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PRODUCTION AND PROCESSING OF SINGLE CELL PROTEIN (SCP) - A REVIEW

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ABSTRACT

In 1968, the 'single cell protein' term had introduced in a meeting conducted at the Massachusetts Institute of Technology (MIT) for the replacement of the protein with low aesthetic value i.e. 'petroprotein' and 'microbial protein' as these terms were initially documented. Utilization of microorganisms as the food supplement might come out to be improper for a number of inhabitants however the thought of utilization of microorganisms as the food additive intended for human and animals consumption would definitely pioneering to resolve the universal food crisis. Single cell protein possesses numerous applications within feed and food industries. Microbial species which could be employed as single cell protein contain a range of bacteria, molds, microalgae from marine environment and yeasts. Making of single cell protein by means of inexpensive resources as substrate offers an economically reasonable protein source for animal feeding or the formation of compounds for human eating, as this frequently meet up dietary needs of protein. A lot of microorganisms had been exploited for conversion of a variety of substrates into the biomass producing single cell protein. Technological advancements appeared as a potential approach for resolving the crisis of global protein deficiency. They progressed as the bioconversion practices that changed products of low value into the products having additional dietary and market worth and as single cell protein are the inexpensive protein products in the marketplace, its manufacturing is cost-effective.

KEYWORDS: Single cell protein, Fermentation, Algal species, Bacteria, Filamentous Fungi, Yeasts.

INTRODUCTION

Deficiency of proteins is increasing which is becoming a major problem throughout the world. Malnutrition is becoming a serious problem in many developing countries of the world. Rapid increase in the population result in the proteins and nutrients deficiency as observed in human food along with animals feed. Extensive efforts have been done to explore new, alternative and unconventional proteins since early 1950s. In 1996, because of this issue, new sources for the single cell proteins are introduced. Single cell protein is referred as dried microbiological cell mass or total extracted protein content from pure culture of microbiological cells such as bacteria, fungi and yeasts.[1] Microbiological biomass is thought to be an alternative to the previous conventional resources of Food grade (food supplements to humans) or Feed grade (food supplements to animals).[2] Use of single cell proteins (SCP) within animal nutrients is seen as the stuffing poultry, calves, fish breeding and pigs. Inside food, its applications are as the carriers of aroma and vitamin, emulsifier and enhancing the nutritional value of bakery items such as soups, readymade foods, and recipes and in the technological areas such as processing of paper pulp and leather and along with foam stabilizing agent.[3]

Production of single cell protein on the large scale has following interesting characteristics,

- The wide range of methods, raw materials and microbial sources can be utilized for this process.
- Substrate is converted with high efficiency.
- Rapid growth rate of microbial cells results in high productivity.
- Seasonal factors show no effect on this process.

The first microorganism which was recognized as important animal feed additives was yeast approximately a century back. Through World War I, Germany used yeast in place of half of the imported sources of proteins. The first single cell protein used as animal feed supplement on the commercial level was pruteen. From a nutritional point of view, the main hindrance in the usage of SCP as supplement is its content of nucleic acids (NA).

NA excessive intake results in precipitation of uric acid, causing health problems such as formation of kidney stones and gout. So, while utilizing SCP as human food supplement, its NA content should be minimized below 2%. Many techniques, including both enzymatic and chemical processes, have been reported to minimize its NA content. Both the enzymatic and chemical methods have drawbacks.[1] Microorganisms which can be used for the production of SCP are bacteria (*Alcaligenes*, *Cellulomonas* etc.), algae (*Rhizopus*, *Trichoderma*, *Fusarium* etc.) and yeast (*Saccharomyces*, *Candida* etc.). The composition of the main groups of microorganisms is shown in Table 1.[4]

Table 1: Average composition of different microorganisms (% dry weight)

Composition	Bacteria	Algae	Fungi	Yeasts
Protein	50-65	40-60	30-45	45-55
Nucleic acid	8-12	3-8	7-10	6-12
Fat	1-3	7-20	2-8	2-6
Ash	3-7	8-10	9-14	5-10

Microorganisms have capability to exploit a broad diversity of substrates such as wastes and effluents from agriculture and other industries, natural gas such as methane etc that is also helpful in decomposition of environmental pollutants.[5]

Definition of SCP

Various microorganisms and substrates are being utilized for the production of SCP. Yeast is the most suitable microbial source for SCP production as its nutritive value is evidenced by Table 1. Additive cereals having SCP, particularly yeast, enable them as efficient to be use as animal protein.[5]An important factor, while using SCP, is to demonstrate the absence of toxic and cancer causing compounds derived from the substrates, synthesized by microbial cells or produced during processing.

Two of the most significant factors such as high NA content and less cell wall digestibility limit the nutritive and toxicological worth of yeast for human and animal supplementation.[6] As components of NA purine nitrogenous bases in human food undergo metabolism to produce uric acid of which increasing concentration can lead to health problems such as gout and kidney stones. However, NA has no toxicological effects and it causes bad impact on physiology at higher concentration like any other vital dietary component taken in higher amount. It has been estimated that 250 tons of proteins are produced by 100 lbs of yeast during 24 hours. In one year, Algae grown within ponds be capable of forming 20 tons (dry weight) of proteins for each acre. Bacteria hold high protein content so they have a fast growth rate. The main drawbacks are as follows,

- It is difficult to harvest bacteria from the fermented medium because of their small size and less density.
- In comparison to fungi and yeast, bacterial cells have high NA content. So, an additional step is required during the processing for lowering NA content and thus increases the cost.
- A general observation is that bacteria are dangerous because they produce diseases. So, in order to eliminate this mistaken belief, an extensive awareness program is needed to make people accept the proteins from bacterial sources.[7]

Yeast have benefits like easy to harvest because of their large size, a smaller amount NA, elevated lysine content and capability to grow up at acidic environment. However, the most significant benefit is awareness and acceptability attributable to the long history of its usage in traditional fermentation processes. Drawbacks are slower growth rate, lesser content of protein (45-65%), lesser content of methionine as compared to bacteria.[8]

Filamentous fungi have benefits of ease in harvesting but have disadvantages of slower growth rate, lesser content of protein and acceptability. Drawbacks of using algae are its cell wall containing cellulose which is not digested by humans and its ability to concentrate heavy metals. While using microscopic algae, it should be focusing that, it is not the only target to separate and make use of the sole protein, but to proliferate the entire algal biomass because of technological and economical reasons. Hence, the word SCP is not quite accurate because algal material is something beyond protein. Now, many refined technologies are in use throughout the world for large scale production and processing of photoautotrophic microscopic algae.[9]

Up till now, single cell protein has revealed the following potential regarding its application:[10]

In Animal diet

- Calves having fattening ability.
- Poultry having fattening ability.
- Pigs having fattening ability.
- Fish breeding.
- Laying hens feed.
- Feeding of household animal.

As the Foodstuffs part

- As carriers of vitamin.
- As emulsifying agent.
- As carriers of scent.
- In soups.
- Improving the nutritional worth of baked items.
- In readymade meals.
- Within food recipes.

During the Technological Field

- During processing of paper
- During processing of leather
- Being a foam stabilizing agent

Apart from the formation of microbial biomass that has been explained earlier, it may be stated, lastly, that the making of baker's yeast, brewer's yeast, and the wine yeast, as starter culture, of specific strain using for the purpose of research and treatment, and of the cultures of edible fungi, and of humus cultures for soil inoculations, must be incorporated in the making of microbial biomass.[11]

Historical Background of SCP

Yeast cells have been employed in the production of bread as well as beverages since 2500 BC. During 1781, methodologies for large scale production of yeasts are discovered. Carl L. Wilson coined the term SCP in 1966. During 1970s, the idea "food from the oil" became somewhat popular and in 1976, Champagnat was honored with the UNESCO prize. The Soviets were exceptionally excited while launching well-built "BVK" (belkovo-vitaminny kontsentrat meaning protein-vitamin concentrate) plants close to their oil refineries in Kstovo (1973) and Kirishi (1974). The Soviet Ministry of Microbiological Industry have constructed eight plants of such category through 1989 and then the government made a decision to discontinue them, or switch to some other microbial processes under the pressure of the ecologist movements.

In older times, the filamentous algae *Spirulina* grown within the African Lake Chad were used like food supplement. For the duration of the World War I, Germans consumed *Candida utilis* into the form of sausages and soups. It was also widely utilized for the period of World War II. During 1967, its production on the industrial level was started. Protein resulting from cultures of bacteria, fungi, algae and yeast has been extensively consumed as the food supplement. Brewer's yeast, a side-product of brewing and beverage industry, and Torula yeast has extensively accessible food additives. Cultured microorganisms have the greatest ability to serve as an edible source of protein. Almost 10% of the protein requirement of the world's inhabitants is fulfilled by single-cell fermenters covering 0.8 km^2 area. Chemical, paper as well as food industries side-products can undergo fermentation process via various microbes as economical sources of energy. Such side-products comprise alcohols, methane, cellulose, molasses, starch, and animal waste substances.

Yet lesser necessities are required in favor of algae; photoautotrophic organisms are able to be cultivated within clear ponds provided together with mineral nutrients. Troubles related with SCP have restricted its advancement as the chief food resource. Nearly all SCP are not edible if not treated to remove astringent or distasteful materials. Digestibility of SCP alters by the sources. Algae after cooking have increased its digestibility while the yeast digestibility is slightly changed by the processing.[12]

Production of SCP

The production of SCP can be carried out by utilizing waste materials like the substrates, particularly waste from agricultural such as wood cuttings, crumb, corncobs, and various others. Some of the additional waste substances using as substrates are wastes from food processing, remnants from alcohols manufacturing process, hydrocarbons, or animal and human feces.

The methodology of producing the SCP from every substrate or microorganisms will contain the following vital stages:

- Depending upon the condition of carbon source physical and/or chemical pretreatments may be required.
- Apart from the carbon source, nitrogen, phosphorus and some other nutrients are also required to maintain microorganism optimal growth.
- Contamination is avoided by maintenance of sterile and aseptic conditions. For this purpose, the components of medium may be sterilized by heating or filtration and equipments used in fermentation may be heat sterilized.
- Inoculation of the desired microorganism should be done in the pure form.
- Single cell protein (SCP) procedures are extremely aerobic (excluding those exploiting algae). For this reason, sufficient aeration must be supplied. Additionally, cooling is also essential as significant heat is produced.
- From the medium, recovery of the microbial biomass is achieved.
- In order to enhance its usage and/or storage capacity, processing of the microbiological biomass is essential.[13]

Yeast as SCP

An additional source of extracting SCP is yeast, and have synthesized for a prolonged time. During World War I, Germany produced Torula yeast (*Candida utilis*) and consumed it in making sausages and soups. Currently, outlet of microbial biomass is the major pet food industry. The feed supplementation of dog, cat, and fish is obtained from yeasts; it will make the supplement more edible for the animals.

In vegetarian's diet, food flavoring is usually because of the yeasts. For this purpose, Torula yeast has been commercially utilized. Hickory Smoked Dried Torula Yeast is an example of this kind of product. Apart from the other sources of SCP, yeast has following advantages:

- Harvesting is easy due to their larger size than bacteria (larger than bacteria)
- Malic acid percentafe is higher.
- Lysine content is higher.
- It has ability to grow and maintain at acidic pH.
- It has been traditionally used since long time ago

This microbe has some disadvantages that can be considered as

- It has slower growth rate than bacterial cells.
- It contain lesser protein content (45- 65%) as compared to bacteria.
- Its methionine content is lower than bacteria. So, addition of methionine in the final product is required to increase its value thus adding another step during processing.[14]

Algae as SCP

Studies carried out on SCP had been focusing the scientist's attention to fill the protein gap, from a decade. Since the centuries, the use of algae as Food grade (food supplements to humans) or Feed grade (food supplements to animals) is recognized because East Asia countries along with Central Africa use them as part of their diet. A few algal species like *Soenedesmus, Chlorella, Spirulina* and *Coelastrum* are suitable for large scale production and utilization.[15]

Using algae have following advantages such as:

- It utilizes the solar energy very effectively.
- Its cultivation and production is simple and easy.
- Growth is faster with high nutrient especially protein content.[16]

***Spirulina* cultivation**

Autotrophic, heterotrphic and mixotrophic conditions are used in tropical countries for the cultivation of *Spirulina*. Its Microscopic view is shown in Fig. 1. Its mass production is greatly easier than other algal species cultivation because it can maximally utilize the amount of carbon without aeration of CO2.[17]

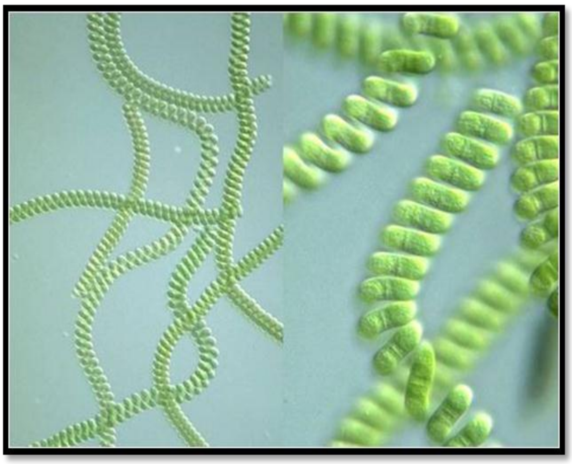

Figure 1: Microscopic view of *Spirulina*

Filamentous Fungi as SCP

History and Background

In 1973, a few species of actinomycetes and filamentous fungi were reported for protein producion by using various substrates, in Second International Conference which was held at MIT. After that various filamentous fungal species have been documented for protein production. Thus, the SCP term is not reasonable for the organism with filament characteristics. In the UK, mycoproteins have been coined by Ranks Hovis McDougall (RHM) for those proteins which are produced on starch or glucose substrates. Throughout the world, almost 3000 fungal species have been isolated and tested as food with better growth and safety.[18]

Synthesis of Fungal Biomass

During the World War II, for the production of protein as food supplement via fementation, the cultures of *Rhizopus* and *Fusarium* were used. *Rhizopus arrhizus* or *Aspergillus oryzae* inoculums are used due to their non-toxicological character. Complex organic compounds can be converted into simpler one by saprophytic fungi. Due to this, large amount of fungal biomass is obtained. On the basis of tupes of organisms and substrates, yield of mycelia can vary greatly. Some hazardous strains of moulds are *Fusarium graminearum, Aspergillus fumigates* and *A. niger*. So, use of these fungal species should be prevented or to be used as SCP toxicological evaluations should be done.[19] For the use of filamentous fungal species for SCP production, the substrates are listed in Table 2.

Table 2: Fungi and substrate used for SCP production

Microorganism	**Substrate**
Fungi	
Aspergillus fumigatus	Maltose, Glucose
Aspergillus niger, A. oryzae, Cephalosporium eichhorniae, Chaetomium cellulolyticum	Cellulose, Hemicellulose
Penicillium cyclopium	Glucose, Lactose, Galactose

Rhizopus chinensis	Glucose, Maltose
Scytalidium aciduphilium, Thricoderma viridae, Thricoderma alba	Cellulose, Pentose
Paecilomyces varioti	Sulphite waste liquor
Fusarium graminearum	Starch, Glucose

Bacteria as SCP

Various bacterial species have been reported to use for producing single cell protein. The generation time of *Methylophilus Methylotrophus* is around 2 hours moreover it is frequently utilized in animal feed supplement. It is considered more favorable as the protein supplement food than yeast or fungi. Flow chart of production of SCP from *Methylophilus Methylotrophus* is shown in Fig. 2. So, the huge amount of SCP being use as animal feed can be manufactured by means of bacteria.[18]

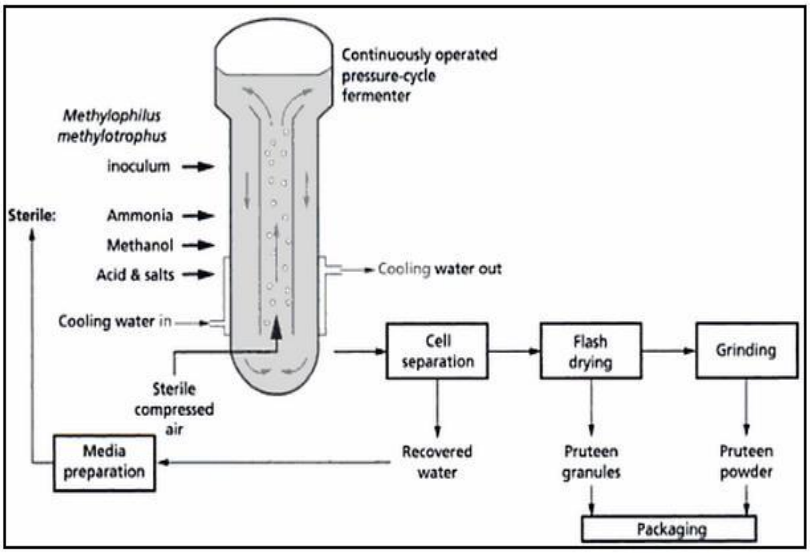

Figure 2: Flow chart of production of single cell protein from ICI UK.'Pruteen' plant

T he properties that enable bacteria appropriate for this purpose consist of:

- fast growth rate of bacterial cells
- Bacteria have small generation times as most of them are able to increase their cell mass twofold within about 20 minutes to 2 hours.
- They have capability of growing on various raw materials, ranging from carbohydrates like starch and other sugars, to petrochemicals such as methanol and ethanol, to liquid and gaseous hydrocarbons like methane and petroleum.
- Nitrogen sources suitable for growth of bacteria include nitrates, ammonia, urea, ammonium salts, and the organic form of nitrogen in waste materials.
- Bacterial culture medium for bacterial growth must contain a mineral nutrient supplement to supply nutrients that are not there within natural waters having concentrations enough to maintain bacterial growth.[19]

Comparison of SCP Sources

The considerations employed via them while evaluating the ranking status of the SCP illustrating that the nucleic acid content from algal source is nontoxic than bacterial and fungal sources.[20] Nucleic acid content from fungal species is greatly safer than bacteria as they have little nucleic acid content as shown in Table 3. Consequently, the ranking order would be as algae > fungi > bacteria.[21]

Table 3: The comparison chart shows the composition of SCP from the respective organisms

Component	Percentage composition of weight		
	Algae	Fungi	Bacteria
True Protein	40-60a	30-70a	50-83a
Total nitrogen (Protein + nucleic acids)	45-65a	35-50a	60-80a
Lysin	4.6-7.0a	6.5-7.8a	4.3-5.8a
Methionine	1.4-2.6a	1.5-1.8a	2.2-3.0a
Fats/Lipids	5-10a	5-13a	8-10a
Carbohydrate	9	NA	NA

Bile pigments and Chlorophyll	6	NA	NA
Nucleic acids	4-6a	9.70	15-16a
Mineral acids	7	6.6	8.6
Amino acids	NA	54	65
Ash	3	NA	NA
Moisture	6.0	4.5-6.0a	2.8
Fiber	3	NA	NA

[a]*The yield differs with the nature of substrate utilized, the specific organism which was exploited and the maintained culturing conditions. NA - Not available*

The Fermentation Process

A fermentation process is required for producing single cell protein. This is achieved by multiplying desired strains of microbes on raw materials suitable for growth in industrial cultivation process heading for the growth of microbial culture, as well as the isolation of resulting cell mass is achieved by separation techniques. Development process starts with the screening of microbe which is obtaining appropriate strains from water, soil, air and biological or inorganic materials swabs samples and subsequent optimization via mutation, selection, or additional genetic system. After that, the methodological conditions for cultivation are established for the strains that were optimized and any cell structures and particular metabolic pathways are determined. Along with these biological examinations, equipment technology and process engineering become accustomed to the technical operation of process as well as the equipments where the microbial biomass production is accomplished with the intention of making use of them on the large scale. At this point, the economic factors (cost, energy) take part in.[22]

In favor of the inclusive conformability of microbial biomass production processes, the raw materials, production along with the energy needs have the main significant role. From a technical, financially viable, and biological viewpoint, great variety of carriers of raw materials must be examined for their suitability and must be formed for the particular biological processes. Safety requirements and queries of ecological safety emerge in order to produce SCP for both the product as well as the process. Lastly, protection and the safety of modernization create authorized and restricted features that are operating licenses, authorization of product for specific applications, in addition to the authorized safety of strains of microorganisms and new processes.

A fermenter is an apparatus that is designed and maintained for conducting the fermentation process chiefly the mass culturing of animal or plant cells. Fermenters are able to differ in sizes from experimental laboratory scale models having capacity of about one to two liters, to large scale or industrial scale models with capacity of many hundred liters. The bioreactor has considered distinctive from the fermenter because of its ability of mass culturing of microorganisms. Chemical compounds formed by these cultured microbial cells like therapeutic agents could be isolated simply from the biomass of cell.[23]

An aeration system is present in both the fermenters and bioreactors which provides oxygen to the aerobic processes. Both are equipped with a stirrer to maintain the medium concentration unchanged. For regulation of temperature, we make use of a thermostat is and a pH detecting device and several other managing instruments, which maintain all the special parameters required for constant growth. The fermentation methods have need of the following steps as shown in Fig. 3.

- Purified cultures of the selected organism which should be in the proper physiological state.
- Medium for growth is sterilized and is utilized for the microorganism culturing in that medium.
- A production fermentation tank, which is the major instrument, employed for managing the medium used for culturing in stable condition.
- Isolation of microbial cells from fermented culture medium is done.
- Cell free supernatant is collected.
- Product is then purified by using purification strategies.
- Effluent is treated.[24]

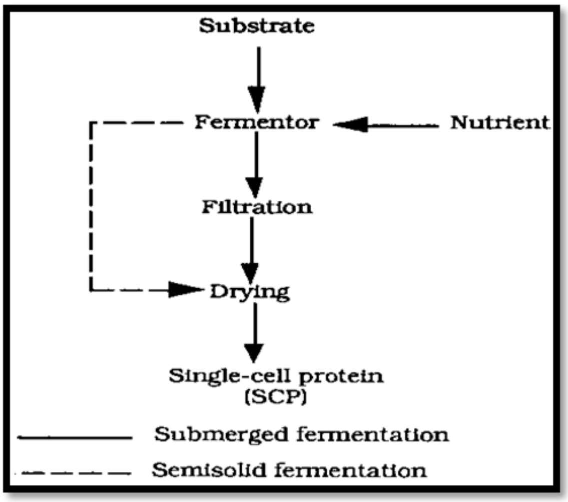

Figure 3: Flow chart of production of single cell protein by Fermentation process

The Raw Materials

The conventional raw materials are materials having monosaccharides and disaccharides, in view of the fact that approximately every microorganism has ability to digest glucose sugar, associated hexoses and pentoses, and the disaccharides.[19] They occur as side-products of the food industry, agriculture, and Whey resulting from timber processing or are produce by Agarian resources (juice of sugar cane). For that reason, these are referred to as renewable raw substances.[25] These sources are also employed in additional industrial branches having an elevated cost level that positions the economic feature of microbial biomass production in suspicion.[26]

Effect of Glucose as Carbon Source on Fermentation

While producing proteins by microbial sources, carbon source perform an imperative role. The striking characteristics to utilize the glucose as carbon source are their lesser cost.[27] SCP production higher than 8 % was obtained by cultivating the microorganisms with glucose. The concentration of glucose considerably influences the SCP production.[28]

Effect of Nitrogen Sources on Fermentation

For the production of proteins, source of nitrogen is one of the essential factors because of the structural characteristics of proteins. While using yeast extract and tryptone, production of SCP using *Haloarcula Spp* IRU1 has been improved. It is not capable of producing SCP after growing in the medium containing peptone and NH_4Cl. Highest yield of SCP was gained when tryptone was complemented at 0.8 % w/v concentration.[29]

Effect of Phosphorous Sources on Fermentation

For producing SCP, NaH_2PO_4 and K_2HPO_4 were the most excellent phosphorous sources.[30] The highest SCP production was attained by microbial cultures growing on the medium containing 0.016% (w/v) concentration of NaH_2PO_4. Elevated concentrations of phosphorous sources brought about an increase in the production of SCP in all experimentations.[31]

High Energy Sources derived SCP

Materials possessing great commercial significance as sources of energy or derivatives of these chemicals e.g. gas oil, methanol, methane, and n-alkanes have bring into being broad commercial interest. The microorganisms used for this purpose are typically bacteria and yeast, and a number of processes are currently operational. As likely expected, the majority of oil corporations have been or are concerned in this field even now. The insight of employing these compounds with high potential of energy for production of food has been doubted by various scientists.

Methane as a source of SCP has been greatly investigated however is currently believed to exhibit various technological obstacles to guarantee exploitation. On the contrary, methanol presents vast SCP economic concern. Fermentation plant on large-scale for production of the methanol-consuming bacterium which is *Methylophilus methtlotrophus* was built by ICI, UK. as shown in Fig. 4. The ICI single cell protein was consumed entirely as animal feed.

Figure 4: ICI UK.'Pruteen' plant intended for producing single cell protein

Methanol is used as a carbon source for SCP production as it has numerous inherited benefits above n-paraffins, methane gas and even carbohydrates composition is not dependent upon seasonal variation. Potential toxicity sources are not present in methanol as it solublizes easily in the aqueous solutions in all quantities.

In the Western world, the ICI Pruteen plant was the single process of its type however could not function economically at current methanol costs and the production has terminated. Methanol corresponds to about 50% of the expenses of the product. The price of SCP resulting from methanol is two to five folds the price of fishmeal in the USA. In the Middle East, methanol low price and higher prices of fishmeal together with a requirement to make supplementary animal products could bring about SCP a striking suggestion.

Ethanol is considered specifically as an appropriate source if the SCP is proposed for human utilization. In the anticipated future, the relative rank of ethanol derived SCP will depend upon indigenous factors i.e. over-capability in ethylene crackers, excess of agricultural carbohydrates and political decisions regarding local economic sovereignty and overseas trade stability.

The n-alkanes as source of SCP substrate have been widely examined in several countries and characterize an exceedingly complicated biotechnological practice. Nevertheless, the majority of these procedures have currently stopped the operation as a consequence of expected health vulnerabilities due to the occurrence of cancer causing agents (carcinogens) in the SCP. The immense technology expanded in this discipline in Japan and other Eastern countries have been directed to the study of alcohol-derived SCP and organic wastes-derived SCP.[32]

SCP from waste materials

The substances that form the waste materials should generally be recycled back and become the part of the ecosystem, e.g. straw, citric acid, bagasse, molasses, olive and date wastes, whey, animal manures and sewage. The quantity of these waste materials can be very high locally and may consider as contributing factor in rising considerable pollution level in waterways. Thus, the exploitation of these materials in SCP practices provides two functions i.e. decrease in pollution level and formation of protein suitable for eating. Widespread programs of specific concern have been investigated to change pig and cattle waters to feed protein. Nevertheless, these studies have been mostly ineffective as a result of technological and sanitary problems.

The global approach with respect to stringent effluent control measures, and corresponding rise in effluent disposal expenses, has directed to the conception of waste as a negative price raw material. Though, the waste might not be appropriate for SCP or its dilution or composition may be so discrete that their transportation to a manufacturing centre may be unaffordable. SCP methods employing waste substrates have been performed on a large scale by means of a variety of yeast organisms in complicated bioreactor organizations. Substrates utilized and producer organisms comprise cheese whey and molasses.

Mushroom Fermentation is a novel development meant for SCP waste, the biotechnological modernization is only currently being complicated in this field however the rewards will be huge. To developing countries, where exceedingly costly systems may be unworkable from the viewpoint of price and be deficient in skillful workers, a lot of the novel biotechnological discoveries might direct to perfection in conventional microbiological processes in a good way.[33]

CONCLUSION

For economic, political and practical causes SCP has not turn out to be the significant supply of foodstuff protein which was predicted in the beginning. The developed countries did not require SCP because they possess copious stock of high value protein in consequence to the agriculture upgrading of the previous forty years. Facts of this are offered by the Grain Mountains and butter, which are present in the USA and EEC. SCP might be considered as a helpful food supplement within tropical region countries in which conventional food items have high carbohydrate content and low protein content. This unending deficiency of protein directs to mental and physical weakening and damage. Having role of feed supplementation, SCP have not been an achievement due to expenses considerations. Feedstock, predominantly those linked to the oil production, normally has amplified in cost, while others that came through competitive protein sources, for example fishmeal and soy bean meal, have reduced in cost.

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REFERENCES

1. Parajó JC, Santos V, Domínguez H, Vázquez M. NH 4 OH-Based pretreatment for improving the nutritional quality of single-cell protein (SCP). Applied Biochemistry and Biotechnology, Nov 1, 1995; 55(2): 133-49.
2. Scrimshaw NS, Dillen, JC, Single cell protein as food and feed. In: single cell protein- safety for animal and human feeding, Garattini S, Paglialunga S and Scrimshaw NS (Eds.), Pergamon press, Oxford, UK, 1977; 171-173.
3. Ravindra P. Value-added food:: Single cell protein. Biotechnology advances, Oct 31, 2000; 18(6): 459-79.
4. Litsky W. Industrial microbiology. Miller BM, editor. McGraw-Hill Companies, 1976.
5. Huang YT, Kinsella JE. Phosphorylation of yeast protein: reduction of ribonucleic acid and isolation of yeast protein concentrate. Biotechnology and bioengineering, Nov 1, 1986; 28(11): 1690-8.
6. Alvarez R, Enriquez A. Nucleic acid reduction in yeast. Applied microbiology and biotechnology, Sep 1, 1988; 29(2-3): 208-10.
7. Becker EW. Micro-algae as a source of protein. Biotechnology advances, Apr 30, 2007; 25(2): 207-10.
8. Becker EW. Microalgae: biotechnology and microbiology. Cambridge University Press; 1994.
9. Richmond A. Biological principles of mass cultivation. Handbook of microalgal culture: Biotechnology and applied phycology, 2004; 125-77.
10. Vahidi H, Mojab F, Taghavi N. Effects of carbon sources on growth and production of antifungal agents by Gymnopilus spectabilis. Iranian Journal of pharmaceutical research, Nov, 2010; 20: 219-22.
11. Schiraldi C, Giuliano M, De Rosa M. Perspectives on biotechnological applications of archaea. Archaea, 2002; 1(2): 75-86.
12. Vrati S. Single cell protein production by photosynthetic bacteria grown on the clarified effluents of biogas plant. Applied microbiology and biotechnology, Mar 1, 1984; 19(3): 199-202.
13. Nasseri AT, Rasoul-Amini S, Morowvat MH, Ghasemi Y. Single cell protein: production and process. American Journal of food technology, 2011; 6(2): 103-16.

14. Bekatorou A, Psarianos C, Koutinas AA. Production of food grade yeasts. Food Technology and Biotechnology, Sep 15; 2006; 44(3): 407-15.
15. Prosser JI, Tough AJ. Growth mechanisms and growth kinetics of filamentous microorganisms. Critical reviews in biotechnology, Jan 1, 1991; 10(4): 253-74.
16. Radmer RJ. Algal Diversity and Commercial Algal Products New and valuable products from diverse algae may soon increase the already large market for algal products. Bioscience, Apr 1, 1996; 46(4): 263-70.
17. Raja R, Hemaiswarya S, Kumar NA, Sridhar S, Rengasamy R. A perspective on the biotechnological potential of microalgae. Critical reviews in microbiology, Jan 1, 2008; 34(2): 77-88.
18. Solomons GL. Production of biomass by filamentous fungi. Comprehensive biotechnology: the principles, applications, and regulations of biotechnology in industry, agriculture, and medicine/editor-in-chief, Murray Moo-Young, 1985.
19. Nigam JN. Cultivation of Candida langeronii in sugar cane bagasse hemicellulosic hydrolyzate for the production of single cell protein. World Journal of Microbiology and Biotechnology, Jun 1, 2000; 16(4): 367-72.
20. Saquido PM, Cayabyab VA, Vyenco FR. Bioconversion of banana waste into single cell protein. J. Applied Microbiol. &Biotechnol, 1981; 5(3): 321-6.
21. Zepka LQ, Jacob-Lopes E, Goldbeck R, Souza-Soares LA, Queiroz MI. Nutritional evaluation of single-cell protein produced by Aphanothece microscopica Nägeli. Bioresource technology, Sep 30, 2010; 101(18): 7107-11.
22. Kuhad RC, Singh A, Tripathi KK, Saxena RK, Eriksson KE. Microorganisms as an alternative source of protein. Nutrition reviews, Mar 1, 1997; 55(3): 65-75.
23. Hedenskog G, Mogren H. Some methods for processing of single-cell protein. Biotechnology and bioengineering, Jan 1, 1973; 15(1): 129-42.
24. Smith ME, Bull AT. Protein and other compositional analyses of Saccharomyces fragilis grown on coconut water waste. Journal of Applied Bacteriology, Aug 1, 1976; 41(1): 97-107.
25. Abo-Hamed NA. Bioconversion of wheat straw by yeasts into single-cell protein. Egyptian Journal of Microbiology (Egypt), 1993.
26. Hongpattarakere T, H-Kittikun A. Optimization of single-cell-protein production from cassava starch using Schwanniomyces castellii. world Journal of Microbiology and Biotechnology, Nov 1, 1995; 11(6): 607-9.
27. Zhao G, Zhang W, Zhang G. Production of single cell protein using waste capsicum powder produced during capsanthin extraction. Letters in applied microbiology, Feb 1, 2010; 50(2): 187-91.
28. Smith ME, Bull AT. Protein and other compositional analyses of Saccharomyces fragilis grown on coconut water waste. Journal of Applied Bacteriology, Aug 1, 1976; 41(1): 97-107.
29. Barnett JA. The Utilization of Disaccharides and Some Other Sugars RY Yeasts. Advances in Carbohydrate Chemistry and Biochemistry, Dec 31, 1981; 39: 347-404.
30. Bräsen C, Schönheit P. Regulation of acetate and acetyl-CoA converting enzymes during growth on acetate and/or glucose in the halophilic archaeon Haloarcula marismortui. FEMS microbiology letters, Dec 1, 2004; 241(1): 21-6.
31. Guimarães LH, Somera AF, Terenzi HF, de Moraes MD, Jorge JA. Production of β-fructofuranosidases by Aspergillus niveus using agroindustrial residues as carbon sources: Characterization of an intracellular enzyme accumulated in the presence of glucose. Process Biochemistry, Feb 28, 2009; 44(2): 237-41.
32. Mølck AM, Poulsen M, Christensen HR, Lauridsen ST, Madsen C. Immunotoxicity of nucleic acid reduced BioProtein—a bacterial derived single cell protein—in Wistar rats. Toxicology, Jun 5, 2002; 174(3): 183-200.
33. Nasseri AT, Rasoul-Amini S, Morowvat MH, Ghasemi Y. Single cell protein: production and process. American Journal of food technology, 2011; 6(2): 103-16.