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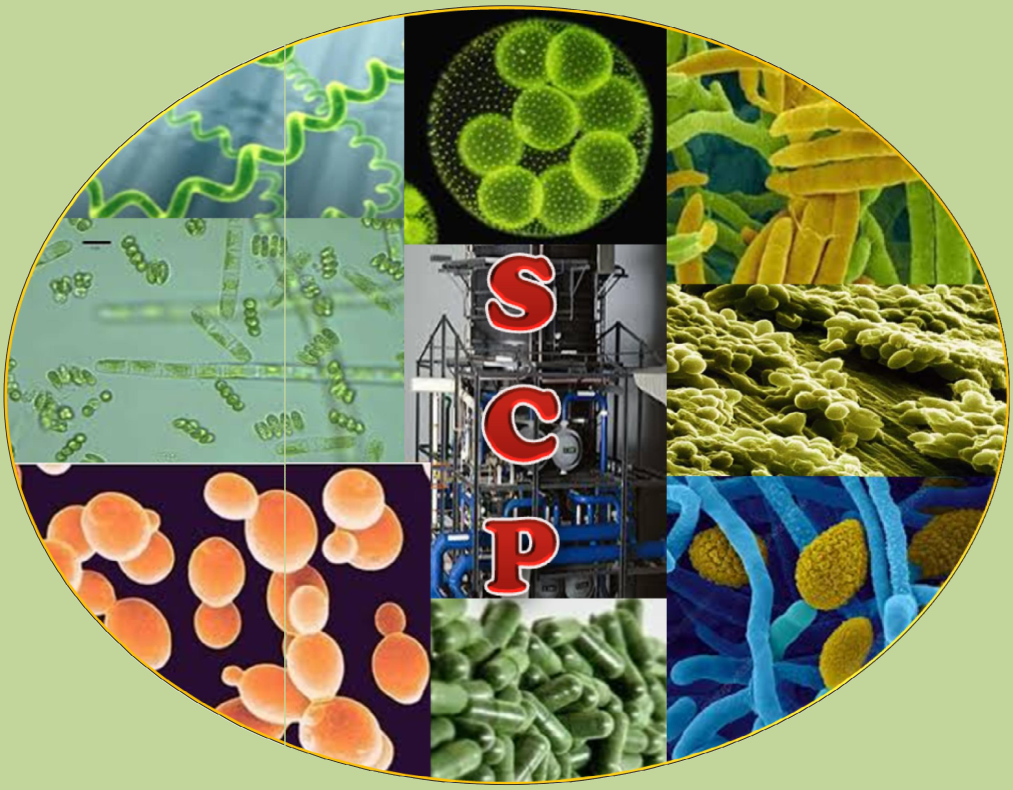
NEWS LETTER

ON

SINGLE CELL PROTEIN



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EDITORIAL

With continuous rise in the global population needs more protein rich food which will not able to sustainably fulfill by the existing conventional meat, poultry, fish and dairy production . Single Cell Protein (SCP) is the protein rich food sources or supplements of other foods derived directly from microorganisms such as algae, yeast, fungi, and bacteria. Single cell proteins have a high nutritional value due to their high protein, vitamin, essential amino acid and lipid content. The SCP can be highly utilized as an important source of protein for humans and animals. In recent, the biotechnological development of production of SCP is a potential alternative option to meet the global protein demand. . Single cell protein can also help in protecting the environment and preventing in land degradation. As the microorganisms for single cell protein production are cultivated on waste material they can help in reducing the waste heaps. The problem of global malnutrition can be addressed through mass production of single cell protein.

(Ashis Kumar Panigrahi)

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Single Cell Protein(SCP) is the proteinaceous food sources or supplements of other foods derived directly from microorganisms. Today new agricultural practices are widespread: high-protein cereals have been developed; the cultivation of soyabeans and groundnuts is everexpanding; protein may be extracted from liquid wastes by ultrafiltration; and now the use of microbes as protein producers has gained wide experimental and commercial success. This field of study has known as single-cell protein production (SCP) referring that most microorganisms used as protein producers grow as single or filamentous individuals rather than as complex multicellular organisms such as plants or animals. Single cell protein basically comprises proteins, fats carbohydrates, ash ingredients, water and other elements such as phosphorus and potassium. Eating microbes may seem strange, but people have long recognized the nutritional value of some large microorganisms, such as mushrooms. Similarly the growth of more simple microorganisms, namely bacteria, yeast, filamentous fungi and algae can be used as the production of proteins.

Industrial Applications of Single cell protein (SCP)

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1. Introduction

The increasing global population needs more protein rich food which will not able to sustainably fulfill by the existing conventional meat, poultry, fish and dairy production because of the low efficiency of converting feed to meat and dairy products. SCPs are known as dietary single-cell microorganisms whose biomass or protein extracts are derived from pure or mixed microscopic algae, yeasts, mushrooms or bacterial cultures (Anupama & Ravindra, 2000). In recent through biotechnological development the Single cell protein (SCP), i.e., protein produced from microbial and algal cells, is a potential alternative option to meet the global protein demand. Single cell protein is dehydrated microbial cell cultures or extracted from pure or mixed cultures of algae, fungi, yeast, and bacteria. The microbial derived single cell proteins can used as an important source of protein for humans and animals due to their high nutritional value with high protein, vitamin, essential amino acid and lipid content. The global market demand of single cell protein(SCP) considerably growing day by day to fulfill the food supplements for the increasing population with malnutrition.

The SCP can be produced from the effective microorganisms (bacteria, cyanobacteria, yeast, filamentous fungi or filamentous algae etc.) having more than 30% of protein and essential amino acids and minerals in their biomass. The microbes also enhance the protein content of fermented foods (Bourdichon et al., 2012). In recent the microbial protein provides a relatively small proportion of human nutrition, but the SCP will occupy an important role in the future global demand for protein (Boland et al., 2013).

Fig 1: Algal organism with SCP production

Source: http://kcbeauty.com.vn/

The SCP is produced from specific microbial species for human consumption but for animal feed protein a wide number of microorganisms can be used. SCP for human consumption is generally produced from food grade substrates, but there is hope that processes will be developed to produce SCP from inexpensive waste materials from the food and beverage processing industries, as well as directly from forestry and agricultural sources (Anbuselvi, et. al., 2014).The production of SCP from different algae, fungi, yeast and bacteria through various steps, are-

(i) preparation of nutrient media, preferably from waste,

(ii) cultivation, including solid state fermentation,

(iii) separation and concentration of SCP, in some cases drying, and

(iv) final processing of SCP into ingredients and products.

2. Single cell protein from industrial waste biomass

The recycling of biodegradable waste into environmentally friendly compounds is one of the bases for waste management. Ecofriendly and cost effective waste management is a significant challenge in the recent time. However, most of the waste is still being recycled using low-added value solutions such as incineration biogas production or bioenergy and biofuel production (Spalvins, et al., 2018; Johnson & Tacon, 2007; Kost, et al., 2013; Browne, et al., 2011). The waste management should be done through application of advance technology to generate revenue and produced high value added products.

The industrial waste residues generate from different industrial operations can be reused as various economic products (Spalvins & Blumberga, 2019). From various industrial waste residues i.e. chemical solvents, pigments, dyes, metal processing waste, radioactive waste, etc., only biodegradable industrial wastes such as sludge, paper waste and production residues, food industry wastes, specific industrial and chemical by-products and waste gases can be used for microbial fermentation (Spalvins, et. al., 2018).

The single or group of microorganisms can be used as protein-rich foods or ingredients of dietary supplements for human and animal consumption (Ugalde & Castrillo, 2002; Ritala et. al., 2017). The SCPs are a good sources of protein and advantage than agricultural origin protein sources, since SCP production needs less water consumption, less land area and does not affect biodiversity, does not contribute to greenhouse gas emissions and climate (Mekonnen & Howkstra, 2014; Tilman, 1999; Vermeulen, et. al., 2012).

The various food industries are disposed their valuable waste and some food industries re-processed their waste and used as a productive food ingredients and increased their economy and sustain in market competition. The different food processing industries categorized as: Fruit and Vegetable industry, Grain Processing, Brewery and Winery, Marine, Meat, and Dairy industry etc.

3. Nutritive value of SCP

The SCP derived from single cell microorganism comprise of various significant nutrients, like high proteins, fats, carbohydrates, ash ingredients, phosphorus, potassium and other essential elements. The composition depends upon the organism and the substrate. The SCP is safe for consumption and high nutritive value with different amino acids and economically viable can be used as staple food for common people (Bhalla et al., 2007).

Fig. 2: Production of SCP

Source:https://www.technologytimes.pk/

The nutritive value of the SCP based on its production micro organisms (Table-1). Various algae like, *Ulva* sp., *Enteromorpha* sp., *Laminaria* sp., *Alaria* sp. and *Porphyra* sp. etc. are the good source for SCP having high protein, fats and vitamins A, B, C, D & E. The Algae are mainly contain 40-60% protein, 7% mineral salts, chlorophyll, bile pigments, fiber, and have very low nucleic acid content (4-6%). Fungi also contain low nucleic acid(9.7%) and 30-70% proteins. Yeast contains thiamine, riboflavin, biotin, niacin, pantothenic acid, pyridoxine, choline, streptogenin, glutathione, folic acid and p-amino benzoic acid (Brock, 1989; Ugalde and Castrillo, 2002; Anupama and Ravindra, 2000).

Table 1: Different compositions of microorganisms (% dry weight)

Composition	Fungi	Algae	Yeast	Bacteria
Protein	30-45	40-60	45-55	50-65
Fat	2-8	7-20	2-6	1-3
Ash	9-11	8-10	5-10	3-7
Nucleic acid	7-10	3-8	6-12	8-12

(Source: Miller & Litsky, 1976)

4. Microorganism used for SCP production

There are a number of effective microbial species of the group Algae, Bacteria, Fungi and Yeast are used as important sources of single cell protein in industrial scale (Table-2, Plate-1).

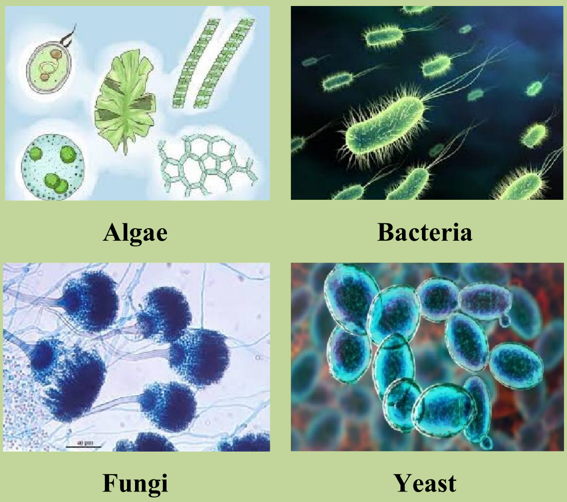

Plate 1: SCP producing microorganisms

Table 2: Microorganisms used for SCP

Major groups	Microbial species
Algae	*Spirulina maxima* *Spirulina platensis* *Chlorella pyrenoidosa* *Chlorella vulgaris* *Scenedesmus sp.*
Bacteria	*Rhodobacter capsulatus* *Methylophilus methylitropous* *Bacillus megaterium*
Fungi (Mycoprotein)	*Trichoderma harzianum* *Aspergillus oryzae* *Fusarium venenatum* *Kluyveromyces marxianus* *Sclerotium rolfsii*
Yeast	*Saccharomyces cerevisiae* *Pichia pastoris* *Candida utilis* *Torulopsis corallina* *Geotrichum candidum*

5. Application of SCP

There are wide applications of SCP to the human society (Plate-2).

- ✓ Provides instant energy.
- ✓ It is extremely good for healthy eyes and skin.
- ✓ Provides the best protein supplemented food for undernourished children.
- ✓ Serves as a good source of vitamins, amino acids, minerals, crude fibres, etc.

6. The different uses of SCP are:

i. As protein supplement food

- It contains more than 30% protein in their biomass and which can provide a healthy balance of essential amino acids.
- It contributes to protein demand when they are used to upgrade the protein content or quality of fermented foods.
- Also source of vitamins, amino acids, minerals, crude fibers, etc.
- Supplemented food for undernourished children

ii. As health food

- Provides instant energy.
- It is extremely good for healthy eyes and skin.

- Provides the best protein supplemented food for undernourished children.
- Serves as a good source of vitamins, amino acids, minerals, crude fibres, etc.

iii. In Therapeutic and natural medicines

- Controlling obesity.
- Lowers blood sugar level in diabetic patients.
- Reducing body weight, cholesterol and stress.
- Prevents accumulation of cholesterol in the body

iv. In cosmetic

- Maintaining healthy hair.
- Production of different herbal beauty products, like- Biolipstics, herbal face cream, etc.

v. Poultry and cattle feed

As it serves as an excellent and convenient source of proteins and other nutrients, it is widely used for feeding cattle, birds, fishes etc.

Energy supplement

Healthy food

Therapeutic use

Animal feed

Plate 2**:** Commercial products of SCP

Conclusion

Single cell proteins are the best solution to manage the nutritious food demand of recent increasing population. Large-scale SCP production has a number of advantages over conventional food production practices but not yet been widely accepted for human consumption. By overcoming the prevailing constrains in mass production of single cell protein, the problem of malnutrition can be addressed. Single cell protein can also help in protecting the environment and preventing in land degradation. As the microorganisms for single cell protein production are cultivated on waste material they can help in reducing the waste heaps.

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Single Cell Protein (SCP): 21st century Food Supplement

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1. Introduction:

Single Cell Protein (SCP) are mixed proteins extracted from pure or mixed cultures of algae, yeasts, fungi, and bacteria, etc. grown on agricultural wastes. Its importance in today's world is immense, helping to cope with the world's population increase trajectory and their nutritional demands. The ever-increasing demand for protein will be difficult to be met sustainably by increasing meat and dairy production.

Fig: Spirulina tablets: Next Generation protein

SCPs are the dry cells of microorganisms, rich in protein content and containing carbohydrates, lipids, vitamins, nucleic acids, and minerals. They can be used as supplements for human consumption as well as animal feeds. Microorganism utilizes vegetable wastes, fruit peels, molasses, and various starch enriched substrates along with lignocellulosic biomass, ethanol, methanol, and other hydrocarbon byproducts to produce SCP concentrates. This offers a unique opportunity to utilize waste materials and convert them into value-added products.

SCPs contains essential amino acids along with vitamins, carbohydrates, nucleic acids and thus can be a very efficient human dietary supplement. Its nutrient density is very high, and thus, consumption in little quantity also helps. In addition to this, it is commercially available as Spirulina, Chlorella, Fusarium and serves good medicated supplements for patients and pregnant women. Humans feeding on microorganisms is not a new concept. Intentionally or unintentionally human the population are dependent over them one way or another. Especially consuming cheese, yogurt and alcoholic beverages produced through the microbiological pathway are in practice since ages.

The production of SCP through biochemical pathway mediated by microorganisms encompasses 4 basic steps (Ritala et al., 2017).

- preparation of nutrient media, possibly from waste,
- cultivation, including solid-state fermentation,
- separation and concentration of SCP, in some cases drying, and final processing of SCP into ingredients and products.

Fig: KnipBio ups production of single cell protein feed products for aquaculture (https://tinyurl.com/ybexvt35)

However, while choosing an SCP, it is to be remembered that it should be free from toxic and carcinogenic compounds either from the decomposed substrates or formed during the process as intermediate products. Research and development for SCP production has been contributed by several fields of Science and technology like microbiology, genetics, chemical and food engineering, biochemistry, toxicology, medicine, agriculture and nutrition (Suman et al., 2015). Development ranged from the field of substrate selection to microorganism efficacy, production technology and toxicology studies.

2. Methods for cultivation of SCPs

The basic process for producing SCps is fermentation of suitable raw materials, preferably, which lacks intrinsic value by a microorganism (Chandrani- Wijeyaratne and Tayathilake, 2000). Efficient microbial strains are isolated from different environment including biological materials, subsequently optimized by the selection, mutation, or other genetic methods. The environmental parameters and technical conditions for cultivation are optimized and evaluated for best cell growth with elevated nutrient content. Along with this, safety assessment is also undertaken for the whole process, keeping in mind the scale-up of the process from laboratory to production scale. Basically, three processes are mainly employed for SCP production. They are.

i). Submerged fermentation: In this process, the substrate is in liquid state inside the fermenter equipped with aerator for aeration, a cooling device to vent out the heat produced due to reactions with continuous churning motion. The formed bacterial and yeast cells are harvested and separated by centrifugation technique and algae is separated through filtration process. Finally, the cells are dried under clean and hygienic conditions (Suman et al., 2015).

ii). Semisolid fermentation: It is a more complex process, where the substrate is used in solid-state. This process requires a special bioreactor which aids in stirring and mixing of a multiphase the system along with a U-loop fermentor for harvesting the formed single-cell protein. Additional Carbon sources like n-alkenes, gaseous hydrocarbons, methanol and ethanol, renewable sources like carbon oxide molasses, polysaccharides, effluents of breweries and other solid substances are used to hasten the process.

iii). Solid state fermentation: This is a rather simple process, where solid biodegradable biomass is seeded with microbes and kept at an incubation temperature in the controlled environment of the bioreactor for several days.

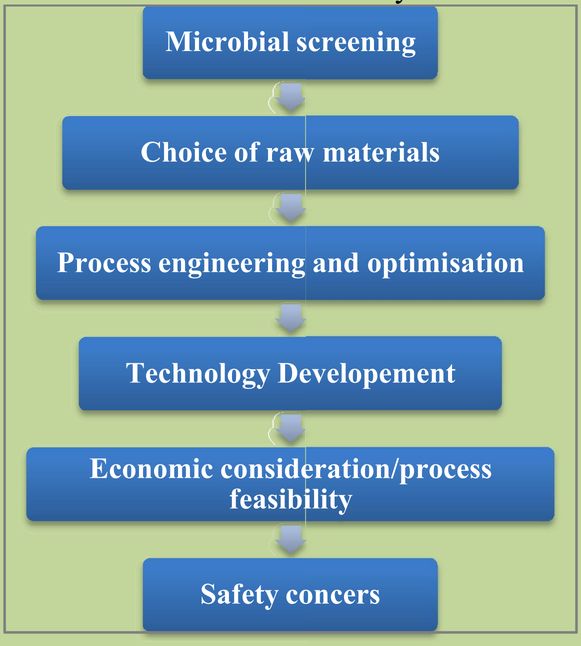

Fig: The production process of SCP can be represented as a flowchart

(Source: Ukaegbu-Obi (2016),)

3. SCP production from Different biomass types

Many natural substrates, as well as wastes (industrial and agricultural), have been evaluated for SCP synthesis. In the early 1960s, scientists from British Petroleum developed the protocol of developing SCP with the help of yeasts, fed on waxy paraffin through a method called "proteins-from-oil process" (Ageitos et al., 2011).

Later the 'Bel' yeast process has been successful in using *Kluyveomyces fragilis* as the organism to produce SCP from lactose. Whey was derived as a by-product from the cheese-making plant, which contained both protein and lactose (about 5% (w/v) lactose). '*Candida utilis* process' and the 'Pekilo process' have been used to produce SCP from wood-pulping waste liquors. Even, Sugar, soya bean meal. Cane, beet, corn and citrus molasses has been used for SCP production

using *C.utilis* or *Saccharomyces cerevisiae* and it has been produced in large volumes by a number of countries. These studies confirmed that organic wastes enriched with cellulose, hemicellulose could be used effectively in the production of SCP (Adedayo et al., 2011). Several studies were conducted on the selection of the fruit residues also to produce SCP. Banana extract, beetroot extract yielded a significant amount of SCP by *Saccharomyces cerevisiae* and *Aspergillus niger* respectively. *Saccharomyces cerevisiae* have also produced SCP on cucumber waste as well as orange peels (Mondal, 2006). *Aspergillus terreus possesses* has been found to be effective in producing SCP using Eichornia and Banana peel. (Jaganmohan et al., 2013). Even in the arid and semi-arid regions lignocellulosic raw material from opuntia (cactus pear) has been found to be a suitable substrate for SCP (Gabriel et al., 2014).

Apart from this, the hydrocarbon substrates also are a well-known source of SCP. The n-alkane fraction in the range C lO-C20 was considered in the period 1960-70 to be a suitable substrate for SCP. Methane gas appears to be an attractive feedstock for SCP: it is a pure feedstock, though adulterations in natural gas, for example, hydrogen sulfides, ethane, and propane, are precarious in fermentation, might impart unpleasant odor, or inhibit the growth of organisms. Methanol seems to have the dual mileages of a clean, reliable substrate giving a high yield of SCP together with the availability and a reasonable price. Methanol technology has great potential for areas of the world with methane supplies and a need for an indigenous source of high-quality protein.

4. Microorganism and substrate used for single-cell production

Organism preference is critical and highly dependent upon numerous factors. First, the choice of an organism depends upon the substrate available, the next major criterion is safety. The organism must be demonstratively safe during growth, processing, and utility as a feedstuff. The selection of the microbial strain is done by a two-stage screening process. The primary screening stage is to select and discriminate the microorganisms which would be able to exploit the substrate most efficiently.

Secondary screening investigates growth rate, cell yield with respect to the carbon source optimum temperature and pH for growth, cell composition or product, absence of toxicity and finally, nutritional value. The most widely used species are tabulated below (Table 1).

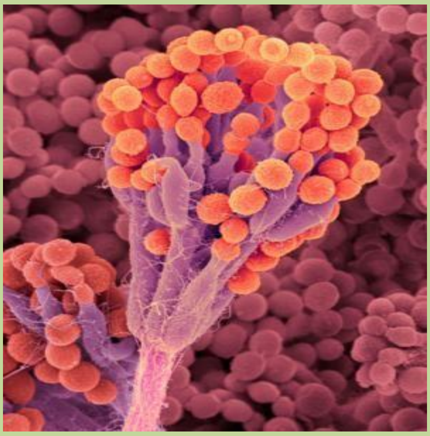

Fig: SCP- Filamentous Fungi

Table 1.The most widely used species used for SCP (Source: biomaster2011.blogspot.com)

Microorganism	Substrate
Bacteria ***Aeromonas hydrophylla*** ***Areomobacterdelvacvate*** ***Acinetobacter calcoacenticus*** ***Bacillus megaterium*** ***Bacillus subtilis,*** ***Cellulomonas sp.*** ***Lactobacillus sp.*** ***Methylomonasmethylotrophus, M.clara*** ***Pseudomonas fluorescens*** ***Rhodopsedomonascapsulata***	Lactose n- Alkane Ethanol Non- protein nitrogenous compounds Cellulose, hemicellulose Glucose, Amylose, Maltose Methanol Uric acid and other non-protein Nitrogenous compounds Glucose
Fungi ***Aspergillus fumigates*** ***Asoergillusniger*** ***Penecilliumcyclopium*** ***Rhizopus chinensis*** ***Seytalidiumacidupgilium***	Maltose, glucose Cellulose, Hemicellulose Glucose, Lactose, Galactose Glucose, Maltose Cellulose., Pentose

Yeast ***Amoco torula*** ***Candida tropicalis*** ***Candida utilis*** ***Candida novellas*** ***Candida intermedia*** ***Saccharomyces oereviciae***	Ethanol Maltose, Glucose n-Alkenes Lactose Lactose Lactose, Pentose, Maltose
Algae ***Chlorella pyrenoidosa, chlorella sorokiana, Chondruscrispus, Scenedesmus sp.***	Carbon dioxide through Photosynthesis

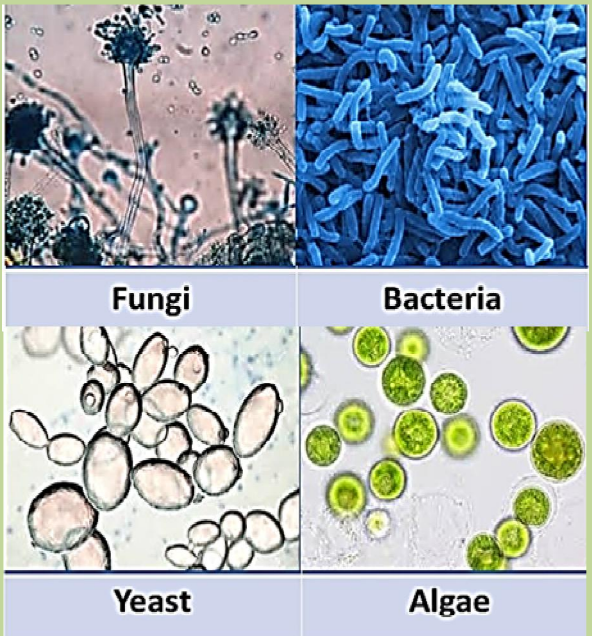

Plate: Different Miproducing SCP

5. Advantages and Disadvantages of SCPs

As summarized by Ukaegbu-Obi (2016), the advantages are they have high protein and vitamins but low-fat content can be produced throughout the year, generation time is less, produce useful byproducts in the process like organic acids, utilizes waste and relatively easy to produce with simple facilities. The disadvantages are simultaneous production of toxic compounds during the process, contaminating the SCPs can pose an allergic reaction in certain individuals, can produce gastrointestinal problems due to their high nucleic acid content and often requires costly high-level sterile conditions in the production facility.

6. Conclusion

Single Cell proteins have huge potential for applications in food, feedstock and in Industries. Some of the areas in the food sector are used as aroma carriers, vitamin carriers, emulsifying aids and to improve the nutritional value of baked products in diet recipes. Apart from this, they have applications in animal nutrition as fattening calves, poultry, pigs and fish breeding. In industries, they have been stated to be used in paper processing, leather processing, and foam stabilizers. Therefore, such a wide range of application demands the process of production to be economically feasible, with less cost for energy consumption in large scale production along with safety considerations and environment protection.

Fig: Recently Unibio looks to build single cell protein plant in Saudi Arabia

(Source:https://tinyurl.com/ydfwqvrd)

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Industries involed in SCP production

- **Algaeon Inc**. produces β-glucan and whole cell products from the photosynthetic protist *Euglena gracillis*. Started in 2011 in U.S.A.
- **BlueBioTech Int. GmbH**, a microalgal biotechnology company, which has operated for more than 10 years, producing large quantities of *Spirulina* and *Chlorella*.
- **Calysta Inc**. Started 2011, produces FeedKind® from methane at a pilot facility in the UK, and began distributing commercial samples in 2017.
- **Cangzhou Tianyu Feed Additive Co., Ltd** is a manufacturer and trading company located in Hebei, China since 2004. Produces Yeast Powder, Choline Chloride, Betaine, and Allicin having markets in Southeast Asia, Eastern Asia, Oceania, South Asia, and South America.
- **CBH Qingdao Co., Ltd** has been supplying a range of ingredients and additives for feed and food industries. They can supply products which meet FAMI-QS, ISO, GMP, KOSHER, and HALAL standards.
- **Cyanotech Corporation** is one of the world leading producers of *Spirulina* with sales in the US and 30 other countries. Their turnover in 2016 was almost 32 million US$. FDA has given GRAS status for Cyanotech's *Spirulina* as a food ingredient.
- **The progenitor of Earthrise**, Proteus Corporation was founded in 1976. They produce *Spirulina* with GRAS status.
- **E.I.D Parry Ltd.,** Parry Nutraceuticals Division is part of the 4.4 billion US$ Murugappa Group. They use micro-algal technology to produce nutraceuticals like *Spirulina* and *Chlorella*.
- **Euglena Co. Ltd**. was founded in Japan in 2005. Amongst other products derived from *Euglena gracillis*, Euglena Co. Ltd. is developing de-fatted Euglena as a source of protein-rich animal feed.
- **KnipBio** was founded in 2013 in the U.S.A. with a focus of providing affordable feed for aquaculture. They produce KnipBio Meal from methanol using a methylotrophic bacterium.
- **Lallemand Inc**. is a Canadian company specializing in the development, production, and marketing of yeast and bacteria. They produce SCP for human consumption (LBI, Lake States®, Engevita™) from the yeast *S. cerevisiae* and *Torula*.
- **LeSaffre** produces yeast (*S. cerevisiae*) and yeast derived products including SCPs such as Lynside® Nutri, Lynside® ProteYn and related products (Lesaffre Human Care products), as well as yeast-based flavour ingredients (Biospringer products).
- **Marlow Foods Ltd** produces the mycoprotein Quorn™. Quorn is classified as a safe, well-tolerated food by regulatory bodies across the world, including FDA, and the UK's Food Standards Agency (FSA).
- **Nucelis Inc**. was founded in 2010 in the U.S.A., but became a subsidiary of **Cibus Global** in 2014. Along with squalene, vitamin D and nutritional oils, Nucelis Inc. is developing high protein flour from the yeast *Yarrowia*.
- **Nutrinsic** is based in the USA, with subsidiaries in China. Nutrinsic focuses on the use of waste waters from the food, beverage and biofuel industries to generate feed and fertiliser products. They market a SCP for animal feed called ProFloc™.
- **Tangshan Top Bio-Technology Co., Ltd** is a manufacturer and trading company located in Hebei, China (Mainland). Their main products are: brewer's yeast, autolyzed yeast, yeast cell wall and yeast extract, including a 100% natural, non-GMO, pure yeast powder as animal feed additive.
- **TerraVia Holdings, Inc**. is a publicly held American company which focuses on providing ingredients for food and care products from eukaryotic algae.
- **UniBio A/S, Denmark** is an SME that owns rights to a unique fermentation technology—the U-Loop technology, which enables natural gas to be converted into a high protein product—UniProtein® used in feed for animals.
- **Unilever** produces yeast extract Marmite® from brewer's spent grain.
- **Vega Pharma Ltd** is located in Zhejiang, China. Manufacturing, and marketing pharmaceuticals, nutritional ingredients, animal health products, and probiotics. They offer a SCP, with up to 65% protein and containing relatively high threonine levels, for animal feed as a by-product of monosodium glutamate production.

Source: Ritala et al., 2017, *Front. Microbiol.*, *8*, 2009. https://doi.org/10.3389/fmicb.2017.02009

FORTHCOMING EVENTS		
Events	**Date**	**Place & Correspondence**
ICEBP 2020: 14. International Conference on Environmental Biotechnology and Phytotechnology	August 27-28, 2020	Paris, France https://waset.org/environmental-biotechnology-and-phytotechnology-conference-in-august-2020-in-paris
ISER-788th International Conference on Nanoscience, Nanotechnology & Advanced Materials (IC2NAM)	2nd - 5th July, 2020	Okinawa, Japan http://www.iceeb.org
5th International Conference on GIS and Remote Sensing	16-17th September, 2020	https://gis-remotesensing.environmentalconferences.org/ Rome, Italy
3rd International Conference on Nanomaterials and Biomaterials (ICNB 2019)	Dec 2, 2019 - Dec 4, 2020	http://www.icnb.org Lisbon,Portugal

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