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The business of Alternative protein: Mycoprotein

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Abbreviations

Acronym	Abbreviation
CAPEX	Capital costs
B2C	Business to customer
B2B	Business-to-business
FDA	Food and Drug Authority
eFSA	European Food Safety Authority
EU	European union
DSP	Downstream processing
OPEX	Operating costs
SWOT	Strength, weakness, opportunities and threats
l	litres
g	Grams
hr	hours
GRAS	Generally recognized as safe
GM	Genetic modulation
GFI	Good food institute
R&D	Research and development

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Abstract

Global shortage of protein, high consumption of protein, food insecurity, improved income level, population growth, sustainability (in terms of judicious use of resources such land, water, energy and low carbon emission) and changing in consumer eating or dietary shift have necessitated the search for alternative product such as mycoprotein which will augment and stabilize the protein consumption.

Mycoprotein is a fungi protein often derived from fungi such as *Fusarium venenatum*, is a relatively new and innovative source of protein that has gained attention as a potential alternative to conventional protein sources like animal-based proteins (meat, dairy, and eggs) and plant-based proteins (soy, legumes, etc.). Its application is highly utilized in the food and feed industry segment. The aim of study is the use of the mycoprotein fungi as alternative protein (science aspect) and how to develop a business plan for a young entrepreneur producing raw bulk mycoprotein (business aspect).

The business tool, SWOT analysis has strategically been used to assess the business of a younger entrepreneur producing a raw mycoprotein. Osterwalder business model was used to develop a business model or plan for a company producing bulk refined mycoprotein for purpose to be assessed by an investor. Based on secondary data, market segmentation was conducted on the mycoprotein-producing company to identify the various customer or market segments within the business and what they need and the benefit or value they are expecting from the purchase of the product.

By relying on secondary data, regulatory compliance such as safety and GMO compliance of the product must heed or go through were established. Decision making matrix business tool was employed to select and compare mycoprotein business concept with other alternative protein such as plant-based protein, insect-based protein and lab cultured meat based on the following key of business success: cost efficiency, product quality, consumer adoption, maturity in the value chain and product evaluation in terms of price.

we realised that young generation are champion and lead customer for mycoprotein related final product under the customer segment which have shaped the food processing or manufacturing industry in business customer segment for the usage and patronize of raw mycoprotein product to produce other related mycoprotein products.

Apart from price, taste, quality which motivate consumers, sustainability, health and animal welfare are values sort by consumers.

1. Introduction

Global population growth coupled with consumption per person rise for the past two decades have resulted to an increase percentage of meat consumption and demand (Whitnall & Pitts, 2019). Global population growth has also resulted in increased urbanization, poverty, deteriorating and loss of environmental integrity, high food insecurity, food production, emission of greenhouse gases and migration. These negative effects aforementioned pose threats to global food production, food security and the global food value chain.

In addition, arable lands meant for conventional farming and agricultural purposes in both developed and developing countries are impacted negatively due to change in land use, urbanization and exploitation of minerals. Arable and farmable lands or lands yard marked for conventional farming and agricultural purposes are seen to loss it purposes of use to other purpose such as Estate development as result of population explosion and urbanization.

Global population is projected by the United Nations to increase to around 8.5 billion in 2030, 9.7 billion in 2050 and 10.4 billion in 2100 (UN 2022). The world's fastest growing population is observed among the least developed countries, and the resultant effects and challenges posed by the rapid growth are compounded by factors such as climate change and sea level rise.

Due to the challenges accompanied by rapid population growth, there is an observed increase in Research and Development by many institutions and governments in both developed and developing countries to curb the effects. Academicians, entrepreneurs and scientists have realized solving the emerging global threat to food production, food security, climate and sustainability through devising greener models and cellular agriculture gear. The greener models are focused on producing food in an environmentally sustainable or greener way with the use of less land, low emission of greenhouse gases, low carbon footprint and recycling or reuse of biowaste to curtail the emerging threat of food insecurity from the exponential population growth coupled with climate change.

1.1 Greener business model and cellular agriculture

Greener business models or concepts and cellular agriculture revolutionized by scientists, entrepreneurs and academics as a result of the urgency to solve food production and climate change control technology. Some greener business models which have revolutionized include the following :reuse and recycle of plastic waste and the use of petrochemical feedstock to develop micro plastic digester to harness biowaste, (biowaste as an essential commodity or opportunity identification to create methane gas and organic fertilizer from biowaste), the use of biowaste to reared insects and harvest and processed it into high value product such protein(novel protein) for both human and animal, the use of agricultural waste as mushroom substrate to grow mushroom, the use of agricultural waste in airlift fermenter to grow proteinaceous fungi called mycoprotein and serve as a novel protein, vertical farming: cultivation of vegetable in enclosed structure where all plant environmental conditions are monitored and controlled, utilization and use of seaweed as alternative ingredient in aqua and animal feeds and the production of cultured meat under lab conditions by introducing muscle cells (especially a biopsied from donor bovine animals) to a culture medium, where they allowed to proliferate under controlled conditions and develop into muscle fibres and used as a meat(Post, 2012) . The objectives of all these greener business concept models and cellular agriculture are geared toward an increase in food production to augment or supplement or alternative substitute of the protein need of our growing population, to minimize and utilize available arable land marked for food production and to reduce carbon footprint.

1.1.1 The role and importance of the Green business model and cellular Agriculture

Green business models or concepts are aimed at utilizing sustainable materials to produce products. Cellular Agriculture is an innovative method or way of producing food in vitro way or the laboratory. Green businesses and cellular agriculture operation systems tend to use little amount of water, energy and raw materials while they try as much as possible to cut down on greenhouse carbon emissions to produce a product. Under this concept or model, resources are judiciously utilized in a renewable and eco-friendly way without putting much pressure or strain on the natural resources and the environment. In some case, waste generated is treated as an essential commodity by reusing it as energy or raw material. Holistically, products

produced under such a model are considered on how they positively would affect the environment and climate.

1.2 Why alternative protein/Novel proteins are needed.

Alternative protein is an umbrella term that encapsulates plant-based meat, seafood, and dairy, enabling insect protein (cricket snack), mycoprotein, lab cultured meat. This protein produces a substantial amount of protein with less use of natural inputs.

such as land, and water to produce the product as compared to conventional way of producing protein (i.e., poultry production, cattle rearing, fish and pork production). These proteins of which mycoprotein form part, are sometimes described as Novel protein food because of the different amino acids they compose, and these amino acids are responsible for providing lean meat and good health. The alternative proteins depend on processes like advanced fermentation (plant-based burger), biomass(mycoprotein) and cellular agriculture (cultured meat or lamb or seafood). They often also involve cutting-edge technologies, such as cultivating meat and seafood through stem cell lab processes under precision fermentation.

As the population continues to grow, the demand and consumption for protein near future will continue to go up and it is important to search for alternative goods and quality sources of protein to augment the existing protein needs for human and animal consumption. The existing conventional protein sources for the next decade would not be sufficient to meet the protein requirements for the next decade and some of them have been shown to negatively affect the environmental integrity through their activities by contributing the amount of greenhouse gas emissions. Food security has been a challenging concern in the light of the increasing population, especially in the developing countries.

Diary meat and dairy-related products (such as milk, and cheese,), comminuted meat products (such as sausage, and minced meatballs), seafood, eggs, vegetables and offals are some of the major sources of conventional protein in both developed and developing countries. However, these sources of convectional proteins are not sufficient to meet the protein demand for the ever-growing population. studies have shown that using conventional rearing of animals for food and meat production takes a large chuck of natural/environmental resources inputs in terms of land, water, energy and feeds. The animal rearing system is also contributor/responsible for large emissions of greenhouse gases (GHG) (Kumar et al., 2017).

Animal production/livestock has been a major contributor to emission of three major greenhouse gases carbon dioxide, methane, nitrous oxide, 9%, 39% and 65%, respectively (Shadow, 2006). According to a study conducted/initiated by Stockholm International Water Institute, producing 1 kg grain-fed beef requires 5–40 times more water than producing 1 kg cereal grains (Falkenmark et al., 2004). A further study by (Pimentel & Pimentel, 2003) estimated that water requirement during the production of meat from conventional animals, 100 times more water is consumed/needed as compared to water consumed during the production of food crops.

According to (Post, 2012), the use of livestock animals to produce conventional meat to fulfil human protein needs also comes with the following enlisted challenges/issues/concerns as shown (Fig 1)

1) Environmental issues—livestock rearing accounts for some of these challenges such as environmental pollution, deforestation, depletion of natural resources, etc.
2) Animal welfare issue—animals reared under the system are sometimes subjected to such concerns as cruelty and unethical treatment of animals during rearing, transportation and slaughter.
3) Public health issues—such as overconsumption of meat are responsible for a quarter of all ischemic/coronary heart disease responsible for over 1.8 million deaths annually.

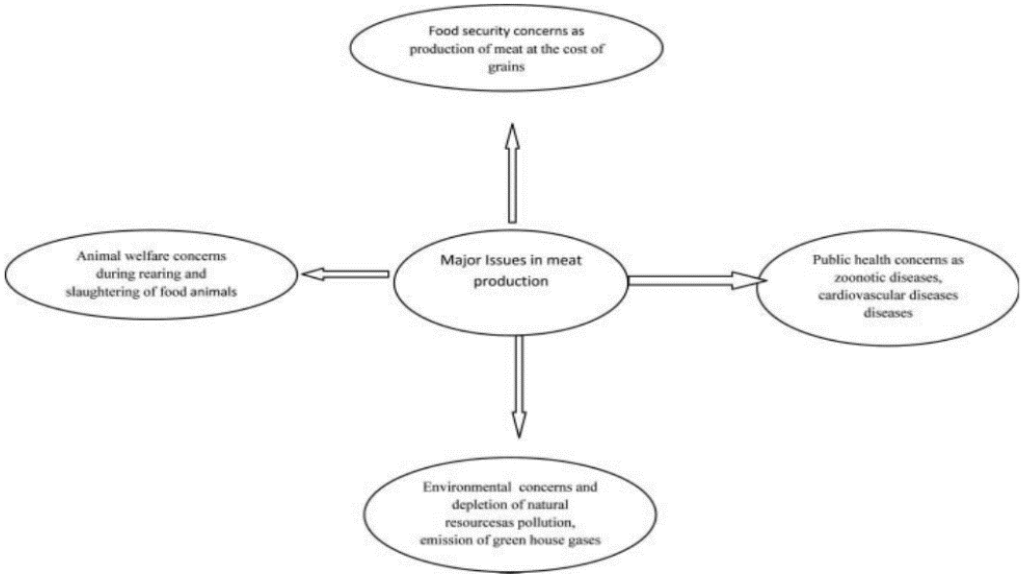

Figure 1:some of major issues/concerns arisen as result of conventional meat production. (source:(Kumar et al., 2017))

Antibiotic resistances

These elaborated concerns about the use of conventional animal for meat and inadequacy or insufficient to meet the growing demand of consumer and the growing population, has necessitated the search for alternative sources of good quality protein for human consumption, which is also greener (eco greener), co effective, sustainable and contribute to circular bioeconomy. Some of these novel protein sources have come to the light and now used as an alternative protein for food production and to replace or augment the protein need for humans and which can be used as meat analogue or substitute includes the following source of protein as also in table (1): plant-based protein /meat source such as **oilseed based protein**|: fermented soya cake (i.e., tofu and tempeh) or (i.e., wheat), they are used as meat analogue and they are traced back to Asian communities in the 10th century. Textured vegetable protein is derived from protein.

Table 1 shows a summary of real products that can be used as meat substitutes from novel sources of proteins are applied **source:** *(Kurek et al., 2022).*

Type of protein	Source of Protein	Type of product with similarities to meat		Source of data
Legume (plant-based protein)	Faba bean	Texturized product after high-moisture extrusion (HME)	The best parameters of HME: 130 and 140 ◦C, water: product ratio = 4 and feed rate 11 rpm (1.10 Kg/h), good bite-feeling, good elasticity/firmness, positive sensory attributes	(Saldanha do Carmo et al., 2021)
	Mung bean	Texturized product after extrusion cooking	Optimized extrusion parameters: 49.33% feed moisture, 80.66 rpm screw speed and 144.57 ◦C barrel temperature, partial protein unfoldment, fibrous structure, high retention of amino acids	(Brishti et al., 2021)

Oilseeds (plant-based protein)	Soy protein Isolate–gluten	Couette cell product	More layered and fibrous structured products, formation of anisotropic structures in the microscale	(Krintiras, Göbel, Van der Goot, & Stefanidis, 2015)
	Lima bean and African oil bean seed	Texturized vegetable protein (TVP)	Higher overall acceptance than cooked meat, Concentrations of essential amino acids range between 0.90 and 7.3% with a near absence of anti-nutritional factors (0.0022–1.0008) g/kg	(Arueya, Owosen, & Olatoye, 2017)
Cereal and pseudocerealL	Pea protein dry-fractionated, pea protein isolated, soy protein isolated and oat protein.	Extrudates from twin-screw extruders	Lower water absorption for samples with oat protein; intense odour and taste profile for samples with pea protein dry-fractionated and oat protein	(De Angelis et al., 2020)
	Oat protein concentrate and pea protein isolate	Texturized product after extrusion cooking	Extruded product with minimum recommended amounts of essential amino acids for adults but lower content of phytic acid 1.5%	(Kaleda et al., 2020)
	Rice flour	Meat-based sausages	Lower cooking loss and better emulsion stability for the samples with rice flour	(J. Pereira, Zhou, & Zhang, 2016)
	Black quinoa	Bologna-type sausage	Better emulsion stability, lower water activity and lipid oxidation values	(Fernández-López et al., 2020)

Algae	spirulina platensis flour	Lupin protein-based meat analogues	Improved physicochemical and nutritional properties	(Palanisamy, Töpfl, Berger, & Hertel, 2019)
	Spirulina	Spirulina-soy extrudate for pasta filling	Decreased liking of products with higher content of soy-spirulina filling	(Grahl, Strack, Mensching, & Mörlein, 2020)
Insect based protein	*Alphitobius diapering*	Insect-based meat analog	Hardness texture and protein composition like meat	(Smetana et al., 2018)
	Mealworms	Restructured jerkey analog	Similar texture and nutrient quality to animal meat	(Kim et al., 2022)
Edible fungus protein	Filamentous fungus (mycoprotein)*Fusarium venenatum*	QuornTM meat substitute or cooking ingredient	A meat-like texture and flavour, high-fibre, low-fat food ingredient, an average protein content of 45%	(Denny, Aisbitt, & Lunn, 2008; Souza Filho, Nair, Andersson, Lennartsson, & Taherzadeh, 2018)
	Aspergillus oryzae fermented with the soybean miso,	used in hamanato, and shoyu	5–10% protein content, meaty flavour, long-shelf life	(Singh et al., 2021)
	Lentinus edodes, Coprinus comatus and Pleurotus ostreatus	*Mushroom-based meat sausage Analog*	Texture and flavour close to beef, a satisfactory level of consumer acceptability	(Yuan, Jiang, Zhang, Liu, & Sun, 2021)

1.3 Cellular Agriculture

1.3.1 Lab-cultured meat

The lab grown or cultivated meat is driven by precision fermentation technology to cultivate or aggregate animal cell under restrictively controlled lab conditions. Fermentation is the enabling technology used to grow or tissue culture cells in the lab and used as a protein source to produce food such as meat and production of functional ingredient. Fermentation technology is the enabling technology that are employed in the alternative protein industry used in the production of a standalone protein and other functional ingredients.

In the fermentation technology, animal cells and microorganisms such as the filamentous fungi, and bacteria are programmed to express specific proteins or fat and then the entire proteins are harvested and used to produce high-value products.

1.4 Insect-based protein

Insect has been an integral part of the feeding habit and lifestyle of avian, and fishes as well as diet in human being. Insect proteins are generally utilized as animal feed and human food. The benefit of using insect proteins is like that of plant-based proteins. Insect proteins are very nutritious but due to their unavailability in terms of high volume, but it’s to be very expensive in terms of price. Insect protein is generally used in food applications as raw/whole insect, coated (Bars, Candy, Chocolate, Cookies, Snacks Packs and others), powder/flour form and paste form.

In some parts of Asia, whole insect is prepared and seasoned and used served as dish or food while in the EU/UK, in the food industry, most insects are thoroughly cleaned and processed (milled) into high value flour, which is then further used for food product formulation (e.g., EatGrub fruit-flavoured insect-based chocolate bars) in order to increase consumers acceptance. Currently, in the food industry, insects are normally used in bakery, chocolate bars, muffins, biscuits.

1.5 Plant-based proteins

They are generally protein which are sourced from plants. This type of alternative protein is generally eco-friendly, more sustainable, affordable, nutritious and healthy. The challenge

with some of these proteins is dealing with some anti nutritional factor in some of the plant sources used in production. Its application is extensively used in the food and food industry. They are normally used as an extract, whole seed or powder.

1.6 Mycoprotein

Mycoprotein is a fungal-based protein, and it belongs the Fungi kingdom as an edible Mushroom. Edible Fungus proteins and mycoprotein in general are now gaining ground and popularity as alternative protein in the world because of their insignificant impact on the environment. They are cheaper and less resource-intensive protein alternative sources to replace meat or meat products. Edible Fungus based protein has generally been utilized as food as functional food because of its high nutritional value. In some rare cases, some of the species, which are known to have medicinal properties, have been cultivated and utilized to produce medicine. The difference between Mushroom and mycoprotein lie on the protein content /the nutritional value, as well as the structure.

Mycoprotein is a filamentous fungal based which have long fibres which make it to create a meat like texture. The long fibre with similarity to the body skeletal muscle fibres, that make it mimic conventional meat texture and flavour and it makes a perfect substitute for conventional meat. Because of its excellent texture that mimics muscle fibre, it has been adopted as meat alternative protein for humans and as feed for animals.

The filamentous fungus called *Fusarium graminearum* A3/5 was discovered in the late 1960s, in a quest to search for alternative protein from starch fermenting fungus which led to the discovery of the filamentous fungus (Whittaker, Johnson, Finnigan, Avery, & Dyer, 2020).The Quorn™ was the first and most successfully commercialized fungi-based alternative protein (mycoprotein) released in the market. Mycoprotein is produced by biomass fermentation technology by relying on carbon substrate from agricultural and food by-products while its counterpart alternative protein produced from animal cell culture or lab cultured makes use of precisions fermentation technology.

The demand and consumption of mycoprotein is driven by consumers who are health conscious, increased in number of conventional meat-eating ill health related problems such as obesity and chronic heart disease. A shift for demand for mycoprotein as alternative protein have necessitated by the rise in awareness and concern among consumers regarding environmental sustainability and animal welfare. There is a growing trend of a large meat-eating consumer population has shifted the focus toward plant-based diet for procure origin the necessary nutrition or to harness their protein requirement from plant based.

1.6.1 Possible bomass that can be utilized /used for the cultivation of mycoproteins

Generally, waste from agricultural streams or Agri-food industry are relied on and used as carbon source substrate to produce mycoprotein biomass as well as other single cell proteins or microbial proteins are also grown on this variety of waste stream from Agri-food industry biomass to produced sustainable source of protein for human and animal consumption (Acosta et al., 2020; Matassa, Boon, Pikaar, & Verstraete, 2016) . Agricultural waste and agro-industrial byproducts are sourced and used as substrates or biomass for the production of mycoprotein and other single-cell protein because of it tendency to reduce the total cost production of the protein(Anupama & Ravindra, 2000). The cost and the value of producing the protein depend on the type of substrate utilized. Waste streams from agro-industrial byproducts and Agric food industry are seen to be inexpensive carbon sources as well as for sustainability perspectives. However, due diligence is done on the selection of the feedstock or substrate from the various waste sources to ascertain safety, which sometime may be challenging. The possible disadvantage/effect of using waste realized from some agro industry waste streams has do with the transfer or accumulation of toxic contaminants like pesticides or heavy metals into the produced microbial biomass (Acosta et al., 2020).

Agricultural wastes have been the main feedstock or biomass, or substrates used as carbon sources to produce mycoprotein biomass and some of the single cell proteins both experimental and large-scale base and several studies have reported or attested to the use of agro industrial waste as shown in the Table 2 below:

Table 1 Examples of some of carbon source substrates from Agro industrial by-product and waste stream used to cultured or produce the Mycoprotein Biomass (source:(Ahmad, Farooq, Alhamoud, Li, & Zhang, 2022)

Type of cultivation	**Carbon source (Substrate)**	**Microorganisms**	**Key parameters**	**Yield**	**Composition**	**References**
	Seaweed and seaweed waste	*Paradendryphiella salina*	Inoculum preparation on Cornmeal Seawater Agar (CMSWA); substrate volume: 20 g/L dry matter; incubation: 121 ◦C for 15–20 min; filtration followed by centrifugation at 3300g at 4 ◦C	Mycoprotein biomass (seaweed) yield: 564 g/k	Protein: 31%; fat: 1.2%; carbohydrates: 30%; energy: 253 Kcal/100 g	(Salgado, Muñoz, Blanco, & Lienqueo, 2021)
	Ulva spp. (green algae)	*Paradendryphiella salina*	Inoculum preparation on CMSWA; substrate volume: 25 g/L dry matter; incubation: 25 ◦C with agitation at 200 rpm; filtration followed by	Mycoprotein yield: 561.3 g/kg,	Protein: 48%; fiber: 3%; carbohydrate: 20%; energy: Kcal/ 100 g	(Landeta-Salgado, Cicatiello, & Lienqueo, 2021)

			centrifugation at 3300g at 4 ◦C			
	Potato Protein Liquor (PPL)	*Rhizopus oryzae*	Inoculum preparation on PDA; cultivation on PPL, incubation: for 54 h at 35 ◦C; followed by harvesting and sterilization at 120 ◦C for 20 min	Mycoprotein yield: 72.63 g/L sugars content	70 g/kg nitrogen content	(Zamani & Taherzadeh, 2017)
	Pulse husk broth (PHB)	*Aspergillus niger*	Inoculum preparation on PDA; cultivation on PHB; incubation: 26 ◦C at a speed of 120 rpm for 8 days; filtration followed by washing and drying	Mycoprotein yield: 1.178 g/100 g Under best condition		(Rajeshwari, Naik, & Ajayan, 2012)
	Stale bread and brewer-spent grain (BSG)	*Neurospora intermedia and Rhizopusoryzae*	Inoculums preparation on PDA; fermentation with substrates (15 g of dry weight);	Neurospora intermedia mycoprotein biomass	Protein: 46.7%; fat: 4.4%; carbohydrate: 42%; energy: 326 Kcal/ 100 g	(Gmoser et al., 2020)

			incubation: 25 ◦C for 6 days, filtration followed by centrifugation at 3220g at 4 ◦C for 15 min			
	Brewer-spent grain (BSG) and grape bagasse	*Agaricus blazei, Auricularia fuscosuccinea and Pleurotus albidus*	Inoculums preparation on PDA; fermentation with substrates; incubation: 28 ◦C for 15–20 days; colony drying 24 h at 4 ◦C; filtration followed by centrifugation at 3220g at 4 ◦C for 15 min	Pleurotus albidus mycoprotein yield: 125 g/kg	Protein: 22.6%; total amino acids: 7.85%; dietary fiber: 34.35%	(Stoffel et al., 2019)
	Pea-processing industry byproduct (PpB)	*Aspergillus oryzae, Fusarium venenatum, Monascus purpureus, Neurospora intermedia) and Zygomycota (Rhizopus oryzae)*	Inoculums preparation on PDA; cultivation (3 mL/L spore suspension) on PpB, incubation: 35 ◦C at 150 rpm for 48 h, sieved,	Rhizopus oryzae produced highest Mycoprotein : 260 g/kg	Protein: 18%; fat: 2%; carbohydrates : 56.3%	(Souza Filho et al., 2018)

			washed, and dried at 70 ◦C		
	Date juice	*Fusarium Venenatum ATCC 20334*	Inoculum preparation on agar-solidified Vogel slants; fermentation with date juice (5% v/v); incubation: 30 ◦C	Mycoprotein dry weight biomass yield: 5.46 g/	(Reihani & Khosravi-Darani, 2018)
	Cassava, wheat starch, potatoes, rice or cane juices				(Hosseini & Khosravi-Darani, 2011; Wiebe, Robson, Cunliffe, Trinci, & Oliver, 1992)

The fungal protein fermentation utilized for above substrate mostly from agricultural agro industrial wastes stream and food industry for the mycoprotein biomass is either submerged liquid culture or solid-state culture for filamentous fungus and edible mushrooms, which produces fibrous structure similar and mimic to muscle tissues or skeletal muscle of farm animal with higher protein, dietary fibre, and micronutrients and lower fat content (Stoffel et al., 2019).

The yield of mycoprotein biomass and nutritional composition of the product is also dependent on the type of carbon substrate utilized to produce the mycoprotein (Santo et al., 2020).

1.6.2 Filamentious fungi contribution to the circular economy.

Filamentous fungi (which mycoprotein forms parts) in general and as general part of alternative protein is used or utilized as a climate technology to minimize waste or utilize refine waste streams from the agriculture and food sector to create new products or high-value products such as food ingredients, feed components and biodegradable material.

Agriculture and food industries generate large amounts of waste which contain valuable resources that could be reused. Fungi including mushrooms as well as filamentous fungi(mycoprotein) are used as a concept to utilize the refined wastes from the agriculture and food industry. Waste minimization and efficient and effective use of resource is the one of the key cores of circular economy. The circular economy is a recycling strategy aimed at treating WASTE as an essential or valuable resource and turned these resources for the manufacturing of other products as well as food production. for instance, wood waste is used as a substrate to grow different kinds or variety of Mushroom.

1.6.3 Importance of mycoprotein

Mycoprotein is a good source of protein and fiber. The fiber composition is made up of about one-third chitin and two-thirds β-1, 3 and 1, 6 glucans. Because it possesses dietary fibre make it a good source of prebiotic in the lower gut. A study conducted by (Turnbull & Ward, 1995) shows that mycoprotein consumption on acute glycemia and insulinemia in normal healthy individuals showed that glycemia was reduced post-meal compared to the control and was statistically significant at 1 h (13 % decrease). Insulinemia was also reduced post-meal compared to the control and was statistically significant at 0.5 and 1.0 min (19 and 36 % reduction, respectively).

Because of its enormous health benefit and versatility of mycoprotein, they are generally utilized in the food industry as a whole product or ingredient in formulation of numerous non-conventional meat related product’s.

Studies have proven or established the following health benefits, which are derived from Mycoprotein consumption or its inclusion in product.

1. It has effects on total cholesterol by having the capability of decreasing the low-density lipoprotein cholesterol and increasing the high-density lipoprotein cholesterol (Homma et al., 1995; Nakamura et al., 1994).

2. Its effect on satiation or having satiation properties by regulating appetite.

1.7 The technology behind mycoprotein production.

The technology behind mycoprotein production is utilizing the fungal organism to convert starch carbohydrate into protein in controlled environment.

Mycoprotein is produced commercially from continuous flow fermentation in sterilized airlift fermenter of the of *Fusarium venenatum* in the high-grade sustainable glucose substrate (Edwards, 1986).The fermentation process is carried out under aerobic sterile conditions as shown in fig 2. The *Fusarium venenatum* which form core of the mycoprotein allowed to grow under continues supply or feeding of nutrient such as vitamins and minerals to supply essential nutrients for growth, whilst a proportion of the culture broth is simultaneously removed to maintain a constant volume of fermentation medium.

The added nutrients and fungi organism combined to form the mycoprotein solid. The solid mycoprotein biomass is continuously removed from the fermenter after five to six hours. The removed mycoprotein are then subjected to short heat treatment to reduce the RNA-nucleic acid content from 10% to 2% content of dry weight. The short heat treatment activates the activity of endogenous RNAse enzymes.

Centrifuge is used or employed to remove water from the heat culture broth leaving the mycoprotein paste or pastry dough. A range of eggs and seasonings are mixed with the mycoprotein pasta or dough to bind them together to give it the texture and flavor that mimic the resembles of conventional meat.

The product is further steam cooked for about 30 minutes and then chilled. Later, the chilled mycoprotein product is chopped into pieces or minced. The product is then frozen. In the process, the ice crystals help to push the fibres together, creating bundles that give Mycoprotein its meat-like texture.

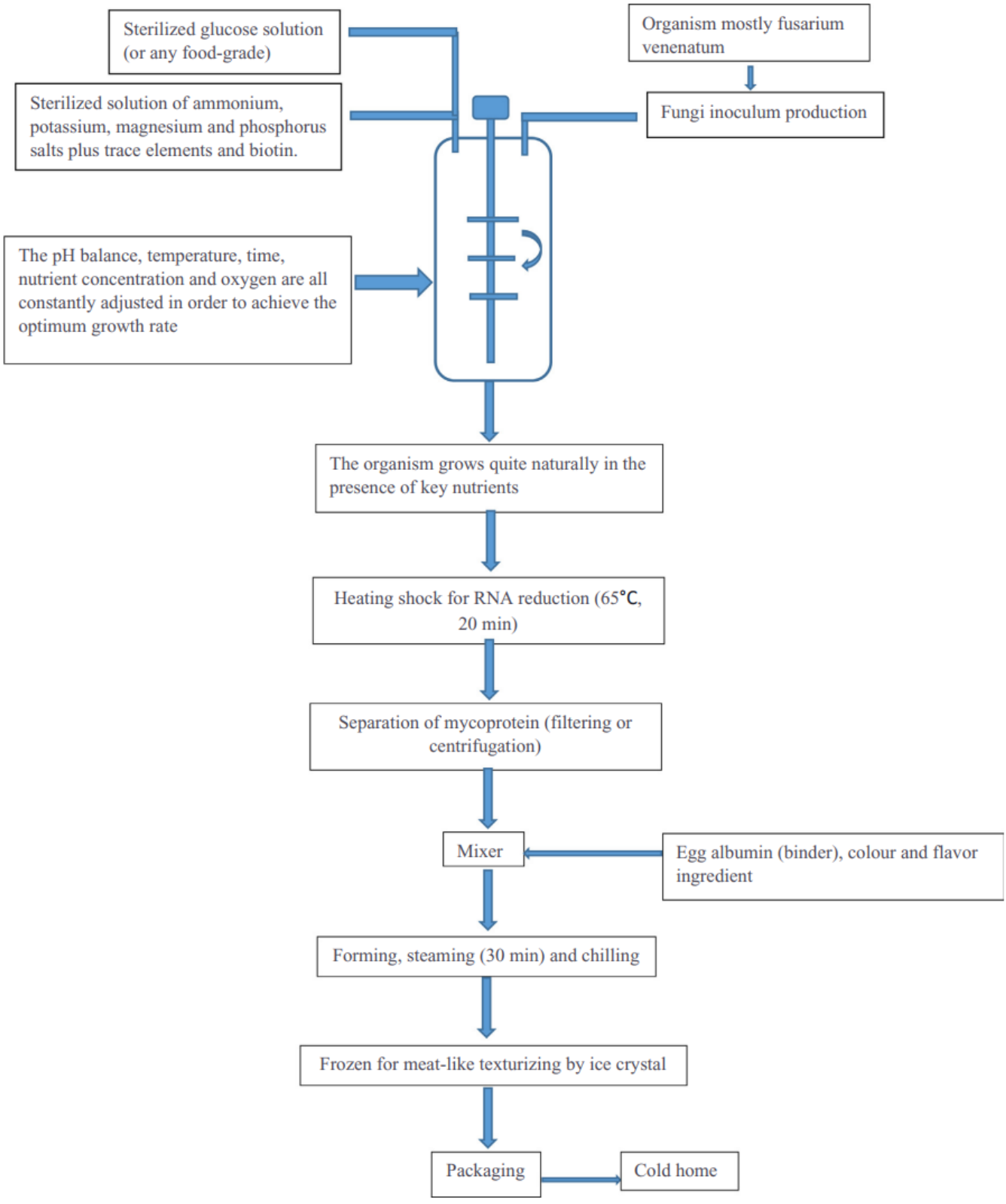

Figure 2The flow chart of the stepwise direction of mycoprotein manufacturing process. Source:(Hashempour-Baltork, Khosravi-Darani, Hosseini, Farshi, & Reihani, 2020).

1.8 Aim of the study

The main aim of the thesis is the use of the mycoprotein fungi as alternative protein (science aspect) and how to develop a business plan to produce mycoprotein (business aspect).

1.8.1 Specific objectives

To be to achieve the above aim, the following underlined objectives were fulfilled or adhered to:

1. The possibilities and challenges of setting up an mycoprotein producing company.
2. Market segmentation for mycoprotein product.
3. Consumer acceptance and adoption for the new protein source and competing product of the mycoprotein product.
4. Evaluation of the technology behind the mycoprotein production (has been also captured in the introduction of Chapter 1.7).
5. Regulatory barriers need to be considered with the introduction of mycoprotein protein in the beachhead location, Norway.
6. Using Decision making matrix to compare mycoprotein concept with other new source of protein such as insect-based protein, plant-based protein and lab meat protein.

2. Methods

Grey literatures| were sourced from the internet and the following company websites:

- Mycoprotein: The Next Alternative Protein - Symrise
- Mycoprotein—A Meat Alternative New to the U.S. - IFT.org
- ENOUGH - delicious, nutritious, sustainable (enough-food.com)
- The Good food institute Plant-based and cultivated meat innovation | GFI

A range of secondary data which were sources or mined from scientific journals and company data from industry player were used to plan a market segmentation, draw a business plan, industry analysis, decision making matrix for the product with other known alternative protein sources such as insect protein and lab cultured meat.

The following business tools, market segmentation canvass, Osterwalder's business canvas (i.e., which is a strategic management template used to develop a business model and used to further document existing business) were used to formulate business model for whole refined mycoprotein producing company and SWOT (strength, weakness, opportunities and threat) analysis strategic management business tool.

Decision making matrix tool was employed to evaluate the mycoprotein with plant-based protein, insect-based protein and cultured lab meat. The tool was used to select the best alternative protein business concept options.

2.1 Market segmentation canvas

This business tool help to visualizes the mycoprotein business in a whole by defining or identifying the various target customer or market segment within the mycoprotein business. The canvas helps you in information gathering and organizing about different target customer groups to make more informed marketing decisions and in selection of the beachhead market.

2.1.1 Decision makers

Various persons influence the for the patronising of the product or form the decision markers within the stated beachhead market: the primary economic buyer and the End user. The economic buyer is the person give the authority for the purchase for the mycoprotein and see to determine whether the value the customer gets from the product is worth the cost but he or she does not used the mycoprotein. The end user is the person whose use the mycoprotein product to create a value. However, both the End user and the Economic buyer are in involved or influence decision making in the patronised or purchase of the product. The champion is the person in decision making unit advocate for the product. (He can be the end user him/herself) or in other case, the economic buyer and the champion are the same person as the end user.

Aside the primary economic buyer, champion and End user, there are other person or things that influence target/potential customer or the decision making, and these people are called INFLUENCERS. These influencer can be the purchasing department of the business to business company or advertisement or government policy.in the case of the mycoprotein and other alternative protein in the EU zone is highly influenced by EU policy of encouraging business within the EU enclave to embark on green business model or green policy target environmental sustainability .The business to customer segment it influenced by communication such as advertisement, consumer health and wellbeing, negative issue relating to animal welfare in the conventional animal and other related drivers

2.2 Osterwalder’s business canvas tool

The Osterwalder’s business model canvass tool which was developed by Alex Osterwalder & Yves Pigneur were used to holistically to plan and create a how to capture value for a young entrepreneur into production of mycoprotein by defining the customer or who is the customer, value or what value is the customer want or creating- value preposition, (how) value chain and how the value capture or profit mechanism. The model is used to helps to successfully structure the company path towards an innovative business model.

2.3 SWOT analysis business tool

The SWOT analysis tool is used to identify and evaluate the `strength`, `weakness`, `opportunities` and `threat` situation of the mycoprotein business. It is strategic management tool used to identify the internal and external analysis or effect of the business.by conducting internal analysis of the business, the tool helps us to identify and evaluate the organizational strengths and weaknesses of the intended mycoprotein business as well as by conducting external analysis, the tool helps us to identify and evaluate the threats and opportunities of the mycoprotein business in competitive environment.

The tool is employed and used for strategic planning and management for the intended business as well as to use it build organisational strategy and competitive strategy.

2.4 Decision making matrix

Decision making matrix were quantitatively used to evaluate mycoprotein alternative business concept with the other alternative protein business concepts. The decision-making matrix tool help, entrepreneur to make a rationale decision from several similar options or concepts. The tool was used to evaluate the mycoprotein business concept with the following plant-based protein, insect protein and lab cultured meat and select the best option. The following criteria were used for the evaluation for mycoprotein with other alternative protein concept and the criteria are also key success factor and importance: product quality (sensory properties and nutritional level) cost efficiency (low production cost, scalability), consumer adoption (access to consumer and consumer trust), and maturity in the value chain(security&traceabity, sustainability, economics)(Belderok, Broersen, & Zerktouni, 2021).

The rating or ranking start from 0 to 5 but the concept with the Highest total score from the matrix was the best option or concept or choices.

- Product quality is defined as in terms of which of the businesses or alternative protein concepts (mycoprotein, plant-based protein, insect-based protein and lab grown meat) that provide superior quality in term of taste, texture, quality ingredients in terms of natural and nutritious.

- Cost efficiency is defined in terms of which of the businesses or alternative protein concepts (mycoprotein, plant-based protein, insect-based protein and lab grown meat) that can produce at a low cost, and it can meet the demand of consumers.
- Consumer adoption: Is generally bored to how consumers get access to product and how feed/food processing/manufacturing company convince retailers to purchase the product in high volume and quantities.it also entail how the product are able to deliver to shelve for consumer assess.

3. Results

3.1 Challenges and possibilities of setting up mycoprotein producing company.

Several challenges may confront the setting up of mycoprotein in the beachhead location. Some of these challenges that may be confronting the industry may be technological /technical in nature, consumer acceptances, environmental and regulatory. Technological, some of the challenge emanates from the technology itself on how to produce or creation of the pleasant meat like texture from mycoprotein food which mimic the conventional meat source and the marketing of mycoprotein as food. Studies show that, scientist and researchers are confronted with the challenge of developing meat analogue/plant-based protein/novel protein that may have exact resembles sensory attributes or properties as the conventional meat (Kumar, Sharma, Kumar, & Kumar, 2012).

Technological challenges associated with setting up of mycoprotein in the beachhead location will have to be.

- Finding continues sustainable source of carbon.
- Level of nucleic acid produced.
- Morphological variant of mycoprotein itself
- Production of mycotoxin or Mycotoxin is produced from its production.

Other challenges that the industry may envisage will as to do with safety challenges, which still is uncertain. Some of this safety challenge might be emanating from type of agricultural carbon substrate used for the biomass fermentation, whether it contain heavy metals, pesticides and other obnoxious chemicals, which might affect the final finished product.

3.2 Market segmentation for the mycoprotein product

Market segmentation was conducted by brainstorming and desk researching through secondary data to identify potential customers, end user and market opportunities for a factory producing raw mycoprotein and processed frozen mycoprotein burger. The customer or market segment is groups of potential customers that share the same or certain traits. The

segmentations more often carry out based on the following: demographic features (e.g., age, income, gender, occupation), geographic (e.g., nation, region, urban vs. rural), and lifestyle (e.g., single vs. family oriented). Socio-demographic predictors

3.2.1 Market segmentation matrix for the mycoprotein product(for both the whole mycoprotein biomass and a processed product-mycoprotein burger).

A young startup business industry or factor which is into production of bulk mycoprotein will be produced or realised two grades of the product. The largest quantities, high value of the mycoprotein product that will be realised from the factory will be food grade and surplus, which are of low quantities will be feed grade. A market segmentation for a startup company producing bulk refined raw mycoprotein will be as show the table below.

Table 2 Market Segmentation Matrix for A Business a Whole Refined Mycoprotein

No	Market Segment Name /industry	**Segment 1:** Selected Food processing companies / manufacturing companies **(Business to business-B2B)**	**Segment 2** Feed manufacturing companies(B2B)	**Segment 3:** Selected (Quick and full service) restaurants. **(B2B)**	**Segment 4:** Health conscious and educated individuals between the age of 18-50 who are keen concern on their consumption based on health, environment and eager looking different taste. **(B2C)**	**Segment 5:** Selected supermarket or food groceries shop**(B2B)**	**Segment 6:** Institutional segments such as the airline catering, cooperate catering, Aged& health care **(B2B)**
1	End User	• Food nutritionist in a food processing	• Feed nutritionist • Pet owner • Aqua/animal farmer	• Chef in the restaurant	• Individual consumer	• Chef in the restaurant •	• Cater or a chef

3	Task	• To be used as a versatile ingredient in all kinds of food application. • Used as ingredient to produce or create meat related products and other products such as pet feed. • Used as for producing full meat analogues product such as burgar,nugget and meat steak • Used as inclusion ingredient in formulate product such milk or high value protein.	• To be use as ingredient or as alternative protein to soy and additive to formulate animal feed or complete product or as part of complete product such as pet food, aquafeed.	• Used as replacer for convectional burger meat.	• Consumer are looking for a meat related product low in carbohydrate , free from cholesterol, high in fibre, vitamins and beta glucan		

4	Benefit	• Have excellent amino acid profile, which make a good alternative protein source. • Rich in vitamins and other elevated minerals essential for body development. • Used as meat substitute for health-conscious people. • It provides superior nutritional level. • Cost effective ingredient for processed food.	• The feed grade is excellent source of high value protein in pet feed, aquafeed and animal feed which enhance growth and boost	• It provides excellent protein requirement. • Culinary innovation • Used as a Versatile ingredient	• Health and Wellness focus		

5	Urgency of Need	• Consumer are looking for product that green(eco-innovative) and cost effective. • Consumer are looking for product that protect environment. •	• As the price of convectional protein keep on going up and as depleting of fish the ocean, has necessitated the need to search for alternative protein which is of high quality, eco-friendly and can harnesses in large quantities and volume with less use of resource.	• Consumer are looking for product that lay much emphasis on their health and wellbeing	• Consumer are looking for an alternative product that look like the convectional meat burger but taste better and less expensive. •		
6	Example of End users	• Dietician, • Food nutritionist • Chef	• Pet owners • Farmers bo • Animal nutritionist				
7	Lead Customers	• Quorn Foods (Marlow Foods Limited): the company produce mycoprotein as well as processed	• **PEKILO®** mycoprotein has been used successfully for more than 15 years in animal nutrition and is approved for this use in the European Union.	• KFC	•		

		it to mycoprotein related products. • Mycorena • MycoTechnology • Dalco Food Meeat Food Tech Oy s • Rebl Eats	• PEKILO® P65 mycoprotein as a sustainabe alternative to soy in aquafeed				
8	Willingness to Change	• Food Companies are willing to bring product that consumers are willing want it. •	• Animal farmers are looking an alternative protein product that will promote health, growth and wellbeing of their animals.And mycoprotein is a feed processing are looking for to create value and solve farmer's needs.	Consumers are willing to switch the product, which align to their interests.			
9	Decision makers	• Director or CEO • Food nutritionist • Production manager	• Director or CEO • Feed nutritionist • Production manager • R&D deparment(head)				

		• R&D deparment(head) • Head,sale and marketing	• Head,sale and marketing				

3.2.2 Beachhead market and selection of beachhead/ target market for the mycoprotein product

Table 3 selected beachhead market for the intended mycoprotein business.
Table 4 selected beachhead market for the intended mycoprotein business.

Beachhead market	**Segment:** selected food processing industries or food services industry (B2B)
Product type	Whole raw mycoprotein protein product
	Under this beachhead market or market segment, customers are well funded or have the resources to purchase the whole raw refined product and used it as whole, partial or functional ingredient or used the whole product in formulating all sort of products such burger, nugget, used in milk.
Market size	the general market size for alternative protein (mycoprotein inclusive) stand at USD 14 bn.(Belderok et al., 2021)
competition	With the upsurge new emerging sources of alternative protein place the competition in the market very.

3.2.3 End user profiling for the mycoprotein product.

The end user profile for a mycoprotein product will be health-conscious consumer who want to consume the product based on health or sustainability value or A farmer in the aqua and animal farm who use to feed their animals with the product based on healthy growth and sustainability value.

Table 5 End user profiling for the Beachhead market target end user.

End user profile for whole mycoprotein product will be health-conscious consumer who want to consume the product based on health or sustainability value or A farmer in the aqua

and animal farm who use to feed their animals with the product based on healthy growth and sustainability value.	
Age	20% are between 20 to 30 of Age,80% are between 30 to 40 of Age.
Gender	80% of them are male while 20% are female
Income	30,000 Nok
Location	Oslo
Marital status	Married, single
Location	Oslo
Education	Some who understand the benefit of the product.
Fear	
Aspiration	To add variety to his or her dishes or recipes
Fear	
Motivation	Growing concern of customer moving toward consuming greener and healthy product with minimal effect on the environment.
Interest	Frequent social media user
Proxy product	Plant-based meat, mushrooms, lab -cultured lamb or goat meat.
Watering hose	Online media library

3.2.4 Consumer acceptance and adoption of mycoprotein product

Consumer acceptance of plant-based protein or meat analogues such as mycoprotein is less challenging now in term of its availability to be in the market and consumer are now becoming familiar with the product. According to this study(Mancini & Antonioli, 2022),technological

progress, price, communication and institutional support strategies are some of the key factors that promote the acceptance and diffusion of the alternative protein such as mycoprotein .

Communication as well as the role of information and promotional strategies on the health-related issues and environmental sustainability of product are now used as a leveraging the product on the market as compared to the other novel protein sources such as the cultured meat. Strategies from the scientific community and policymakers are some of the drivers and promotion of alternative protein such as mycoprotein, insect protein and other alternative protein (Pojić, Mišan, & Tiwari, 2018).

On the aspect of consumption, some of the key factors or drivers, young consumers are using in accepting alternative protein such as mycoprotein is supported by their ethical principles.

Food safety, nutritional value, health and economic are some of the drivers for consumption acceptance of plant or fungal based alternative protein product such as mycoprotein.

Some of the customer acceptance of fungal based protein is based on animal welfare. (i.e., the way some of conventional animal husbandry practise subjected to animal into inhuman practise and pain).

According to a study by (Parry & Szejda, 2019) there are various motivators/drivers that ginger or enhance or influence the consumer decision in purchasing of alternative protein and these motivators or drivers include: the price, familiarity and tradition, freshness, health, price, specific nutritional claims, altruistic benefit and the showed how consumer ranked the various primary motivator or influencers or deriver for alternative protein include mycoprotein as shown in fig 3 below:

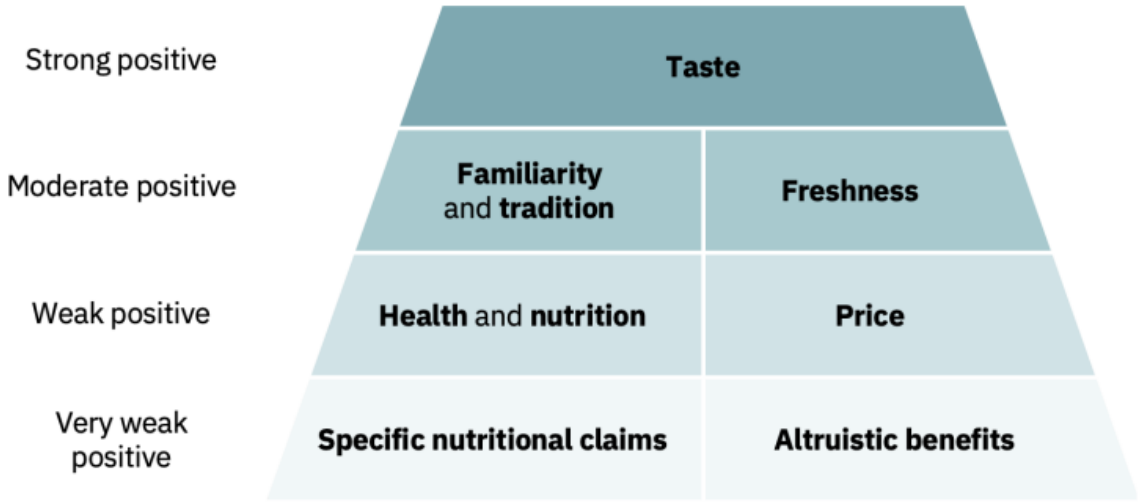

Figure 3 The primary motivator/derivers/influencers of consumer decision in purchasing the product. (Source:(Parry & Szejda, 2019)

However, the greater proportion of the consumer accept the product based on Taste which is the major primary driver for the product.

3.2.5 Competing products for the whole refined mycoprotein raw .

There are several competing products especially from the conventional sources as well as from emerging products from the alternative proteins streams itself such plant base alternative protein meat, meat product from precision fermentation, which will compete with Ethe final product from the business biomass fermentation product (ie. The mycoprotein). Examples such competing products and sustainability criteria such as Environments, safety and health, consumers used in purchasing and accepting the products as shown in the table below:

Table 6:Refined raw mycoprotein competing/ alternative products and how the product is scrutinized based on Environmental impact, consumer acceptances and safety, health benefit.

Competing/alternative products	Environment	Health	Acceptance	safety
Beef/meat from conventional source such cattle and pork industry	highly resources consuming or demanding and its potential contribution to global warming(Sonesson, Davis, Flysjö,	Its Consumption has been associated with some lifestyle diseases such as cancer. And it has known to contains highly bio-	It is widely accepted and consumed except in some cultures, the consumption of beef is	Highly perishable and short shelf life, with numerous outbreaks regarding

	Gustavsson, & Witthöft, 2017).	available nutrients, including essential amino acids, heme iron, and vitamin (P. M. d. C. C. Pereira & Vicente, 2013).	associated with the images of strength and power (Kumar et al., 2017).	spoiled products have been reported in the past years (Gul, Singh, & Wani, 2016).
Poultry and poultry related product	Pose less environmental threat			
Fish including the farmed and wild catch				
Cultured meat (Emerging product from alternative protein streams itself).				
Plant based protein such as soy (Emerging product from alternative protein streams itself).				
Mushrooms				

3.3 Business plan for mycoprotein production company.

Osterwalder business model canvas

The business idea/model is relying on highly carbon agro waste and biowaste generated in the beachhead location to produce whole mycoprotein and processed mycoprotein burger targeting business to business customer and business to customer within the business beachhead location. The business concept is how best to harness the agro industrial biowaste in the beachhead location to create a high valued add products which will intend contribute the development of the circular bio economy of the beachhead location. The proposed area of the business or company sitting generate tons of high grade of biowaste from agro industries sector, food industry as well as feed manufacturing the make use of seaweed in formulating of aquafeed,

The purpose for the business plan is how best to captured value from the mycoprotein product created and how best to use to reach the target customer.

*Table 7:*Osterwalder business model canvass or plan for young Entrepreneur producing refined bulk mycoprotein.

Designed for: Francis mycoprotein production and processing industry business model.	**Designed by**: Francis osei sarfo.

Key partners	**Key Activities**	**Value preposition**	**Customer relationship**	**Customer segment**
1. Academic institutions (such as the universities) 2. Research institutions 3. Industry experts 4. Ingredient suppliers including Farmers and food industry for the reliable supply of carbon substrate sources. 5. Logistics companies 6. Flavour supplies 7. Regulatory body	1. Strain optimizations entail strain selection and cultivation. 2. Upstream processing (carbon source, culture media. Cultivation or seeding, fermentation) 3. Downstream processing 4. Biomass Processing and handling 5. Packaging, labelling, quality control and certification. 6. Regulatory compliance 7. Research and development(R&D) 8. Market engagement	1. We shall serve you with a versatile ingredient/mycoprotein raw product produce locally from efficient and sustainable way that will enhance juiciness and flavour of food product.	1. All the known various social media platform 2. Online brochures 3. Advertisement both on the electronic and print media. 4. Online media library 5. Digitally or e-newsletters	*Business to business market(B2B) mar*ket • Selected Food processing factory-beachhead market

	Key resource 1. Carbon substrate resources from 2. Machinary (Plant or fermenter) 3. facilities 4. intellectual property 5. suppliers 6. financial resources 7. quality control equipment		**Channels** 1. Direct /Factory sale outlet 2. Authorised food services Distributors	

Revenue stream	**Cost structure**
1. Proceed from sale of whole refined bulk mycoprotein product to selected food processing companies or industries customer (B2B) through receiving direct bank transfer, cash payment or wire payment.	1. The total cost of production (entail the capital cost (CAPEX) and operating cost (OPEX). The CAPEX entailed the investment cost for the establishment of the processing and production unit. The OPEX entailed the cost of carbon substrate, research and development R&D, logistics and packaging cost.

The total cost is general all the cost involved in the building the mycoprotein plant and running of the plant to produce the mycoprotein product. The capital cost is the funds received from investor or a mother company. The operating cost is the cost used in the running of the business or factory to the point of sale of the mycoprotein product to the selected beachhead market(selected food processing or manufacturing company).

3.4 Regulatory barrier status

Mycoprotein as considered as novel food or feed or feed ingredient need to be thoroughly undergone investigation and screening to be declared safe for human consumption. According to EU (European union) definition of Novel food as a food that had not been consumed or eaten to a significant degree or level by human in the EU area before 15th May1997, when the EU implemented the first EU regulation novel food came to food.

For mycoprotein to accepted in the beachhead location as alternative novel protein source must subjectively regulated under the food, drug and cosmetics legislation framework for safety and food hygiene. The same food safety regulation processes are applied to the other source or novel protein sources.

In the united sated, the FDA (Food and Drug Administration) deem that all novel food must fulfilled the following regulatory pathway; GRAS (generally recognized as safe) pathway and Food additive petition pathway while in the countries the EU zone, the eFSA (European Food Safety Authority) the regulatory authority required that novel foods or innovative food and ingredient required:

1. Premarket authorization needs before it can be sold.
2. If the novel food or ingredient was produced under GM (Genetic modification) condition, Novel food and ingredient regulation on GM regulations must apply.
3. And if produced without GM, Novel food regulations must be applied.
4. All studies including risk assessments studies commission or pertaining the product, or the novel food, feed or ingredients must be disclosed in the application for approval at the regulatory authority.
5. And if the Product or Novel Food, Feed or ingredient is approved the eFSA authority, it must further have to approve by the EU countries before it can be released into the EU market.

3.5 Decision making matrix for selecting Mycoprotein concept vis-à-vis plant based protein,insect based protein and lab cultured meat protein

For the different type of alternative protein producing business concept, an investor or entrepreneur weight the different business alternative protein concepts on the following key of success or criteria (i.e., product quality, cost efficiency, consumer adoption and maturity in the value chain), in the decision-making matrix below:

Table 8:Decision making matrix for selecting Mycoprotein concept vis-à-vis plant-based protein, insect-based protein and lab cultured meat protein.

Criterion		Rating score with 1-low/poor and 5-high/excellent job			
		Mycoprotein score	Insect based protein score	Lab cultured meat score	Plant based protein
Product quality	Sensory properties in terms of taste, texture and ingredient quality	5	3	3	5
	Nutritional level	5	5	4	4
Cost efficiency	Low production cost	5	2	1	3
	scalability	5	4	1	3
	Short development time	5	4	1	5
Consumer adoption	Consumer trust	5	3	2	5

	Closeness of product to the animal-based protein product	4	1	5	3
Maturity in the value chain	Security and traceability in terms of continuous sourcing of raw material, production consistent	5	4	3	4
	Sustainability in terms of environmental impact and being sustainable protein sources	5	5	4	4
Product evaluation	Economics-Price per product ($ per kg,100% protein)	13(low)=**4**	• 41(medium)=**3**	300(high)=**1**	5.0 to 7.5(low)=**5**
	Total score	**43**	**34**	**25**	**41**

Rating Scale/scores:

- **5:** Excellent
- **4:** Very Good
- **3:** Good
- **2:** Fair
- **1:** Poor

The highest score from the decision-making matrix is the indication of the concept being better or good option or excellent.

3.6 SWOT analysis for the business producing raw mycoprotein

SWOT analysis business tool was employed to assess a young entrepreneur who wants to establish a mycoprotein production and processing unit in a planned Agrarian area of Hamar, Norway. The SWOT Tool is a strategic planning tool used to assess and examine the mycoprotein business' strengths and opportunities in addition to its weaknesses and threats.

Table 9:SWOT analysis for a young Entrepreneur producing refined bulk mycoprotein.

STRENGTH	**WEAKNESS**
1. Abundance and availability of carbon substrate or feedstock from both agriculture and aquaculture waste streams or agricultural derivatives from a factory located in the factory's intended area. 2. Mycoprotein Products can be produced anywhere at any time under a 24-hour production cycle. 3. It has a complete and simple production setup design which can be used to produce high quality protein. 4. Strong and rapid R&D 5. Product taste can easily adjust to suit the customer and consumer preference. 6. Final product has longer and improved shelf life and better than conventional protein source 7. The system biomass fermentation used in mycoprotein is efficient and reliable.	1. High investment cost as well as investment dependency 2. Challenge about downstreaming processing and product recovery. 3. Customer or consumer eagerness to understand how meat is produced under the system. 4. Regulatory challenges: time consuming and costly regulation approval processes. 5. Product premium price 6. Some reported Allergic concern with the consumption of the product and production of mycotoxin

8. Partnerships in the business already existed. 9. The biomass technology process is efficient, and its controlled processes shield from volume and price volatility that are independent from climate, economic/political factors. 10. High nutritional value of the product 11. Utilized cheaper and low volume agricultural or input to produce a kg of meat. 12. The technology behind mycoprotein production is familiar to the food industry. 13. There is enormous high support from the food industry and positive consumer perception of the mycoprotein product. 14. Health and environmental benefit 15. There is growing demand for alternative protein because it benefits on health, environment.	
OPPORTUNITIES	**THREAT**
1. A lot of proof of concepts pertaining the biomass fermentation technology available 2. Abundance of carbon resource 3. Consumers are looking for sustainability and products that promote sustainability. 4. Fast changing consumer demand for cleaner products. 5. Animal welfare issues relating ethics to convectional animal farming are driving the technology. 6. Government support funding for cleaner projects such biomass fermentation	1. Other emerging markets within the alternative protein market stream such as Lab cultured meat, plant based alternative protein, cultivated seafood, cultivated lamb. 2. Convectional Animal improvement geared toward flashing out the use of Antibiotics to a switch to the use of probiotic and prebiotic in curbing or fighting diseases in convectional animal rearing tend to attract new segment of consumers or customer to its product which pose existential threat to alternative protein. 3. High energy cost tends to pose a threat to production at low cost and its final price.

technology, cellular agriculture in the alternative protein streams. 7. Climate sustainability issues in developed countries and food security issues in developing countries are driving and spreading biomass technology used to produce mycoprotein. 8. Change in consumer eating patterns or lifestyle. 9. In developing countries, technology is driven by food security issues. 10. Government support in area of R&D support, tax incentives and regulatory support 11. Emerging of new technical talents in the area 12. There is a lot or upsurge of incubation support for startup businesses and entrepreneurs, who want to venture into the industry. 13. Dietary shift 14. There is scientific advancement & innovation in industry. 15. Strong media campaign or advocacy of alternative protein including mycoprotein. 16. High influx of investment in the general alternative protein industry.	4. Impact of Sanctions and outbreak of pandemic such the covid will tend disrupt the global supply chain or line of the product. 5. Low price and high volume of related and alternative products emanating from other emerging alternative protein such as plant-based protein and convectional protein sources. 6. Supply chain interruption 7. Externally Challenge with Consumer adoption 8. In some countries, there are mixed signals, concerning ban on or criticism of alternative protein especially lab grown meat. 9. There is an increased number of small alternative protein brands. 10. Potential safety risk that may arise from the carbon sources from the agricultural stream that have been contaminated with pesticide and herbicide. 11. uncertainties about health implication on the consumption of the product /unknown health implication on long term consumption of the product.

4. Discussion

4.1 Customer or consumer willigness to purchase the product

Taste, price, availability and product quality in terms of safety are some of purchasing drivers for the product. There is competition in the alternative protein market, which is highly influenced by the price. Low product prices tend to influence consumer purchasing power in terms of volume. Aside the taste, price, availability and product quality, consumer willingness to purchase the product, it is purely based on the following key areas, based on ethical issues concerning animal welfare, health grounds, food security especially in the developing world where there is population explosion and sustainability issues about environmental impact. They are a category of customers or consumers who are generally motivated by sustainability.

According to a study by (Belderok et al., 2021) on alternative protein, under the business to customer segment(B2C), young generation tend to be patronized, lead and champion the consumption of meat analogues or alternative protein meat such as mycoprotein product. A Boost and substantial grow in the alternative protein market is as a result of strong consumer pull in the younger generation who are looking for more sustainable, animal friendly and healthy food. And because of their keen interest shown by this huge customer or consumer segment, have positively influenced and shaped the food processing factory and food service companies in producing the product and use the product as well as diversifying their protein from conventional animal protein into these alternative protein products such as mycoprotein and its related product.

The euphoria surrounding consumers eagerness to patronize and consume and adopt alternative protein such as mycoprotein bore to consumer education. Consumer education through advertisement has promoted consumer trust and adoption of the product.

Consumer education on the mycoprotein erases consumers barrier of uncertainty and unfamiliarity about mycoprotein and other alternative protein such lab cultured meat, lamb or seafood, provides them the awareness, boost and motives their interest of use and accepting the product or accepting alternative protein such mycoprotein.

4.2 Market segmentation for mycoprotein

Young generation within the Business to customer segment(B2C) for the use of mycoprotein related product. tend to be champion and lead user. Their eagerness, motivation and choice of using related complete product have shape the food processing industry their use and application of raw food grade mycoprotein to product different types of products. The food processing industry tend be the business segment which well resourced, well-funded and have the capacity, well established and developed sale and delivery channels to deliver complete product. Consumers within the segment are looking for heath and sustainability value and these driving force for the selected food processing or manufacturing companies to make use the mycoprotein product produced by young entrepreneur who is into producing a raw mycoprotein. The food processing industries are utilizing the mycoprotein ingredient in producing of the following range of product. mince, chicken-style pieces, sausages, burgers and ready meal

The food industry is the beachhead market and largest user for the raw mycoprotein because it enormous strategic advantage it holds. The food processing industry used market entry approach specifically target specific market or consumer segment before it expands to broader market. The food processing industry introduce the product or serve as the first prime starting point for the mycoprotein product. Apart from use the mycoprotein to produce a product, they further involved in a role in marketing and educating the public about the benefits of mycoprotein proteins product and why consumer must shift towards more sustainable and diverse protein sources such the product.

With the food industry, they are looking for an alternative protein which can satisfy their consumer value of sustainability, health, taste.

Feed processing/manufacturing is another segment within the market segment for a business producing raw refined mycoprotein. The feed processing companies have the capacity and technology to turn feed grade mycoprotein from the factory to various mycoprotein related animal product such as pet feed, aquafeed.

4.3 The business model for raw mycoprotein

The business model for a young entrepreneur with an established industry or company producing raw bulk mycoprotein is a mycoprotein product sale model to businesses. The model makes use of biomass fermentation technology and innovation to harness the abundance agricultural and food waste to create high value bulk mycoprotein product (wealth creation) through sale to selected food industry (wealth/value capture). The competitive advantage of mycoprotein over lab cultured meat is less expensive, low-cost investment and cost efficiency. The input which is meant to create value for the mycoprotein can easily be harness from agriculture and food waste derivatives or stream. Lab cultured meat which uses precision fermentation technology run under high usage of electricity which indirectly have impact on environment.

4.3.1 Value preposition

The value preposition for the company is purely based on greener model of producing nutritious, healthy and sustainable alternative protein source which contribute environmentally conservation and integrity. And additionally with the less use of resource input such as land and water.

But for the beachhead market (i.e Selected Food processing/industry)-B2B they are looking for alternative protein which contribute to environmentally conservation, health and sustainability and which can be used as versatile ingredients in the producing of different product.

For the farmer/pet owner end user with within the feed processing industry is expecting is healthy growth and improved feed efficiency with minimal impact on the environment.

However, for the individual consumer, B2C, they willingness to purchase or consume the product made from mycoprotein is purely based on sustainability, nutrition and health point of view.

4.3.2 Cost structure for the busines model

The cost pertaining to commercialization of the model includes intellectual property (IP) development and strategic (Indirect cost-support services) which form part of operating costs (OPEX).The total cost structure for the business(which is the funds or money needed to biomass fermentation plant and to the run the plant and business) is sum of operating cost

(OPEX) and the capital cost(funds which comes from an investor or mother company).some of the direct cost which form part of OPEX is raw materials, chemicals, chilled water, electricity, etc. Labor cost, R & D expense, administration, insurance, IP strategy and development, laboratory, cost of sale are the indirect cost (support services) part of the OPEX. The operating cost for the business is the sum of the direct cost (product relate) and indirect cost (support service).

The operating cost for the biomass fermentation for business is highly affected by the raw material price. And since the mycoprotein business sourced its inexpensive carbon substrates from agricultural and food waste stream makes its more profitable and cost efficient than lab cultured meat and other alternative protein sources. On the other hand, the capital cost (CAPEX) for the business is highly influenced or affected by the size of equipment or the fermenter in terms of productivity of rector(g/L,hr) and purification yield(%) of the mycoprotein from the downstream processing(DSP).

4.3.3 The revenue stream for the business model.

Value capture in form of revenue for the business is realized by direct product sale to the selected beachhead market in food processing/manufacturing industries through the means of cash transfer or cash or cheque deposit or payment. Profit is realized as result of subtracting total operating cost from the revenue (**Profit=revenue-operating cost OPEX).**

4.4 Decision making matrix for selecting Mycoprotein concept vis-à-vis plant-based protein,insect-based protein and lab -cultured meat protein.

4.4.1 Cost efficiency

In terms of cost efficiency criteria, mycoprotein scored high point followed by plant-based protein and insect-based protein. Low score/rate was recorded in lab cultured because high capital investments cost, high energy consumption. One of the attributions of highest score for mycoprotein business concept in terms of cost efficiency is over relying on inexpensive and constant availability of carbon source or substrate from agricultural and food industry waste used in the production of mycoprotein’s.

4.4.2 Consumer adoption

Consumer adoption of for any of the alternative protein also depend on how accessible the product to the consumer. Accessibility and affordability of the product boost the consumer trust in the product. For the B2C concerns is how often to find the product in shelves and for the B2B how often the product is delivered from the manufacturer to retailer. Consumers adoption of the product is also enhanced by how the alternative protein is closer to the normal convection animal or fish-based protein. From the decision, matrix mycoprotein and plant-based protein to have consumer adoption.

Low adoption in term of lab cultured and insect-based protein has to do consumer unfamiliarity.

4.4.3 Product evalution

- In terms of the economic (price of sale per kg)-plant based protein scored high point in term price per kg fellow by mycoprotein, which make more affordable by consumer. Price is key motivator that consumer pay keen attention.
- Price per kg for lab cultured meat tend to be high and it deter consumer from purchase and consuming the product. Affordability and consumer willingness to pay for more the product depend on price. Consumers' willingness to consume and pay for more depends on taste followed by price.

4.5 Industry analysis of the alternative protein industry.

Mycoproteins form part of novel alternative protein or climate technology solutions. the alternative protein industry which mycoprotein forms part of it are driven by fermentation technologies. A few companies in the industry used one of these three forms of fermentation technology (except insect protein which relies on raising or rearing of insects and harvesting and homogenised.) which drive the industry, namely: precision fermentation method used to produce cultured, or cultivated or lab grown meat, biomass fermentation used to produce mycoprotein and traditional fermentation method used to produce plant-based protein.

Innovation and investment in fermentation in the industry have paved the way for or allowed a diversity of other new off products on entry of new off product in the market and such off product includes meat by the following companies (Natures Fynd, meati, chunk.the better meat co.,) seafood (Aqua cultured foods, Koralo,Agama), Eggs(Sacha protein,osomefood),

Dairy(perfeet day,formo,Sophies bionutrients,superbrweb food), Fat & oil(mycorena,nourish ingredients,Melt & Marble).

5. Conclusion

The study main was the business of alternative protein with the focus of mycoprotein producing company and find a suitable market for the company. The food and feed processing industry were identified to be the major stakeholders and market segment in terms of having capacity and the resources to convert raw mycoprotein into different related products. With the consumption of the product made from mycoprotein, we realized, young generations who are heath conscious are lead consumers and patronize of the product. From the study, it came to realization that taste was topmost priority followed by price that influenced market segment. On the feed processing market segment, it came realization that, farmer both in the aquaculture and agriculture sectors were looking alternative protein that will boost their animal growth and heath without have negative impact on the environment.

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Appendix