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Single Cell Protein Technology

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SINGLE CELL PROTEIN PRODUCTION

Microorganisms have been used for the synthesis of high protein products like cheese and fermented soybean products. They have natural ability to convert low protein organic mass into high protein organic products by various processes. This ability of microorganisms is being used to fight the problems of malnutrition and poor protein diet in third world country and to manufacture protein rich food for animals. One of the most important examples is Single Cell Protein (SCP).

Single Cell Protein is term coined in 1960's to embrace the microbial biomass products which are produced by fermentation. According to Marriem Webster Dictionary, "protein that consists of processed microorganisms (as yeasts or bacteria) grown in culture and that is used as a source of food esp. for livestock".

History

Research on Single Cell Protein Technology started a century ago when Max Delbruck and his colleagues found out the high value of surplus brewer's yeast as a feeding supplement for animals. During World War I, Single Cell Protein Technology proved to be more than useful as Germany used it to replace more than half of its imported protein sources by yeast. In 1919, Sak in Denmark and Hayduck in Germany invented a method named, "Zulaufverfahren" in which sugar solution was fed to an aerated suspension of yeast instead of adding yeast to diluted sugar solution. After the end World War I, interest of Germany declined in fodder yeast, but it revived in 1936 by the 'Heeresverwaltung', when both brewer's yeast and variety of yeast especially mass cultured were used as supplement for human and animals. In post war period, problems of humanity were highlighted and a number of international organizations were emerged for this task under the umbrella of United Nations. One such organization was The Food and Agriculture Organization of the United Nations (FAO) which emphasized on hunger and malnutrition problems of the world in 1960, with introducing the concept of protein gap, showing that 25% of the world population had a deficiency of protein intake in their diet. It was also feared that agricultural production would fail to meet the increasing demands of food by humanity. By the mid 60's, almost quarter of a million tons of food yeast were being produced in different parts of the world and Soviet Union alone produced some 900,000 tons by 1970 of food and fodder yeast, to compensate agricultural protein production deficiency. Advance in Biotechnology techniques has participated in the development of SCP technology and helped in improving its quality and use of different organisms along with yeast for the production of SCP.

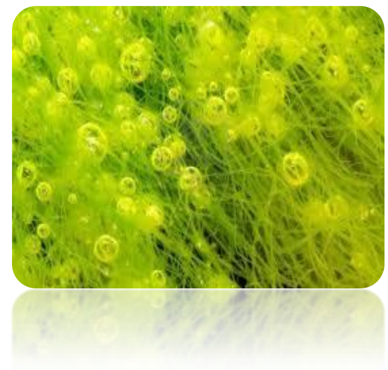
Sources

Following are the chief sources of protein production that can be utilized for SCP technology.

- Alga

- Yeast
- Bacteria

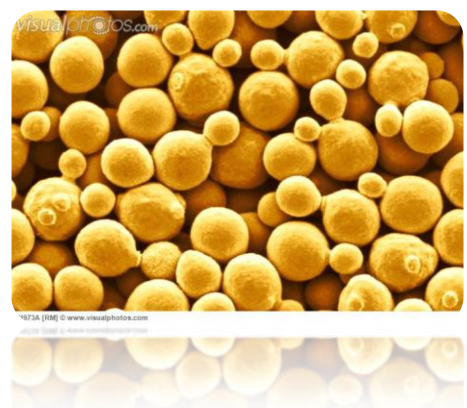
Alga



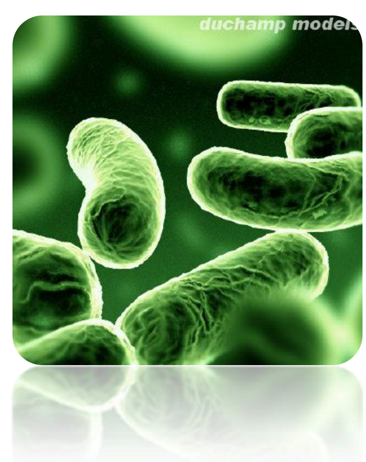
Since ancient times, *Spirulina* was cultivated by people near Lake Chad in Africa and the Aztecs near Lake Texcoco in Mexico. They used it as food after drying it. *Spirulina* is the most widely used alga, even astronauts bring to in space during their space travel. Similarly, biomass obtained from Chlorella and Senedessmus is harvested and used as source of food by tribal communities in certain parts of the world. Alga is used as a food in many different ways and its advantages include simple cultivation, effective utilization of solar energy, faster growth and rich in protein content.

Yeast

Many fungal species are used as asource of protein rich food. Among these, most popular are yeast species *Candida*, *Hansenula*, *Pitchia*, *Torulopsis* and *Saccharomyces*. Many other filamentous species are also used as source of single cell protein. In 1973, in Second International Conference convened at MIT, it was reported that actinomycetes and filamentous fungi were reported to produce protein from various substrates. During the World War II, trails were made to utilize the cultures of Fusarium and Rhizopus grown in fermentation as a source of protein food. The inoculum of Aspergillus oryzae or Rhizopus arrhizus is selected because of their non-toxic nature. Saprophytic fungi grow on complex organic compounds and convert them into simple structures. High amount of fungal biomass is produced as a result of growth. Mycelial yield vary greatly which depends upon organisms and substrates. There are some species of moulds, for example, *Aspergillus niger*, *A. fumigatus*, *Fusarium graminearum* which are very dangerous to human, therefore, such fungi must not be used or toxicological evaluations should be done before recommending to use as SCP. Very recently, SCP technology is using fungal species for bioconversion of lignocellulosic wastes.



Bacteria



Among bacterial species, *Cellulomas* and *Alcaligenes* are the most frequently used bacterial species as a single cell proteins source. Potential phototrophic bacterial trains are recommended for Single Cell Protein production. Some researchers also suggest use of methanotrophic and other bacterial species for single cell protein production. Generation time of *Methylophilus Methylotrophus* is about 2 hours and this bacteria is used in animal feed; in general produce a more favorable protein composition than yeast or fungi. Therefore the large quantities of Single Cell Protein animal feed can be produced using bacteria. Characteristics that make bacteria suitable for this application include rapid growth of bacteria, short generation times of bacteria almost can double their cell mass in 20 minutes to 2 hours, they are also capable of growing on a variety of raw materials that range from carbohydrates such as starch and sugars to gaseous and liquid hydrocarbons which include methane and petroleum fractions, to petrochemicals such as methanol and ethanol, nitrogen sources which are useful for bacterial growth include ammonia, ammonium salts, urea, nitrates, and the organic nitrogen in wastes, also it is suggested to add mineral nutrient supplement to the bacterial culture medium to fulfill deficiency of nutrients that may be absent in natural waters in concentrations sufficient to support growth.

Cultivation of Single Cell Protein

There are two types of fermentation processes which are used for production of single cell protein namely

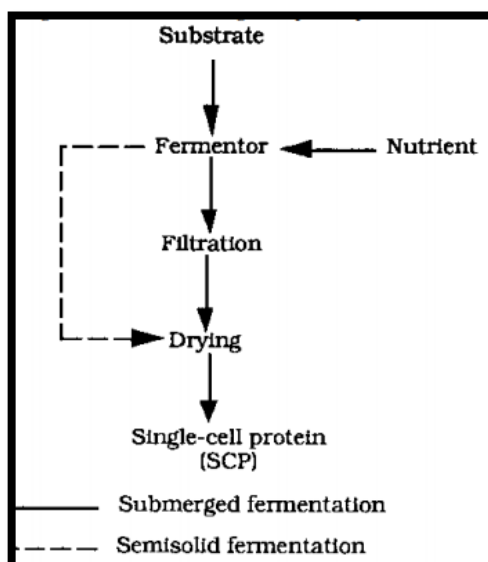
- Submerged fermentation
- Semisolid state fermentation

Submerged fermentation

In the submerged process, the substrate used for fermentation is always in liquid state which contains the nutrients needed for growth. The fermentor which contains the substrate is operated continuously and the product biomass is continuously harvested from the fermenter by using different techniques then the product is filtered or centrifuged and then dried.

Semisolid fermentation

In semisolid fermentation, the preparation of the substrate is not as cleared; it is also more used in solid state e.g. cassava waste. Submerged culture fermentations require more capital investment and have high operating cost.



The cultivation involves many operations which include stirring and mixing of a multiphase system, transport of oxygen from the gas bubbles through the liquid phase to the microorganisms and the process of heat transfer from liquid phase to the surroundings. A special bioreactor is designed for intensifying mass and energy transportation phenomena, called U-loop fermenter. Production of Single Cell Protein involves basic steps of preparation of suitable medium with suitable carbon source, prevention of the contamination of medium and the fermenter, production of microorganism with desired properties and separation of synthesized biomass and its processing. Carbon source used can be n-alkanes, gaseous hydrocarbons, methanol and ethanol, renewable sources like carbon iv oxide molasses, whey, polysaccharides, effluents of breweries and other solid substances. In cultivation, aeration is important operation as heat is generated by various methods. Single cell organisms which include yeast and bacteria are recovered by centrifugation while filamentous bacteria are recovered by filtration. Recovery of as much water as possible before final drying process is important under clean and hygienic conditions.

Nutritional Benefits of Single Cell Protein Technology

To assess nutritional value of Single Cell Protein, many factors must be considered which include nutrient composition, amino acid profile, vitamin and NA content as well as allergies and gastrointestinal effects. To assess toxicological and carcinogenic affects, long term feeding trails are also required, also processes of drying, harvesting and processing has an effect on the nutritive values of the finished products. Single Cell Protein is basically composed of proteins, fats, carbohydrates, ash ingredients, water and other elements such as potassium and phosphorus. The composition of SCP depends on the nature of substrate and also on organism used, protein not only provide nutritional value but also perform number of other functions. Single Cell Protein from yeast and fungi has up to 50-55% protein it has high protein-carbohydrate ratio than forges. It contains more lysine less amount of methionine and cysteine. It also has good balance of amino acids and it has high B-complex vitamins and more suitable as poultry feed. Single Cell Proteins produced by using bacteria contain more than 80% protein although they have small amount of sulphur containing amono acids and high in nucleic acid content. Some yeast strains with probiotic properties such as *Saccharomyces cerisiae* and *Debaryomyces hansenii* improve larval survival either by colonizing gut of fish larvae, which triggers the early maturation of the pancreas. But many yeast supplement s are lacking sulfate amino acids particularly methionine which restricts their extensive use as sole protein source.

Nutrients	Fungi	Algae	Yeast	Bacteria	(% dry weight)
Protein	30-45	40-60	45-55	50-65	
Fat	2-8	7-20	2-6	1.5-3.0	
Ash	9-14	8-10	5-9.5	3-7	
Nucleic Acid	7-10	3-8	6-12	8-12	

Aside from the nutritional benefits of Single Cell Protein, another benefit of Single Cell Protein Technology is its through-out the year production. Also it plays its role in waste management as waste materials are used as substrate. Small area of land is required and SCP is made in less time. Some organisms synthesize useful by-products such as organic acids and fats.

Drawbacks of Single Cell Protein Technology

Although SCP shows very attractive features as a nutrient for humans there are many problems that deter its adoption on global basis. These problems are high concentration of nucleic acids which is 6-10% which elevates serum uric acid levels and becomes cause of kidney stone formation. About 70-80% of total Nitrogen is present in amino acids while rest occurs in nucleic acids and this concentration of nucleic acid is higher than conventional protein which is characteristic of all fast growing organisms. The problem associated with high concentration of nucleic acid is increase in uric acid concentration in the blood causing heath problems like gout and kidney stone. Another problem is presence of cell wall which is non digestible, in case of algae and yeast, there may be unacceptable color and flavors, cells of organisms must be killed before consumption, there is chance of skin reaction from taking foreign proteins and gastrointestinal reactions may occur resulting in nausea and vomiting. SCP obtained from algae is not suitable for human consumption because they are rich in chlorophyll. SCP from yeast and fungi has high nucleic acid content. SCP obtained from bacteria also has high nucleic acid content, high risk of contamination during the production process and cell recovery also causes many problems.

Comparison of various parameters for SCP production from algae, fungi and bacteria

Parameter	Algae	Bacteria	Fungi (Yeast)	Fungi (Filamentous)
Growth rate	Low	Highest	Quite high	Lower than bacteria and yeast
Substrate	Light, carbon dioxide or inorganic samples	Wide range (Refer Table 3)	Wide range except carbon dioxide	Mostly lignocellulosics
pH range	Upto 11	5–7	5–7	3–8
Cultivation	Ponds, Bioreactors	Bioreactors	Bioreactors	Bioreactors
Contamination risks	High and serious	Precautions needed	Low	Least if pH is less than 5
S-containing amino acids	Low	Deficient	Deficient	Low
Nucleic acid removal	–	Required	Required	Required
Toxin	–	Endotoxins from gram-negative bacteria	–	Mycotoxins in many species

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