Tampere University of Applied Sciences

Low-tech mushroom production

Hang Nguyen

BACHELOR'S THESIS
November 2019

Degree Programme in Energy and Environmental Engineering

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Degree Programme in Energy and Environmental Engineering

HANG NGUYEN:
Low-tech mushroom production

Bachelor's thesis 33 pages, appendix 0 page
November 2019

The thesis work was commissioned by Helsieni Oy, which is a mushroom production company in Helsinki, Finland. The thesis answered two research questions: how mushrooms were cultivated industrially and whether exotic mushrooms could be produced in Finland.

While one of the two purposes of this study involved acknowledgement of the procedure of low-tech mushroom production in small-farm scale, the other purpose was to acquire the success rate of growing exotic mushrooms from Asia under Finnish climatic conditions.

The study was conducted with two approaches accordingly with two research questions. To answer the first research question, the method was to participate a short intensive course with field trips to medium-sized mushroom production units in Vietnam. To answer the other research questions, the testing was performed under supervision of Helsieni Oy in Vantaa, Finland with three types of mushroom: Oyster mushrooms, Lingzhi mushrooms and Big Cup mushrooms.

It was found that there were six main phases in mushroom production process, which were: substrate preparation, pasteurization/sterilization, inoculation, incubation, fruiting and harvesting respectively. The testing illustrated that out of three types of tested mushrooms, Oyster mushrooms were the fastest and most economical mushroom type to grow, while Big Cup mushrooms were quite the opposite.

The findings indicate that even in small-scale or large-scale production, these main phases of mushroom production remained somewhat the same. In addition to that, the testing results reveal that exotic mushrooms from Asia can be produced in Finland. Considerably more time should be put in the testing to gain more findings for further analysis.

Key words: mushroom, production, testing, phases, exotic, Helsieni Oy

CONTENTS

ABBREVIATIONS AND TERMS

°C	Celsius degree
$CaCO_3$	calcium carbonate
CH_2O	formaldehyde (formol)
cm	centimeter
g	gram
GEPC	European Mushroom Growers' Group
L	liter
NIH	National Institutes of Health
Oy	osakeyhtiö (in Finnish), limited company (in English)
U.K	United Kingdom
U.S	United States

1 AIMS

The thesis work was done partially for a Finnish company «Helsieni Oy», whose services included: production of fresh oyster mushrooms in capital areas (Espoo, Helsinki and Vantaa); global sale of mushroom growing kits; and educational workshops for individuals or organizations.

The work answered two research questions:

- How are mushrooms cultivated industrially?
- Can exotic mushrooms from Asia be cultivated under Finnish climatic conditions?

The aims of the work consist of gaining in-depth knowledge about traditional mushroom production with literature review and practical experience (1) and testing growing possibilities of exotic mushrooms from Asia in Finland (2). Moreover, the thesis should be a reliable source of information on mushroom production guidance.

2 LITERATURE REVIEW

.

2.1 Mushroom production

Mushrooms are commonly acknowledged as vegetables; however, they are not entirely plants (What is a mushroom?). They indeed belong to fungi world. Fungi, which is the plural form of word *fungus*, are one of the most abundantly widespread species on Earth with about 144 000 discovered species of organisms, including molds, yeasts, smuts, mildews, rusts and mushrooms. They are distinctive for two principle modes. The first one is the principle of vegetative growth: growing from tips of filaments into mycelia and the second one is their nutrient intake: digesting externally organic matters then absorbing them into mycelia. Many of them that are often found in soil or water, are known to be very essential to the ecosystems and medical usage. (Ahmadjian, Alexopoulos & Moore.) Mushrooms are not an exception, yet they contain several significantly good vitamins and minerals that are commonly found in meat, beans and grains (Mushroom nutrition). The general nutrition facts of many kinds of mushrooms can be found in table 1 below. It should be taken into notice that table 1 illustrates the general idea of which minerals and vitamins that several edible mushrooms possess, not to any specified type of mushroom. In addition to that, mushrooms in Asia have been long used to cure disease and boost the immune system, also known as herbal medicine (Asian Mushrooms – More Mushroom History).

TABLE 1. Mushroom benefits (Mushroom nutrition; NIH, modified)

Vitamin/Mineral	Commonly found in	Function
B vitamins	Meat, wholegrains, fruits, eggs and dairy products	Energy provision to subdivide proteins, fats & carbohydrates
		Nervous system being affected
Dietary riboflavin (vitamin B2)	Eggs, organ meat, milk, nuts, green vegetables, bread and grain products (Riboflavin)	Hormones production
		Nervous system being affected

Niacin (vitamin B3)	Animal-based foods, nuts and grain products (Niacin)	Maintenance of healthy red blood cell
Pantothenic acid (vitamin B5)	Almost all plant- and animal-based foods. Richest sources are beef, chicken, organ meats, whole grains and some vegetables (Pantothenic Acid)	Efficiency control of digestive and nervous systems
		Healthy skin maintenance
Selenium	Seafood and organ meats are richest source (Selenium)	An antioxidant to protect body's cells
Ergothioneine	Red beans, black beans, kidney beans, oat bran, liver and king crab (Mushrooms are good sources…)	An antioxidant to protect body's cells
Copper	Richest sources include shellfish, organ meats, nuts, chocolate and whole-grain products (Copper)	Red blood cell production
		Healthier bones and nervous
Potassium	Fruits, vegetables and nonalcoholic beverages (Potassium)	Control of blood pressure
		Elements to help nerves and muscles function properly
May have beta-glucans		Under investigation

The mushrooms selling at the supermarkets are literally the fruiting bodies of the whole fungus. In nature, almost everything happens underground, when mushrooms live as mycelia. They need to reach certain favorable weather conditions to start fruiting, normally during spring and fall. (At What Time of…) However, with modern technology, the weather conditions including temperature, lighting, nutrients input, water input, humidity and clean atmosphere can now be controlled by the help of technology and machinery so that mushrooms would be cultivated all year round with stable productivity, controlled diseases and diminishing usage

of chemical pesticides. (Sánchez 2004, 756.) It should be taken into notice that transgenic mushroom strains are not yet available for commercial use. Instead, there are some institutes and private sectors are providing mushroom strains for mushroom production units. In Europe, some of the most common names include Ann Miller's Speciality Mushrooms Ltd (U.K), Amycel (The Netherlands), Myclelia (Belgium) and Sylvan Inc (U.S).

Mushroom production started in China 600 years A.D with artificial inoculation of twigs with wood-ear mushrooms. Meanwhile in Europe, it started in Paris with button mushrooms 300 years ago under the ruling time of Louis XIV. Mushroom production has now spread to all continents of the world with the distribution portions that can be seen in figure 1. Commercial mushroom cultivation, most of the times, depends hugely on agro-forestry wastes raging from straw, sawdust, tree leaves to several husk types. There is no limit with waste recycling, in fact, mushroom cultivation on lignocellulosic wastes generated through forestry, timber industries and several agro-industries, proves to be one of the most economically and cost-effectively organic recycling processes nowadays. (Rühl & Kües 2007, 556-558.)

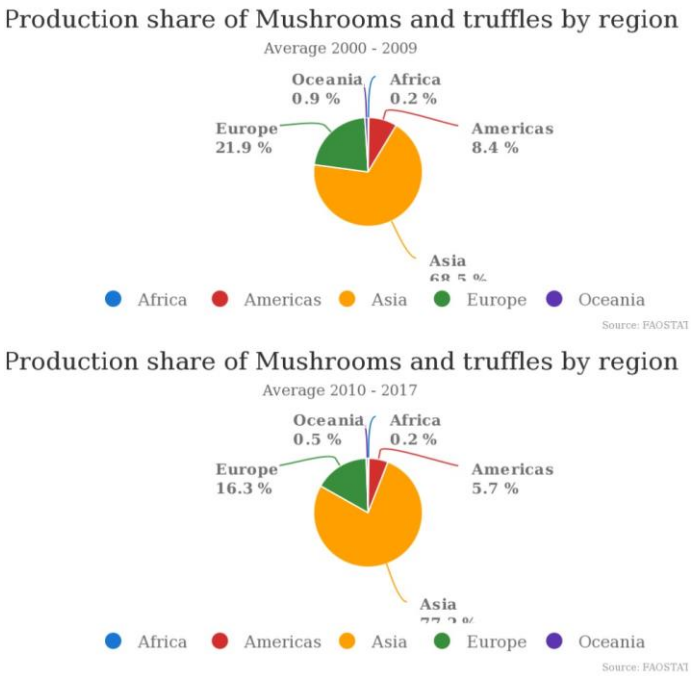


FIGURE 1. Continental distribution of mushroom production 2000-2017 (FAOSTAT, modified on 22.06.2019)

It is clearly illustrated in figure 1 that Asia was the leader of mushroom production since the beginning of 21st century, while Europe took the second place in this industry. There was a huge increase in distribution portion for Asian areas with almost 10% gap between the first decade (68.5%) and the second decade (77.3%) of 21st century. Meanwhile, Americas was the third player in the industry with a fairly small portion of less than 10% for both first decade of 21st century. Lastly, Oceania and Africa rarely produced mushrooms with less than 1% production share for both continents. According to figure 2, the world top 5 mushroom producers in 2014 were China (Asia), Italy (Europe), the U.S (Americas), the Netherlands (Europe) and Poland (Europe).

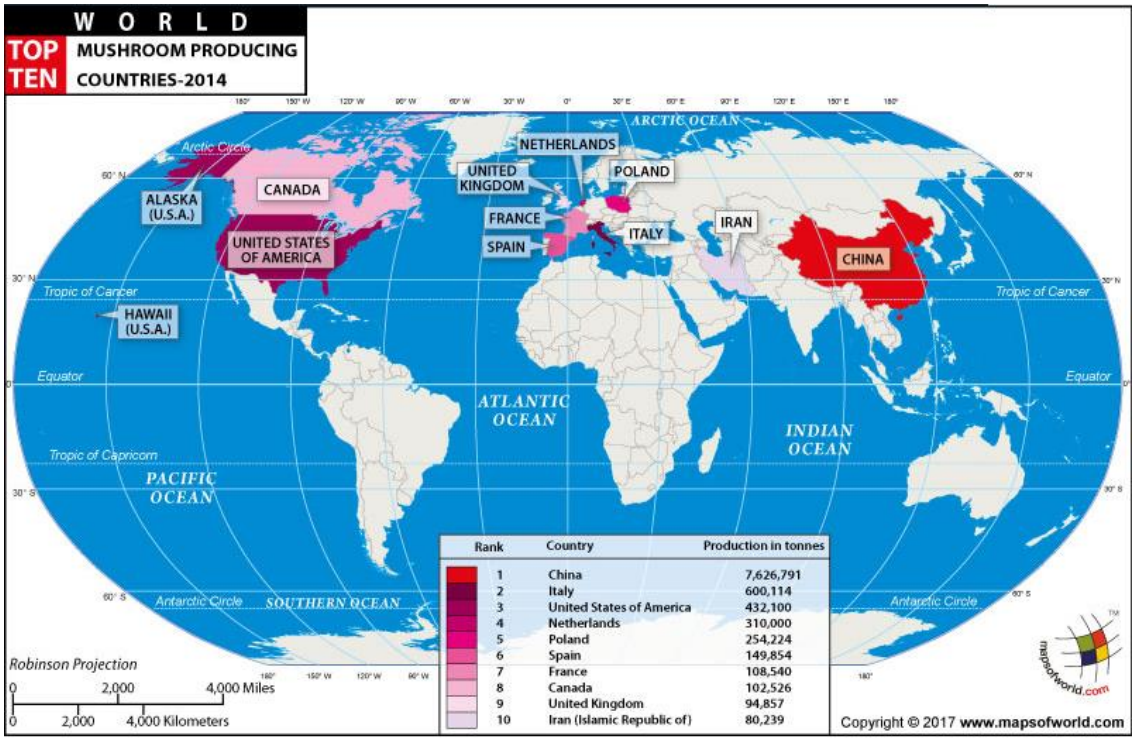


FIGURE 2. The world top mushroom producers in 2014 (www.mapsofworld.com)

According to statistics from GEPC, 10 of its member countries stood for 90% of the total European production of mushroom, which can be seen in figure 2 with 1,119,600 tons – feet cut. In addition to that, 65% of the products went to end-users and the rest 35% went to processed market. (European Mushroom Growers' Group.) As can be seen from figure 3, Finland, however, was not yet a huge player in mushroom production industry. Meanwhile, according to a survey of participation in mushroom picking in Finland in 2004 conducted by a group of experts from University of Helsinki, the statistics showed that 2/3 Finns (age 15-

74) had skills to pick wild mushrooms. The study also represented regarding Everyman's right in Finland, wild mushroom picking was a part of Finnish culture and at the same time, a traditional outdoor activity. (Sievänen, Pouta & Neuvonen 2004, 2-7.) Noted that Finland is Europe's most heavily-forested country with 74.2% of land area being forests (Finland – Forests and Forestry).

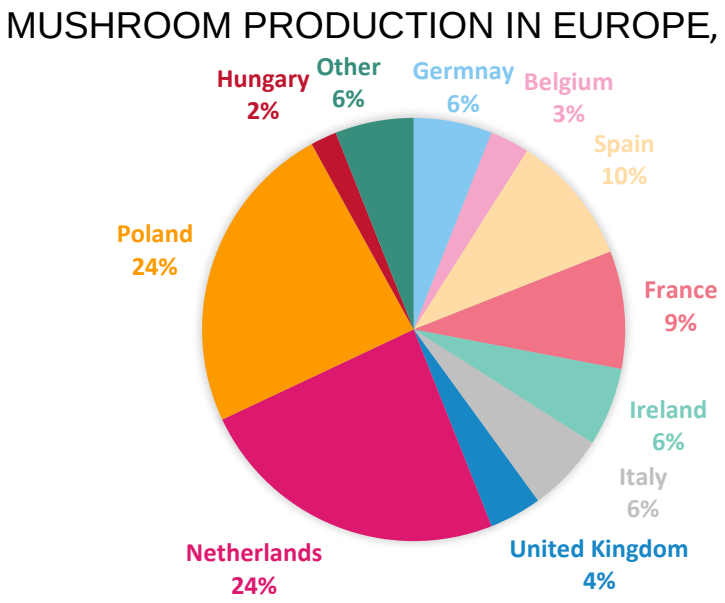


FIGURE 3. European mushroom production in 2016 (European Mushroom Growers' Group, modified on 22.06.2019)

There are 3 most popular mushroom species in terms of mushroom production in Europe. They include: button mushroom, ear fungus and oyster mushroom (figure 4). Out of 3 mushroom species, button mushroom is the world most cultivated mushroom and the only type of mushroom that can be automated cultivated with machines. (Cultivation of Edible Mushrooms.) In Finland, this mushroom species is widely purchased in supermarkets and considered as one of edible ingredients to several dishes, especially white button mushrooms. People in Finland can easily recognize this mushroom compared to the other 2 species as these two are less common, not to say exotic. Helsieni Oy is one of the 2 farms in the whole Finland producing fresh oyster mushrooms and the mushrooms go directly to the end users and the only producer in capital area.

FIGURE 4. 3 most cultivated mushrooms in Europe (Google image, modified)

2.2 Mushroom types

Each mushroom species requires different environment conditions to be able to wholly develop and compete with other surrounding bacteria to start fruiting. It is vital to gain knowledge about the nutrition and growing conditions of the mushroom species before going into mass production. According to the purpose of this thesis, Oyster mushroom, Lingzhi mushroom and Big cup mushroom would be then studied further for this section.

2.2.1 Oyster mushroom

There are several kinds of edible oyster mushrooms available on the market nowadays. These include: pearl oyster (*Pleurotus ostreatus*), blue oyster (*Pleurotus ostreatus var. columbinus*), golden oyster (*Pleurotus citrinopileatus*), pink oyster (*Pleurotus salmoneo stramineus*), phoenix oyster (*Pleurotus pulmonarius*) and king oyster (*Pleurotus eryngii*). As in the name of this mushroom species, oyster mushroom is identified based on the oyster-shaped cap feature. The cap size of an oyster mushroom is about 5-25 cm wide. It has white flesh and most of the time light white to brown cap. The best time to find oyster mushrooms is during fall. Since they are saprotrophic, oyster mushrooms are usually found in shape of clusters on rotting or fallen logs/trees in forests. Its nutritious factors are quite similar to other mushroom species: proteins, several vitamins and minerals such as potassium, magnesium and folate. (Oyster Mushrooms 101….) In mushroom production, oyster mushroom is considered one of the easiest mushrooms to grow.

FIGURE 5. King oyster mushroom in nature (right) and in farm condition (left) (Google image, modified)

2.2.2 Lingzhi (Reishi) mushroom

Lingzhi (Reishi) mushroom has scientific name as *Ganoderma lucidum* and is originally found in China under Han dynasty. While Ling Zhi means ‘tree of life’ in Chinese, Reishi means ‘divine’ or ‘spiritual’ in Japanese. This mushroom species is mainly found in tropical, sub-tropical and temperate climates they grow on the truck skin of the trees. The mushroom species has several colors: green, white, black, yellow and purple. Its main nutrition sources include mainly rich cellulose material and some other nutrition such as vitamins and proteins. The shape of the mushroom looks like a fan or kidney-shaped when fully grown, but like an egg when it starts shaping. (Reishi (Ling Chi) Mushroom.)

FIGURE 6. Lingzhi mushrooms in nature (right) and in farm condition (left) (Google image, modifed)

Its fruiting body has size of 0.8-13.8 inches (2-35 cm) width and 1.6-3.1 inches (4-8 cm) thickness. It is a polypore mushroom, meaning that it has pores underside of the cap. This mushroom species is well-known for its properties and nutritious values. It is perceived as a medicinal mushroom since it has been long used in Asia for thousand years to cure diseases such as diarrhea, blood pressure problem or digestive malfunction. The mushroom is also a powerful antioxidant that is used for anti-aging purposes. It is commonly used in drink such as tea and alcoholic drinks. (Reshi (Ling Chi) Mushroom.) In Asia, the nutritious properties are even extracted from the mushrooms for further usage.

2.2.3 Big Cup mushroom

Big cup mushroom has scientific name as *Clitocybe maxima*, *Basiodiomycota* branch. It is new to the edible mushroom world since their existence has just been discovered in 1999 by scientists. The shape of full-grown mushroom looks like a huge cup and it has brown pink skin and white flesh. The cup has a size of 8-30 cm diameter width and the chunk is around 3-10cm tall. The nutritious values of this mushroom species include: 32% protein, 49.7% amino acids, vitamins and minerals such as cobalt, zinc and molybdenum. The mushroom species require a huge amount of nitrogen resources while developing and fruiting. (Cultivation of Giant clitocybe.)

FIGURE 7. Big cup mushroom (Google image, modified)

Since the mushroom species is quite new compared to other mushroom species in edible mushroom world, companies and mushroom industry are trying to promote the culinary possibility of this mushrooms to the end users.

3 APPROACH

As mentioned above, there were 2 research questions needed to be answered: how mushroom production was made and the mushroom testing with the company. There would be different approaches to answer each research question as following.

3.1 Mushroom production

Short intensive course from the Agricultural Genetic Institute of Vietnam was performed in order to gain knowledge and practical experience from one of the best mushroom experts in laboratory environment. The course included theorical knowledge, workshops, practices and a field trip. After the course, participant would grasp the whole mushroom production process. In this course, Lingzhi (DT, Vietnamese type) mushroom was studied in-depth. Besides that, literature review from books and the Internet was additionally studied to contrast with gained knowledge from the course to reach the best results.

On the first day of the course, student would learn how to mix the substrate manually with given recipe. Usually in mushroom production, this activity of mixing substrate would be performed by machines. However, as the purpose of that day was to learn the principle of mixing, student and a supervisor did the mixing manually with shovels. The tasks required fine sawdust (no chemicals, no oil), chalk water ($CaCO_3$ mixed with water, pH 12) and shovels. The process would stop when the moisture of mixture reached the optimum moisture percentage (60 - 65%). To know the moisture percentage, a tool can be used or with experienced mushroom producers, they simply know when the mixture reaches the required moisture with the feel of hands. Then it would be incubated for a week with cover on top. After that, this mixture was then mixed with some other supplements to boost the fruiting rate of mushroom: sugar, corn bran, rice bran and ginger. The substrate was then packaged into identical heat-proof plastic bags and sealed. In total, the substrate was prepared for 8 days: 1st day to mix sawdust, 6 upcoming days for incubation and last day to do the rest for 86 bags size 25*35 cm.

FIGURE 8. Substrate preparation (Nguyen 2019, modified)

After that, these plastic bags, which were sealed, were moved to autoclaves (figure 9) for sterilization. Since this was a laboratory setting, laboratory autoclaves were utilized (Hirayama autoclave 85 L) instead of a huge tank often seen in mushroom production units. The purpose was to understand the principle of sterilization and the optimum temperature should be reached (124 °C) in a period of time (often 2 hours). These plastic bags were sterilized inside the autoclaves and then put outside to cool down. The process could be done immediately after plastic bags were sealed. It took half a day to a day for bags to cool down after sterilization depending on the size of the bags and the number of bags as well. For the bags the student prepared, they took half a day to cool down. When taking out of the autoclaves, the bags were not sealed anymore, yet they had a filter system through the cotton neck.

PICTURE 1. Autoclaves and plastics bag when cooling down (Nguyen 2019, modified)

Meanwhile, student had a day to learn theoretical knowledge of the whole mushroom production process. Materials were delivered to students with guidance from supervisor. A field trip to a medium-sized mushroom production unit was arranged for students to grasp the bigger picture of what a real procedure of mushroom production from the beginning to the end looked like.

PICURE 2. Field trip to a mushroom production unit (Nguyen 2019, modified)

After these plastic bags were cooled down, they were put into the inoculation room so that the strains could be inoculated into these bags. This activity was done very fast and carefully as the faster the strains were inoculated, the less bacteria got inside the bags. The required tools were: strain bottle, alcohol, a

fume hood and a sterilized long stick. The inoculation room should be very clean and should be often cleaned with CH_2O 0.5%.

FIGURE 9. Inoculation steps (Unicode_Bai 5…)

Then these bags containing grain strains were shifted to the incubation room until a fruition started forming from the cotton neck. The room temperature should fluctuate from 25 to 30 °C. The moisture percentage should be around 70 - 80% with dim light. After a week putting in the incubation room, mushroom producers would then know which package was contaminated by other species (figure 13) and which was healthily developed. Those that were contaminated should be eliminated outside of the incubation area as soon as possible in order not to contaminate the other healthy bags. When the mycelia developed to half of the bag length, the outside part of cotton should be taken out and the clean inside part should stay in the neck. Another 10 days after changing the cotton, the white fruition should start forming.

FIGURE 10. White fruition starts forming (Unicode_Bai 5…)

PICTURE 3. Contaminated bags (Nguyen 2019, modified)

After fruition started forming, these bags were then moved to fruiting room, where the temperature was between 25 – 32 °C. The fruition started growing larger as the size of an egg. The moisture needed to be controlled by spraying water all over the room with machine. The temperature was strictly monitored as if the temperature dropped below 20 °C, the fruition could not develop and remained the same size. When the body of the mushroom started developing, mushroom producers should water mushroom twice to three times per day. It took another 70-80 days more to start cultivating manually the first batch of mushrooms. It should be taken into notice when Lingzhi mushroom can only be cultivated when the top of the mushroom reaches the same colour.

PICTURE 4. From baby mushroom to mature dried cultivated Lingzhi mushrooms (Nguyen 2019, modified)

3.2 Mushroom testing

The second research topic was answered with the approach of testing with company Helsieni Oy's facility in their mushroom farm once located in Vantaa (now located in Espoo), Finland. The mentor was Stéphane Poirié, co-founder of Helsieni company. The testing was performed by the student with the guidance and supervision of mentor. The ingredients and equipment were provided by Helsieni company as illustrated in figure 16. The strains were provided by the student: Lingzhi and Big cup with a small test with Oyster mushroom strain from the company. The testing was illustrated in figure 15 below. The data gained from the testing would be then collected and utilized for further analysis.

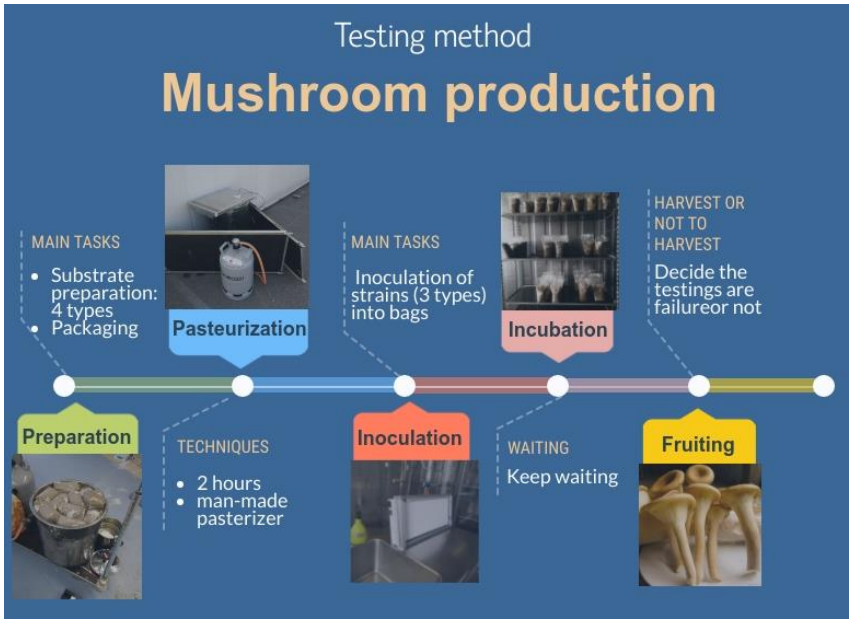


FIGURE 11. The whole process of testing (Nguyen 2019)

As can be seen from figure 15, there were 5 main testing phases for mushroom production with Helsieni company. Each phase would take place in a different location with different techniques and different equipment. While the preparation phase and pasteurization only took a day respectively to accomplish, the other 3 phases took a longer time to reach the results.

For Preparation phase, mushroom substrate would be prepared and packaged in heat-proof plastic bags. The phase took place in the production room. The proximate amount of time to finish the task of mixing the substrate was about 2.5 hours. There were 4 different substrate ‘recipes’ to test, two of which were for Lingzhi mushrooms and Oyster mushrooms and the other two were for Big Cup mushrooms as illustrated in table 2. The required materials and equipment included: a cement mixer, all ingredients of substrate (Alder woodchips and beech woodchips from Biltema Espoo; wheat bran from local farm; straw pellets from Baltic Straw; $CaCO_3$ from Nordkalk; hot water).

PICTURE 5. All ingredients and equipment used in preparation phase (Nguyen 2019)

Mush-room type	No.	Dry weight(kg)	Recipe		
			Percent (%)	Ingredients	Weight (kg)
Lingzhi	1.1	3.25	8	Wheat bran	0.25
			92	Beech woodchips	3
	1.2	3.25	1.5	Chalk ($CaCO_3$)	0.05
			6.5	Wheat bran	0.2
			92	Beech woodchips	3
Big Cup, Oyster	2	5	40	Straw pellets	2
			50	Alder woodchips	2.5
			1.5	Chalk	0.075
			8.5	Wheat bran	0.425
	3	6	40	Straw pellets	2.4
			50	Beech woodchips	3
			1.5	Chalk	0.09
			8.5	Wheat bran	0.51

TABLE 2. Substrate recipes testing (Nguyen 2019)

When the substrates were all mixed, they then were packed into 34 filter plastic bags and went straight to pasteurization phase. Since the facility was limited, the manual mix of pasteurization and sterilization was performed as illustrated in figure 17 below. The temperature reached 100 °C and remained at this temperature for 3 hours. The bags were then left aside for cooling down. The whole process of pasteurization took place the same day as the preparation phase.

PICTURE 6. Pasteurization phase (Nguyen 2019)

After a day of cooling down, these plastic bags were then moved to inoculation room. Student along with supervisor inoculated the strains into these bags and sealed spontaneously. After that, these bags were moved into an incubation room. Students along with the supervisor checked the room once to twice per week and constantly moved all contaminated bags outside of the incubation area. The remained healthy bags were then moved to fruiting room for the mushrooms to start fruiting.

PICTURE 7. Plastic bags containing strains inside incubation room (Nguyen 2019)

PICTURE 8. Inoculation room, incubation room and fruiting room of Helsieni company (from left to right side) (Nguyen 2019)

4 RESULTS

4.1 Low-tech mushroom production

Each mushroom species would have a slightly different mushroom production process. However, they would go through the same main primary phases as illustrated in figure 20: (1) substrate preparation, (2) pasteurization/sterilization, (3) inoculation, (4) incubation and (5) fruiting and (6) harvesting. The duration of the whole process relies heavily on the mushroom types so there is no strict timeline for the whole process. In addition to that, even though each mushroom type has their favourite growing season, by controlling the environment, almost all kinds of mushroom can be grown all year round. Moreover, the type of mushroom should be considered carefully since it affects the substrate recipes, the environment it favours and the way taking care of them, resulting in different results in production cost and revenues.

FIGURE 12. General mushroom production process (Nguyen 2019)

For the first phase, substrate preparation, it is vital to ensure to get the suitable ingredients with right portions for the whole substrate. That is because each mushroom will 'need' different types of nutrients to start developing mycelia. One huge issue with the ingredients for the substrate is that it heavily depends on the geographical features. It means that some ingredients that are admittedly known to work with a particular mushroom in one area, may not be found in some other areas, which leads to the fact that producers have to adapt and test out locally available ingredients. The second phase is extremely important in mushroom production process as it creates the small controlled environment for mushrooms to develop mycelia. If this phase was not done efficiently, meaning some other bacteria were not killed, it leaves the environment quite contaminated and affects the growth rate of mushrooms afterwards. Addition to that, it is highly recommended that the inoculation phase would take place in highly hygienic area, a laboratory would be the best option. This is because of contamination issue since there are so many other bacteria in the air, which could possibly get into the substrate while inoculating. When it comes to fruiting phase, controlling the environment is the foremost step to consider. Noted that each mushroom type would favour different growing environment, so that producers should conduct abundant of research on the temperature, humidity percentage and light requirement. This phase would be the longest phase of the whole production process. To sum up, each phase of mushroom production would require techniques and knowledge, so that researches beforehand are highly appreciated for long-term production.

4.2 Testing exotic mushrooms in Finland

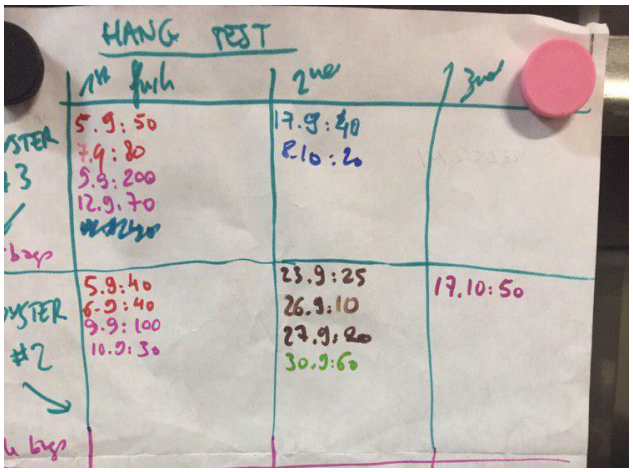
The testing procedure took place from 01.08.2019 until 23.10.2019, for 84 days, almost 3 months. For 3 types of mushrooms, which were Oyster mushrooms, Lingzhi mushrooms and Big Cup mushrooms, the substrate preparation phase was performed on the same day that was Thursday 01.08.2019. The inoculation phase was conducted also for 3 types one after another on Friday 02.08.2019. These bags of substrate would then be moved to incubation room also on Friday. The testing started with 31 bags: 10 bags of Lingzhi mushroom (6 bags substrate #1.2 and 4 bags substrate #1.1), 10 bags of Oyster mushroom (6 bags substrate

#3 and 4 bags substrate #2) and 11 bags of Big Cup mushroom (6 bags substrate #3, 5 bags substrate #2). In the end, there were 19 ‘surviving bags’ as can be seen from figure 21, mostly Oyster mushrooms: 6 bags of Lingzhi mushroom (4 bags substrate #1.2 and 2 bags substrate #1.1), 9 bags of Oyster mushroom (5 bags substrate #3 and 4 bags substrate #2) and 4 bags of Big Cup mushroom (3 bags substrate #3 and 1 bag substrate #2).

PICTURE 9. Surviving bags during fruiting phase (Nguyen 2019)

As expected, the Oyster mushrooms were the fastest growing mushroom type out of 3 tested types of mushrooms. During 84-day period, there has been 3 harvesting times: 1st harvest (05.09.2019 – 12.09.2019), 2nd harvest (13.09.2019 – 08.10.2019) and 3rd harvest (09.10.2019 - 23.10.2019). It can be seen from figure 22 that the first harvest with substrate #3 was the most fruitfull harvest with the yield was almost 10 times more the the second harvest. However, with substrate #2, the first harvest, with 210 g of collected mushrooms, was only about 2 times more than the second harvest with 115 grams of collected mushrooms. Together, 460 grams of oyster mushrooms could be collected from the substrate #3. Meanwhile, the figure for substrate #2 was 375 grams, with almost 100 grams in difference (18%). The only difference between these 2 substrate types was the type of woodchips being used. While Alder woodchips were used for substrate #2, Beech woodchips were used for substrate #3. As the results show, using Alder woodchips would yield smaller but stable amount of mushroom after each harvest. And by using Beech woodchip, the first harvest would be so fruitful that

it had the yeild of both harvest of substrate #2. This means that the Oyster mushroom liked the substrate so much that it sucked all the nutrients out from the very first harvest. The downside of this Beech woodchips is that it is in fact quite an enpensive woodchip type and not available broadly in store in Finland. The beech trees are instead growing in central and western European, not common found in Finland.



PICTURE 10. Harvesting results of Oyster mushrooms (Nguyen 2019)

While Oyster mushrooms have already been cultivated 3 times in the given period, the Lingzhi mushrooms showed quite slower results in fruiting phase. After 84 days of testing, these mushrooms had only formed white fruitions as in figure 23. It was common that Lingzhi mushrooms took considerably longer time to form the fruiting body. In the middle of fruiting phase, 2 bags of Reishi mushroom substrate #1.2 were moved back to incubation room, where the environment was reasonably different from the fruiting room. This was due to their delay in forming fruitions and the distorted forms of the developed white fruitions. In the end of the testing phase, these bags showed much better result in forming fruitions compared to 4 bags left in fruiting room. The environment settings in the incubation room were as following: 65% humidity, 21 °C and dim light. Meanwhile, the settings in fruiting room were: 82% humidity, 10 °C and day light. This testing assures that the alters in environment settings can have a huge influence on the fruiting of mushrooms and very likely to affect the yield of mushroom production. Another conclusion can be drawn from this testing is that it is optimal to set different environments for different mushrooms when it comes to producing different kinds of mushrooms.

PICTURE 11. White fruitions (upper part: fruiting room, lower part: incubation room) (Nguyen 2019)

For Big cup mushrooms, it seems that they only developed the mycelia and delayed in developing the fruiting body. It can be attributed to the wrong techniques in growing since in some literature review, the mushrooms need some compost or industrialized soil to start growing the body. Out of 11 bags from the beginning, only 4 bags lasted with 7 bags being contaminated (reasons mainly came from the problem of sealing after pasteurization). For the first few week, Big Cup mushrooms were thought not to develop the mycelia since there were no sides of mycelia forming at all. It took Big Cup mushrooms 3 weeks for the mycelia to be visible. Out of all 3 tested types, Big Cup mushrooms were the slowest one to produce in given 84 days.

In conclusion, for the testing procedure, all 3 types of mushroom illustrated positive results, even with several contaminated bags being thrown away. The contamination mainly came from the sealing problem and could be recognized easily with green molds. Out of 3 mushroom types for the testing, Oyster mushroom showed the best result in cultivation and proved to be the fastest and strongest mushroom to produce. Meanwhile, the other 2 types of mushroom require different techniques and thoughtful supervision. The result of the study is concluded in the table 3 below.

Mushroom production testing (01.08.2019 – 23.10.2019)							
Mushroom type	**Sub-strate (#)**	**Original bags (bag)**	**Final bags (bag)**	**Harvest (kg)**			**Total (kg)**
				1st	**2nd**	**3rd**	
Big Cup	2	5	1	x	x	x	x
	3	6	3	x	x	x	x
Lingzhi	1.1	4	2	x	x	x	x
	1.2	6	4	x	x	x	x
Oyster	2	4	4	0.210	0.115	0.050	0.375
	3	6	5	0.400	0.060	x	0.460
Total		31	19	0.610	0.175	0.050	0.835

TABLE 3. Final result of the testing

5 DISCUSSION

Several understandings can be drawn from the two different approaches mentioned above. While learning to understand how mushroom growing in a laboratory environment, participant could grasp the theorical idea of what a mushroom production process should look like. However, when it comes to a real mushroom production environment, basic concept regarding general steps to produce mushrooms is probably the only matter that mushroom growers follow strictly. Other than that, mushroom producers would modify everything else accordingly to all kinds of external issues to fit their needs, including financial situation, the produced mushroom species and geographical features to consider locally available ingredients for substrate. There always comes different troubles and problems on each growing period. This means that the mushroom production requires producers/technicians to have abundantly experience in the field in order to recognize the problems of production lines. In addition to that, the two approaches showed that there were several ways and methods to gain the ultimate results. The techniques can vary from region to region, however, the conceptual principles remain the same that there are 6 main phases to produce mushroom traditionally. There is no technique better than other technique. It is only a matter of perspectives and experience. Imagine that one can work more efficiently with papers and pens and the other one can work better with monitors and keyboards. Yet both produce the same result as a method to imprint knowledge to the brain. The same concept can be applied to mushroom production.

The result of testing was quite expected and luckily all 3 types of mushrooms survived and developed throughout the given period. Oyster mushrooms proves to be a highly efficient mushroom to produce with its ability to withstand severe conditions and its flexibility to adapt to the environment. Lingzhi mushrooms, however, showed that with not-so-favoured environment, they would start distorting their fruitions, resulting in distorted mushroom forms. The quality of these mushrooms remains to be unanswered since the testing time has ended with Lingzhi mushrooms has not yet fully developed. During the pasteurization phase, all 3 types of mushrooms were put in the same tanks and they went through the same pasteurizing process. However, during the fruiting phase, several bags of Lingzhi

and Big Cup mushrooms became contaminated with the sign of green molds and only a bag of Oyster mushrooms encountered the same problem. This once again shows the vulnerability of Lingzhi and Big Cup mushrooms. This also shows that these 2 types need careful supervision for the whole production process. Further research on how Big Cup mushroom is produced should be conducted since according to this testing, this type of mushroom appears to be a hard type to produce. The result also illustrates that production of exotic mushrooms from different geographical areas is extremely possible in Finland with controlled environment, locally available ingredients for mushroom's nutrients and thoughtful care from producers.

Mushrooms have been widely in demand for its multi-purposes in daily lives. As several people go vegan and vegetarian nowadays, mushrooms prove to be one of the most vital food ingredients for them with its highly nutritious elements. Thanks to the trend of environmental protection, several people have now acknowledged the importance of mushrooms with its multi-purpose. Several products are coming out every year from mushroom production. For those who have not yet encountered mushrooms before, this thesis study would partly bring some insights and hopefully create some interest towards mushroom usage.

For mushroom production, there are now two different approaches to the mushroom production business. The first one is that if mushroom producers want to go small and try to stick with zero waste, they need to test all the time with all their resources until the ultimately optimal growing environment and nutrition for their produced mushroom species are found. Otherwise, there is nothing to cultivate and the production process would fail. This approach takes enormous amount of time usually until the final standard mixture for substrate is found, however, the growing environment is still a huge problem for optimization. This approach requires a small amount of financial investments and it is fast to make the business profitable. Even when something happens, the total loss would be fast to cover. The second approach is that if mushroom producers want to invest hugely on the production process, meaning that they must stick with one best production line from the very beginning. Most of the time, this would shorten the time of research and testing and go straight into yielding huge results. However, it takes a lot of

time and dedication until the business turns profitable. The medium-sized business would not be a wise choice since it cannot beat with the low-price range of the same products from high-tech mushroom production units and at the same time, cannot sell with higher price for the same products compared to the small business. If something wrong happens, it is hard to cover up the total loss. In other words, a risk-taker would go big and a safe-player would go small. Mushroom growers should consider this factor seriously as it is the vision of their business model.

REFERENCES

Ahmadjian, V., Alexopoulos, C. & Moore, D. Article: Fungus. Britannica. Read on 26.10.2019. https://www.britannica.com/science/fungus/Annotated-classification

Borealforest.org. Finland – Forests and Forestry. Read on 22.06.2019. http://www.borealforest.org/world/world_finland.htm

Copper. 2019. Fact Sheet for Health Professionals. National Institutes of Health (NIH). Read on 19.06.2019. https://ods.od.nih.gov/factsheets/Copper-HealthProfessional/

Cultivation of Edible Mushrooms. Material of Botany Department. University of Hawaii. United States.

Cultivation of Giant clitocybe: Clitocybe maxima. Unicorn Imp. & Mfg. Corp. Read on 19.07.2019. https://unicornbags.com/cultivation/clitocybe-maxima/

Fry, M. At What Time of the Year Do Mushrooms Grow? Read on 22.08.2019. https://homeguides.sfgate.com/time-year-mushrooms-grow-68769.html

McHugh, A. Blog: Asian mushrooms – More mushroom history!. Read on 20.08.2019. http://blog.crazyaboutmushrooms.com/asian-mushrooms-mushroom-history/

Mushroom Council. Mushroom Nutrition. Read on 18.08.2019 https://www.mushroomcouncil.com/nutrition-benefits/

Mushrooms are good sources of Antioxidants. 2017. Lacto Bacto. Read on 16.2019. https://lactobacto.com/tag/ergothioneine/

Niacin. 2019. Fact Sheet for Health Professionals. National Institutes of Health (NIH). Read on 19.06.2019. https://ods.od.nih.gov/factsheets/Niacin-HealthProfessional/

Oyster Mushrooms 101: A Complete Guide To Oyster Mushrooms. GroCycle. Read on 17.07.2019. https://grocycle.com/oyster-mushrooms-guide/

Pantothenic Acid. 2019. Fact Sheet for Health Professionals. National Institutes of Health (NIH). Read on 19.06.2019. https://ods.od.nih.gov/factsheets/PantothenicAcid-HealthProfessional/

Potassium. 2019. Fact Sheet for Health Professionals. National Institutes of Health (NIH). Read on 19.06.2019. https://ods.od.nih.gov/factsheets/Potassium-HealthProfessional/

Reishi (Ling Chi) Mushroom. Temperature Climate Permaculture. Read on 18.07.2019. http://tcpermaculture.com/site/2014/02/20/reishi-ling-chi-mushroom/

Riboflavin. 2019. Fact Sheet for Consumers. National Institutes of Health (NIH). Read on 19.06.2019. https://ods.od.nih.gov/factsheets/Riboflavin-Consumer/

Rühl, M. & Kües, U. 2007. Wood production, wood technology, and biotechnological impacts. Germany. Universitätsverlag Göttingen. 555-559.

Sánchez, C. 2004. Modern aspects of mushroom culture technology. Applied Microbioloy and Biotechnology. Springer-Verlag. 756-757.

Sceltamushrooms. What is a mushroom? Read on 18.08.2019. https://www.sceltamushrooms.com/en/themes/what-is-a-mushroom/

Selenium. 2019. Fact Sheet for Health Professionals. National Institutes of Health (NIH). Read on 19.06.2019. https://ods.od.nih.gov/factsheets/Selenium-Health-Professional/

Sievänen, T., Pouta, E. & Neuvonen, M. 2004. Publication: Participation in Mushroom Picking in Finland. Japan Society of Forest Planning Press. Read on 22.06.2019. http://www.metla.fi/metinfo/monikaytto/lvvi/artikkelit/participation-mushroom-picking-2004.pdf

Unicode_Bai 5- Ky thuat NT Nam Linh Chi. 06.2018. Material for intensive course of Agricultural Genetic Institute of Vietnam. Agricultural Genetic Institute of Vietnam. Hanoi, Vietnam.