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Establishment of a mushroom production system at Obrobibini Peace Complex (OPC)

Internship Report

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1. Introduction

1.1. Obrobibini Peace Complex

“Obrobibini Peace Complex (OPC) is an association of people from high- and low-income countries that support the freedom and happiness of the people[...]. By maintaining centres of learning, OPC provides platforms for people to unfold their full potential. Thereby, we focus on people from low-income countries who do not have the necessary resources to realize their ideas [...]. OPC’s first centre is located in Ghana. We aim at contributing to the eradication of the root causes of poverty by building a centre of learning to support the health of the people and the environment through practical education in the areas of sustainable agriculture, healthy diet and sports, herbal medicine, natural sanitation, waste recycling and renewable energy.” (<https://obrobibini.org/about-us/> , 2.9.2019)

The OPC land was grouped into three main areas. An agroforestry system was planted about half the size of the land. Second, a vegetable garden was created and last the living area with a built platform and the mushroom house.

As I planned the Internship, I wanted to contribute something useful to OPC. My decision came upon quickly to establish an organic way of growing mushrooms on the land. As access to protein sources in Africa are quite limited, alternative protein sources are necessary to be found in order to provide enough proteins for the prospective growing population in Africa. On a dry-weight basis, Oyster mushrooms have substantial protein, ranging from 15-35% (Stamets, 2000; p. 283). Moreover, they contain significant quantities of free amino acids and vitamins. Besides a new source of nutrition, cultivating mushrooms means also having a valuable, high quality product with a big demand. Selling those mushrooms means cash for the people. Hence, especially for people in development countries, growing mushrooms is way of getting out of poverty.

Producing mushrooms is, compared to other crops, quite profitable. Due to low input cost, high yields and profitable marketing possibilities, it is an interesting alternative of making a living for rural farmers. Agricultural by-products like sugarcane bagasse, sawdust, shredded plant matter can be used as substrate and give an additional value to the “waste products”.

1.2. Mushroom Biology

In a narrow sense, the word mushroom refers to only the fruitbody of fungus, the part which appears in the fruiting stage out of the substrate. Mushrooms, unlike plants, are heterotrophs. They are not able to practise photosynthesis and therefore, they need to take up their nutrients from other sources. The nutrition sources on which the mushroom settles and grows is called substrate.

Mushrooms can be classified into three basic ecological groups: *mycorrhizal*, *parasitic* and *saprophytic*. Most commonly grown mushrooms are saprophytic mushrooms. They are able to decompose organic matter like wood, leaves and straw by specific enzymes. Mushrooms require carbon, nitrogen and inorganic compounds as its nutritional sources. The main carbon sources are such as cellulose, hemicellulose and lignin (Mushworld, 2004). That means, undigestible carbons can be turned into food for mankind through mushrooms.

Mushrooms have a vegetative and a reproductive stage. The two different stages in the Mushrooms' life cycle require different environmental conditions such as temperature, humidity, light and ventilation. Generally said, the vegetative stage requires higher relative humidity, higher temperature, higher CO₂ content and less light influence than the reproductive stage. By maintaining optimal conditions at each growing stage and for each species, the cultivator can produce the desired yield of quality mushrooms. Following, the steps will be explained how to create an appropriate environment for a successful mushroom cultivation.

2. Mushroom production system

2.1 Production setup

In order to maximize mycelium growth and accordingly maximize mushroom yield, an appropriate environmental surrounding must be achieved. Each mushrooms strain requires their own specific environmental parameters, as well as substrate formulation for prospering. Since Oyster mushrooms (*pleurotus ostreatus*) are quite easy to grow due to their environmental adaptability, productivity and ability to grow on a wide range of organic waste, the oyster mushroom strain was chosen to be cultivated for the project. The mushroom spawn was provided by a mushroom spawn laboratory, based in Accra, Ghana. Following, all the steps of the mushroom production will be explained.

2.1.1. Building of the Mushroom House

Basically, almost all mushrooms need a shaded and moisty environment to be able to grow. Thus, a mushroom house was necessary to be build to create an artificial environment, which is most suitable for mycelium growth (Fig. 1). At first, the slopy area was flatten. Second, a skeletal structure was built out of red hardwood. The outside walls and the door were made of Raphia wood and the roof was made of split bamboo. The interior shelves were made of wood rests and planks. For controlling, maintaining and spawning processes, a small table for better handling was built. Furthermore, a hygrometer for observing humidity was installed. The capacity of the mushroom house is enough to cultivate about 500 bags of mushrooms at the same time.



Figure 1. House for mushroom cultivation

2.1.2. Preparation of the Substrate

As already described above, one significant advantage of the Oyster mushroom is the ability to grow on a wide range of substrates. They thrive on most all hardwoods, on wood by-products like

sawdust, paper, all the cereal straws, corn and corncobs, sugarcane bagasse, coffee residues, banana fronds, cottonseed hulls, soy pulp and numerous other materials containing lignin and cellulose (Stamets, 2000; p. 282).

For the mushroom project at OPC, sawdust was chosen to serve as substrate. The sawdust was mainly generated from hardwood trees and obtained from local carpenter's workshops for free. For each mushroom production cycle about 200 kg of sawdust substrate was prepared. The amount of sawdust substrate equals 150 -200 filled bags.

Initially, the sawdust was piled in a shaded area to achieve constant temperature and appropriate composting conditions. Following, 1% lime (2kg) and 5% wheat bran (10kg) were added and mixed together with sawdust. Lime increases and buffers the pH-value and furthermore contributes necessary minerals (Calcium, Magnesium, Sulphur) to the substrate. When sawdust is supplemented with a nitrogen-rich additive, the yields of most wood-decomposers are enhanced substantially (Stamets, 2000; p.149). Wheat bran was used as a nitrogen source. More nitrogen offer enhances mycelium growth but also encourages other microbes to grow and expand. The more nitrogen is contained in the substrate, the more likely it is to become contaminated and unsuitable for mushroom production. A value of 5% of an added nitrogen-source and the following boost of mushroom growths outreaches the disadvantage of contamination. Alternative to wheat bran rye, corn, oat and soybean bran can be used as additives, depending on their availability and preferences of the cultivator. The substrate pile was turned over about 15 times with space of 4-5 days. Before the bagging could get started, another 1% lime (2kg) and 5% wheat bran (10kg) was added and mixed with the substrate. Moreover, the moisture content of the substrate had to be checked. Ideally, the sawdust substrate contains 60-65% water. Depending on the previous days before bagging, the substrate had to be covered with a tarp early enough in case of rain or has to be wetted when the substrate is too dry. If you squeeze the substrate with force by hand and few drops are appearing on the outside of your hand, then the substrate mix has the right water content. Furthermore, the ideal water content differs from each mushroom species and the experience of the mushroom cultivator plays an important role in terms of the right water content of the substrate.

2.1.3 Bagging of the Substrate

The most common and easiest way in mushroom cultivation is the cultivation in heat resistant plastic bags. The plastic bags were tightly stuffed with the prepared substrate (Fig. 2). Hollow spots inside the bags are likely to become contaminated, so controlling of the tightness of the bags was necessary after stuffing. Afterwards, the plastic opening was led through a plastic ring and stored for sterilization.



Figure 2. Filling the bags with the prepared substrate

2.1.4. Sterilization

To minimize the threat of contamination during the stage of mycelium grow, the substrate had to be sterilized before inoculation of the substrate. An old drum was used for steam pressure cooking, functioning as an autoclave. Small holes were drilled inside the lid for pressure release. Big stones were placed on the ground in order to provide a stable stand of the drum and to be able to light up a bonfire underneath the drum for heating. Next, a wooden rack was placed on the bottom of the drum. The drum was slightly filled with water, so the contact surface of the rack remained dry. The bags were stacked into the drum until it was full of bags (Fig. 3). To avoid the entering of water

droplets into bags, the bags of the top layer were placed upside down. The lid was closed and the wood was inflamed to heat up the water in the drums. Firewood was gathered and dried some days before sterilization started. A low heat, steady burning fire is to be pursued for optimal sterilization result. After the first steam emerged out of the holes on the lid, about 4 hours of pressure cooking is enough to kill all microbes in the substrate. After cooling down the drum, the lid was opened and the plastic holes, formed by the plastic rings, were stuffed with cotton wool to reduce contamination. The sterilized bags were stored in the mushroom house.



Figure 3. Almost fully stacked drum

2.1.5. Inoculation

After the bags were cooled down, the substrate was ready to become inoculated by mushroom spawn. The mushroom spawn of the species *pleurotus ostreatus* was obtained from a mushroom laboratory in Accra. As I couldn't get any information of the used spawn substrate, I assume that

millet was used as substrate. Other spawn substrates such as rye, wheat and rice grain are commonly used, as well.

The mushroom spawn was delivered in glass bottles and the content of each bottle was enough to inoculate 15-20 substrate bags. The more spawn is used per bags, the faster is the growing rate of the mycelium through the substrate. A faster growth rate reduces contamination as the oyster mushroom mycelium is superior to pathogens and competitive microbes.

To minimize the contamination risk, the place, as well as the hands, should be cleaned and disinfected with rubbing alcohol (70 vol %) before starting. Next, the cotton wool plugs were removed and the bags were opened. The mushroom spawn was poured on top of the bags (Fig. 4). Afterwards the bags were closed with a plastic ring and cotton wool. Additionally, a piece of paper was fixed with a rubber band on top of the cotton wool to avoid any kinds of physical damage. After the process is done for each bag, the bags were labelled and stored upright in shelves (Fig. 5).



Figure 4. Inoculation of the sterilized Substrate



Figure 5. Inoculated bags

When mycelium starts to grow, heat is generated of the enhanced metabolism. Regardless of the species, the incubating bags must be spaced apart to preclude a high thermogenesis. Once the temperature threshold of 35-38°C is surpassed, dormant thermophile microbes spring to life, threatening the mushroom mycelium's hold on the substrate (stamets, 2000; page 160). A spacing of about 2 cm of each bag apart from each other is enough to avoid a high thermogenesis.

The inoculated bags are left in the shelves for approximately 40 days, until the substrate is settled by the mycelium. The time of fully colonization differs and is influenced by temperature conditions, mushroom species and the amount of used spawn.



Figure 6. Almost fully colonized substrate bag by the mushroom mycelium

2.1.6. Harvesting and Maintaining

As the substrate is fully colonized by the mycelium, it is ready for cropping. To initiate the fruiting stage of the mushroom, environmental changes are necessary. The bags were cut open at the top and the plastic was removed afterwards. As the bags were opened, spraying at least twice a day was necessary to keep up humidity. Moreover, for insect repellent, neem leaves were crushed, sieved and mixed together with the water solution. The mushroom mycelium was slightly sprinkled with the solution. The rest of the house was generously sprinkled. After opening the bags, small mushrooms appeared after few days (Fig. 7). The mushrooms were cut by knife when the mushroom caps were fully opened (Fig. 8). When the cropping has started, the mushrooms will produce their crops in cycles within 3 months. The productivity declines with each cropping cycle.



Figure 7. Fruiting oyster mushrooms few days after opening the bags



Figure 8. optimal harvest stage

To avoid any infections of microbes and attraction of pests, the mushroom house needs to be as clean and tidy as possible. Mushroom and Substrate residues were removed right away.

After the first mushrooms appeared, pest beetles made their way to the mushrooms. The beetles were damaging the mushrooms and therefore decreasing the quality and amount of the harvest. I tried to stop the propagation by collection the beetles each day in the morning. Even though I did the procedure each day, the problem of the beetles remained. Possible solutions will be discussed later on.

3. Economical & ecological value

3.1. Economical Value

Mushroom production is, compared to other agricultural branches, a quite profitable income. Low capital investment is needed to get started. An appropriate shelter is needed. This can be realized by building a mushroom house or a simple shelf, covered by a tarp. Building a mushroom house is more expensive than a shelf, but in the long run term the production is easier to handle regarding to space and observation. The capital investment for a house can widely differ depending on the used materials, labour input and creativity of the constructor. As the mushroom house or shelf is established, the main investment is done. Further acquisitions are a drum for sterilization. Old drums can be used for this process. Old drums are usually sold quite cheap.

The most economical way for obtaining substrate is to analyse all the potential substrates in the local area. For example, agricultural wastes accumulated at a farm. The waste can be either composted or can be recycled for substrate and get an additional value due to mushroom production. Moreover, sawdust can be obtained for low money or even for free at local carpenter's workshops.

The cost of one bottle of mushroom spawn is 3 Ghana Cedis. One bottle of mushroom spawn is enough to inoculate 15-20 bags of mushrooms. Assuming that a filled bag contains about 1 kg of substrate, a bottle of mushroom spawn is enough to inoculate 15-20 kg of substrate. For a production cycle with 200 kg of substrate per cycle 10-13 bottles are needed. This is resulting into 30-39 Ghana Cedi for input cost.

Mushroom strains vary in their ability to convert substrate materials into mushrooms as measured by a simple formula known as the “Biological Efficiency (B.E.) Formula”. This formula states that 1 pound of fresh mushrooms grown from 1 pound of dry substrate is 100% biological efficiency. Considering that the host substrate is moistened to approximately 75% water content and that most mushrooms have a 90% water content at harvest, 100% B.E. is also equivalent to

- Growing 1 pound of fresh mushrooms for every 4 pounds of moist substrate, a 25% conversion of wet substrate mass to fresh mushrooms, or
- Achieving a 10% conversion of dry substrate mass into dry mushrooms (Stamets, 2000; p. 55)

For a rough calculation of the mushroom production, I assume a water content of 70% of the substrate and a biological efficiency of 50%.

200kg of wet substrate with a 70% water content result into 60kg of dry substrate. With a biological efficiency of 50%, you get about 30kg of mushrooms out of one production cycle. Assuming, that the market price is about 5 Ghana Cedi per 100g of mushrooms, 1500 Ghana Cedis are generated during one production cycle.

Disregarding of the investment of the mushroom house and the labour cost, the mushroom spawn is the only input cost over the long term.

3.2. Ecological Value

After the production cycle is finished, the remaining substrate can be either composted or used as animal feed. Fresh mushroom compost contains about 1-2% nitrogen, 0.2-0.3% phosphorus, and 1.3-2.4% potassium. About 94% of the total nitrogen is in organic form. Fresh mushroom compost should not be used for fertilizing and soil amendment because it contains a lot of salt. It should be weathered for at least six months. During weathering, very little nitrogen and phosphorus is lost, but potassium decreases considerably due to leaching (Anonymous, 2004a; Steward et al., 1998, Uzun, 2004).

After weathering, the resulting compost can be used in organic farming to improve soil water infiltration, water holding capacity, permeability and aeration. Mushroom compost does not

contain any pest or weed seeds due to sterilization and thus a good option for mulching and weed suppression. When it is used as fertilizer, nutrients are released slowly over a longer time by microorganisms and can be used by plants more effectively. By applying the compost, soil structure is improved by organic matter and microbial activity is enhanced, resulting to a more diverse microflora and fauna.

4. Conclusion

Growing mushrooms can lead people in developing countries out of hunger and poverty. Due to the low investment and input cost for the production set up, farmers are able to establish their own mushroom productions and get an additional income. New jobs are being created and this contributes to the economy and welfare of a country. The demand for mushrooms is high and the price is compared to other agriculture products more stable and on a higher selling level.

Moreover, non-edible waste resources are converted into high-nutrition edible products by growing mushrooms without competing for agriculture used lands. This leads to a better, more stable food supply for the population and counteracts the world hunger problem.

As many rural farmers are not familiar in growing mushrooms, knowledge has to be imparted to these people. In future, members of OPC will give lectures and workshops on the land for interested farmers and spread the knowledge, secrets and experiences in the field of mushroom growing. So hopefully, more mushroom farmers will appear in Ghana due to the help of OPC.

4.1. Solutions and optimization of the production

First trials of growing mushrooms were successfully conducted. Even though it worked out quite well in general, problems turned out. The sterilization process is the first to be optimized. As the bags were stacked up to dense in the barrel, the hot water steam couldn't enter the surface of the bags uniformly. This led to a not fully sterilization of the inner bags. Consequently, the mycelium had to compete with more microorganisms. This resulted to a slower or non-settlement

of the substrate. Hence, an ineffective production is resulting. This problem can be solved by installing separation racks between the bag layers (Fig. 9).

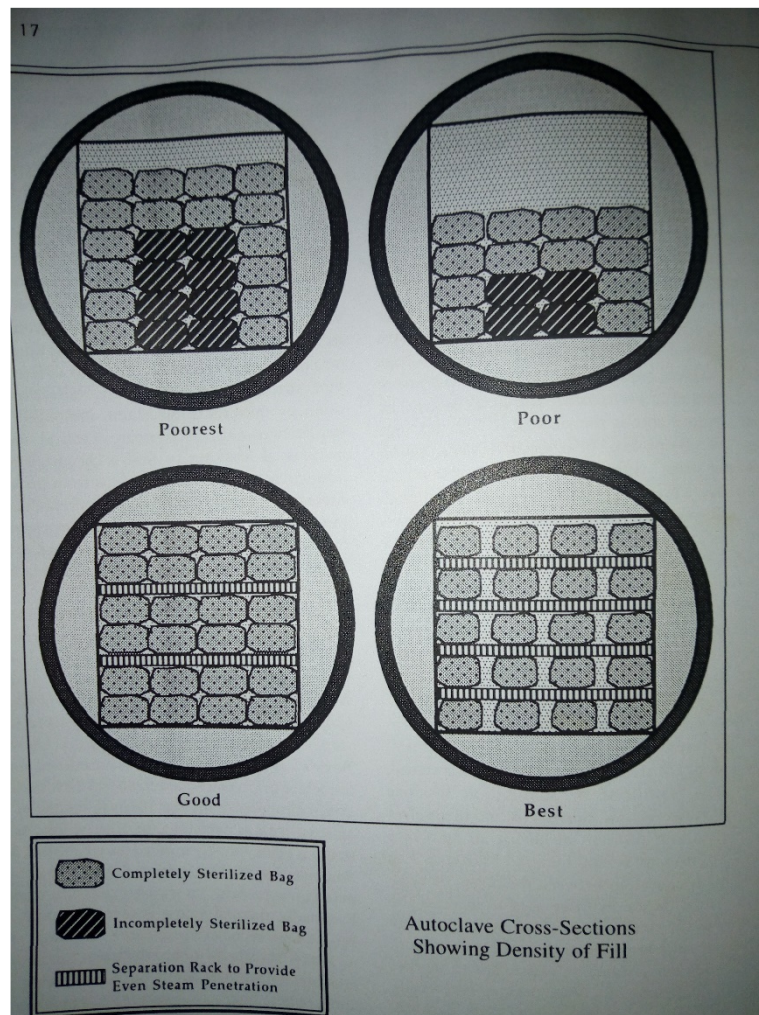


Figure 9. Affection of packing the bags into the autoclave. (Stamets, *Growing gourmet and medicinal mushrooms*; p. 156)

A major problem turned out when the bags were cut open and the fruiting stage was initiated. As already mentioned, beetles appeared and propagated rapidly in the mushroom house. By spraying neem solution and collecting the beetles, the number of beetles was declined but not fully eliminated. To have a bug-free environment, insect nets need to be installed at the entrance and outside walls. As the first mushroom house was just finished, no insect nets were installed ahead. The solution for the pest-problem therefore, is to build another mushroom house which is only used for fruiting and secured against the entering of pests.

The fruiting house can be smaller in size than the already existing mushroom house. The floor of the new mushroom house should be made of cement. Cement floors are easy to be cleaned. The floors can be rinsed thoroughly with water, substrate and mushroom debris can be detected and removed better and in result, hygiene conditions will be improved. As already mentioned, insect nets need to be considered in the fruiting house. When the shell construction is finished, insect nets need to be installed on each outside wall, as well as the ceiling and door. Moreover, the nets should be connected to the cement floor. After installing the nets, the whole surface should be checked for holes and gaps. In ideal circumstances, pest insects are not able to enter the fruiting room.

In order to obtain the best environmental conditions for the fruiting stage of the mushrooms, ventilation and light windows should be considered in planning. Adjustable windows at the lower and upper part of the house are needed to regulate the fresh air supply in the fruiting house. Moreover, adjustable windows for light regulation are important. With this design, the fruiting conditions can be matched with the mushroom's needs and consequently cropping is optimized.

4.2. Future outlooks

The potential of mushroom production at OPC land did not reach its peak so far. After the new fruiting house is built, the production cycle should be optimized. One staff member is supposed to be in charge of the whole production. That means, he/she should make a production schedule, coordinate personal labour, control the production and react to growing anomalies of the mushrooms. A steady, continuously cropping cycle is needed for an optimal market supply.

Mushrooms are tending to spoil quick after harvest. They need to be delivered as far as possible at the same day to the market or costumer. If there's a lower demand or a surplus of mushrooms, a drying shelf is a good solution for preservation. This way, the mushrooms can be dried, grinded and stored for a long time for later selling.

5. Personal reflection

I had a great time during my stay in Ghana. It was a new experience for me to live in a tropical climate area for a longer time. Even though I had to struggle with some health issues, I was always in the mood of excitement and pleasure. Living together with local people on the OPC land gave me

lots of impressions of African culture and the African way of living. The knowledge exchange regarding to farming, society and culture helped me to understand where the difficulties and struggles are between the western society and developing countries.

The happiness and vitality of the Ghanaian people really amazed me, even though they had to struggle with daily actions which are self-evident in our society. Opening the water tap and water is flowing out, switching on the stove for cooking, turning on the laundry – all these things are handled differently in Ghana. This made me aware of our luxury we are living in our society. Our “problems” which we are facing in Europe are becoming small and more unnecessary after this time of living.

I hope that the mushroom project will prosper in future and that more people can pick up and implement the idea of mushroom growing. After the 5 months, I can say that the experience developed my personal attitude towards society and natural environment.

Last, I want to thank Christian for giving me the opportunity to join the OPC family and do my internship in Ghana. Thanks to Basti, my good friend who joined me on the adventure in Ghana. Thanks to Moses who mediated his knowledge about tropical farming to me. We had great conversations about farming. Thanks to Noora, Black Stone, Pages ak funny guy, Sibiri, Thomas, Noah, the Young Boys Enok and Joel for the hard work at the agroforestry and Joeman for the management. I had the biggest pleasure to work together with all these guys. It was always a good time full of joy and laughing with you on the farm, even times were not easy sometimes. I hope to come back to the OPC land and see all these guys and a wonderful flowering farm again.

OPC – freeeeeeeee!!

6. Sources

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