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Research Article

# The Prospect of Future and Current State Supply Food & Feed: Alternative Protein Sources

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## ABSTRACT

One of the main problem is the deficiency of water around the world which causes drought as well as vanishing natural resources, thereby this phenomenon has converted to the dearth of forage, animal feed, and destroying inhabitants, and it also is the major problem in fishery, domesticated animals, and poultry. Moreover, deficiency of protein sources, increasing population growth and high protein content of microbial cells have led to the utilization of other protein sources derived from microorganisms (as feed and food) rather than common protein sources. Single cell protein (SCP) is a microbial protein that is fermented by various microorganisms (bacteria, yeasts, fungi, or algae) on low-cost substrates like sulfate and industrial effluents and sewage, cellulose waste from paper mills, polishing, rice, beet pulp, molasses, bagasse, sugarcane, dairy industry waste (such as whey), agricultural waste (citrus waste) and animal fertilizer and liquor waste (as a carbon and energy source for biomass production, concentrate protein or amino acids) are obtained. The term is not appropriate for a substance with the protein content less than 65%. Nutritional deficiencies can be partially eliminated by consuming microbial proteins (SCPs).One of the most causes of those problems is the lack of water resources within the world and consequently, the occurrence of drought, and the loss of natural resources. This has led to the shortage of livestock feed, and therefore, the destruction of many habitats, becoming one of the most important concerns of the livestock, poultry, and fisheries industries. However, microbial protein is not popular as feed owing to the present low cost of other protein sources such as soy and fishmeal. In this study, the types of microorganisms and substrates available, the process of biomass production, nutritional value, safety, benefits, and limitations of SCP and products in good manufacturing practices (GMP) and their optimization were discussed.

**Keywords**: Single cell protein; SCP; Biomass; Microorganisms; Microbial protein; Nutrition; Protein deficiency; Feed

## INTRODUCTION

People have used yeasts in bread and beverage productions since 2500 BC. For the first time, some methods were discovered to generate high biomass of yeast in 1781 [1]. During World War I, Max Delbrück and his colleagues declared that the high value of surplus brewer's yeast can be used for animals as an supplement for animals at the Institut für Gärungsgewerbe in Berlin [2]. They used brewer's yeast from beer production, although the rate of protein was inadequate to solve some problems associated with protein in feed, and a large proportion of yeast biomass was attained by aerobic fermentation in a medium including

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ammonium salts as a nitrogen source. Sak from Denmark and Hayduck from Germany administrated a process called Zulaufverfahren in 1919 that yeast was grown on sugar solution instead of growing yeast on a diluted sugar solution in the fed-batch fermenter which is still used today for making bread [3]. Carol L. Wilson named the term single cell protein during 1966. Food from oil was popular among people in the 1970s, and the first use of products belonged to poultry and cattle. After World War I, German decided to use a process called Heeresverwaltung around 1936. In that process, diverse yeast, especially mass cultured and brewer's yeast was used not only for humans but also for animals. As a result, the merits of aerobic products of baker´s yeast is a rich wort had been identified in a large scale industrial installations. Soviets established a great company named BVK producing vitaminny kontsentrat called Belkovo. They used concentrate of protein-vitamin in the variety of plants besides their oil refineries in Kstovo in 1973 and Kirishi in 1974, and the company of Soviet Ministry of Microbiological industry maintained eight plants of this kind by 1989, but their center was shut by the government under the pressure of the environmentalist [4]. In the past, inhabitants of Chad in Africa harvested filamentous algae Spirulina from the lake and consume it as a food. In World War I, Germans employed Candida to utilize it as a flavor in soups and sausages. This product was produced in a large scale in 1967s [5].

For reducing the cost of SCP in the future, many factors should be considered as the quality of downstream, fermentation process, and development in the producer microorganisms due to the mixture of DNA development and genetically factors [6]. Single cell protein can be made by some carriers like aroma, vitamin, and emulsifiers enhancing the nourishing value in baked products ranging from prepared food soups. Apart from food, they are exploited in other industrial fields like paper, leather, and foam stabilizers [7]. The idea of using oil to produce SCP became common in 1970s when the UNESCO Science Prize belonged to Champagnat the during that time, many countries grew yeast on paraffin and used to that product as poultry and cattle feed [8].

## HISTORY

The first international conference on SCP was held in 1967s at the Massachusetts Institute of Technology (MIT). At this time most of the projects were in the laboratory stages. At the Second Conference, held in 1973, many companies in different countries began producing SCP on industrial scale [9]. At the First International Conference, the British Petroleum Corporation (BP) became the sole provider of SCP industrial production. Since then, several factories in different parts of the world have started to produce SCP industrially, which mainly uses two sources of hydrocarbon substrate and carbohydrates for the growth of microorganisms [10]. Sources of carbohydrate substrates mainly include agricultural waste, food industry wastewater, and wood and paper industries, while hydrocarbon substrates mainly include petroleum derivatives, ethanol, and methanol. The production of SCP meets two main goals: one is to eliminate environmental pollution, and the other is to produce protein products at a low price, excellent quality, and very high nutritional value [11].

Industrial production of SCP in the middle of the 20th century (1964 - 1985) has importance and it started simultaneously with the demand for isolating branch hydrocarbons from unbranched hydrocarbons in the petrochemistry industry. Some countries have reached their goals successfully like England, Germany, Japan, and Russia. The imperial Chemical Industries is a big chemical company producing bacteria biomass from methanol called Pruteen as poultry and animals feed. Britannia and Hooksett oil companies produced SCP from n- paraffin on a large scale [12].

### SCP derived from high energy

Valuable commercial substances including gas oil, methane, methanol, N-alkanes, and Involved microorganisms such as yeast and bacteria. Hydrocarbons in crude oil are divided into five different groups: isoalkanes, alkanes, normal alkanes, cycloalkanes, and aromatics. Although liquid normal alkanes are used for SCP production as carbon and energy sources. Botrytis cinerea can absorb paraffin. Unsterile condition, Candida tropicalis growth on paraffin. Moreover, Micrococcus sphaeroides isolated from the soil in the charging gas station were able to grow on hydrocarbons. British petroleum co. utilized two different yeasts: Candida lipolitica and Candida tropicalis that their substrates were alkanes with 12-20 carbons from wax in gas oil. BP Company produced production called TOPRINA and this product tested in terms of toxicity, and this was replaced with fish meals and dry milk powder as high protein supplements in markets. In 1972, a special committee decided to use petroleum productions for producing SCP as a feed; however, Japan decided to forbid the production of protein from petroleum chemistry. In 1977, Italy also ceased the production of protein from alkanes owing to the high cost of oil, and the cost of soy became competitive. Nowadays, none of the companies produce protein from SCP [13].

Methane as a source of SCP was extensively investigated. Bacteria biomass from methane contains more than 75% crude protein, and it has necessary amino acid-like lysine and vitamins. One of the disadvantages is the use of methane. Firstly, the solubility of this in water is remarkably low and the mixture of this with oxygen and air can be combustion and explosion. Methane uses bacteria like (methanotrophs) which is obligate aerobic and belongs to the Methylococcacea and is divided into five classes: Methylomonas, Methylobacter, Methyiococcus, Methylosinus, and Methylocystis. The plenty of research has been administrated for producing SCP from methane, so far one of the companies was Shell in England where Methylococcus capsulatus producing SCP by methane as a carbon source and ammonium and nitrate salt as a nitrogen source although it was in semi-industrial scale, the optimizing of it faced huge problems, therefore methanol was replaced by methane [14].

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Pruteen in Imperial Company with 72% protein derived from Pseudomonas methylotrophus was the only Producer by methanol as a substrate in the west however, it was not able to compete with the cost of methanol, but also it was not able to compete with the nutrient value of soy and fishmeal and this production was stopped. In the United States, the cost of SCP by methanol was 2-5 times more than the cost of fishmeal although in the Middle East where the price of methanol is inexpensive while the cost of seafood is high, so using of methanol is recommended. In addition, the use of methanol can be a great source of human food. This process was done by the Ameco Company in the United States by Torula. This product was named Torutein, and it was sold in Canada and Sweden. In fact, this product contains 52% protein and substituted with the protein of milk, meat, and egg which could boost the favor of food. Unfortunately, it was not successful in the United States, since soy was abundant and cheap and was able to substitute with meat and egg diet. Using N-alkane as a substrate for SCP has been widely studied in many countries while it causes cancer, thereby producing SCP from alkane was stopped [16, 17].

## SCP from wastes, suitable substrates

Lignocellulosic stocks as a carbon source for generating SCP for animal feed, fishmeals, and poultry have been significantly regarded. Wheat bran, sugar beet, starch, potato skins, wood wastes, and whey are other wastes that can be regarded. Because Iran is one of the top twenties sugarcane producers, it can be used as a valuable and available substrate for SCP production [18].

## Cellulose

Cellulose derived from agriculture and forest resources is the most degradable resource in the world, as an important substrate for producing SCP. Cellulose can be found with lignin, hemicellulose and, starch. in nature. Lignocellulose also needs pre-treatment, such as alkaline or acidic treatment, water steam with high pressure or even X-ray. Today, lignocellulosic waste is used only for producing fungi. Some fungi have lignocellulosic enzymes that can grow in Asia and Africa, and they have economical importance in industrial scales such as Volvariella spp., Lentinus edodes, Pleurotus spp. [19].

## Starch

Starch is known as a cheap substrate with the carbohydrate origin for Producing SCP. This carbohydrate is abundant in rice, corn, and cereals. In tropical nations, cassava is a great source of SCP. In Sweden, the process of Symba has been developed from starch waste and two yeasts should be co-cultured; first is Endomycopsis fibuligera producing amylase, and another is Candida utilis which is rapid-growth. This process includes two parts; 1) Starch waste enters by the heat exchanger, then they will be stilled. After that, it enters to a bioreactor where hydrolysis starch is in it, and starch is hydrolyzed, 2) hydrolyzed liquid enters to the second bioreactor since the situation is suitable for growing Candida [20].

## Whey

It is a great substrate for dingle ell protein. The company of French dairy in 1956 called Fromageries Bel set-up a scheme for producing SCP-yeast from whey. It used Kluyveromyces fragilis called K. marxianus [21]. Producing SCP from whey became prevalent about 6 decades ago on a large scale. They were consumed as the food of poultry and cattle, however, after that, some of them were employed as a human supplementary. Generally, it is predicted that all factory can produce 500 kilograms of natural crude protein and three tons of yeast protein [22].

As Iran is the importer of these products, using whey substrate for producing SCP should be the main goal of it. Although whey is cheap, the cost of maintenance of it and special freezers caused that using it has not been considered significantly. Hopefully, with activating large industrial companies with high capacity, the production of this product will be possible [23].

## SCP-producing microorganisms

It agreed that the criteria used to measure the production of SCP, with total protein (39-73%) and nucleic acid content (1 to 1.5%) should be considered [24].

**Table 1**: The Average of diverse compounds from the important groups of microorganisms base on (% dry weight).

| Compositio n | Fungi | Algae | Yeast | Bacteria |
|---|---|---|---|---|
| Protein | 30-45 | 40-60 | 45-55 | 50-65 |
| Fat | 02-Aug | Jul-20 | 02-Jun | 01-Mar |
| Ash | Sep-14 | 08-Oct | 05-Oct | 03-Jul |
| Nucleic acid | 07-Oct | 03-Aug | 06-Dec | 08-Dec |

## SCP from yeast

Yeast was initial microorganism to be accepted as a supplement for animals nearly one century ago. Yeasts have plenty of benefits such as their larger size (easy to harvest), lower nucleic acid content, high lysine content, and the ability to grow in acidic pH. However, the main important advantage of yeasts is their long-term use in traditional fermentations. Yeast cells are considered alternative to SCP in animal feed due to their small size, high protein, and low production cost. Aqua-yeast is the best candidate for marine feed production due to its easy culture in fermentation, high cell density, and high amino acid content. It is estimated that 100 pounds of yeast (approximately 45 kg) produce 250 tons of protein in 24 hours. Kluyveromyces marxianus yeast produces an enzyme that can produce SCP from whey. The amount of protein produced was 91%. The most popular yeast species used in SCP production include Candida, Hansenula, Pitchia, Torulopsis, and Saccharomyces. Yeasts contain thiamine, biotin, niacin, riboflavin pantothenic acid, pyridoxine, amino benzoic acid, streptogenin, glutathione, and choline folic acid [2, 25].

First commercial of SCP protein was Pruteen that is used as a feed supplement. The disadvantages of yeast include low growth rate, lower protein content which was 40 to 60%, and lower methionine levels in comparison with bacteria. Furthermore, due to the presence of a thick and complex layer of mannoprotein in the yeast cell wall, which is the main barrier to digestion, one of the limitations of SCP in aquatic feed production [26].

## SCP from algae

From time immemorial, people live near Lake Chad in Africa, as well as the Aztecs near Lake Texcoco in Mexico, have been collecting spirulina algae from the water and using it after drying as a food. It is most commonly used among algae, spirulina, or even chlorella, and is even carried by astronauts during space travel. The single cell proteins produced from algae contain 40 to 60% protein, fat, vitamins A, B, C, D, E, and about 7% mineral salts, chlorophyll, fiber, and bile pigments. Also, these types of SCPs have the lowest amount of nucleic acids (4 to 6%).

Algae should be emphasized for both technical and economical reasons, the main purpose of isolating and using protein is not only, but also to reproduce the entire biomass of algae. Therefore, the term SCP is not fully correct, and microalgae are definitely more than one protein [27]. More than 75% of the annual production of microalgae biomass is used to produce powder, tablets, capsules, or pastilles. Two main species for this purpose: Mononuclear Green Algae: chlorella, and Blue-green filamentous algae: cyanobacteria and spirulina. However, only a few studies have addressed the possibility of using microalgae as SCPs, and more attention has been paid to the use of fungi and bacteria. Algae proteins can be equated with plant proteins, but due to high production costs and technical problems, the use of algae as a protein is still being evaluated [28].

Restrictions on the consumption of SCP from algae are good sources of nutrition, there are some boundaries to human eating. The principal important point is the algal cell wall (which accounts for about 10% of its dry weight). Second, they can contain heavy metals. Humans lack the cellulose enzyme and are unable to effectively digest the cellulose in the algae wall. If used as human food, the algae cell wall must be digested before the final product. If used as animal feed, cellulose digestion is not required because there are commensalism bacteria and protozoa that destroy cellulose and in their rumen [29].

## SCP from fungi

The single cell proteins from fungi contain different valuable substances like B-complex vitamins, thiamine, riboflavin, biotin, folic acid so on. They contain sulfur-rich amino acids and protein content of between 30% and 40%. The sale of fungal proteins for human consumption was confirmed in 1985 in the United Kingdom and later years in other European countries (Belgium 1992, Netherlands 1993, Ireland 1994, Switzerland 1995, and Sweden 1998). This fungal protein, under the brand name Quorn, is used as a meat substitute in many food products such as sausages. In 1988, the US Food and Drug Administration (FDA) approved the use of fungal proteins for consumption of human [22].

One of the problems with fungal proteins is the high level of RNA, which is metabolized in humans to insoluble uric acid and causes kidney stones, gout, and joint pain. The maximum daily dose of ribonucleic acid in humans is 2 grams. For this reason, it is necessary to reduce the bioavailability of fermentation RNA by a thermal process. Their next problem is mycotoxins, particularly Aspergillus flavus and Aspergillus parasiticus, which are main barriers for using them known toxin cause many allergic reactions to liver cancer in humans and animals [2]. Toxins must be eliminated before producing SCP from fungi. Due to, microbiological, chemical, and toxicological analysis, the production of SCP from Aspergillus niger has been proven as a suitable animal feed (Table 2). When grown in single culture, it produces almost twice as much protein as the standard material [1].

**Table 2:** Combination of SCP from Aspergillus Niger compared to standard FAO (Food and Agriculture Organization).

| Amino acid (%) | | | | | | |
|---|---|---|---|---|---|---|
| | **Valine** | **Lysine** | **Leucine** | **Isoleucine** | **Methionine** | **Cysteine** |
| FAO standard | 4.2 | 4.2 | 4.8 | 4.2 | 2.2 | 2.8 |
| A. niger | 4.3 | 4.5 | 6.8 | 3.7 | 1 | Trace |

## SCP from bacteria

The rate of growth and multiplication in bacteria is high, and they can grow at higher temperatures than yeasts or fungi and usually contain more protein. The amount of protein reported for a single-cell protein is about 50 to 80%. They contain specific essential amino acids. Their crude protein contain about 80% from the total dry weight. Nevertheless, their nucleic acid, particularly RNA, is remarkably high, and it is reported to be between 15 to 16%. The single cell proteins from bacteria is rich in methionine (about 2.2 to 3%), that is relatively higher than algae which was (1.4- 2.6%) and fungi which was (1.8-

2.5%). As mentioned, bacterial proteins have the highest levels of nucleic acids. So this rate is higher than the allowable limit for human consumption. This leads to the deposition of uric acid in the blood and gout. Therefore, bacteria are used as poultry feed and farmed fish because these organisms do not have problems caused by the urea cycle. Selenomonas and Alcaligenes are common bacterial species for SCP production [30].

The bacterial cells are small and dense, therefore, harvesting the product from the fermentation media is difficult and costly. Bacterial cells contain more nucleic acid than fungi and yeasts to reduce the level of nucleic acid and additional processing steps must be added, increasing the cost of that. Some people believe that all bacteria can be harmful and cause diseases. A long-term program should be prepared to address the misconception of bacteria proteins and accept it [31].

## SCP product ranking

The parameters demonstrate that the content of nucleic acid in algae is lower than bacteria and fungi. Also, fungi are lower than bacteria. The fungal SCP is rich in both lysine and methionine. The lysine content of fungi is more than that of bacteria or algae (Table 3). For this reason, priority can be given first to algae, second to fungi, and finally to bacteria [24].

**Table 3:** Comparison of SCPs from algae, fungi, bacteria, and yeast.

| Parameter | Algae | Bacteria | Yeast | Fungi |
|---|---|---|---|---|
| Growth rate | Low | Highest | high | Lower than bacteria and yeast |
| Substrate | Light and CO2 | Wide range | Wide range | Lignocellulosic |
| pH | Up to 11 | 05-Jul | 05-Jul | 03-Aug |
| Cultivation | Ponds, Bioreactors | Bioreactors | Bioreactors | Bioreactors |
| Risk of contamination | High and serious | Caution needed | Low | Least |
| Amino acid | Low | Deficient | Deficient | Low |
| Nucleic acid removal | No | Needed | Needed | Needed |
| Toxin | No | Endotoxins from gram negative bacteria | No | Mycotoxin |
| Ture protein | 40- 60% | 50- 83% | 45- 55% | 30- 70% |
| Lysine | 4.6- 7% | 4.3- 5.8% | NA | 6.5- 7.8% |
| Methionine | 1.4- 2.6% | 2.2- 3% | NA | 1.5- 1.8% |
| Lipids | 5- 10% | 8- 10% | 3- 6% | 5- 13% |
| Carbohydrate | 9% | NA | NA | NA |
| Nucleic acid | 4- 6% | 15- 16% | 6- 12% | 9% |
| Ash | 3% | NA | 5- 10% | NA |
| moisture | 6% | 2.80% | NA | 4.5- 6% |

## Fermentation

Fermentation may be aseptic, continuous fermentation is generally used, and to maximize the efficiency of the continuous system, this type of fermentation is usually performed at the maximum growth the rate of the microorganism (logarithmic growth phase).

After fermentation, the produced biomass is separated from the culture medium by filtration or centrifugation and can be consumed directly as a protein source or possibly extracted by downstream processes such as washing, cell damage, extraction protein, purification, and pasteurization [32].

## Submerged fermentation

During this process, the liquid substrate contains the rich nutrients that should be used for growth. Then, the fermentor has to open continuously while biomass should be continuously harvested from the fermentor by diverse techniques. Having been sieved by centrifuge, they, they should be dried. During this cultivation, aeration is remarkably important. In other words, heat is generated and then it is removed by air-conditioning. After harvesting, microbial biomass like bacteria and yeast are recovered by centrifuge and filamentous fungi are harvested by filtration. Besides, water should be sprayed, and final drying should be done under a clean and hygienic situation [33, 34].

## Semisolid fermentation

This process is not cleared and it needs financial investments and a high cost. For cultivating substrates, we should serve the multiphase system includes stirring, mixing, transporting oxygen in the form of gas through the liquid to the microorganisms while heat transfer to the setting of the liquid stage. For this purpose, a unique bioreactor called U-loop Fermentor is used for recognizing mass, and energy transportation. For producing single cell protein appropriate medium with carbon source is necessary while unwanted microorganisms as contamination should be prevented. Carbon sources can be obtained by different hydrocarbons ranging from gaseous hydrocarbons to n-alkenes. Moreover, other carbon sources such as ethanol, methanol and renewable sources ranging from molasses to polysaccharides can be considered for producing SCP [35].

## Solid-state fermentation

Various bioreactors have to be designed for Solid-state fermentation (SSF). In this process deposit of solid culture substrate such as rice as well as a wheat bran should be put on flatbeds after seeding with various microorganisms; however, the temperature of the substrate should be at room temperature and controlled for several days. . Liquid phase fermentation is administrated in special tanks that are between 1,001 to 2,500 square meters at an industrial scale. These bioreactors are proper for growing unicellular organisms like yeasts and bacteria. Oxygen should be transferred by stirring to achieve aerobic fermentation. Generally, some important factors like temperature, ionic strength, pH, soluble oxygen, and controlling nutrients are necessary for this type of fermentation [36].

## The reduction of nucleic acid content

Consuming a diet containing nucleic acid causes the production of uric acid which accumulates in the body owing to the deficiency of the enzyme urease. Therefore, if this component are used in diverse SCPs, they should be declined to an acceptable level. To eliminate nucleic acid, it used a treatment solution at 60 to 70 °C for 20 minutes, alkaline hydrolysis, and modification of culture conditions according to the amount of nitrogen, carbon, phosphorus, and zinc. However, alkaline hydrolysis at high temperatures causes toxic compounds like lysinoalanine which is an unusual amino acid that interacts with alkaline proteins. Lysinoalanine has been proved to decrease digestion and cause kidney alters in mice, and some people have developed allergic reactions. Yeasts contain significant a quantity of endogenous ribonuclease activity that is used for hydrolyzing RNA in yeast and also reduce the level of nucleic acid in the protein of yeasts. On the other hand, exogenous nucleases are added to decline the amount of nucleic acid in SCP. Pancreatic ribonuclease (Rnase A) and the fungal ribonuclease Aspergillus candidus strain M16 are used to decease the level of it in yeast cells. Bacterial and pancreatic nucleases have also been studied to eliminate nucleic acid from yeast cells [37].

## Remove toxins

Toxins are secondary metabolites that are produced during the growth of several fungi and bacteria. Algae generally do not produce harmful toxins. When SCP is used as animal feed, its toxicity is higher than human consumption. Some toxicity tests can only be performed on model animals.

## Mycotoxins

There are plenty of reports of fungal toxins, however aflatoxins are more important that other groups. Aspergillus spp. like (A. parasiticus, A. oryzae, and A. flavus) produce aflatoxins B1, B2, G1, and G2. In addition to aflatoxins, ochratoxin is one of the most important mycotoxins, of which ochratoxin A is the most toxic and abundant. It has been shown that these metabolites are presented in different species like Aspergillus and Penicillium and cause damage both the liver and the kidney. Trichothecene is an important group of mycotoxins that cause skin reactions and hematopoietic effects. Research on removing mycotoxins from SCP has focused mainly on aflatoxin [38]. Among many methods which were tested, ammonia is the most successful (one of the methods of destroying method of aflatoxins in food and pistachios uses alkaline compounds such as ammonia. Ammonia, both in gaseous and soluble form, can be used to make food safety from aflatoxins, which can destroy more than 95% of toxins. Experiments have shown that foods processed with ammonia have no toxic effects. Ammonia compounds appear to be the most effective and economical compounds for reducing aflatoxin in a variety of foods. Description of the effect of ammunition on the destruction of aflatoxins by Liang has been reported [**39**]. This method can reduce the level of aflatoxins by 99% [4]. Also, A. flavus is cultured with other microorganisms, and its toxin production decreases. Moreover, these methods, molecular techniques have also helped to eliminate them, such as cloning, and so on. The afl R gene, for example, is a kind of regulatory gene which controls the production of not only aflatoxin, but also sterigmatocystin toxins in Aspergillus spp. The unique target gene is inhibited in order to control the manufacture of mycotoxins in Aspergillus spp. [40, 41].

## Safety

New protein sources play a role in human nutrition of people in two ways: 1) consumption of protein source in the novel formulation directly, and 2) animals that are considered sources of protein for humans. The second case requires fertile land, labor, time, and energy. Five main sources must be calculated if there is a new protein source [42].

- Not toxic.
- Be economically available.
- It is easy to ready and eat.
- It must be accepted by people in society.
- It must be suitable regarding taste. This issue is strikingly important because it is possible that food is acceptable regarding nutritional value, but it does not have a good taste, it will not be accepted [1].

## SCP process technology: Current status

1. In the past, the Soviet Union was the largest producer of SCPs using petroleum hydrocarbons, lignocellulosic, and carbohydrate waste as animal feed [43], 2. L'Institut francais du petrole's pilot-scale (IFP, France), use methanol as a feedstock to produce yeast SCP [44]. In the Bel fromagerie's process, whey from is treated to produce two products: (1) Kluyveromyces fragilis, and (2) refined unassimilable protein like lacta-albumins [45], 3. In free-market economies system, the most successful SCP plant is called ICI (Agricultural Sector, Billingham, UK). The process began in 1968. Methanol was selected as the primary substrate due to its cost-effectiveness and availability, and the bacterium Methylophilus methylotrophus due to methanol absorption efficiency (50%) was selected. The amount of protein M. methylotrophus approximately 74% by weight, compared to soy protein (45%). Also, the bacterial content contains more methionine, cysteine , and lysine. The brand was Pruteen®, 4. In Vienna, the process changes sweet whey into SCP. The organism which is used can be a type of Candida

intermedia yeast, 5. In Germany, Hoechst AG has produced SCP for human use. He copperated with Uhde, uses Methylomonas clara (70 wt% protein) in producing SCP, with trade-named Probion®, from methanol, 6. Environcon, Ltd in the Canadian venture will build a pilot plant in British Columbia in order to manufacture protein-supplemented for animals. Lignocellulosic wastes are used in this process. The solid-state fermentation process is carried out with the fungus Chaetomium cellulolyticum [46], 7. The company of ITT Rayonier, in the U.S., Inc., investigated SCP in Washington to reduce the demand of biochemical oxygen of the factory's waste materials. The product with trade-named RayPro®, includes of bacterial SCP, and its final composition after drying process is 16 weight total t% wax, 53 weight total % crude protein, and 16 weight total % crude fiber, 8. Opposition began in Japan. However, this is not the case, as questions about SCP health and public safety have been raised in the country for several years. And it has reduced the overall acceptance of microbial proteins. However, the company of Mitsubishi Gas, chemical company, and Japan's largest ethanol producer, use methanol-absorbing yeasts.

## CONCLUSIONS

Single cell protein is a promising industry since not only the raw materials are free but are cheap. Moreover, it has a benefit to reduce environmental pollution and increase recycling. Single cell protein probably plays an important role in not only the food, but feed in decades to come. However, this issue is often hidden behind the word of single cell protein due to the viability of the economy [1]. The history of SCP has been recorded as a protein source. Despite all problems in this way, there were many success in the new food market with the microbial origin, one of that was the production of QuornTM mycoprotein. SCP products are safe, their production is easy to control, and the genetic background of the microorganisms is well known. Their production will continue as an alternative to the protein market. Shafaati and etal, view is to create a market for microbial-derived products from the cheese whey substrate which is considered as a liquid-waste with the aim of animal feed in Iran to use the simultaneous potential of bacteria, fungi, and yeast in its production. Achieving easy and cheap protein resources is always a basic need for all nations due to population growth in the last decades [47].

In the future, the production of SCP heavily depends on declining production costs and developing the quality and acceptance of people. Today, the downstream process and recombinant DNA technology have contributed to quality and cost reduction and profitability. However, the boundaries of using SCP production for human are bound to be sociological to technological. In animal feed, SCP is also used as a supplement. Yeast has been used for a long time as traditional fermentation microorganisms there is no problem in using them in the SCP industry. The use of algae goes back to before Christ (BC). Algae have high-grade markets for human food and feed. Most algae supplements contain omega-3, vitamins, fatty acids, carotenoids, and protein is considered a component of their biomass. The interest in using micro-proteins has also increased, and many countries offer to their patents in this field. The use of bacterial protein requires strong training and building culture [48].

The time is rapidly approaching, and SCP can still have a paramount role in the world where the living standard is highly important. The principles valuable aspect of SCP is that it produces economically viable products from waste and low-cost substrates. Further research and development will be ensured the usage of microbial biomass as a single cell protein or as a diet supplement in developing nations. However, without a shadowing doubt, the company called Dabur in India is producing spirulina as a supplement for human's diet.

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