Operating a successful low-tech, small scale mushroom farm

Kellogg Rural Leadership Programme

Course 44 2021

Breen Cowie

Disclaimer

In submitting this report, the Kellogg Scholar has agreed to the publication of this material in its submitted form.

This report is a product of the learning journey taken by participants during the Kellogg Rural Leadership Programme, with the purpose of incorporating and developing tools and skills around research, critical analysis, network generation, synthesis and applying recommendations to a topic of their choice. The report also provides the background
for a presentation made to colleagues and industry on the topic in the final phase of the Programme.

Scholars are encouraged to present their report findings in a style and structure that ensures accessibility and uptake by their target audience. It is not intended as a formal academic report as only some scholars have had the required background and
learning to meet this standard.

This publication has been produced by the scholar in good faith on the basis of information available at the date of publication, without any independent verification. On occasions, data, information, and sources may be hidden or protected to ensure confidentially and that individuals and organisations cannot be identified.

Readers are responsible for assessing the relevance and accuracy of the content of this publication & the Programme or the scholar cannot be liable for any costs incurred or arising by reason of any person using or relying solely on the information in this publication.

Scholar contact details may be obtained through the New Zealand Rural Leadership Trust for media, speaking and research purposes.

Acknowledgments

I would like to express my special thanks to my program coordinators, Patrick, Scott, Desley, Lisa and Chris for their timely guidance and endless inspiration. I would also like to extend my gratitude to the whole Kellogg cohort for all their time and input in helping me reach the end goal of this project. Thanks for all the laughs along the way and valuable insights. Last but not the least, I would like to thank everyone who is involved in the project directly or indirectly. The completion of this project could not have been possible without their assistance and participation.

I wish to thank the Kellogg Programme Investing Partners for their continued support. With additional special thanks to Agmardt.

Strategic Partners

Programme Partners

Service Partners

Table of Contents

Table of Figures

Executive Summary

This business concept works to research the potential outcome of starting and operating a successful low-tech, small scale specialty mushroom farm in the North Island of New Zealand. It is a short overview of a new business venture idea that will be further expanded into a business plan once the concept has proved probable. Starting in Northland, the long-term idea is to be able to move around and transport the mushroom farm accordingly. The farm will be producing oyster mushrooms (*Pleurotus ostreatus)* for the first year and introduce more specialty varieties in the following years, such as Shiitake *(Letinula novae-zealandiae)* and Enoki (*Flammulina velutipes)*.

The report explores the possible outcome of a successful mushroom farm by:

- Understanding the NZ mushroom industry dynamics and the market demand for speciality mushroom varieties and potential trends that are on the rise
- Potential challenges and risks that could arise and ways to mitigate them
- Gaining insight into the requirements needed to start the farm and the DIY options for establishing a producing fruiting room
- Other profitable ventures that arise from the production of fungi.

The New Zealand mushroom industry is small but well established. With only one fully integrated commercial mushroom farm in the country and multiple, small at home start-ups selling gourmet mushroom varieties, the industry is not yet overly saturated in terms of low-tech start-ups. The vision is to be a major supplier of quality specialty variety mushrooms in Northland and expand into the rest of the North Island. To achieve the set vision, the intention is to practice low tech farming practices by growing edible gourmet mushrooms in a controlled environment and using locally sourced substrates as much as possible.

The recommendations will show the most achievable way to reach the goal of a successful mushroom farm is to work with small harvests with high quality fruit. The farm can be built by DIY practises that suit the grower and help to keep the costs down.

1 Introduction

1.1 Introduction to Mushrooms

In any farming enterprise, profitability and costs are highly variable. They depend totally on the market (both local and international), seasonal weather conditions, decisions of the farmer and the limitations set in place by governing bodies. Their profits can greatly increase or decrease depending on how the grower chooses to spend their time, money, and work to optimize production efficiency.

Low-tech mushroom farming does not require the expensive and energy-intensive equipment that is normally used in commercial large scale mushroom growing operations. The harvest is year-round, and seasonal weather conditions are not an inhibiting factor as they are grown in a controlled, indoor environment. Retailers including Whole Foods and Kroger predict mushrooms will be one of 2021's top trending foods (OHLEMEIER, D, 2021). Their low carbohydrate levels, high nutritional value, high immunity boosting properties, adaptability in many dishes around the world and inclusion in popular eating plans such as Keto and Paleo. They are also available year-round.

The surging of mushrooms ingredients in various food products and versatility fuels the market growth. The mushroom possesses various nutritional properties such as low cholesterol and low fat which is utilised as prominent food for high cholesterol or obesity patients. In turn, this factor stimulates the growth of the market. However, the low shelf life of the mushroom increases the preservation cost and presents the grower with a race against time from the moment of harvest to the end consumer purchase. The medical and food industry and direct consumption are all end users of the mushroom market (Zhang, J., Chen, Q., Huang, C., Gao, W., & Qu, J, 2015).

Mushrooms are the spore bearing, fleshy fruiting body of a fungus. By extension, the name mushroom can also refer to either the entire fungus when in culture, the thallus (called a mycelium) of species forming the fruiting bodies called mushrooms, or the species itself. The inclusion of mushrooms being grouped together with vegetables is misleading as they represent a separate kingdom from botanicals and as a result their growth cycles are not similar.

The published list for edible species around the world varies considerably. The earliest reports of mushrooms being consumed by humans are from Spain (18,700

years ago), China (5,000 to 6,000 years ago), and Egypt (4,600 years ago) (Chang, 2006; Power, Salazar-García, Straus, Morales, & Henry, 2015; Straus, Morales, Carretero, & Marín-Arroyo, 2015; Zhang, Chen, Huang, Gao, & Qu, 2015). The exact process by which early humans identified edible mushroom species—those that were safe and suitable to eat—is unclear, but there is little doubt it was by trial and error. While 21st century identification of mushroom species is quickly becoming molecular, the standard methods for identification are still used by most and have developed into a fine art ageing back to medieval times and the Victorian era, combined with microscopic examination.

The presence of juices upon breaking, bruising reactions, odours, tastes, shades of colour, habitat, habit, and season are all considered by both amateur and professional mycologists. (Ammirati et al., 1985, pp. 40–41). The most important microscopic feature for the correct identification of mushroom species is the spores. Their shape, size, colour, attachment, and reaction to chemical tests often can be the crux of an identification. The most widely used chemical tests to identify fungi varieties include Melzer's reagent and the use of potassium hydroxide. Melzer's reagent is an aqueous solution of chloral hydrate, potassium iodide, and iodine used to expose cells or fungal tissue to the reagent. Depending on the formulation, it consists of approximately 2.50-3.75% potassium iodide and 0.75–1.25% iodine, with the remainder of the solution being 50% water and 50% chloral hydrate (Largent D, et al. 1977). Spores that stain bluish grey to bluish black are amyloid. Spores that stain brown to reddish-brown are dextrinoid (Largent D, et al. 1977). By knowing what type of spores the mushroom has as a resulting reaction to the chemical test, the genus of the mushroom is able to be correctly determined. The more inexpensive option to test for fungal varieties is with potassium hydroxide. A 3–5% aqueous solution of KOH is applied to the flesh of a mushroom and the researcher notes whether the colour of the flesh changes (Elix, J.A.; Stocker-Wörgötter, Elfie (2008). Species are identified based on the colour-change reaction.

1.2 The New Zealand Mushroom Growing Industry

Mushrooms were first grown for sale in New Zealand in the 1930s (Wassilieff,2008). Growing techniques greatly improved by the 1960s, and an industry began. Most mushrooms grown in New Zealand are sold locally and fresh. The three types that occupy our grocery store shelves are all versions of the same species, *Agaricus bisporus* also commonly known as White button mushrooms, Swiss browns, and Portobello flats. Button mushrooms have been the focus of NZ mushroom growers for over 50 years.

Farms are present from the Far North to the deep south with both large scale, commercial operations to small scale hobbyist and backyard mushroom enthusiasts. The Commercial Mushroom Growers Federation New Zealand Ltd is an industry group that was incorporated in 1983 and represents the mushroom growers of New Zealand. It is a collaborative group of mushroom growers selling under one label who share their knowledge and experience, in addition to fostering the growth of the New Zealand mushroom industry. Public knowledge about the industry group is very limited and it is an optional invitation to join the grower's federation when becoming a mushroom grower.

One of the biggest mushroom farms in New Zealand, Meadow Mushrooms, is based in Canterbury where is began around 50 years ago. It is also the only integrated mushroom farm in NZ. In 1995 meadow Mushrooms brought NZ Mushrooms who were closing due to being unable to afford the rising cost of containing the smell from its composting plant. This had a huge effect on the local community, with over one hundred jobs lost (Rowan, J. 2020). Since shutting down the NZ Mushroom operation, Meadow Mushrooms has dominated the industry.

In January 2020, Te Mata Mushrooms, who are based in the Hawkes Bay applied for recourse consent to both regional and district council for permit to discharge contaminants into the air from their composting and mushroom production activities.[1] The large-scale mushroom farming operations face environmental challenges associated with the composting stage of the mushroom growing. Such mass areas of compost produce foul aromas that are displeasing to the surrounding areas and to

[1] https://www.hbrc.govt.nz/assets/Document-Library/Consents/Notified-Consents/Te-Mata-Mushroom-Files/LJB-120563-1-313-1-Notice-of-Appeal-The-Te-Mata-Mushroom-Company-Ltd.pdf

the environment. Small scale mushroom farms can be kept in backyards and even urban environment and go undetected due to the small scale of the farm.

1.3 Specialty Mushroom Varieties in New Zealand

The New Zealand specialty-mushroom industry has been developing since the mid-1980s (Wassilieff,2008). Mushroom shoppers who gravitate toward the culinary versatility and health benefits of the fungi, can also expand their palates to try specialty mushrooms. Today, there are several specialty mushrooms that are grown in NZ thanks to overseas influence from countries such as Asia and Europe where special mushroom varieties have been eaten for many centuries. Oyster (*Pleurotus ostreatus*), Shiitake *(Lentinula edodes)* and Enoki (*Flammulina velutipes*) are a few of those speciality varieties that are now present in NZ and becoming ever so popular due to their colour, shape, and flavour.

The first NZ shiitake farm started in Auckland in 1985 (Buchanan, Peter K., and John Barnes). It was a large-scale operation, exporting up to 7 tonnes of fresh mushrooms a week to Asian markets, but failed two years later when its parent company collapsed. Since then, a few smaller shiitake farms have started up, supplying local restaurants and supermarkets and attending local farmers markets. Shiitake is not found naturally in New Zealand, but a closely related edible species, *Lentinula novaezelandiae*, is grown in NZ and can be found on fallen logs in native forest.

Previously, government restrictions prevented growers from importing the spawn needed to cultivate Oyster Mushrooms *(Pleurotus ostreatus)*. It wasn't until 1994 (Wassilieff,2008) that the restrictions were lifted, and the spawn was able to be brought into the country. Oyster mushrooms have many advantages as a cultivated mushroom: high ability for saprophytic colonisation, rapid mycelial growth, simple and inexpensive cultivation techniques and several kinds of species available for cultivation under different climatic conditions. In addition, consumption of oyster mushrooms has positive effects on general human health because of several special substances (Kues and Liu, 2000). The nutritional information provided by the USDA shows one cup of raw, sliced oyster mushrooms (86g) contains 28 calories, 2.9g of protein, 5.2g of carbohydrates, and 0.3g of fat. Oyster mushrooms are an excellent source of niacin, fibre, and riboflavin. Although these large fan-shaped vibrant colour

fungi are a relatively easy to grow variety, production levels are low in NZ, as few people know how to cook them.

Accounting for 25% of total world production of cultivated mushrooms, the oyster mushroom is the second most important mushroom in production in the world (OECD, 2006). Oyster mushrooms are grown worldwide, with China the leading producer. Oyster mushrooms were first cultivated in the USA in 1900 and several other species of the oyster mushroom such as *Pleurotus sajor-caju* were initially cultivated in India after the late 1940s (OECD, 2006). The oyster mushroom has also been regarded as one of the most profitable cash crops in Korea, accounting for 65% of total domestic mushroom production.

Importing mushroom varieties into New Zealand poses a lengthy and expensive challenge. Biosecurity and phytosanitary requirements need to be met due to the risk of disease they can bring into the country and devastation they can cause to the primary industries. The pure grey oyster mushroom *(Pleurotus Ostreatus)* for example, cannot be imported into New Zealand because it could pose a risk to our forest industry. The Ministry of Primary Industries published that all submissions to import pure *Pleurotus Ostreatus* have been refused. MPI has a very strict outline for certain types of edible fungi that can be brought into the country. The fungi are only allowed to pass through the border if the consignments are identified by DNA sequencing as the correct species by MPI Plant Health and Environment Laboratory. New Zealand is fortunate enough to have three unique endemic varieties. Shiitake *(Letinula novae-zealandiae),* the giant pink oyster mushroom *(Pleurotus parsonsaie)* and an endemic Lions mein relative called *Hericium novae-zealandiae.* According to MPI, these varieties can be legally grown and sold without applying for species testing.[2]

[2] https://www.mpi.govt.nz/import/plants-flowers-seeds-plant-growing-products/importing-fungi-growing/steps-to-importing-fungi-for-growing/

Figure 1 L

Figure 2 Pleurotus parsonsaie

Source: iNaturalist

The problem with the endemic variety and the imported version is that they are ultimately the same mushroom that has been evolving for many years on different sides of the world. The difference is so slight that *Pleurotus parsonsaie* was first originally described as *Pleurotus Djamor*, commonly known as the pink oyster mushroom and only barely makes the threshold to be a different organism in the gene bank. Perhaps the most interesting development was Dr Jerry Cooper of Landcare NZ who found some differences with the now called *Hericium novae-zealandiae*. The name was originally Coral Tooth Fungus, labelled the same name found in the USA. All the fungarium entries had to be renames and all the observations on iNaturalist (Cooper, J. 2016).

2 Understanding Low Scale Mushroom Farming and the Industry

Perhaps the most important thing to consider when venturing into low scale mushroom farming is that the fruit production time frame is quite different to other crops. There are things to consider such as indoor growing versus outdoor log production. Namely, with logs being maintained as a perennial crop, since inoculated logs will remain producing for three seasons. Indoor substrates generally only last for an average of 6-8 weeks, so therefore could be considered more like an annual crop. Oyster mushrooms can produce a saleable crop in just 3-4 weeks from start to finish. A strain of mushroom that works great for one grower might not work for another. Different spawn, different sterilization methods, different types of substrates and different climate control methods. These are all conditions that cannot be factored ahead of time. The only true way to know which method best fits with the chosen permaculture approach to growing the farm, is to run trials and see which ones perform the best. Trial and error until the desired result is achieved.

In this business report we will be focusing solely on indoor mushroom production with low-cost DIY alternatives to large commercial scale mushroom farm operations. The idea being it can be managed by one person and can be grown at home.

3 Covid-19 Response and Action Measures

Since the pandemic, E-commerce has successfully reached much of the population and has not spared a single sector (OECD. 2020) This is a win-win for both seller and consumer. Ordering fruit and vegetables online has become synonymous with fresh. People can make their mushroom order online, saving them time and having it delivered within the following days. Advantages of which include having less product waste. Mushrooms are only harvested as they are ordered meaning the consumer is receiving only the freshest of produce and less product is wasted. A general estimate of the quantity of sales each week can be built up over time and the accompanying amount can be produced and grown to meet the demand each month.

Setting up a mushroom farm during the time of a global pandemic isn't the worst idea. People will always need food and prefer local produce compared to imported produce. The farming can be done at home and can still operate safely during an outbreak or ‘lockdown’. People are also more likely to experiment with food with

COVID pushing consumers to try different things at home due to meal fatigue (Janssen, M., Chang, B. P. I., Hristov, H., Pravst, I., Profeta, A., & Millard, J. 2021).

4 Mushroom farms and the environment

Growing mushrooms is a waste-recycling activity. Mushroom farms benefit the environment by using many hundreds of tonnes of straw-bedded horse manure, mulch hay, and poultry manure. These are all considered agricultural waste products and if it were not for mushroom production, they wouldn't have a home. Mushroom production is both a science and an art with many complex and distinct stages.

Mushrooms are not green plants because they do not have chlorophyll, and they lack the ability to use energy from the sun. Mushrooms extract their carbohydrates and proteins from a rich medium of decaying, organic-matter vegetation (Jo Feeney, M., Miller, A. M., & Roupas, 2014). This rich organic matter must be prepared into nutrient-rich substrate composts that the mushroom can consume. The wonderful thing about mushrooms is they are designed to recycle. When a tree falls in the forest or bush, it's the mushrooms that often break down the complex molecules in the wood and recycle them back into the food chain for insects, bacteria, and other fungi to return to the soil (Jo Feeney, M., Miller, A. M., & Roupas, 2014).They play a crucial role in the cycling of nutrients and their ability to do this makes them perfect for recycling a wide range of organic waste streams. When mushroom farming on a commercial scale, the growing stages need to largely mimic the same life cycle that mushrooms go through in the wild. But with some key changes to maximize yield and other factors, such as size and colour.

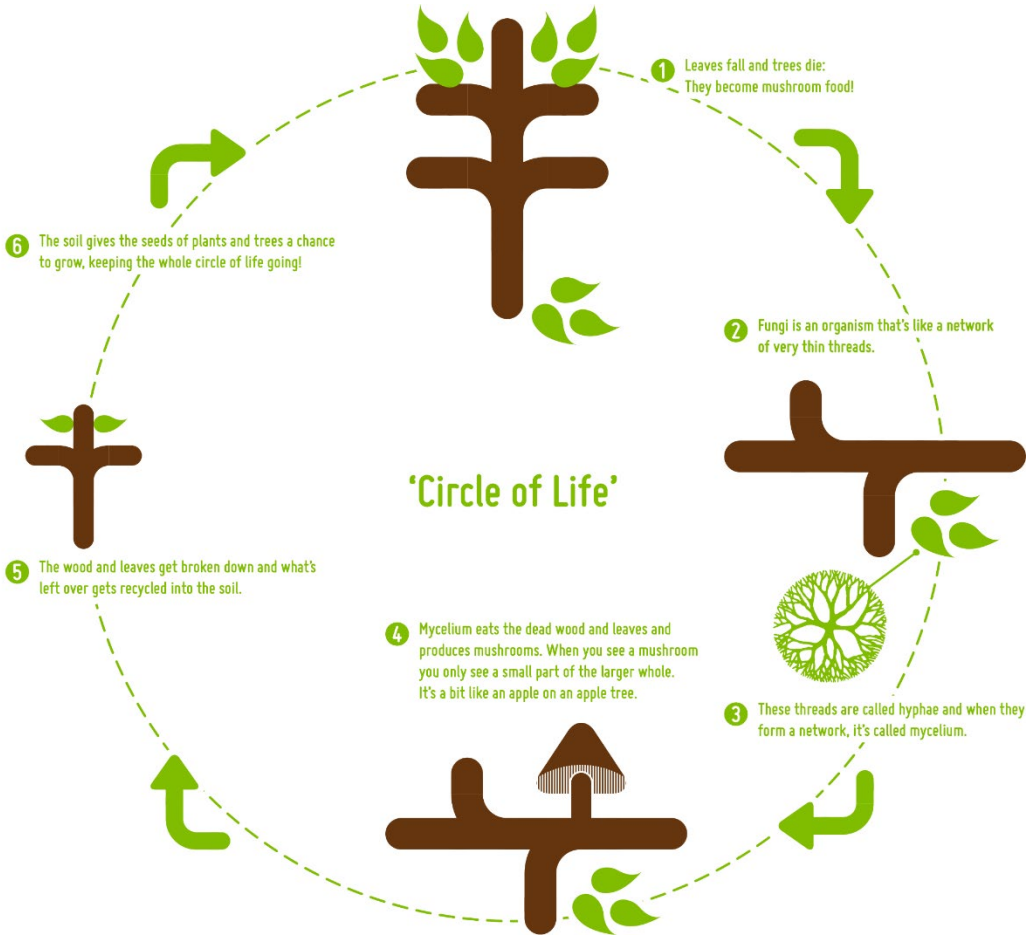

Figure 3 The Mushroom Growing Life Cycle

Source: Grocycle March 2021

Nutrient wise, mushrooms are a sustainable protein. Meat is the world's main source of protein; however, its production depends on huge amounts of scarce resources such as energy, land, and water. Oyster mushrooms are high in protein, (taste like bacon) and require relatively small amounts of these scarce resources, providing a low-impact alternative protein and nutrient rich plant-based option.

Mushroom farms can be grown vertical with shipping containers stacked upon containers to create a big farm with little land use. Mushrooms are one crop that is suited to urban agriculture where both the waste products needed for growing and demand for fresh food is high. They can be grown in empty spaces, abandoned warehouses, add to urban food security and are one of the original vertical farming innovators.

A new speciality variety mushroom farm in Loburn, North Canterbury that started operating in mid-2019 is planning an eight-fold expansion in order to keep up with demand for its speciality mushroom crop. Woodland Downs Produce, a vertical farm producing spray-free shiitake mushrooms, owner Millen Wood says demand has increased so rapidly that he is already planning his next move. “Demand is growing, and we are quadrupling our output to keep up. We are in the process of increasing our farm four-fold and then we will double that.” “We use very little water and the water we do use is not contaminated by pesticides, herbicides or fungicides because we don’t need to use any. In addition, our farm can improve the production of a secondary crop, use a waste product to produce food, capture and store greenhouse gases and produce native trees.” Millen says demand for his product has grown primarily due to the quality and taste of the mushrooms.

“Research indicates 0.453592 Kg of mushrooms requires only 6.81374 Litres of water. That is remarkably low compared to many other food sources” says Sean Steller, director of business development for Phillips Mushroom Farms Mushrooms. “One acre of land can produce over 450 tonnes of mushrooms annually.”

4.1 CO2 Production from Mushroom Growing

Mushrooms produce CO2 like all other living beings. They absorb Oxygen and emit Carbon dioxide. It is a natural by-product of their metabolism. Although it is not a huge amount, it is still adding to the greenhouse gases. One mushroom grower in Christchurch combats the CO2 production by growing Microgreens alongside his mushrooms to absorb the gas. These microgreens can be sold alongside the mushrooms at local farmers markets.

5 First things first - Sourcing the Substrate, Growing the Mycelia

Mushrooms grow from a culture which can be purchased from various places depending on the species. The Spawn is a mixture of nutrients and spores from which the fungus grows. Souring local is best so the spawn is freshest when it arrives at the farm. Alternatively, NZ Cultures is an online store that specialises in selling native strains.

The substrate is the growing medium which the mushroom mycelium can grow and establish itself in. It provides the mushrooms with all the essentials they need to grow and fruit. The carbon sources that are suitable for mycelial growth are fructose, cellulose, starch, glucose, mannose, maltose, sucrose, pectin, and lignin. Ethanol is also a source of carbon for mycelial growth. The optimal temperatures for growth of the mycelium throughout the substrate are around 25-28 °C. The range of pH is about 5.5 to 6.5. The tolerance of mycelia for CO2 is rather strong. The mycelia of oyster mushrooms can still grow flourishingly at a carbon dioxide concentration of 15 to 20%. Only when the concentration of CO2 is raised to 30% does the growth of mycelia rapidly decrease (Chang and Miles, 1989).

Normally the substrate ingredient such as sawdust, straw or compost is heated to a high temperature to pasteurise and kill off any competitor organisms that will hinder the mushroom growth. The low-tech method is designed to bypass this expensive and energy-intensive step or find low energy ways to achieve the same outcome. It is a necessary step prior to inoculating the substrate with spawn.

The decision of pasteurising over sterilising depends on the substrate used for a growing medium. If the substrate is low in nutrients like cardboard, paper and straw, then pasteurisation is adequate and cheaper than sterilizing.

Coffee grounds are a viable option to grow oyster mushrooms on as the grounds are already pasteurised from the brewing process. Espresso is a better choice as filter coffee can be too wet. It also gives another life to a product that would be disposed of anyway. When a cup of coffee is made, less than 1% of the coffee biomass ends up in the cup. After all the huge amount of energy it takes in producing, packing & shipping coffee beans around the world, all the value is placed on the liquid extract of their flavour. By taking a local waste product to grow the mushrooms on we can increase the local food production and minimise the energy inputs. The biggest mistake which can be made when using coffee grounds as a substrate is using coffee grounds that are too old. They need to have been brewed in the last 24 hours to ensure no other organisms like mould have started to grow. With a bustling cafe scene in most of the larger regions in NZ, coffee grounds will be plentiful. Working locally with cafe owners in the Whangarei region, a deal to take away their used coffee grounds free of charge could be negotiated. This also keeps it local, which is desirable in this pandemic era.

Sawdust pellets are another option as they are pasteurised by the heat created during their production.

The third option is straw, which is easily pasteurised by soaking in a high pH cold water bath. A hot water bath for pasteurization also works but is not favourited as a low-tech method due to the difficulty, cost and carrying around hot wet straw is detrimental. With Northland being vastly a farming region, straw is in abundance, but at a cost.

Example grow trial of oyster mushroom in coffee grounds

- *3kg fresh coffee grounds*
- *600g pasteurised straw*
- *300g Oyster mushroom spawn*

1) Oyster mushroom spawn (10% of coffee weight)

2) Pasteurised straw or hydrated sawdust pellets (20% of coffee weight)

Note: Adding straw or hydrated sawdust pellets breaks up the density of the coffee grounds and creates better air exchange in the substrate.

Figure 4 Oyster Mushroom Mycelium Growing on Coffee Grounds

Source: Grocycle

6 The Main Stages of The Mushroom Growing Cycle

There are three main stages of the growing process, each requires a different space:

1. Inoculation and mixing - The mushroom spawn and substrate ingredients are mixed and bagged.
2. Incubation - The bag is moved to a warm and dark space that allows the spawn to grow throughout the bag
3. Fruiting - The bag is now colonised from the incubation and is exposed to humidity, fresh air and a little bit of light which will cause the mushroom the fruit.

The first stage can be completed in any space with the use of some basic equipment. A compost tumbler to mix the spawn and substrate together thoroughly, a workbench and some sterile, easy to clean shelving.

Figure 5 A Simple Mixing Room Set Up Possible in Existing Shed Space

Source: Grocycle

The incubation stage needs to be a controlled temperature around the 20–24-degree mark. A 20ft shipping container is ideal as it can be transported and fully insulated to control the temperature. As of 24th August 2021, Trade Me has five 20ft shipping containers for sale in the Whangarei region with an average price of $6396. The

shipping container will need to be fitted out with shelving once insulated and a controlled temperature system is in place. The 20ft space works well for smaller bags which are used for small scale production of Shiitake and Oyster mushrooms. Alternatively, hanging rails can be used for bigger column bags if oyster mushroom sales are going well and there is a chance to upscale production.

Figure 6 Oyster Mushroom Mycelium Growing in 12kg Hanging Column Bags on Coffee Grounds

Source: Grocycle

During the incubation stage, the spawn creates a complex network of cells called mycelia which is similar to that of a plant root system. Mycelium can either be a single organism or several different organisms working together to achieve just one goal - to keep its species going. It does this by growing pin heads which eventually turn to mushrooms which produce spores and reproduce. Appropriately, the circle of life begins again.

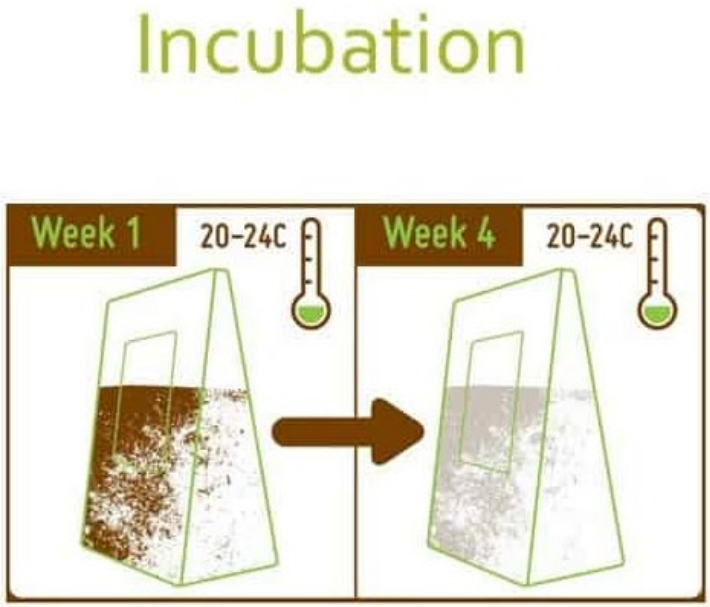

Figure 7 Mycelia Spreading Through the Substrate During the Incubation Stage

Source: TeAra.govt.nz

Source: GroCycle

In terms of the fruiting stage, there are 2 options to be considered for a low-tech fruiting room that doesn't take up much space and is easy to move around.

1. Shipping container - ex-refrigeration shipping containers converted into growing room
2. Hydroponics tent

As of 24 August 2021, TradeMe has 1 20ft refrigerated container located in Auckland for $11,500 + GST. New Install Single Phase 10 Amp 240v.

As a cheaper and more manageable option, Amazon sells a 36"x36"x72" Mylar Hydroponic Grow Tent for $81.59 + $79.25 shipping to NZ.[3] It is lightweight and portable and with a height of 11'', has a decent size for the quantity of mushrooms for one person to handle. A 12m^2 fruiting room can produce 30-50kg of mushrooms each week in the space provided.

[3] https://www.amazon.com/VIVOSUN-Hydroponic-Observation-Window-Growing/dp/B01DXYMKIO

The fruiting tent needs a small hydrofogger to create the dehumidification. A small DIY one can be made following YouTube videos and 5 simple products found at local hardware stores.

1. Plastic container with rubber seal
2. Ultrasonic humidifier
3. Small 12 or 24V fan
4. Screws to hold the fan in place
5. Plastic bolt head to attached pipe to and run into the Hydroponics tent

The fruiting room will also need 150-watt good, strong LED lights and a Meanwell driver, The final part to the fruiting room is an exhaust fan with ducting. These 3 components create the main environmental factors in mushroom farming – light, temperature, and air flow. They can be adjusted by the grower accordingly to suit the needs of the fungi.

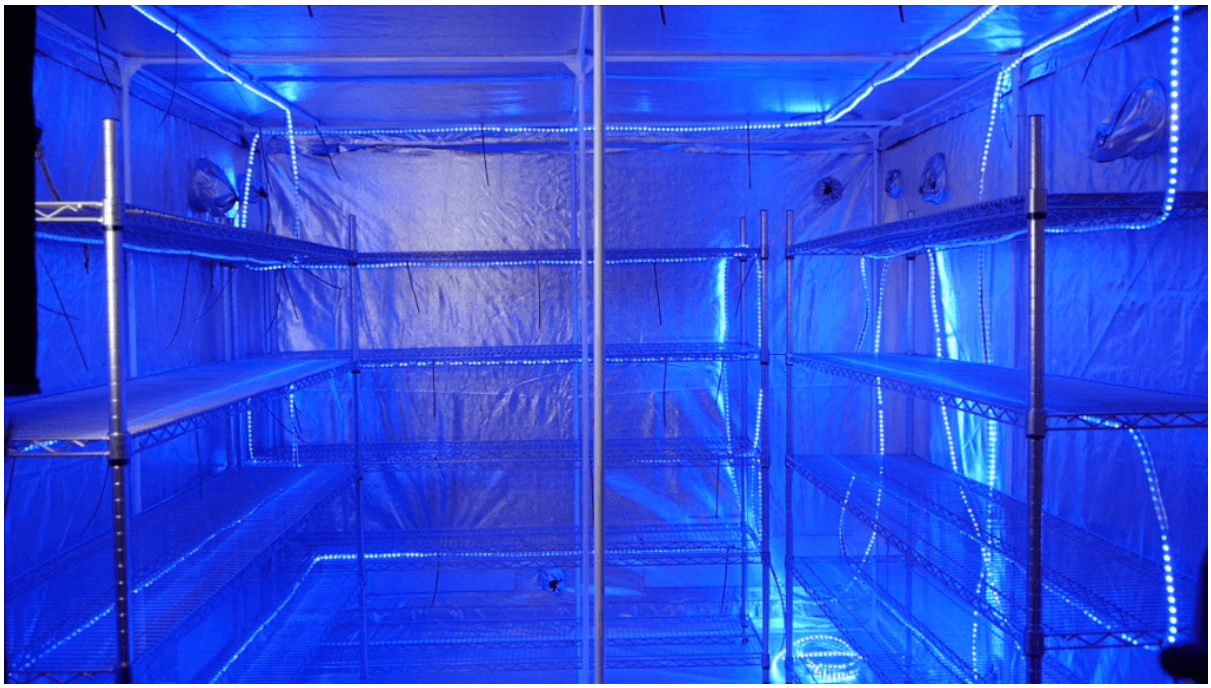

Figure 8 Hydroponic Grow Tent Set up with Shelving and LEDs as a DIY Fruiting Room

Source: GroCycle

For successful fruiting body formation, CO2, light and temperature are key environmental factors to be controlled. When the CO2 concentration in the growing bags is higher than 600 ppm (0.06%), the stipe elongates, and the growth of the caps will be prevented (OECD 2006). The formation of primordia and the growth of

fruiting bodies have different requirements of light. The former requires light of 200 lux intensities for over 12 hrs. The growth of the fruiting body requires light of 50 to 500 lux intensities. The colour of the caps is closely related to the intensity of light, and if it is low, then the colour will be pale. The optimal temperatures for the development of fruiting bodies can range from 10 to 18 °C (Chang and Miles, 1989).

Table 1: Environmental Parameters for Fruiting of Oyster Mushroom

Species	Temp. (°C)	Relative humidity (%)	CO_2 (ppm)	Light (lux)
P. pulmonarius	21-29	90-95	<1,000	500-1,000
P. cystidiosus	21-27	85-90	<2,000	500-1,000
P. djamor	20-30	85-90	500-1,500	750-1,500
P. eryngii	15-21	85-90	<2,000	500-1,000
P. euosmus	21-27	90-95	<1,000	750-1,500
P. ostreatus	10-21	85-90	<1,000	1,000-1,500
P. pulunonarius	18-24	85-90	400-800	1,000-1,500
P.tuberregium	30-35	85-90	<2,000	

The first indication of a lack of sufficient light and fresh air the oyster mushroom is the fruit bodies begin to grow with small caps and long stems. They will produce long stringy steams with tiny caps or no caps at all. The best way to troubleshoot this unappealing crop is to remove the entire cluster and then reposition the fruiting bag to a more suitable environment.

Figure 9 Oyster Mushrooms Grown in an Environment with Lack of Fresh Air and Light

Source: Sporeshift Mushrooms NZ

Next, it's harvest time! When the top of the oyster mushroom caps begins to flatten out it’s time for harvest. You can twist the clusters off or cut them from the growing bag with a knife. After two days the growing bag can be submerged in water overnight to rehydrate the substrate to produce a second crop or ‘flush’.

Once the growing bags start to produce a volume below what is commercially viable the disused substrate that the mushroom is grown in can be sold on. Usually after the second flush, the crop is no longer viable. The substrate may still likely contain active mycelia which produces a crop that would be better suited to a smaller scale mushroom farm or mushroom hobbyists. The growing material can also be used as garden compost. One type of substrate disposal is to recycle it back into fields for other agricultural crops. Although the quantity, storage, handling, and transport cost would be higher than with chemical fertilizers, the long-term benefits of the material need to be highlighted. Research at Penn State and around the world continues to show the value of post mushroom substrate as source of nutrients for many crops and plants. Spent compost is a source of nutrients and water holding properties for such crops such as corn and other vegetables.

Common strains of mushroom can be grown at 100% Biological Efficiency or more according to Aloha Medicinals, a lab run by a group of scientists and health care experts interested in growing Reishi mushrooms. In oyster mushroom cultivation, 200% BE is possible. It is a tangible measurement of successful production and high yields. “BE is the comparison of dry weight substrate to fresh harvested mushrooms” says Aloha Medicinals. “If you buy 1000 pounds of dry weight sawdust, and you can harvest 1000 pounds of fresh mushrooms, that is a 100% BE. If you start with 1000 pounds dry straw, and harvest 1500 pounds of fresh Oyster Mushrooms, that is a BE of 150%”. Noting that mushrooms are mostly composed of water, which is constantly being added to the substrate as the fruit is established, the final harvest can be anywhere from 50% to 90% water. With these percentages in mind, the weight of the bags filled with the substrate should be measured, as well as the harvested mushrooms weight from that bag. Without the BE figures, it would be challenging to optimize production and accurately predict the yield ahead of time.

7 Post-Harvest

7.1 Where to sell the mushrooms

Alongside the high quality and freshness of the mushrooms, other selling points include the mushrooms are locally grown using sustainable methods and are highly versatile in many dishes.

- The local farmers market: farmers markets have become massive in recent years as people seek out high quality produce from small local artisan producers. The Whangarei Growers Market runs every Saturday offering an array of local seasonal produce. There is currently one stall that sells NZ native oyster mushroom *(Rare Pluerotus Pulmonarius)* at $40 a kilo.
- Nearby health or wholefoods stores: people who appreciate fresh & local food tend to either get a veg box or they shop for it at specialist food stores.
- The best restaurants in the area: good chefs would instantly recognise the high quality and taste of fresh mushrooms – especially if they can advertise as locally sourced on their menu.
- Local veg box CSA scheme: having a diverse selection of locally grown crops really helps generate interest. Adding bright and interesting looking mushrooms will excite box customers & keep them happy through the leaner produce months.
- Sourcing a place to sell less-than-perfect mushrooms helps to reduce the waste and creates another level of grading for the mushrooms to be grouped into. Options such as drying the mushrooms or using them in animal feed. Chicken pellets in particular use mushrooms as a main ingredient.

7.2 Mushroom storage

Mushrooms are an earthy and delicate vegetable that needs to be stored similar to its natural environment. When stored correctly, you will reduce the amount of ‘slime’ found on mushrooms which is a result of bacteria growing within an excess of moisture. The mushroom fruit shrinks when it is cooked due to the naturally high-

water content. If the moisture surrounding the mushroom is kept similar to its natural environment, they will hold their size and not become slimy and shrink.

A common white button mushroom can be stored at around 2 degrees centigrade in as high as possible humidity, for around 4 days with little deterioration. Weight loss can occur during storage as they continue to grow once picked. During this process a lot of moisture releases and changes.

Storage at ultra-low temperatures has proved to be the most successful method for the prevention of degenerative changes in filamentous fungi. Therefore, for long term storage, liquid nitrogen storage is generally used for oyster mushrooms. International Mycological Institute (IMI) reported the successful storage of oyster mushroom mycelia in liquid nitrogen for 23 years (Smith, 1993).

The mushrooms need to be stored/presented/sold in porous brown bags or recycled cardboard boxes with perforated shrink wrap for moisture to escape and air to move.

7.3 Other Sources of Income for the Mushroom Farm

- Street food/festival stall: take mushrooms to a weekly food market or to festivals and cook them up in all sorts of delicious ways to add extra value. Not enough knowledge on how to cook specialty mushrooms or what to do with them is a barrier to customers purchasing these gourmet varieties.
- Mushroom growing kits: producing kits that help people to grow their own mushrooms at home. Gives a secondary life to the spawn used to grow batches of Oyster mushrooms on the farm. They also make unique gifts and another form of marketing for the business with branding all over the kits.
- Farm tours and workshops: once mastered the growing process, you can run courses and short workshops teaching people what you do and why mushrooms are great to grow at home.
- Mushroom based snacks at the farmers market: you can add extra value by turning some of your crop into mushroom burgers, tempura or croquettes – perfect healthy veggie snacks for people roaming around the markets looking for tasty treats.

- Partnership with social enterprises/charities working with disadvantaged groups: growing mushrooms is a great activity to get stuck in and use your hands, as well as learning a wide range of other skills.
- Innovative products such as mushroom chips, mushroom jerky and meat replacements.

The Ministry of Primary Industries is helping New Zealand dive into the rapidly growing market for plant-based products and meat alternatives. Thanks to a $147,000 investment from MPI's Sustainable Food and Fibres Futures fund (SFF Futures), a diverse new range of processed vegetable products is now available on supermarket shelves. The 2-year long project led by Food Nation kicked off in mid-2019 using mushroom seconds and an array of other novel plants. "There's a growing global market for alternatives to meat-based protein, and our support of this project will help New Zealand to tap into that market much faster. Many of the current 'fake meat' meals on the market revolve around trying to reflect the taste and texture of meat. This project specifically works to showcase and highlight the goodness of the various plants the meat alternatives are made of. Meadow Mushrooms has jumped on board to work in partnership with Food Nation to showcase the culinary versatility of the mushroom. This investment will have benefits for New Zealand businesses looking to enter the market and help build our plant-based food sector." says Steve Penno, MPI's director of investment programmes.

8 Negative Side Effects of Growing

Despite the usefulness as food and bioconversion materials, two notable disadvantages persist in the cultivation of oyster mushrooms. First, like many varieties, the oyster mushroom is quick to spoil and so is presentable to the market for only a few days. Secondly, the spore load generated within the growing room can become a potential health hazard to workers thus pickers can become allergic to the spore. Sporeless strains, which tend to have short gills and are thicker fleshed, prolonging storage, are highly sought after by oyster mushroom growers.

Although the mushroom itself is a fungus, it can in turn be affected by a range of fungal pathogens, viral diseases, bacterial diseases, and insect pests.

9 Summary

Mushrooms can be cultivated with low start up and ongoing costs and lowland use. They are distinct due to their nutritional properties and are growing ever popular due to their culinary versatility and red-meat alternative. The specialty mushroom farm is a viable operation as a start up with a one-man (woman) band running the day-to-day operations.

10 Conclusions

This business concept aimed to investigate the possibility of running a successful low-tech, small-scale mushroom farm, growing a small selection of specialty varieties. New Zealand has a small mushroom industry and even smaller specialty variety industry which has not yet lived up to its potential. With diets around the world changing and consumers turning to plant-based options as meat alternatives, there is no time like the present for mushrooms to burst through as a leading dinner time option. Their culinary versatility and nutritional benefits are only some of the reasons why mushrooms are the next best thing. The grower is in the ideal situation to be able to grow from anywhere and not be hindered by environmental factors. The ability to control the environment and the physical structure of the farm, vertical vs sprawl across land, leads the way in sustainable ways to farm without consuming scare reasons such as land and water. The profitability of the crop depends on the success of the yield and the price received.

The option to create a DIY farm at home is possible with the help of a few YouTube videos and online forums. Tools needed to build the three production stages of the farm can all be purchased online and do not require previous building experience.

There are a variety of channels that's the mushrooms can be sold through, post-harvest, the waste products can also be repurposed to serve a second use.

11 Recommendations

It is recommended that further research be done into the actual man hours required for the establishment of the farm under a DIY approach with low tech methods. In addition, the costs of replacing large scale operations machinery with low tech options. Do the benefits outweigh the alternative?

The most achievable way to reach the goal of a successful mushroom farm is to work with small harvests and a high quality of fruit. Starting with the oyster mushroom variety as the first mushroom to master growing. The simplicity of growing this variety compared to other endemic varieties ensures a higher probability of success in the first grow trials and less challenges when only just starting out.

Research into potential yields and simplicity of growing additional specialty varieties that can be grown and sold alongside the oyster mushroom. Varieties such as Shiitake and Enoki.

A more in-depth competitor analysis, once the covid lockdowns of 2021 allow, is required to develop a unique value proposition. Attend local farmers markets to get a gage on the competition and how best to sell and display the specialty varieties to the recreational consumer.

Trial and error harvests are considered necessary to pinpoint the perfect climate control settings to suit the Northland region weather.

12 References

Ammirati JF, Traquair JA, Horgen PA (1985). Poisonous Mushrooms of Canada: Including other Inedible Fungi. Markham, Ontario: Fitzhenry & Whiteside in cooperation with Agriculture Canada and the Canadian Government Publishing Centre, Supply and Services Canada. ISBN 978-0-88902-977-4.

Buchanan, Peter K., and John Barnes. 'The mushroom industry in New Zealand.' Mushroom International 87 (2002): 3–5.

Chang, S.-T. (2006). The world mushroom industry: Trends and technological development. International Journal of Medicinal Mushrooms, 8(4), 297–314.

Cooper, J. (2016). Pleurotus in New Zealand. *INaturalist NZ*. Published. https://inaturalist.nz/posts/6864-pleurotus-in-new-zealand

Janssen, M., Chang, B. P. I., Hristov, H., Pravst, I., Profeta, A., & Millard, J. (2021). Changes in Food Consumption During the COVID-19 Pandemic: Analysis of Consumer Survey Data From the First Lockdown Period in Denmark, Germany, and Slovenia. Frontiers in Nutrition, 8. https://doi.org/10.3389/fnut.2021.635859

Jo Feeney, M., Miller, A. M., & Roupas, P. (2014). Mushrooms-Biologically Distinct and Nutritionally Unique: Exploring a "Third Food Kingdom". Nutrition today, 49(6), 301–307. https://doi.org/10.1097/NT.0000000000000063

Kues, U. and Y. Liu (2000), Fruiting body production in basidiomycetes. Appl. Microbiol. Biotechnol. 54:141-152.

Largent D, et al. 1977. How to Identify Mushrooms to Genus III: Microscopic Features. Arcata, CA: Mad River Press. ISBN 0-916422-09-7. p 25–26.

Maggy Wassilieff, (2008) 'Mushrooms and other cultivated fungi', Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/mushrooms-and-other-cultivated-fungi (accessed 27 July 2021)

Medicinals, A. (2021, April 1). *Low Cost and Low Tech Methods For Growing Mushrooms.* Aloha Medicinals - Medicinal Mushroom Supplements. https://alohamedicinals.com/low-cost-and-low-tech-methods-for-growing-mushrooms/

Mushrooms, oyster, raw. FoodData Central. U.S. Department of Agriculture. Published April 1, 2019.

OECD (2006), "Section 11 - Oyster Mushroom (PLEUROTUS SPP.)", in Safety Assessment of Transgenic Organisms, Volume 1: OECD Consensus Documents, OECD Publishing, Paris. DOI: https://doi.org/10.1787/9789264095380-14-en

OECD. (2020, October 7). E-commerce in the time of COVID-19. https://www.oecd.org/coronavirus/policy-responses/e-commerce-in-the-time-of-covid-19-3a2b78e8/

OHLEMEIER, D. (2021, September). *Year of The Mushroom*. Produce Business. https://www.producebusiness.com/year-of-the-mushroom/

Petersen, R.H.; Krisai-Greilhuber, I. 1999: Type specimen studies in Pleurotus. Persoonia - Molecular Phylogeny and Evolution of Fungi 17: 201-219

Power, R. C., Salazar-García, D. C., Straus, L. G., Morales, M. R. G., & Henry, A. G. (2015). Microremains from El Mirón Cave human dental calculus suggest a mixed

plant–animal subsistence economy during the Magdalenian in Northern Iberia. Journal of Archaeological Science, 60, 39–46.

Rowan, J. (2020, September 17). Locals blame mushroom farm for job losses. NZ Herald. https://www.nzherald.co.nz/nz/locals-blame-mushroom-farm-for-job-losses/Z5BUD6RSPUVAYHZ5ITHJIQV26M/

Smith, C.A. Macrosynteny analysis between Lentinula edodes and Lentinula novae-zelandiae reveals signals of domestication in Lentinula edodes. Sci Rep 11, 9845 (2021).

Smith, D.(1993), Culture collections.. In Genetics and Breeding of edible mushrooms. Pp15-35 Ed. S.T. Chang, J. A. Buswell, and P. G. Miles (eds.) Gordon and Breach Science Publishers. U.S.A.

Straus, L. G., Morales, M. R. G., Carretero, J. M., & Marín-Arroyo, A. B. (2015). “The Red Lady of El Mirón”. Lower Magdalenian life and death in Oldest Dryas Cantabrian Spain: An overview. Journal of Archaeological Science, 60, 134–137.

Zhang, J., Chen, Q., Huang, C., Gao, W., & Qu, J. (2015). History, current situation and trend of edible mushroom industry development. Mycosystema, 34, 524–540.

https://www.hbrc.govt.nz/assets/Document-Library/Consents/Notified-Consents/Te-Mata-Mushroom-Files/LJB-120563-1-313-1-Notice-of-Appeal-The-Te-Mata-Mushroom-Company-Ltd.pdf First accessed October 2021

https://www.mpi.govt.nz/import/plants-flowers-seeds-plant-growing-products/importing-fungi-growing/steps-to-importing-fungi-for-growing/ First accessed July 2021

https://www.nzherald.co.nz/business/former-policeman-becomes-mushroom-farmer-now-hes-becoming-a-youtube-hit/56U2DYNYOMK7JRTVMEVYWEDTZA/ First accessed July 2021

https://www.tradetested.co.nz/p/gardening/bins-bags/compost-bins/compost-bin-tumbler-190l?gclid=Cj0KCQjwjo2JBhCRARIsAFG667WKc15-UOBx1dIwTuXK4gU8UIGKOT0cpHaG_JuJ5UWNXAfhoGuNzXIaAmWbEALw_wcB&gclsrc=aw.ds First accessed July 2021