Topic: SINGLE CELL PROTEINS (SCP)

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SINGLE CELL PROTEINS (SCP)

Introduction: Need for alternate food source

The term 'single cell protein ' refers to total proteins produced or derived from the pure cultures of of a single-celled organism, used as a food supplement microorganisms (e.g. yeasts, algae, filamentous fungi, bacteria- -dead or dried cell biomass) and can be used as food substitute especially rich in protein for humans and animals. Besides its high protein content (about 60-82% of dry cell weight), single cell protein also contains fats, carbohydrates, nucleic acids, vitamins and minerals.

Humans and animals consume protein as a source of nitrogen and essential amino acids, from which they build new structural and functional (e.g., enzymes and hormones) proteins that enable them to survive. In extreme conditions, proteins may also be used as a source of energy. The nutritional value of a protein is determined by the amino acid composition; Twenty basic amino acids are commonly found in dietary protein, of which several (i.e., phenylalanine, valine, threonine, tryptophan, methionine, leucine, isoleucine, lysine, and histidine, arginine with cysteine, glycine, glutamine, proline, and tyrosine also being beneficial) cannot be synthesized by humans or animals and are thus essential and have to be supplied through the diet. Both essential and nonessential amino acids affect a broad range of physical and mental processes of animal and human body. Recent studies indicate that amino acids are cell signalling molecules as well as being regulators of gene expression and the protein phosphorylation cascade. The majority of the neurotransmitters is composed of amino acids and can influence biological functions related to brain-body interactions. Amino acids are key precursors for syntheses of hormones and low-molecular weight nitrogenous substances with each having enormous biological importance.

By the year 2050, the world would need to produce approximately 1,250 million tonnes of meat and dairy per year to fulfill global demand for animal-derived protein at current consumption levels. However, for the growing demand for protein new solutions are needed. Single cell protein (SCP), i.e., protein produced by microbial cells, is an option with immense potential.

History

- Since 2500 BC yeasts have been used in bread and beverages production. In 1781, processes for preparing highly concentrated forms of yeast were established.
- Since early fifties, efforts have been made to explore new, alternate and unconventional protein.
- M.I T. Professor Carroll L. Wilson coined the term **"single Cell Proteins**" which was initially termed as microbial protein.
- In 1960s the idea that dried microbial cells can become the ultimate part to solve the problem of obtaining alternate protein source crisis.
- For this reason, in 1996, new sources mainly bacteria, yeast, fungi and algae were used to produce protein biomass named Single Cell Protein (SCP)
- **"Food from oil"** In the 1960s, researchers at British Petroleum developed what they called "proteins-from-oil process": a technology for producing single cell protein by yeast fed by waxy n-paraffins, a product produced by oil refineries. Initial research work was done by Alfred Champagnat at BP's Lavera Oil Refinery in France; a small pilot plant there started operations in March 1960s.

- Pruteen was the first commercial SCP used as animal feed additive. It was produced from bacterium *Methylophilus methylotrophus* cultured on methanol and had a protein content of 72%.

SCP Production in India:

- Central Food Technological Research Institute(CFTRI)
- National Botanical Research Institute (NBRI).

Why microorganisms are preferred for production of SCP:

- Grow at a faster rate.
- The quality and quantity of protein is considered better (controversies prevail).
- Wide range of raw materials can be used.
- The production process is easy and simple.
- Microbes can be subjected easily to desired genetic manipulations.

Raw Materials for SCP production

SCP production requires microorganisms that serve as protein source and the substrate that is biomass on which they grow. There is variety of both the sources. Waste materials can be used substrates like agricultural wastes of sawdust, corn cobs, wood shavings etc. Other waste substrates: Sewage, food processing wastes, residue from alcohol production, hydrocarbons or human and animal excreta.

Microorganisms Used in Single Cell Proteins

Algae, fungi (filamentous), yeast and bacteria are used for SCP production. The used microorganisms must be (i) non-pathogenic to animals and man, (ii) of good nutritional value, (iii) easily and cheaply produced in large scale,(iv) toxin free, (v) easy to separate from medium and dry etc.

Algae

Common genera like *Spirulina* sps, *Chlorella pyrenoidosa*, *Senedesmus* sps etc are widely used and grown in tanks/ponds/lakes. 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. Similarly, biomass obtained from *Chlorella* and *Senedesmus* is harvested and used as source of food by tribal communities in certain parts of the world. Algae are used as a food in many different ways and its advantages include simple cultivation, faster growth and rich in protein content about 60% crude protein. The production of algae could be limited by certain conditions such as the need for warm temperatures and plenty of sunlight in addition to carbon dioxide. Another disadvantage associated with using algae as single cell protein is that digestibility is low with algal cells because of indigestible cell walls; rich chlorophyll content which is unsuitable for human use, recovery method is less cost effective.

Yeasts and fungi-

Many fungal species are used as sources of protein rich food. Among these, most popular are yeast species, *Candida utilis*, *Candida tropicalis, Hansenula, Pitchia, Torulopsis* and *Saccharomyces* cerevisiae. Many other filamentous fungal genera like: *Aspergillus fumigates, Aspergillus niger, Rhizopus cyclopean* are a used as sources of single cell protein. Cultures of *Fusarium* and *Rhizopus* have been 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, Aspergillus 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 Single cell protein. Yeasts are probably the most widely accepted and used microorganism for single cell protein.

TABLE. Some important features of different microorganisms and the SCP produced from them. Ref: Microbiology R.P. Singh.

Feature	Algae	Bacteria	Yeast	Filamentous fungi
Growth rate	Low	Highest	Quite high	Lower than bacteria and yeast
Substrate	Light, inorganic carbon sources, *e.g.*, CO_2 (preferably)	A wide range of substrates	Most substrates, except hydrocarbons and CO_2	Limited substrates (mostly starchy and cellulosic materials)
pH range	Upto 11	5-7	5-7	3-8
Cultivated in	Open ponds, tanks; in sun-light	Bioreactors	Bioreactors	Bioreactors
Risk of contamination	Serious	High; precautions necessary	Low	Low if grown below pH 5
Biomass recovery	Difficult and costly with unicellular algae	Problematic; improved methods are needed	Easy; by centrifugation	Easy for filamentous or pellet forms
Protein content (crude)	Upto 60%	80% or more	55-60%	50-55%
Amino acid profile	Genrally good; low in S-containing amino acids	Generally good; a small deficit in S-containing amino acids	Generally good; deficit in S-containing amino acids	Low in S-containing amino acids
Nucleic acid content	—	Very high (20% RNA)	High (15% RNA)	High (15% RNA)
Removal of nucleic acids	—	Necessary	Necessary	Necessary
Toxins	—	Gram-negative bacteria may produce endotoxins	—	Many species produce mycotoxins
Other features	1. Low yield (1-2 g dry wt/l) 2. High chlorophyll content; unsuitable for humans	—	High B-vitamin content	Chitin may contain a significant proportion of N-content which is unavailable.

Bacteria

Among bacterial species, Pseudomonas fluorescens, Lactobacillus ,Bacillus *megaterium*, *Methylophilus methylotropus*, *Cellulomas* and *Alcaligenes* are the most frequently used bacterial species as a single cell proteins source . Potential phototrophic bacterial strains 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 bacterium 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 .The use of bacteria is somewhat limited by poor public acceptance of bacteria as food, small size and difficulty of harvesting and high content of nucleic acid on dried weight basis.

Some important features of different microorganisms and the SCP produced from them

Production of Single-Cell Protein

The production is carried out in the following basic steps:

- Selection of suitable strain and suitable biomass.
- Preparation of suitable medium with suitable carbon sources and other nutrients.
- Cultivation of suitable strain of microorganisms
- Prevention of contamination
- Fermentation.
- Harvesting(Separation of microbial biomass)
- Post-harvest treatment.
- SCP processing for food.

Single cell proteins develop when microbes ferment waste materials (including wood, straw, cannery and food processing wastes, residues from alcohol production, hydrocarbons, or human and animal excreta). Like any other microbial culture, production of pure microbial cultures for desired protein products requires a nitrogen source, carbon sources and other nutrients like phosphorus to support optimal growth of the culture. Contamination is prevented by maintaining strict sterile conditions throughout the process. The components of the culture media are either heat sterilized or filtered through micro porous membranes. The selected microorganism is then inoculated in pure conditions. Most of the processes are highly aerobic, except algal fermentation; hence a good supply of oxygen is an indispensable requirement. After the multiplication of the biomass, it is recovered from the medium and purified further for enhanced usefulness and or storability.

Selection of strain:

- A very critical step as quality of protein depends on the used microbes.
- Thus careful selection of strain should be done.
- Care should be taken that the selected strain should not produce any toxic effect on consumer.

Fermentation:

- It is carried out in fermenter or Bioreactor which is equipped with aerator, pH, thermostat etc or in ponds, lakes or trenches.
- Microbes are cultured in fed-batch cultures.
- Engineers have developed deep lift fermenter and air lift fermenter.

Harvesting:

- With full development of colonies microbes are harvested.
- Bulks of cells are removed by decantation.

Post-harvest treatment

- It includes steps like separation by centrifugation, washing, drying etc.

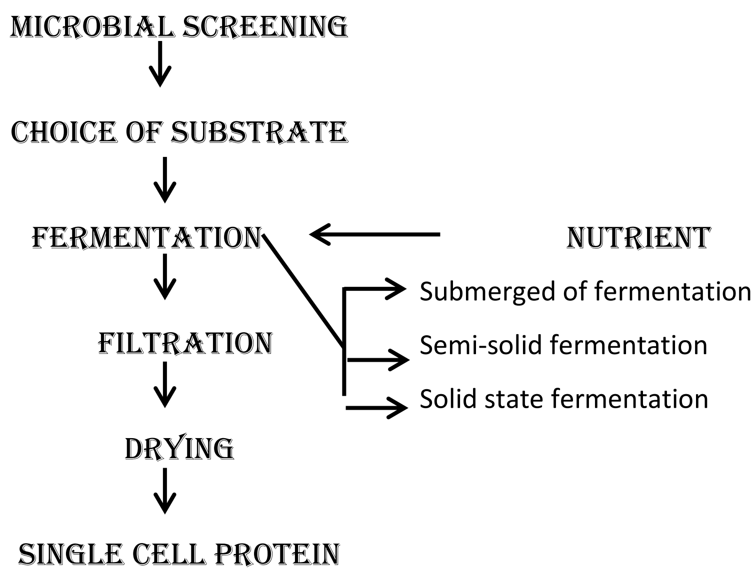
Processing for food – It includes

A. Liberation of cell proteins by destruction of indigestible cell wall.

1. Mechanical Methods –
   Crushing,crumbling, grinding, pressure homogenization etc.
2. Chemical Methods –
   Enzymes and salts are used to digest and disrupt cell wall Salts like NaCl, sodium dodecyl sulfate etc, whereas nuclease enzymes are used.
3. Physical Methods – Freeze, thaw, osmotic shock, heating and drying.

B. Reduction of nucleic acid content

- Chemical and enzymatic treatments are preferred.
- Chemical used includes acidified alcohol, salts, acids and alkalies.
- Use of such chemicals leads to formation of lysine-alanine which causes skin irritations.
- Enzymes include ribonucleases and nuclease enzymes.
- These enzymes can be used exogenously or endogenously.



FLOW DIAGRAM OF SCP PRODUCTION

Advantages of SCP:-

(i) It serves as rich source of protein in human diet.

(ii) It reduces pressure on agricultural production system for the supply of protein requirement.

(iii) It helps in reducing environmental pollution.

Limitations of using SCP:-

- Nucleic acid content is very high (40% algae: 10-15% bacteria and 5-10% yeast)
- Presence of carcinogenic and toxic substances
- Contamination of pathogenic microorganisms
- Indigestion and allergic reactions
- Production of food grade SCP is expensive

Applications:

1. As protein supplemented food
2. As health food
3. As medicines
4. In cosmetics
5. Poultry and cattle feed.
