SINGLE CELL PROTEINS

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What are single cell proteins (SCPs)?

- Dried cells of microbial (yeast, fungi, bacteria and algae) biomass used as protein supplements in human foods and animal feed.
- Convert low protein organic mass into high protein organic products.
- Yeast was the first microorganism whose importance as animal feed supplement was recognized a century ago by Max Delbruck.
- During World War I, Germany replaced half of its protein supplement by yeast.
- Pruteen was the first commercial SCP used as animal feed additive

Implications using SCPs as human food

- Low cell wall digestibility and High nucleic acid content of SCPs limit its use as human food.
- Excessive intake of nucleic acid leads to uric acid precipitation resulting in gout or kidney stone formation.
- Nucleic acid content is reduced below 2% by chemical or enzymatic methods which are disadvantageous.

Microbes as SCPs and nutritional composition

- Bacteria – *Cellulomonas, Alcaligenes*

  Algae – *Spirulina, Chlorella*
- Yeast – *Candida, Saccharomyces*

  Molds – *Trichoderma, Fusarium, Rhizopus*
- Utilize substrates like agricultural wastes and effluents, industrial wastes, natural gas like methane etc.,

Table 1: Average different compositions of the main groups 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	9-14	8-10	5-10	3-7
Nucleic acid	7-10	3-8	6-12	8-12

Miller and Litsky (1976)

Algae

- 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 *Scenedesmus* is harvested and used as source of food by tribal communities in certain parts of the world.
- Algae 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 a source of protein rich food. Among these, most popular are yeast species *Candida, Hansenula, Pitchia, Torulopsis* and *Saccharomyces*.
- 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.
- 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.
- Generation time of *Methylophilus methylotrophus* is about 2 hours and this bacteria is used in animal feed.
- 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

Comparative analysis of different microbes as SCPs

Microbes	Advantages	Disadvantages
Bacteria	High in protein (50-80%) Rapid growth rate	Small size and low density Difficult and costly to harvest High nucleic acid content Additional processing required Public thinking as bacteria are harmful
Yeast	Large size Easier to harvest Low nucleic acid content High lysine content Grows well at acidic pH Familiarity and acceptability 100 lbs yeast produces 250 tons of protein in 24 h	Lower growth rate Lower protein content (45-65%) Low methionine content
Fungi	Easy to harvest	Low growth rate Low protein content Low acceptability
Algae	Produce 20 tons per acre per year	Cellulosic cell wall Concentrate heavy metals

Comparative analysis of different microbes as SCPs

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

Table 2: Microorganism and substrates used for single cell protein production

Microorganism	Substrate
Bacteria	
Aeromonas hydrophylla	Lactose
Acromobacter delvacvate	n-Alkanes
Acinetobacter calcoacenticus	Ethanol
Bacillus megaterium	Non-protein nitrogenous compounds
Bacillus subtilis, Cellulomonas sp., *Flavobacterium* sp., *Thermomonospora fusca*	Cellulose, Hemicellulose
Lactobacillus sp.	Glucose, Amylose, Maltose
Methylomonas methylotrophus, M. clara	Methanol
Pseudomonas fluorescens	Uric acid and other non-protein nitrogenous compounds
Rhodopseudomonas capsulata	Glucose
Fungi	
Aspergillus fumigatus	Maltose, Glucose
Aspergillus niger, A. oryzae, *Cephalosporium eichhorniae, Chaetomium cellulolyticum*	Cellulose, Hemicellulose
Penecillium cyclopium	Glucose, Lactose, Galactose
Rhizopus chinensis	Glucose, Maltose
Scytalidium aciduphlium, Thricoderma viridae, Thricoderma alba	Cellulose, pentose
Yeast	
Amoco torula	Ethanol
Candida tropicalis	Maltose, Glucose
Candida utilis	Glucose
Candida novellas	n-alkanes
Candida intermedia	Lactose
Saccharomyces cereviciae	Lactose, pentose, maltose
Algae	
Chlorella pyrenoidosa, Chlorella sorokiana, Chondrus crispus, Scenedesmus sp., *Spirulina* sp., *Porphyrium* sp.	Carbone dioxide through photosinthesis

Bhalla *et al.* (2007)

Cultivation of SCPs

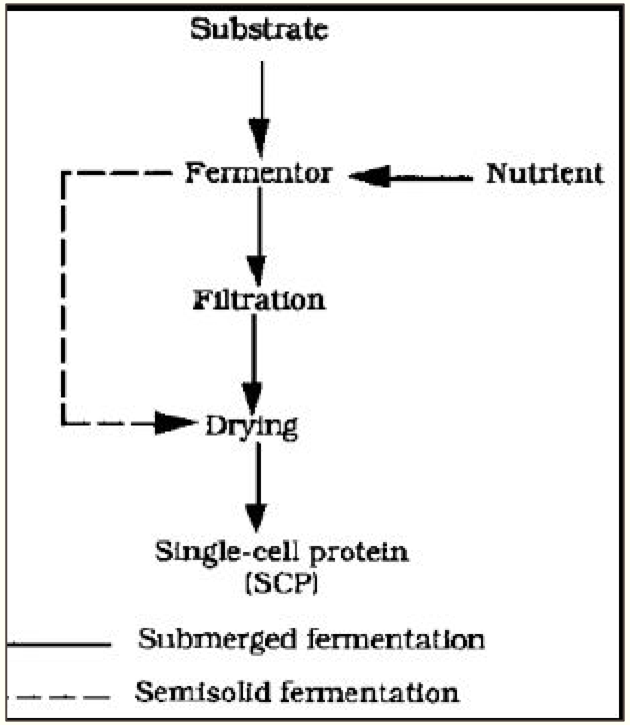
- Submerged fermentation
  - In the submerged process, the substrate used for fermentation is always in liquid state which contains the nutrients needed for growth.
  - The fermentor which contains the substrate is operated continuously and the product biomass is continuously harvested from the fermenter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

Cultivation of SCPs

- 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.

Cultivation of SCPs

- Production of SCP involves basic steps of
  1. preparation of suitable medium with suitable carbon source,
  2. prevention of the contamination of medium and the fermenter,
  3. production of microorganism with desired properties and
  4. separation of synthesized biomass and its processing.



Cultivation of SCPs

- Carbon source used can be n-alkanes, gaseous hydrocarbons, methanol and ethanol, renewable sources like carbon di 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

- 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.
- SCP from yeast and fungi has up to 50-55% protein and it has high protein-carbohydrate ratio.
- 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.

Nutritional benefits

- SCPs produced by using bacteria contain more than 80% protein although they have small amount of sulphur containing amino acids and high in nucleic acid content.

- Some yeast strains with probiotic properties such as *Saccharomyces cerivisiae* and *Debaryomyces hansenii* improve larval survival either by colonizing gut of fish larvae, which triggers the early maturation of the pancreas.

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
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Nucleic Acid	7-10	3-8	6-12	8-12

Economic importance

- Round the year production
- Plays a role in waste management as waste materials are used as substrate
- Small area of land is used for cultivation
- Requires less time for mass production
- Some organisms synthesize useful by-products such as organic acids and fats.