Production of Single Cell Protein

1. Introduction

Many countries in the world are facing malnutrition by means of protein deficiency in human and animal food. It is vital to produce protein in large quantities in all available methods. The increasing demand forced the producers to look into non-conventional protein sources. Single Cell Protein (SCP) refers to sources of mixed protein extracted from pure or mixed cultures of algae, yeasts, fungi or bacteria that are grown from agricultural wastes. The microbial biomass contains about 45 to 55 % protein on an average. In some bacteria, the protein content is as high as 80%. Along with protein, the biomass also contains other essential nutrients so that it is an ideal supplement to conventional food supply.

2. Production process

SCPs are produced, when the waste materials including wood, straw, cannery and food processing wastes, hydrocarbons, residues from alcohol production, human and animal excreta are subjected to fermentation by microbes. SCPs are found in very low concentrations and thus extracting SCPs from the waste remains a challenge. Precipitation, centrifugation, floatation, coagulation and the use of use of semi-permeable membrane are the alternate ways developed by the engineers to increase the SCP yield.

2.1. Choice of microorganism for SCP production

The criteria used in choosing appropriate strains for SCP production includes, substrate must be used as carbon and nitrogen source with high specific growth rates and productivity. It should be able to show tolerance towards pH and temperature, nonpathogenicity and absence of toxins. The microorganism must be easily available for harvesting with high protein yield.
A variety of bacteria, mould, yeast and algae are being employed in SCP production are listed below.

Bacteria	Algae	Yeast	Fungi
Brevibacterium	*Chlorella pyrenoidosa*	*Candida utilis*	*Chaetomium celluloliticum*
Methylophilus methylitropous	*Chlorella sorokiana*	*Candida tropicalis*	*Fusarium graminearum*
Acromobacter delvaevate	*Chondruscrispus*	*Candida novellas*	*Aspergillus fumigates*
Bacillus megaterium	*Scenedus musacutus*	*Candida intermedia*	*Aspergillus niger*
Lactobacillus species	*Porphyrium sp*	*Saccharomyces cerevisiae*	*Rhizopuschinensis*
Cellulomonas species	*Sprulina maxima*		*Tricodermaviridae*

2.2. Microorganisms and their properties

The usage of microorganisms for the production of SCP has both advantages and disadvantages.

(a) Bacteria:

They are generally high in protein and possess faster growth rate. The disadvantages include the small size of bacterial cells and low density which affects harvesting of biomass from fermented medium, which ultimately increases the cost of operation. The nucleic acid content is quite high in bacteria which have the tendency to increase uric acid level in human blood upon consumption.

(b) Yeast:

The larger size of yeast facilitates easier harvesting of the product. The lower nucleic acid content, high lysine content and ability to grow in acid pH are the added benefits of yeast. Despite this, yeast has lower growth rate, low protein content and low methionine content, when compared to bacteria.

(c) Fungi:

Filamentous fungi are easy to harvest, but they have low productivity, because of their lower growth rate and low protein content.

(d) Algae:

They bear cellulosic cell walls in it that are hard to digest by human beings. There are also chances of concentrations of heavy metals in the product, when algae are used in the medium.

2.3. Potential substrates for SCP production

a) Sulphite waste liquor – *Candida utilis* biomass has been produced as a protein supplement by fermentation of sulphite waste liquor.
b) Cellulose – cellulose from wood waste and natural sources are the starting material for SCP production
c) Whey
d) Glucose

The carbon source present in the medium must be able to cultivate heterotrophic organisms. Examples of those carbon sources includes fossil carbon like n-alkanes, gaseous hydrocarbon, methanol, ethanol, renewable sources like carbon dioxide molasses, polysaccharides, distilleries, confectionaries and canning industries. Solid substrates like salts of potassium, manganese, zinc, iron and ammonia are also included in the medium to facilitate cultivation of many microorganisms.

2.4. Types of fermentation

Microbial cells are produced (a) as a source of protein for animal or human food or (b) for use as a commercial inoculum in fermentation of food, agriculture products and in waste water treatment. SCPs are produced generally by two types of fermentation.

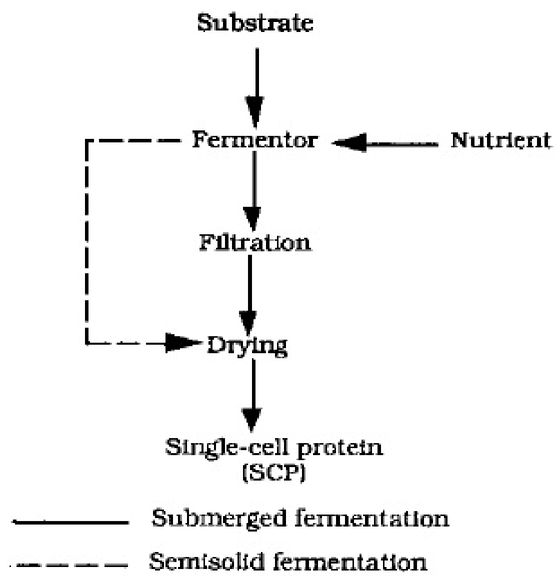
- Submerged fermentation
- Semisolid state fermentation

Submerged fermentation is the one, where the substrate to be fermented is necessarily placed always in a liquid that containing nutrients needed for the growth. The substrate is held in fermentor that is operated continuously and simultaneously biomass product is continuously harvested. The obtained product is further filtered/centrifuged and dried. This process has higher operating cost. In semisolid fermentation, the substrate preparation is a simple solid waste (Ex. Cassava waste).

The basic steps involved in SCP production are:

- Production of suitable medium containing proper carbon source
- Prevention of contamination of medium and fermentor
- Production of appropriate microorganism
- Separation of microbial biomass and processing

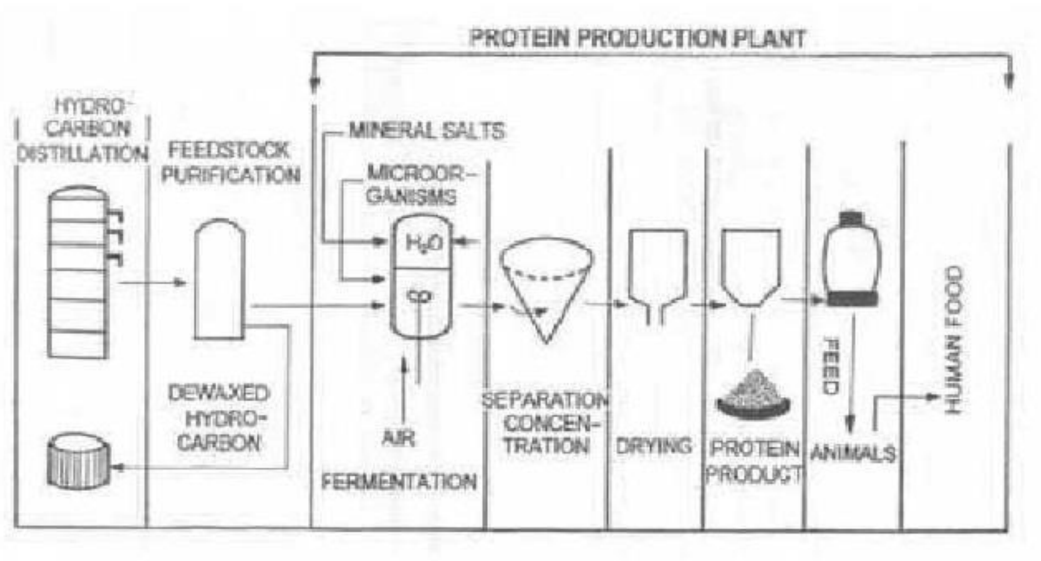
The process of SCP production involves some engineering operations likely stirring, mixing of multiphase system, heat transfer from liquid phase to surroundings and transport of oxygen. The flowchart for SCP production is shown below.



One of the important operations in the SCP production is aeration. Generally heat is generated in the cultivation process and that should be subsequently removed by a cooling device. If heat is generated in higher rate without proper removal, it is more likely to affect the survival of the microorganism inside the fermentor. Harvesting the produced microbial biomass involves major considerations. Single cell organisms are usually recovered by the process of centrifugation (Example: yeast and bacteria). Filtration with appropriate membrane is used, when the biomass contains mostly filamentous fungi. Major portion of the water content from the media should be removed in early stages as much as possible. The final drying of the product must be carried out only under clean and hygienic conditions.

2.5. Commercial production of SCP

Manufacture process used by the British Petroleum Industry for SCP from hydrocarbons is shown below.



The estimated yield of 250 tons of protein in 24 hours is achieved by using 100 lbs of yeast. A 1000 lbs steer can synthesize only 1 lb of protein in 24 hrs after consuming 12 to 20 lbs of plant proteins. Algae that are grown in small ponds can produce upto 20 tons of protein. The obtained yield is 10 to 15 times higher than soybean and 25 to 50 times higher than corn. The below table shows the yield of protein when specific microorganisms are used with their appropriate substrates.

Organism	Substrate	Crude Protein (%)
Candida species	n-Alkenes	65
Candida utilis	Ethanol, sulphite waste liquor	50-55
Saccharomyces cerevisiae	Molasses	53
Cephalosporium eichhomiae	Cassava starch	48-50
Penicillium	Cheese whey	47
Kluyveromyces fragilis	Cheese whey	45-54

3. Economics of SCP

Initially, British Petroleum entered SCP production, reasoning it as production of low cost and high value SCP from petroleum for preparation of protein additive to animal feed. The main consideration was to remove imported protein additives such as soya bean meal. In 1973, the dramatic increase in oil price and decrease in price of agricultural products such as soya bean caused a major impact in SCP production. When oil prices increased in 1973, and the cost of substrate for SCP production reaches 40 – 60% of total manufacturing cost, the negative impact on hydrocarbon based SCP occurred. Agricultural crops are the major competitor to SCP for production of animal feed and those crops respond to market forces and maintained price stability. If SCP is to be used successfully, it should be up to four main criteria:

1. The SCP must be safe to eat
2. The nutritional value must be high (dependant on amino acids)
3. It must be acceptable to general public
4. It must possess certain functionality

4. Advantages of SCP

As compared with traditional methods of producing proteins for feed or human foods, large scale production of the microbial biomass includes the following advantages:

i. Microorganisms have high rate of multiplication
ii. Microbes possess high protein content
iii. They can utilize large number of carbon sources
iv. Strains with high yield and good composition are produced easily
v. Microbial biomass does not depend on seasonal and climatic variation

5. Nutritional benefits of SCP

To estimate the nutritional value of SCP, factors such as nutrient composition, amino acid profile, vitamin and nucleic acid content, allergies and gastrointestinal effects should be considered. SCPs are good source of vitamins, particularly B-complex, with modest amino acid composition furnished with thiamine, riboflavin, glutathione and folic acid. Yeast SCPs are playing a greater role in synthesizing aquaculture diets. Yeast strains with probiotic properties boost larval survival by colonizing the gut of fish larvae. The amino acid composition of SCP synthesized from *Candida utilis* is given below.

Amino acid	**Amount (mg/g)**
Aspartic acid	66.5
Threonine	34
Serine	36
Glutamic acid	90.5
Glycine	28
Alanine	46
Cysteine	24
Valine	40.5
Methionine	15.5
Isoleucine	32
Leucine	44
Tyrosine	26
Phenylalanine	30
Histidine	16
Lysine	76
Arginine	38
Proline	24

The average composition of some main groups of microorganisms are listed below

Nutrients (% dry weight)	**Fungi**	**Algae**	**Yeast**	**Bacteria**
Protein	30-45	40-60	45-55	50-65
Fat	2-8	7-20	2-6	1.5-3
Ash	9-14	8-10	5-9.5	3-7
Nucleic acids	7-10	3-8	6-12	8-12

6. Disadvantages of SCP

Some microorganisms are capable of producing toxins and periodic quality checks must be performed to ensure that biomass product does not contain such particles in it. For some humans, microorganisms that are consumed causes indigestion and allergenic reactions. The high nucleic acid content is also undesirable. The need of high operating cost and necessity to maintain aseptic conditions renders SCP production, an expensive operation in developing countries.