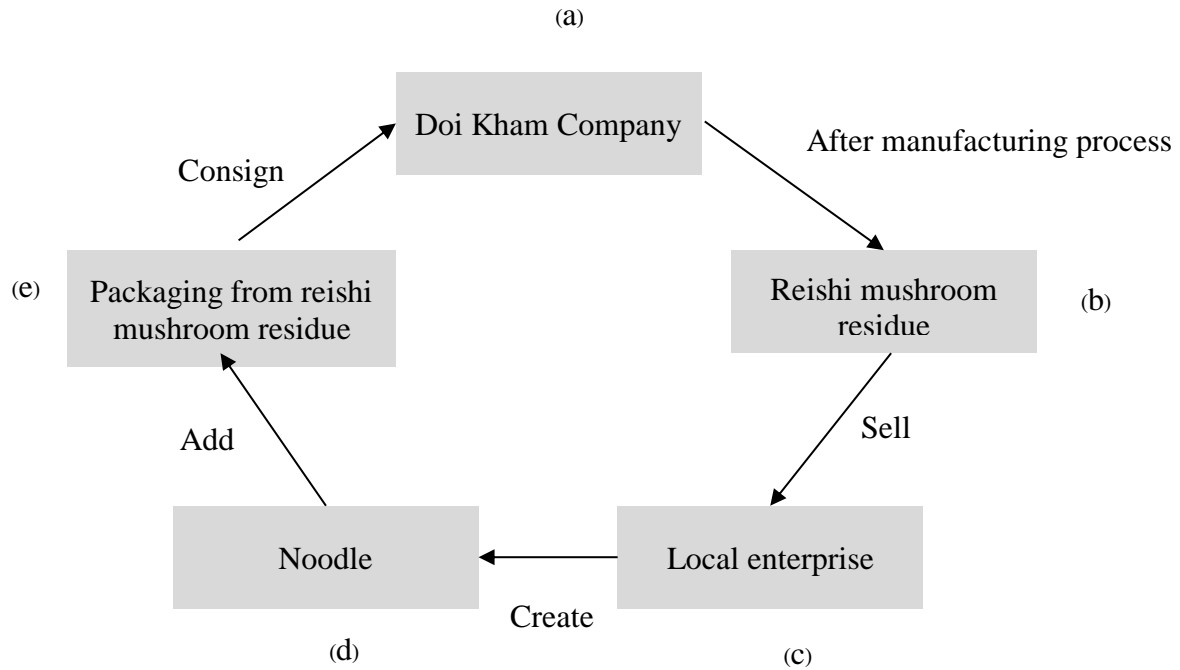


Figure 15: The optimal solution for the reishi mushroom residue

Figure 15 illustrates the optimal solution and explains the plan of our project. According to **Recommendation 3**, Doi Kham can grind and sell the reishi residue powder to local enterprises (**Figures 15b-c**). The local enterprise can add the powder to its existing local products. The noodle is one of the products that can use the reishi mushroom powder (**Figure 15d**). The existing noodle local businesses already have the experience and other practical supports in this area. For example: one shop has their own Facebook page, another has their regular buyer in a restaurant in Bangkok. Furthermore, one of the distribution channel nearer to home is of course at Doi Kham shop at the First Factory museum.

To produce the reishi mushroom residue paper, we suggest Doi Kham create sustainable product by packaging products (**Figure 15e**). In order to add a special value to the products, these can be available only from Doi Kham shop in order to add value to the product. This will show that Doi Kham has collaborated product with the local community and it can improve in both relationship with local people and image of the Doi Kham company. Moreover, this packaging support the recycle concept and it is environmentally friendly because it made from the reishi mushroom residue which is fully biodegradable. Therefore, it can attract more people who concern about the environmental which is a famous concept at these day. The attractive packaging will increase value and profit of the product as shown an example in **Appendix F**. Furthermore, the cost of the reishi mushroom pasta including packaging, it is approximately 27 baht/boxes as shown in **Appendix E**.

Conclusion

The reishi mushroom residue is unavoidable by-product of Doi Kham's concentrated reishi mushroom extract manufacturing process at the First Royal Factory located in Fang, Chiang Mai. To develop the most feasible and effect plan for repurposing reishi residue, we established 5 objectives which are: to study the relationship between Doi Kham and Ban Yang resident, to study the manufacturing process of producing concentrated reishi juice, to determine the most effective technique to determine the reusable benefits in the reishi residue, to develop a plan to fully utilize the reishi residue, and to create and test the prototypes that utilize the reishi mushroom residue. The study results show that the relationship between Ban Yang resident and Doi Kham is good and there are several local enterprises that are willing to cooperate with Doi Kham. Moreover, we found that around 20 kilograms of the reishi mushroom residue is produced each month. The mushroom residue is hard and tough. We are certain that there still are active ingredients in Doi Kham's reishi residue. So, we came up with three plans. Firstly, the residue will be sent for an analysis determine the amount of remaining benefits by using UV-spectroscopy. Secondly, the analysis results showed some beneficial components are not yet completely extracted out. So, to obtain the highest concentration, the residue should be grinded and extracted for a second time. Thirdly, to repurpose the final residue after extraction, we searched for a small-scale solution that is the most feasible and at the same time create co-operation between Doi Kham and the villagers of Ban Yang. We created reishi residue in powder form which noodle maker in the village can use to produce new flavor of noodle. The remaining rough powder was turned into hard paper. Thus, we were able to create two sustainable product prototypes which involve Doi Kham and the local businesses together, are economically feasible as well as environmentally friendly.

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Appendix

Appendix A: Interview with the sponsor

Questions

Expectation of Doi Kham

1. What is the expectation of Doi Kham?
2. Why do you concern about this particular waste?

Manufacturing Process of the concentrated reishi mushroom extract

1. How is the reishi mushroom is treated during the process?
2. How often is the production of the reishi mushroom juice?
3. How much waste is produced during the process?
4. How is the waste is treated?
5. How much does the waste treatment cost?
6. What is the characteristic of the reishi mushroom before and after the process?

Others

1. What is the relationship between Doi Kham and the local people?
2. Is there any related research about this topic that Doi Kham had been studied?

Appendix B: Interview with local community

Question

1. What do you do for living?
2. Is the current income enough for your well-being?
3. What is your life quality?
4. What is the relationship between Doi Kham and the local people?
5. How does the waste from the factory affect you?
6. Do you consider working with Doi Kham?
7. Do you interested about applying the reishi mushroom waste with your product?

Interview local people

Ban Yang's headman

Ban Yang community is a small community that contains approximately 250 family. Most of Ban Yang's residents are farmer which grow seasonal fruit such as lychee and longan; however, according to the change in weather, the agricultural products are decrease. Thus, the farmers should adapt their style of farming into integrated farming system. Furthermore, there are lack of teenager and working age because most of them move to work in the tourism industry as a guide. Also, some resident creates homemade food products as a second job in high season. Most of food products are the processed food such as fermented vegetable, Yunnanese noodle and Kao Soi tad.

Moreover, the lifestyle of Ban Yang community is independent. There is almost no cooperation among the local people as we can see from the previous experience when they tried to gather people to create a group project, the result failed because of the conflict between members.

According to the small size of community and lack of transportation, Ban Yang community is not as popular as the other well-known tourist attraction such as Doi Ang Khang. In the past, the Ban Yang's headman attempted to promote the community through several media to attract tourist. however, the attempt was not successful because that the tourist only travels to only several businesses in the community.

The relationship between Doi Kham and local people, many residents work part-time in the first royal factory. Doi Kham also bought the agricultural products from the local people in a limited amount but this amount is small compared to the large amount of the agricultural products per season. In the local people perspective, they want Doi Kham to buy all of the agricultural products and distribute to the town because it is more convenient for them to sell directly to Doi Kham factory. However, most of agricultural products are sold through the middle mans.

Mr. Suay (villager)

Most people living in the Ban Yang community is Yunnan people and work as farmer. In this recent year, the amount of agricultural product is decreasing due to the change in weather. Therefore, many people started to have a second job or own business such as processed food products. Ban Yang community has small number the teenager and middle-aged man because they went to work out of the village after they graduated. In the past, the agricultural products in this community were sold to Doi Kham company such as oranges and lychee.

Nowadays, lychee is not popular for selling because the price is decreasing. Moreover, in this community, there is no reishi mushroom cultivation. If the reishi mushroom can be turned into more valuable products or something new, they will interest. But they want the marketing channel to distribute their product.

For the relationship with the Doi Kham company, in the past, there was a conflict with the company about water pollution, but the company already solved it.

Mrs. Usa (villager)

Mrs. Usa is a farmer who own the local enterprise. Her enterprise sells variety of products including dried bananas, tea and the famous Yunnanese noodles. She already has strong distribution channel which sell her product via store and online method across Thailand and even China.

Konjac noodles' owner

This local enterprise is very famous for their konjac noodle. The noodle itself has several flavors including original, black sesame, rice berry, dragon fruit and egg flavor. This enterprise has industrial machine which can make large amount of the noodle. The production method starts from mixing flour with the flavoring. Then, the mixture was threshed and rolled several times. After that, the dough was put in rolling machine then cut it into noodles. The noodle was hang and rest until it dried enough to be cut and packed up into its package. If buy directly at their factory, the noodle cost 35 baht per one bags.

Khao Soi Tads' owner

Khao Soi Tad is one of the famous local enterprise in Ban Yang community. Owner of this local enterprise make Kao Soi Tad as her main occupation, and she has growth lychee as her second source of income. There are several distribution channels for this local enterprise. Moreover, she not only sells the original flavors of Khao Soi Tad but also creates the new flavors of it such as strawberry and passion fruit flavor. However, the best seller flavor is the original one. She said that she is interested in the product from the reishi mushroom residue, but she is concerned about the bitter taste of the reishi mushroom.

Khao Soi noodles' owner

The owner sells Khao Soi as main job, she is happy about her current situation where she only sells Khao Soi in limited amount and does not want to produce more e.g. on weekday she only produces 2 kg of Khao Soi noodle and after she runs out of the noodle, she will close the shop.

Appendix C: Pilot-testing questions for the reishi mushroom pasta

Questions

1. Do you prefer rice or noodle?
2. Which concentration of reishi mushroom powder do you prefer in terms of smell and taste?
3. Which concentration of reishi mushroom do you prefer in terms of texture?
4. Which concentration of reishi mushroom do you prefer in terms of appearance?
5. Overall satisfaction: which concentration of reishi mushroom do you consider as the best?

Appendix D: The making process of the reishi mushroom noodle and paper

The making process of the reishi mushroom noodle

Ingredients	Amount
Wheat flour	100g
Olive oil	½ tbs
Salt	½ tps
Egg	1 egg
The reishi mushroom powder	1g and 3g

1) Mix the wheat flour, salt and the fine reishi mushroom powder until evenly distributed. Then, use your fist to make a well in the center.



Prepared ingredients

2) Crack the eggs into the well, then add olive oil; the hole will hold the liquid.



Crack the eggs into the well

3) Gradually mix the egg mixture into the flour using machine or fingers of one hand, bringing the ingredients together into a firm dough.



Making the dough

4) Knead the dough until smooth and elastic. Then, wrap the dough with a little damp cloth for and leave for 30 minutes. Next, roll out the dough.



Rolling the dough

5) Cut the dough with a pasta rolling machine and it with heat.



Cutting the dough

5) Dry the reishi mushroom pasta for 1 day.



Dried reishi mushroom pasta

The making process of the reishi mushroom paper

Ingredients	Amount
Caustic soda or sodium hydroxide	40g
The reishi mushroom powder	200g
Water	900ml

Equipments	Amount
Bowl	1
Scale	1
Corrugated Plastic	1
Blender	1
Filter Cloth	1

1) Weigh 200g of the rough reishi mushroom powder, 40g of caustic soda and 600ml of water. Mix all ingredients together in the bowl and boil for 30 minutes.



Boiling the reishi mushroom powder with caustic soda

2) Wash the mixture with water for 5 times to clean off the caustic soda. Then, pour into the blender. Add 300 ml of water and slowly blend until the mixture becomes dark brown homogeneous in consistency.



Wash with water

3) Pour the mixture through the filter cloth and dry for 1 day.





Dried reishi mushroom paper

Appendix E: The cost of making the reishi mushroom noodle and paper

The cost for the reishi mushroom powder

1. Grinder: 15,900 Baht

- Depreciation cost for grinder= 265 Baht/month*

*Assumed selling price as 0 Baht and expected usage life is 5 years

2) Dried the reishi mushroom residue by infrared for 3 times = 390 Baht

$$\text{Depreciation per annum} = \frac{(\text{Cost} - \text{Salvage value})}{\text{Useful life}}$$

3) Electricity cost for grinder

= 9.93 Baht/time

4) Total number of grinding: 10 times, electricity cost

= 99.3 Baht

Total: 99.3 + 390 + 265

= 754.3 Baht per 20 kg.

Thus, the production cost of the powder totals

= 0.0377 Baht/gram

The cost for the pasta

Ingredients	Amount	Cost (Baht)	Note	Total Cost
Wheat flour	1 kg	21	0.021 Baht/g	2.1 Baht / 100g
Olive oil	5 liters	1,450	0.29 Baht/ml	0.725 Baht / ½ tps
Eggs	30	110	3.6 Baht/egg	3.6 Baht /egg
Salt	500 g	6	0.06 Baht/g	0.15 Baht / ½ tps

1) Pasta 60g = 3.6 Baht

2) Reishi mushroom fine powder 1 g = 0.0377 Baht

Thus, Total: 3.6+0.0377 = 3.64 Baht

The cost of making paper

Equipments	Unit	Cost (Baht)	Note	Total
Caustic Soda	1000 g	50	0.05 Baht/g	170 g/8.5 Baht
Bowl	1	285		
Corrugated Plastic	49x65 cm	36		
Blender	1	1,100	550 W	Electricity cost = 0.109 Baht
Filter Cloth	1	60		
Water	0.5 m ³	4.75 Baht		

1) Grinder: 1,100 Baht

- Depreciation cost for grinder: 18.33 Baht/month*

*Assumed selling price as 0 Baht and expected usage life is 5 years

2) Paper cost: Caustic Soda + water + electricity + reishi mushroom rough powder (100g) + depreciation cost of blender

Total cost: 8.5+4.75+0.109+3.77+18.33 = 35.459 Baht for 5 pieces of A4 paper

Cost / piece of A4 paper = 7.0918 Baht

Costs of Prototype

1) Pasta = 3.6247 Baht/ 60 g

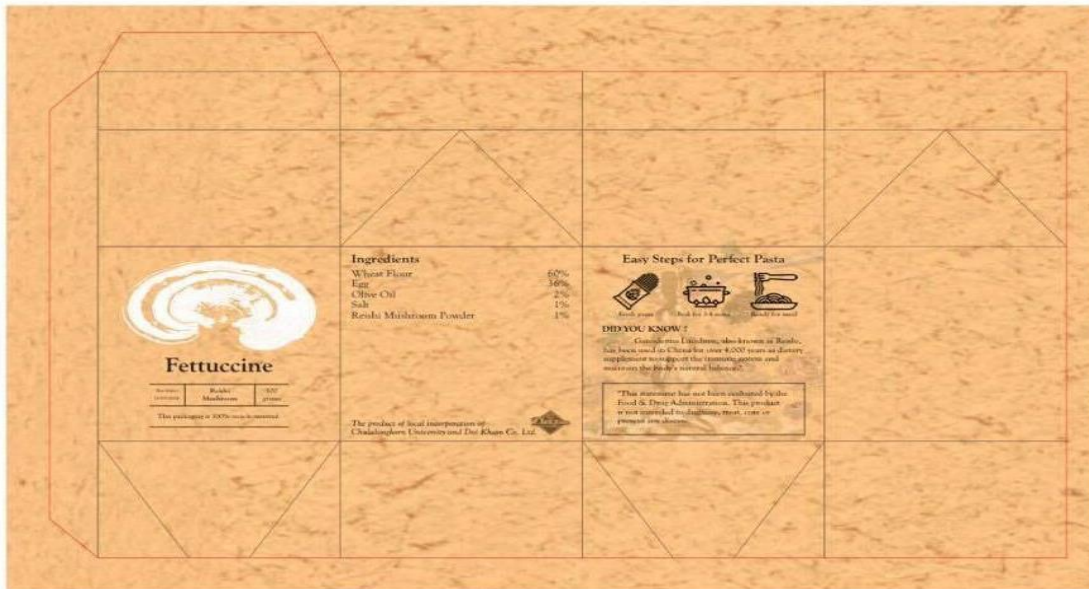
2) Paper = 11.82 Baht/piece

3) Plastic: 8x12 inches = 120 Baht for 170 sheets, 1.42 Baht/bag

4) Laser cut: 1 model = 10 Baht

Total cost = 26.86 Baht

Appendix F: Prototype packaging design



Packaging design



Actual packaging