SINGLE CELL PROTEIN (SCP)

The topic Single cell protein will be discussed under 5 sun units such as

1. INTRODUCTION
2. SUBSTRATES USED FOR SCP PRODUCTION
3. MICROORGANISMS USED IN SCP PRODUCTION
4. PRODUCTION PROCESS
5. ADVANTAGES AND DIS ADVANTAGES OF SCP

1. INTRODUCTION

The term 'Single Cell Protein' (SCP) is popularly known for a protein derived from microorganisms. It was coined by Professor Wilson of the MIT, Cambridge, USA to replace the 'microbial' or 'bacterial' protein or 'petroprotein' (for cells grown specifically on petroleum). The term has since become widely accepted. In the 1950s and 1960s concern grew about the 'food gap' between the industrialized and the less industrialized parts of the world, especially as there was rapid and continuing population growth in the latter. As a result of this concern, alternate and unconventional sources of food were sought. It was recognized that protein malnutrition is usually far more severe than that of other foods. The hope was that microorganisms would help meet this world protein deficiency. It was not thought that SCP would replace the need to increase proteins from plants such as oil beans or from animals such as fish. However, the limitations of conventional sources of proteins were recognized. These include:

a) Possible crop failure due to unfavorable climatic conditions in case of plants;
b) The need to allow a time lapse for the replenishment of stock in case of fish;
c) The limited land available for farming in case of plant production.

On the other hand the production of SCP has a number of attractive features:

a) It is not subject to the alterations/change of the weather and can be produced every minute of the year.
b) Microorganisms have a much more rapid growth than plants or animals. Thus a bullock weighing 10000 kg weight would synthesize less than 400 grams (ie., 1/10000 of its weight) of protein a day, at the same time 10000 kg weight of microbes would probably produce over 50 tons (or over 100 times) of their own weight of protein a day.
c) Furthermore, (c) waste products can be turned into food in the production of SCP.

As had been stated earlier microorganisms began receiving attention as food on a worldwide basis in the late 1950s and early 1960s. Nevertheless they have for centuries been consumed in large amounts, either wholly or as part of a meal or alcoholic beverage by man, although he did not always recognize this. In many tropical countries, palm wine and sorghum beers which have high suspensions of bacteria and yeast have been consumed for centuries. Fermented milks and yoghurts which have been consumed from ancient times right up to the present day contain large amounts of bacteria and yeasts (10^{12} -10^{14} cells/ml). In Central Africa the blue-green alga, *Spirulina* has been eaten for centuries as did also the Aztecs of South America.

The organized and deliberate cultivation of micro-organisms for food, however, is not relatively recent. During the First World War (1914-1918) baker's yeasts, *Saccharomyces* *cerevisiae,* were grown on a molasses-ammonium medium. Development continued in between the wars and in the second world war (1939-1945), *Geotrichum lactis*, *Endomyces vernalis,* and *Candida utilis* were grown for food.

The main purpose of consumption of SCP was due to its nutritional composition, however the nutritional value of SCP depends on the composition of the microbial cells used especially their protein, amino acid, vitamin, and mineral contents. These to some extent also depend on the conditions of growth of the organism. The FAO has set up reference values for the amino acid content of proteins. On this basis, SCP derived from bacteria and yeasts is deficient in methionine. Glycine and methionine are sometimes deficient in molds. These can be improved by supplementation with small amounts of animal proteins.

2. SUBSTRATES FOR SINGLE CELL PROTEIN PRODUCTION

Even though, SCP are produced from microbes, but for the growth of microbes substrates as energy sources are must. Wide varieties of substrates have been used for SCP production and include hydrocarbons, alcohols, and wastes from various sources.

Hydrocarbons – traditionally used substrates for SCP production

Different hydrocarbons have been used such as

a) Aliphatic hydrocarbons are assimilated by strains of yeasts in many genera. Other classes of hydrocarbons, including aromatics may be oxidized but are not usually efficiently assimilated.
b) n-Alkanes of chain length shorter than n-nonane are not usually assimilated, but may be oxidized. Yield factors increase but the rate of oxidation decreases with increasing chain length from n-nonane.
c) Unsaturated compounds are degraded less readily than saturated ones.
d) Branched chain compounds are degraded less readily than straight chain chemical compounds.

Gaseous hydrocarbons

Among the gaseous hydrocarbons, methane has been most widely studied as a source of SCP. Others which have been studied include propane and butane. Methane is the predominant gas in natural gas, whether such natural gas, which is plentiful over the world and also it is cheap. Indeed in many oil fields, it is burned. Perhaps its greatest advantage is the absence of residual hydrocarbon in the single cell protein produced from it, unlike the case with liquid hydrocarbons. One of its major disadvantages is that it is highly inflammable.

Single cultures in methane are usually very slow growing. Single cell protein production from methane has used continuous cultures and a mixed population of microorganisms. The advantages of a mixed methane are higher growth rate, higher yield coefficient, greater stability resistance to contaminations and a reduction in foam production. It has been suggested that the various members of a four-organism mixture had the following functions: *Hyphomicrobium* utilizes the methanol, whereas the other members, *Flavobacterium* and *Acinetobacter* (which do not grow on methane) remove waste products.

Liquid hydrocarbons

The major source of liquid hydrocarbons is crude petroleum. These hydrocarbons were first studied as a source of microbial vitamins and lipids. Later these studies were extended in the late 1940s to the feeding of whole paraffin-grown bacterial and yeast cells to rats. British Petroleum (BP) pioneered the use of petroleum fractions in SCP production and by 1973 had the largest number of patents in the field. Soon after, many other oil companies and governments all over the world set-up research and pilot plants. Plans to build production plants were made by some.

Since the oil boycott of 1973-1974 crude oil prices have risen sharply and the initial attraction to the use of crude oil as a substrate for SCP has been eroded. Consequently it is doubtful that the greatly raised expectations of SCP from petroleum is likely to be achieved. Indeed many of the plans announced by many oil companies for production stage fermentors were soon abandoned.

Alcohols – the next substrates used for SCP production

While work on SCP production from n-paraffin and gas oil was in progress, alternatives to petroleum based substrates were sought. Methanol and ethanol are such alternatives.

Methanol – among alcohols most widely used substrate

Methanol is produced by the oxidation of paraffins in the gas or liquid phase or by the catalytic reduction by hydrogen of CO and CO2, either singly or mixed. The catalysts are mixed such as zinc and chromium oxides.
Methanol is suitable as a substrate for SCP for the following reasons: (a) it is highly soluble in water and this avoids the three-phase (water-paraffin-cell) transfer problems inherent in the use of paraffins; (b) the explosion hazard of methanol is minimized in comparison with methane-oxygen mixtures; (c) it is readily available in a wide range of hydrocarbon sources ranging from methane to naphtha; (d) it can be readily purified in a process which avoids the carry over of the most toxic polycyclic aromatic compounds; (e) it requires less oxygen than methane for metabolism by micro-organisms and hence a lower cooling load.

The use of methanol as a SCP substrate has received attention by oil companies in Italy, West Germany, Norway, Sweden, Israel, the United Kingdom, and the United States. One of the most advanced in all these countries is the project of the Imperial Chemical Industries (ICI) which using the bacterium, *Methylophilus methylotropha* was due to start the annual production of several tons of proprietary ‘Pruteen’ in Billingham, the UK, using the loop fermentor, (‘pressure cycle fermentor’).

Over 20 species from the genera *Hansenula*, *Pichia*, *Torulopsis* and *Candida* have been shown to grow on methanol.

Ethanol – the next best substrate among alcohols

Ethanol may be produced by the fermentative activity of yeasts. In the synthetic process however, it is produced by the hydration of ethylene. Although ethanol can be utilized ordinarily by many bacteria and yeasts, as a substrate for SCP, it is largely used by yeasts. Ethanol has the following advantages:
(a) Since it is already consumed in alcoholic beverages it is not quite as suspect a substrate for SCP as are gas oil and n-paraffins.

(b) It is like methanol, highly miscible with water and hence more easily available than the three-phase paraffin system.
(c) Ethanol in contrast with methane can be more safely stored and transported
(d) As, unlike methanol, it is non-toxic it can be more easily handled.
(e) Ethanol is partially oxidized. For these reasons, the fermentation of ethanol for SCP production requires comparatively less oxygen and hence releases considerably less heat than if it were unsaturated.

The major disadvantage in using ethanol for SCP production is that it is expensive, even when produced by the catalytic method described above. Despite this advantage yeast produced from ethanol is being produced and marketed as a flavor enhancer in baked foods, pizzas, sauces, etc., in the United States by the Amoco Oil Company in a plant which will ultimately produce 15 million lbs per annum. The yeast used is *Candida utilis.*

In Japan the Mitsubishi Oil Company has developed strains of *Candida acidothermophilum* which grow at a lower pH value and higher temperature than *Candida utilis.* These properties should help reduce costs by minimizing the need for asepticity and cooling, as also is the use of unpurified ethanol derived from the process described above. The pilot plant production is 100 tons per annum. In Spain *Hansenula anomala* is used. Ethanol-based SCP is also produced in Czechoslovakia and the USSR. In Switzerland a joint project between Nestles (the food Company) and Exxon (the US Oil Company) utilizes a bacterium *Acinetobacter* species rather than a yeast. Unlike many other plants is directed primarily towards human consumption hence reduction in the nucleic acid content is important.

Waste products – nowadays most accepted substrates for SCP production

In recent times petroleum prices have continued to soar; it is therefore unlikely that petroleum-based substrates such as synthetically produced methanol and ethanol, gas oil, etc., will be much less used in the future. Indeed many projects designed to operate on them are already being closed. It is not however the end of the SCP story, because attention is being turned more and more to substrates derived from plants which are renewable during photosynthesis. Usually however these are obtained as waste products from various sources.

A large number of reports of SCP production from waste material have been reported in the literature is as follows.

(i) Plant/wood wastes
(ii) Starch-wastes
(iii) Dairy wastes
(iv) Wastes from chemical industries &
(v) Molasses

Other than these, a wide variety of substrates may also be used for SCP production. These include coffee wastes, coconut wastes, palm-oil wastes, citrus waste, etc.

3. MICROORGANISMS USED IN SCP PRODUCTION

Generally, microbes used for the production of SCP were industrially important organisms. However all industrially important microbes may not the suitable organisms. In addition to the properties required to be an industrial organisms it should also have have the following properties to be used in SCP production:

(a) *Absence of pathogenicity and toxicity*: It is obvious that the large-scale cultivation of organisms which are pathogenic to animals or plants could pose a great threat to health and therefore should be avoided. The organisms should also not contain or produce toxic or carcinogenic materials.
(b) *Protein quality and content*: The amount of protein in the organisms should not only be high but should contain as much as possible of the amino acids required by man.
(c) *Digestibility and organoleptic qualities*: The organism should not only be digestible, but it should possess acceptable taste and aroma.
(d) *Growth rate*: It must grow rapidly in a cheap, easily available medium.
(e) *Adaptability to unusual environmental conditions*: In order to eliminate contaminants and hence reduce the cost of production, environmental conditions which are antagonistic to possible contaminants are often advantageous. Thus, strains which grow at low pH conditions or at high temperature are often chosen.

The heterotrophic microorganisms currently used for SCP production are fungi, algae and bacteria. Microbes popularly used are yeasts (*Saccharomyces cerevisiae*, *Pichia pastoris*, *Candida utilis (=Torulopsis)* and *Geotrichum candidum* (=*Oidium lactis*)), other fungi (*Aspergillus oryzae*, *Fusarium venenatum*, *Sclerotium*, *Polyporus* and *Trichoderma*), bacteria (*Rhodopseudomonas capsulata*) and most importantly algae (*Chlorella* and *Spirulina*). Microbes typical yields of 43 to 56%, with protein contents of 44 to 60%

4. PRODUCTION PROCESS

The production of single cell protein takes place in a fermentation process. This is done by selected strains of microorganisms which are multiplied on suitable raw materials in technical cultivation process directed to the growth of the culture and the cell mass followed by separation processes. Process development begins with microbial screening, in which suitable production strains are obtained from samples of soil, water, air or from swabs of inorganic or biological materials and are subsequently optimized by selection, mutation, or other genetic methods. Then the technical conditions of cultivation for the optimized strains are done and all metabolic pathways and cell structures will be determined. Besides, process engineering and apparatus technology adapt the technical performance of the process in order to make the production ready for use on the large technical scale.

Single cell Protein Production process commonly have these following steps

- Microbial Screening
- Choice of Raw Materials
- Process Engineering and Process Optimization
- Technology Development
- Economic Consideration / Process Feasibility
- Safety Concerns

Microbial screening: Microbial Screening is the first step in Production process, suitable microbe which yields good amount of protein need to be selected. Microbial strains are collected from various habitats like soil, water, air and or from other biological materials.

Microbes are selected by various studies including mutagenisis and other genetic methods, some times wild types are also used.

Choice of Raw Material: This part is little cumbersome and one need to focus on the correct composition of carbon suppliment which yields higher biomass production in lesser time need to be analyzed. Various carbon sources are like wood waste, straw, other food processing wastes are also can be tried to optimize higher biomass production.

Process engineering: The technical conditions of cultivation for the optimized strains are done and all metabolic pathways and cell structures will be determined.

Technology Development: Technology development is the next step where the adoption of the technical performance of the process in order to make the production ready for use on the large technical scale.

Economic factors: Energy consumption, cost of production are the important factor while going for large scale production phase, this need to be thoroughly analyzed and an energy efficient process need to be developed or else it will end up with loss.

Safety demands & Environmental protection: Since the SCP produced is for human consumption or for feeding animals safety of the product need to be tested. certain microbes produces toxic compounds which can have determinal effect on humans and also for the environment, so the whole process should be monitored properly.

5. ADVANTAGES AND DIS ADVANTAGES OF SCP

Advantages of Single Cell Protein

- Single cell protein have high protein and low fat content.
- Single cell protiens are good source of vitamin.
- It can be produced through out the year.
- Generation time of microbes are less, ie, they multiply rapidly building up the biomass, more the biomass more the protein source.
- Protein content is very high in dried biomass upto 85%
- During the production of SCP biomass, certain microbes produce usseful byproducts such as organic acids.
- Waste (wood waste, food processing waste, hydrocarbons, etc) can be used as a source for carbon for growing microbes there by having advantage of environmental clean up also.
- Doesn't require sophisticated lab setup for algae and certain other microbes.
- High efficiency substrate conversion.

Disadvantages of Single Cell Protein

Even though it single cell proteins have the above mentioned advantages, it has some disadvantages also, the major problem associated with the use of single cell proteins are

- Single Cell Protein diet supplements can pose allergic reaction.
- Consuming SCP, in-taking higher amount of nucleic acids which can lead to gastrointestinal problems.

- Food grade SCP production is expensive due to the need to maintain high level sterility conditions in the production facility.
- Many microbes produce various toxic compounds, so consumption of such toxic can have serious effect on health of humans (Food Grade SCP), or in animals (Feed).

Conclusion: Single-cell protein (SCP) are dried microbial cells or total protein extracted from pure or mixed cultures of microbes such as algae, yeasts, fungi or bacteria (grown on agricultural wastes) used as a substitute for protein-rich foods, in human and as for animal feeds. Since most of the developing countries of the world are facing a major problem of malnutrition, in this case the SCP will be better alternative food. SCP is itself not entirely lacking in disadvantages. One of the most obvious is that many developing countries, where protein malnutrition actually exists, lack the expertise and/or the financial resources to develop the highly capital intensive fermentation industries involved. But this short-coming can be bridged by the use of improvised fermentors and recovery methods which do not require sophisticated equipments.