"Production of single cell protein (scp) from different microorganisms as a protein supplement for human and animal feed" – A Review

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ABSTRACT

The bioconversion of fruit wastes into single cell protein production has the potential to solve the worldwide food protein deficiency by obtaining an economical product for food and feed. Using food processing leftovers in the production of single cell protein as substrate would alleviate pollution. Pineapple peels contain significant quantities of carbohydrates, which can be used as cheap raw materials for production of commercially important products through fermentation. The increased concentration of pineapple hydrolysate enhanced the biomass yield and the protein formation within the yeast cells. Lower carbon utilization by the two yeast strains occurred in the waste containing media, as compared to control, increasing the economic value of the waste obtained after 7-day fermentation. The present finding helps in SCP production from cheap, inexpensive agro waste material.

KEYWORDS: Single cell protein, Bacteria , Yeast , Fungi , Algae , Feed , Food , Large-scale fermentation , Human food , Animal feed

INTRODUCTION

The continual population growth in developing countries has required an increase in animal and human food supply. The increasing world demand for protein rich food led to the search for the formulation of alternative protein sources to supplement the conventional protein sources. Single Cell Protein (SCP) is one of the most important steps for this goal and is an alternative and an innovative way to successfully solve the global food problem[1]. Single cell protein (SCP) is an interesting object in research since early 1950. Single cell protein is the dried cells of microorganism, has been explored for being an alternative protein source as a food supplement or animal feeds as the preventive protein deficiency supply[2] . Some microorganism such as yeast, fungi, bacteria, and microalgae can be used in SCP production. This protein source is named as single cell protein because it describes the protein production from biomass (cell) that different from vegetable protein and animal protein. The production of SCP from various microbes gives some different characteristics either. The production of SCP from fungi and bacteria has been received considerable attention, in contrast, only a few studies have dealt from SCP of microalgae. Comprehensive analysis and nutritional studies have demonstrated that these algae proteins are a high quality and comparable with conventional vegetable proteins [3]. Humans and animals consume protein as a source of nitrogen and essential amino acids, from which they build new structural and functional (e.g., enzymes and hormones) proteins that enable them to survive. In extreme conditions, proteins may also be used as a source of energy. The nutritional value of a protein is determined by the amino acid composition; 20 amino acids are commonly found in dietary protein, of which several (i.e., phenylalanine, valine, threonine, tryptophan, methionine, leucine, isoleucine, lysine, and histidine, with arginine, cysteine, glycine, glutamine, proline, and tyrosine also being beneficial) cannot be synthesised by humans or animals and are thus essential and have to be supplied through the diet[4]. SCP producing microorganisms, yeast continues to dominate the microbial list as they are majorly composed of high protein contents and low nucleic acid contents, making them ideal as protein supplements . Yeast biomass is generally considered as safe for use as foods and feed additives because of its nontoxicity and easy digestibility. The presence of substantial quantities of vitamins, minerals, malic acids and lysine as well as high protein contents makes yeast biomasses ideal candidates for animal feed additives . Yeast cells include a significant role in animal health as its use in feed enhances yeast immunomodulatory effects and thus is important in aquaculture and poultry productions . Based on the literatures, SCP represents an attractive protein supplement with satiation properties that can improve appetite regulation in obese people . The widening gap between the supply and demand for dietary proteins can be bridged by increasing the production of foods and supplementing the existing resources with novel foodstuffs. Development of novel protein sources such as fish protein concentrates, SCPs, soybean proteins and insect proteins has significantly contributed to decrease world protein deficiency [5]. In previous studies, animal based proteins such as fish protein concentrates have been investigated for cardiovascular diseases (due to the high saturated fats and cholesterol consumptions), bone disorders (bone reabsorptions due to sulfur-containing amino acid (AA) linked to animal proteins) and other physiological system diseases [6]. Vegetable proteins are incomplete proteins as they lack one or more essential AAs (EAAs)[7]. This highlights the significance of SCP as an ideal protein supplement for foods and feed uses [8]. The SCP is a dried microbial biomass protein used as protein supplement in human or animal foods[9].In addition to its high protein contents, SCP contains fats, carbohydrates, nucleic acids, vitamins and minerals. Presence of EAAs such as lysine and methionine in SCP, which are limited in most plants and animals, advances them to foods from plant and animal foods [10]. Microbial protein production is independent of seasonal variations and climatic fluctuations, making their production sustainable all the year. The nutritive profile of SCP comprises of low-fat contents, accelerated protein/carbohydrate ratios and high-protein contents with a wide spectrum of AAs [11]. Flexibility in production process and amenability of SCP production using waste substrates make SCP foods superior sources [10]. Production of SCP from low-cost agricultural and industrial wastes is a feasible and financially viable process which is very important as it provides a sustainable solution to the management of these wastes and the environmental pollution caused by their disposals. Although extensive studies have been carried out on production of SCP from yeasts, the idea of scaling up the production process still faces several difficulties [12]. India is the second major producer of fruits and vegetables in the world. It contributes 10% of world fruit production. According to India Agricultural Research Data Book 2004, the total waste generated from fruits and vegetables comes to 50 million tons per annum. Fruit wastes rich in carbohydrate content and other basic nutrients could support microbial growth [13,14]. Thus fruit processing wastes are useful substrates for production of microbial proteins. The utilization of fruit wastes in the production of SCP will help in controlling pollution and also in solving waste disposable problem to some extent in addition to satisfy the world shortage of protein rich food[15]. A number of agricultural and agro industrial waste products have been used for the production of SCP and other metabolites, including orange waste, mango waste, cotton salks, kinnow-mandarin waste, barley straw, corn cops, rice straw, corn straw, onion juice and sugar cane bagasse [16], cassava starch , wheat straw , banana waste [17], capsicum powder and coconut water . The usage of such wastes as a sole carbon and nitrogen source for the production of SCP by microorganisms could be simply attributed to their presence in nature on large scale and their cheap cost.

SINGLE CELL PROTEIN

Single-cell protein (SCP) refers to dried microbial cells or total protein extracted from bacteria, yeast, fungi and algae which serves as feed or/and food supplements grown in large-scale fermentation systems for use as protein sources in human food or animal feed.The name 'single-cell protein' was used for the first time, in 1967 by the M.I.T. professor. The interest in SCP started already some time before World War I. During the World War I, Germany tried to supplement their protein supply in animal feed by using Baker's yeast. They managed to replace as much as half of all the protein sources imported at that time with yeast [18]. . The yeast was grown on molasses as a carbon source and ammonium salts were used as nitrogen source[19] . After the end of the World War I the interest in yeast as fodder declined but arose again when World War II started. At this point yeast had been included into the army diets, and after some time also into the diets of civilians. However, the high ambition to produce more than 100,000 tonnes of yeast per year was by far never reached [18]. SCP will be an alternative to conventional proteins such as casein, soybean meal, egg protein or meat protein in animal feed. Different substrate and fermentation optimizations are being carried out to maximize SCP production. SCP is one of the alternatives that cannot be affected by climate change. SCP has a high content of protein containing all the essential amino acids. Microorganisms are an excellent source of SCP due to their rapid growth rate, their ability to use very inexpensive raw materials as carbon sources, and the uniquely high efficiency, expressed as grams of protein produced per kilogram of raw material, with which they convert these carbon sources to protein[20]. SCP has many benefits. It is a very fast way of producing protein compared to the production of protein through cultivation of agricultural crops or animal farming. One of the main advantages of SCP compared to other types of protein is the small doubling time of cells [21]as shown in Table.

Organism	Mass doubling time
Bacteria, yeast	10–20 min
Mold , algae	2–6 h
Grass and some plants	1–2 wk
Chicken	2–4 wk
Pigs	4–5 wk
Cattle	1–2 months
People	0.2–0.5 yr

Based on Israelidis (1988)

Compared to fish meal, most sources of SCP (from yeast and bacteria) have similar methionine, lysine and cysteine content, and a higher proportion of threonine and tryptophan contents[22].SCP contains not only proteins but also free amino acids, lipids, carbohydrates, minerals and vitamins[23] .SCP has become a very interesting alternative protein source for inclusion in fish feed[24].Single-cell protein has many advantages, as it is fast growing, renewable and could be grown on industrial waste products. The nutritional value of its constituents, such as proteins, pigments, B-vitamins and b-glucans, has been suggested to be sufficiently high to make it a good replacement for fish protein[25]. The average composition of the main groups of microorganisms (% dry weight) is presented in below table[26].

	Fungi	Algae	Yeasts	Bacteria
Protein	30-45	40-60	45-55	50-65
Fat	2-8	7-20	2-6	1.5-3.0
Ash	9-14	8-10	5-9.5	3-7
Nucleic acids	7-10	3-8	6-12	8-12

Miller and Litsky (1976)

SCP WITH DIFFERENT MICRO ORGANISMS

Several mould, yeast, bacteria and algae have been used for the production of single-cell proteins[27].The main criteria for the selection of a particular microorganism for successful SCP production are (a) the nature of the raw material available, (b) its nutritional composition: amino acid profile, energy value, balanced protein and lipid content, vitamins and palatability, and (c) its toxicological composition: nucleic acid content, allergies and gastrointestinal effects. The ideal microorganism should possess the following technological characteristics: (a) a high specific growth rate and biomass yield, (b) a high affinity for the substrate with a low requirement for growth factor supplementation, (c) the ability to develop a high cell density, (d) a capacity for genetic modification and (e) a tolerance to temperature and pH changes[28,29]. The microorganisms used for SCP production should have reasonable protein content, non-toxicity and non-pathogenesis to animals and humans. Microorganisms possess ability to use a range of inexpensive nitrogen and carbon sources and need moderate growth conditions to convert it into valuable product, which is a precondition for SCP production. Some biochemical and cultural features of various groups of microorganism—algae, fungi, yeast and bacteria—for the production of SCP have and the comparison of SCP from different organisms[30,31].

characteristics	**Bacteria**	**Algae**	**Fungi**	**Yeast**
Growth rate	Highest	Low	Lower than bacteria and yeast	Quite high
Substrate	A wide range of substrates	Light, inorganic carbon sources e.g. CO2	Limited substrates mostly starchy and cellulosic materials	Most substrates except hydrocarbons and CO2
pH range	5–7	Up to 2.0	3–8	5-7
Cultivation	Bioreactors system	Open ponds, tank	Bioreactors system	Bioreactors system
Risk of contamination	High; precautions necessary	High	Low if grown below pH 5.0	Low
Biomass	Sometimes recovery problematic; new improved methods are needed	Difficult and costly with unicellular algae	Easy for filamentous or pellet forms	Easy by centrifugation
Protein	80% or more	Up to 60%	50–55%	55–60%
Amino acid profile	Generally good, a small deficit in S—containing acid	Generally good; low in S—containing amino acids	Low in S—containing acid	Generally good, a deficit in S—containing acid
Nucleic acid content	High (8–14%)	Low (4–6%	High (3–10%)	High (5–12%)
Removal of nucleic acids	Necessary	Necessary	Necessary	Necessary
Toxins	Gram −ve bacteria may produce endotoxins	Three types of toxin:—Endotoxin, Neurotoxin, Heptotoxin	Many species produce mycotoxins	NA

Other features	NA	Low yield (1–2 g dry wt/l). High chlorophyll content unsuitable for humans	Chitin may contain a significant proportion of N content, which is unavailable	High B vitamin content

(Bhalla et al. 2009, Srividya et al. 2013)

SCP From Bacteria

Bacteria also have a long history of use as SCP, particularly in animal feed[32]. Bacterial SCP generally contains 50–80% protein on a dry weight basis and the essential amino acid content is expected to be comparable to or higher than the FAO recommendations [33]. . Their amino acid profile is balanced and their lysine content is high. Bacteria possess the ability to utilize a wide range of substrates, some of which are not metabolized by yeasts. However, a number of bacterial species are pathogenic and have higher nucleic acid content than yeasts, which is detrimental to human consumption. In addition, separation is difficult because of the relatively small size of bacteria[28]. Among bacterial species, Cellulomonas and Alcaligenes are mostly used bacterial species as a SCP source[34]. Potential phototrophic bacterial strains are recommended for SCP production. Some researchers also suggest use of methanotrophic and other bacterial species for SCP production. Generation time of Methylophilus methylotrophus is about 2 h and this bacterium is used in animal feed and in general produce a more favourable protein composition than yeast or fungi. Therefore the large quantities of SCP animal feed can be produced using bacteria.Characteristics which make bacteria suitable for this application include rapid growth of bacteria, short generation times of bacteria— almost can double their cell mass in 20 min to 2 h[35].They are also able to grow on a variety of raw materials which range from carbohydrates such as sugars and starch to gaseous and liquid hydrocarbons which contain methane and petroleum fractions; to petrochemicals such as methanol and ethanol; nitrogen sources which are useful for bacterial growth include ammonia, ammonium salts, nitrates, urea and the organic nitrogen in wastes. It is also suggested to add mineral nutrient supplement to the bacterial culture medium to fulfil deficiency of nutrients which may be absent in natural waters in concentrations sufficient to support growth[36].

SCP from Algae

Spirulina is the most widely used algae. Similarly, biomass obtained from Chlorella and Senedessmus is harvested and used as source of food by tribal communities in certain parts of the world. Algae are used as a food in many different ways and its advantages include simple cultivation, faster growth and rich in protein content [37]. The production of algae could be limited by certain conditions such as the need for warm temperatures and plenty of sunlight in addition to carbon dioxide [38]. Another disadvantage associated with using algae as single cell protein is that digestibility is low with algal cells because of indigestible cell walls[39].

Microalgae which are produced for human or animal consumption typically have high protein content (e.g., 60– 70%;). They also provide fats (with ω-3 fatty acids and carotenoids being of particular interest), vitamins A, B, C, and E, mineral salts, and chlorophyll [40]. They have relatively low nucleic acid content (3–8%). Microalgae are currently used mainly in the form of supplements, available in tablet, capsule or liquid form, but they are increasingly also processed as ingredients which can be included in pastas, baked goods, snacks, and so on [40,41]. The most accessible commercial products are derived primarily from Arthrospira platensis and Arthrospira maxima (sold as spirulina, marketed by e.g., Hainan Simai Pharmacy Co., Earthrise Nutritionals, Cyanotech Corp., FEBICO, and Mayanmar Spirulina Factory), Chlorella (marketed by e.g., Taiwan Chlorella Manufacturing Co., FEBICO and Roquette Klötze GmbH & Co), Dunaliella salina (marketed by e.g., Qianqiu Biotechnology Co., Ltd., primarily for β-carotene) and Aphanizomenon flos-aquae (marketed by e.g., Blue Green Foods, Klamath Valley Botanicals LLC [40].

Euglena Co. Ltd.[42]and Algaeon (http://algaeon-inc.com/#products) are both selling products from Euglena, primarily for the β-glucan content, but including whole cell products. Algae generally feed on CO2 and light, although some products such as Alga Via R are produced by traditional fermentation rather than by photosynthesis. Outdoor production of algae in open ponds is common, but is subject to contamination (not only biological contamination, but also mineral contamination which affects the quality of the final product) and variation in the weather [43] .Indoor photobioreactors are also being used to guarantee the supply of fresh algae as feed for aquaculture [44][45]. Algae are primarily used in aquaculture as a source of omega fatty acids and carotenoid pigments, but their protein also contributes to animal nutrition[46]. For protein production, there are three species most cominsmonly used with a higher commercial value: Chlorella, Spirulina (Arthrospira) and Dunaliella, having 55, 65 and 57% protein content.

SCP From Yeast

Yeasts have been involved in human food for thousands of years, namely for brewing beer, fermenting wine and baking bread. Yeasts are rarely toxic or pathogenic, with most attaining the generally regarded as safe (GRAS) status and can be used in human diets. Thus, yeasts are more readily accepted as a food and feed supplement than are the other microbial groups. Although their protein content rarely exceeds 60%, the concentration of essential amino acids such as lysine (6 9%), tryptophan (1 1.5%) and threonine (4 6%) is satisfactory. By contrast, they contain only small amounts of the sulphur-containing amino acids, methionine and cysteine [28][47]. They are rich in B group vitamins and their nucleic acid content ranges from 4 to 10%. Yeasts are larger in size than bacteria and this facilitates the separation of yeasts from the culture broth. Yeast such as Kluyveromyces spp, Candida spp and Saccharomyces cerevisiae have been successfully used in SCP production[48][49].

SCP from Fungi

Many fungal species are used as sources of protein rich food. Among these, most popular are yeast species, Candida, Hansenula, Pitchia, Torulopsis and Saccharomyces. Many other filamentous species are also used as sources of single cell protein. Actinomycetes and filamentous fungi were reported to produce protein from various substrates. Cultures of Fusarium and Rhizopus have been grown in fermentation as a source of protein food. The inoculum of Aspergillus oryzae or Rhizopus arrhizus is selected because of their non-toxic nature. Saprophytic fungi grow on complex organic compounds and convert them into simple structures. High amount of fungal biomass is produced as a result of growth. Mycelial yield vary greatly which depends upon organisms and substrates. There are some species of moulds, for example, Aspergillus niger, Aspergillus fumigatus, Fusarium graminearum which are very dangerous to human, therefore, such fungi must not be used or toxicological evaluations should be done before recommending to use as Single cell protein [50]. Yeasts are probably the most widely accepted and used microorganism for single cell protein.

Fungi grown as SCP will generally contain 30–50% protein[2][32]. The amino acid composition compares favourably with the FAO guidelines; threonine and lysine content is typically high, but methionine content relatively low, although still meeting the FAO/WHO recommendations[51]. The methionine content of some fungal products such as Marmite R is even lower. Sulphur containing amino acids have been enriched in SCP from K. fragilis by cultivation on whey [52]. In addition to protein, SCP derived from fungi is expected to provide vitamins primarily from the B-complex group (thiamine, riboflavin, biotin, niacin, pantothenic acid, pyridoxine, choline, streptogenin, glutathione, folic acid, and p-amino benzoic acid). The cell walls of fungi are rich in glucans, which contribute fibre to the diet. Low-density lipoprotein cholesterol has been reduced in volunteers who consumed myco-protein from Fusarium venenatum [53] and blood glucose and insulin levels may also be favourably affected [54]. Fungi are expected to have a moderate nucleic acid content (7–10%)[2], which however is too high for human consumption and requires processing to reduce it . The fungal biomass provides a texture that resembles meat products. Yeast extracts provide a good source of five important group-B vitamins, but also protein. In addition to these carbon sources, alkanes and methanol have been used for SCP production by yeast and filamentous fungi.

Substrates for Single Cell Proteins

The production of single cell protein can be done by using waste materials and inexpensive feedstock as the substrate, specifically agricultural wastes such as wood shavings, sawdust, corn cobs. Conventional substrates such as starch, molasses, fruit and vegetable wastes have been used for single cell protein production, as well as unconventional ones such as petroleum by-products, natural gas, ethanol, methanol and also human and animal excreta can be used [36]. Lignocellulosic biomass such as cellulose and hemicellulose waste is used as a suitable substrate for increasing single cell protein production [2][36].

Fruit waste (simple sugar rich)

The content of fruit processing waste is highly dependent on the type of fruit and the part of the fruit that forms the main mass of the waste. If the waste is mainly whole fruit, then a large amount of monosaccharides and disaccharides will be available in the waste, as it is in the case with banana wastes, where 5 to 30% of harvested bananas are discarded as waste due to export regulations [55]. A similar situation exists for figs where, due to incorrect transport, storage and market changes, large quantities of figs are not realized, and they need to be disposed of when they begin to deteriorate[56].

Fruit waste (fibre rich)

Similarly, as for sugar and starch production waste, also fruit processing residues can be used as feed for cattle, however, this is often not possible, or the transportation of the residues is too expensive [57][58]. Consequently, in order to reduce the production costs, usually the waste from fruit processing is simply discarded [58][[59]. Mainly dietary fibre rich fruit processing wastes come from juice and essential oil production factories [58]. Pomace and juice pulps make up to about 25 to 65% of the total fruit volume used for juicing[57]. Considering that about 25% of the harvested fruits are used in industrial processing[57], the global annual amount of pomace and juice pulp produced from apples and citrus fruits is estimated at around 15 million tonnes (FAO, 2018a). From a nutritional point of view, fruit remnants are not suitable for monogastric animal feeds because of their low digestibility and low protein content [57]. Due to the large amount of generated waste and the limited use of it, researchers have looked at ways to improve the nutritional value of fibrous fruit wastes by using them as substrates for the production of SCP [57][58].

PROCESSING OF SCP

Depending on the substrate material and intended food/feed application, various processing steps are required prior to formulation of the final SCP product. In the following section we review the most relevant processing needs for SCP.

Fermentation process:

SCP is produced using the fermentation process[2]. This is done by selected strains of microorganisms. Production of SCP involves basic steps of preparation of suitable medium with suitable carbon source, avoiding the contamination of medium and the fermentor, production of microorganisms with desired properties and separation of synthesized biomass and its processing. Different types of carbon source can be used. These are n-alkenes, gaseous hydrocarbons, methanol, ethanol, renewable sources like carbon dioxide, molasses, polysaccharides, effluents of breweries and other solid substances [60].Fermenters vary in size from laboratory scale to industrial scale of several hundred litres capacity. Fermenters are equipped with an aerator, which supplies oxygen to aerobic processes. Also, a stirrer is used to stir the medium. A thermostat is used for controlling the temperature. pH detector and some other control devices, are used which keep all the different parameters required for growth constant [61][62].Cost is a major problem for producing and harvesting microbial proteins. Such a production even in high rate causes dilute solutions usually less than 10% solids. Single cell protein can be produced by fermentation processes, namely;

i. Submerged fermentation
ii. Semisolid fermentation and

iii. Solid state fermentation

Comparison of solid state and submerged fermentation processes[63][64][65]

Parameter	Submerged fermentation	Solid state fermentation
Substrate condition	Requires continuous agitation and soluble substrate	No agitation required and insoluble polymers as substrate
Moisture	Required in large quantity	Absence of free water
Aerobic conditions maintenance	By agitation	By diffusion
Post fermentation waste	Large quantity, hence effluents polluting the environment	Very little, hence non-polluting
Space	Large	Small
Capital investment	Very high	Low
Aseptic conditions	Highly essential	Not required

(Pandey and Soccol 1998; Tengerdy 1985; 1992; Zadrazil and Puniya 1995;)

PRODUCTION PROCESS:

Single cell protein production process takes the following steps

↓

Microbial screening

↓

Choice of raw materials

↓

Process engineering and Process optimization

↓

Technology development

↓

Economic consideration / Process feasibility

↓

Safety concerns

SCP PROCESSING FOR FOOD

The effective use of microbial protein for human food requires:[2]

• Liberation of cell proteins by destruction of indigestible cell walls

• Reduction of nucleic acid content

Cell Wall Degradation in Single Cell Protein Products

Some SCP are used as whole cell preparations, while in others the cell wall may be broken down to make the protein more accessible. SCP, such as QuornTM, may be consumed without degradation of the cell wall, in which case chitin and glucan from fungal cell walls contribute fibre to the diet[67].SCP derived from Euglena does not require dirsuption since the cells have proteinaceous pellicles, rather than cell walls, making it more readily digestible. Various methods have been used to disrupt the cell wall, including mechanical forces (crushing, crumbling, grinding, pressure homogenization, or ultra-sonication), hydrolytic enzymes (endogenous or exogenous), chemical disruption with detergents, or combinations of these methods[2].

Reduction of nucleic acid content

Although algae generally have low nucleic acid content, the rapidly proliferating bacterial and fungal species have high nucleic acid (RNA) content. RNA content and degradation are affected by growth conditions, growth rate, and the carbon nitrogen ratio [68]. When SCP is produced for human consumption, high nucleic acid content is a problem because ingestion of purine compounds derived from RNA breakdown increases uric acid concentrations in plasma, which can cause gout and kidney ston[69]. SCP with high nucleic acid content which is intended as animal feed is recommended only for feeding animals with short life spans [70].Various methods to decrease the RNA content in SCP have been developed [71] and continue to be in use. Endogenous RNA degrading enzymes (ribonucleases) can be exploited in degradation of RNA, after activation with heat treatment (60–70◦C) as used in the production of QuornTM[72]. Ribonucleases can also be added to the process or used as immobilized enzymes [73][74]. Degraded RNA components diffuse out of the cells, but biomass loss (35–38%) also occurs. The process was improved by using higher temperatures (72–74◦C) for 30– 45 min, with less loss of biomass (30–33% loss; [75]. The temperature increase requires steam input, which is a cost factor, but heat is also needed for final treatment of the biomass at 90◦C after the RNAse activation [76].

CURRENT TRENDS:

Creative Biolabs have developed Single Protein Production (SPP) TM technology for high-throughput protein production.

In the Single Protein Production (SPP) system, live E. coli cells are converted into a bioreactor producing only a single protein of interest in a high yield. A yield of 20-30% of total cellular protein can be obtained with this technology, which overwhelms all protein production methods known so far.

This technology involves the introduction of an mRNA endoribonuclease or interferase in E. coli cells to disrupt the endogenous protein production, however, the cells retain full metabolic activity for RNA and protein synthesis. Therefore, when the mRNA for a protein of interest is engineered to be devoid of the mRNA endoribonuclease recognizing sequence without altering the amino acid sequence of the protein, the cells start to produce any single protein of your choice.

With the evolution of this technology, it is now easy to produce any protein with the SPP system. With the technology, protein yields can be kept unaffected even when the culture is condensed up to 40-fold and this reduces the cost of protein production by up to 97.5%. The technology provides isotope-labeled proteins at a very high signal-to-noise ratio. More than 90% of the isotope can be incorporated into the target protein in the SPP system. Furthermore, a refinement of this technology has eliminated lengthy purification steps in the production of membrane proteins suitable for structural studies[77].

CONCLUSION

Single cell protein shows very attractive features as a nutrient supplement for humans and animals alike. Single cell protein has various benefits over animal and plant proteins in that its requirement for growth are neither seasonal nor climatic dependent therefore it can be produced all round the year. Its additional components of carbohydrate, fats and elements like phosphorous and potassium will help solve the challenge in global requirement of protein and other supplements.

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