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Popular Article

Importance of Single-Cell Protein (SCP) And Its Utilization in Aquaculture

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Abstract

In recent times organic practices have shown enormous potential in using microorganisms to produce high-quality protein sources such as Single-Cell Proteins (SCPs) from different groups of microorganisms, including algae, bacteria, yeasts, and fungi, lowering reliance on traditional feeds and improving industry sustainability. SCP production entails extracting microbial biomass high in protein, lipids, carbohydrates, vitamins, and minerals from various substrates. Fermentation techniques include submerged, semisolid, and solid-state procedures to generate SCP, which is harvested, disrupted, and purified. SCPs have promising nutritional characteristics, with amino-nitrogen accounting for much of their total nitrogen content. They provide balanced amino acid compositions and high quantities of important nutrients, making them good alternatives to conventional aquaculture diets. However, difficulties remain, including SCP's high nucleic acid content and possibly anti-nutritional properties. Addressing these challenges requires improving fermentation techniques and devising strategies for removing unwanted components.
Keywords Anti-nutritional factor, aquaculture, fermentation, Single cell protein (SCP)

1. Introduction

There is a growing demand for cost-effective and sustainable approaches in the field of aquaculture all over the world. This move is mainly because of the twin goals of lowering manufacturing costs and addressing the needs of health-conscious consumers. Organic aquaculture practices have developed as a potentially viable answer to these issues. The use of microorganisms as a high-quality, antibiotic-free protein source is an important tactic in this approach. These microorganisms, including algae, bacteria, yeasts, molds, and fungi, are grown massively in culture systems known as biofilms or bioflocs. Their usage in aquaculture decreases dependency on conventional feeds while improving the industry's overall sustainability by providing single-cell proteins (SCPs) for aquatic feeds. In a 400 g kg−1 diet, methanotrophic bacterial SCP can replace 75% of the fishmeal (Woolley *et al*., 2023).

2. What is SCP (Single cell protein)?

Single-cell protein (SCP) refers to the final protein product extracted from the pure culture of microbial biomass. The use of yeast as a protein source dates back to antiquity. SCP, obtained from unicellular organisms, is an appropriate term for these nutrients. These are high in protein, lipids, carbohydrates, nucleic acids, vitamins, and minerals, making them an important nutritional ingredient. Recognizing their potential, researchers are focusing on harnessing yeast and other microbes for aquafeed applications. Microbial SCP can be used to replace regular fishmeal by up to 30-50%. SCP manufacture uses a variety of substrates, such as starch, cellulose, hydrocarbons, alcohols, and molasses.

3. Principle of Production of Single-Cell Protein

Microorganisms possess the amazing capacity to use inexpensive inorganic elements, like carbon sources and ammonium salts, to generate energy for their growth and metabolic operations. They can quickly convert low-value inorganic waste into lucrative biomass that is rich in protein. Easily obtainable industrial and agricultural wastes can be used to affordably produce single-cell protein (SCP), an effective aquaculture feed alternative. While submerged fermentation makes use of liquid mediums like molasses and nutrient broths, solid-state fermentation employs solid materials like bran, bagasse, and paper pulp. Sterilization is an expensive process that can be bypassed in the production of SCP for aquafeeds because it does not include disease-causing bacteria. This reduces production costs even more.

4. Different sources of SCP in Aquaculture

Numerous microorganisms with a high nutritional value can be used in aquafeeds and these are discussed below.

Algae: Spirulina has long been a staple food for the Aztecs at Texcoco, Mexico, and the tribes living around Lake Chad in Africa. To eat, they would gather and dry this alga (Suman *et al*., 2015). Nowadays, astronauts on space missions use spirulina as a dietary supplement due to its nutritional properties. Aquaculture is using more and more different types of algae, such as *Chlorella sp*., *Spirulina sp*., *Scenedesmus sp*., and *Chondrus sp.* as supplements or replacements for conventional protein feeds like fishmeal and soybean meal. Currently, they account for almost 30% of the world's production of algae used in feed.

Fungi: Fungi are naturally available rich sources of protein. The protein percentage can reach up to 50-55%. Some fungi, such as *Rhizopus cyclopium*, *Aspergillus fumigatus*, *Aspergillus niger*, and *Trichoderma sp.*, have the potential to increase aquaculture productivity. These fungi produce an oil that is a great alternative to conventional supplies of critical fatty acids, like as DHA, EPA, and ARA, which are necessary for larval and broodstock diets in aquaculture.

Yeasts: Yeast typically contains 55-60% protein and about 15% nucleic acids by dry weight.

The commercial cultivation of yeast, particularly the species *Saccharomyces* and *Candida*, has been refined over the past century. To make yeast suitable for consumption, it is necessary to process it to lower the nucleic acid content. Yeast is a prevalent source of single-cell protein in animal feeds and is also a good source of B vitamins. Cucumber and orange peels were tested for producing single-cell protein with *Saccharomyces cerevisiae* through submerged fermentation.

Bacteria: Bacterial single-cell protein (SCP) is highly protein-rich, comprising approximately more than **80%** of its dry weight, and is a source of a good amount of essential amino acids. Species such as ***Bacillus megaterium, Bacillus subtilis, Streptococcus faecium, Streptomyces sp., Thermomonospora sp.,*** and ***Lactobacillus sp.*** are generally used for their advantageous properties in aquaculture, contributing to their sustainability and productivity (Bharti *et al*., 2014).

5. Substrates used for SCP production

Single-cell protein (SCP) production offers a great opportunity to use a wide range of substrates, specifically agricultural byproducts, to produce high-quality protein while lowering effluent biological oxygen demand. Substrate selection depends on using low-grade waste or protein-rich sources (Suman *et al*., 2015). Starch, molasses, and vegetable/fruit wastes are common substrates, while unconventional possibilities include petroleum derivatives, liquids (e.g., methanol, ethanol), gases (e.g., natural gas), and solid biomass (e.g., lignocellulosic materials).

6. Production methods for SCP

The production of single-cell protein (SCP) is done by using different types of fermentation processes. It involves the cultivation of selected microbial strains, which proliferate using appropriate raw materials and nutrients. The technical process is designed to promote the growth of the microbial culture and increase the biomass. Subsequent steps include separating the desired cell mass. The initial stage of process development is the screening of microorganisms to identify suitable candidates for production.

a) Selection of strain

Suitable production strains are obtained from various samples of soil, water, air, or swabs of inorganic or biological substances and are subsequently optimized by selection, mutation, or other genetic methods according to requirements to get the final product.

b) Fermentation

In general, it can be produced by three types of fermentation processes, namely:

Submerged fermentation

The substrate utilized for fermentation in the submerged process is always liquid, allowing nutrients to be added for growth. The entire substrate is contained in a fermentor that is run continuously. The biomass produced by the fermentor is continually extracted using different methods, and the finished product is subsequently dried and centrifuged. Heat is produced during the cultivation process and it is eliminated with the use of specific cooling equipment and an aeration system.

Semisolid fermentation

This particular kind of fermentation process needed significant initial investment with operating costs. Cultivation involves various processes, including multiphase system mixing, stirring, and transporting molecular oxygen from gas bubbles to respective microorganisms and all are carried out through the liquid phase. This process ultimately transmits heat from the liquid phase to its surroundings. A U-loop fermenter which is a bioreactor is used to identify energy and mass transportation phenomena.

Solid state fermentation

This method involves laying a solid culture substrate, such as rice or wheat bran, on flatbeds after seeding it with microorganisms; the substrate is then placed in a temperature-controlled environment for several days.

c) **Harvesting**: The microorganisms are harvested using centrifugation, filtration, or other methods. The harvested microorganisms are then washed and purified to remove any unwanted substances.
d) **Cell disruption:** The microorganisms are subjected to mechanical or chemical methods to break down the cell walls and thereby release proteins.
e) **Separation and purification:** The protein extract is then separated from the other components of the microorganisms and purified using various techniques such as chromatography.

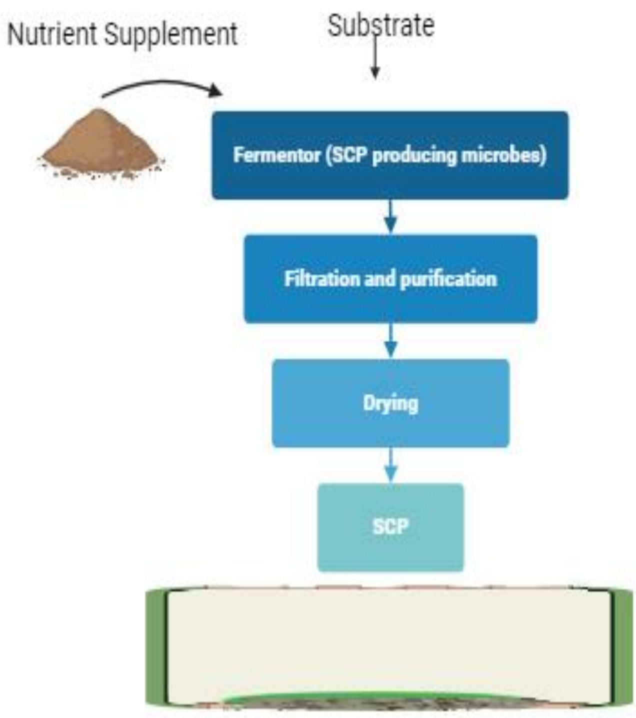

Fig: Flow diagram of SCP Production procedure

f) **Drying and packaging:** The purified protein is then dried using methods such as spray-drying, freeze-drying, or sun-drying, depending on the product requirements. The dried protein is then packaged and stored until it is ready for use.

7. Nutritional profile of single-cell protein

These microorganisms boast an impressive amino-nitrogen content, constituting 70-80% of their total nitrogen, which is a testament to their rich protein profile. The composition of SCP is diverse, encompassing proteins, fats, carbohydrates, ash ingredients, water, and minerals like phosphorus and potassium. This rich blend of nutrients underscores the multifaceted benefits of SCPs, extending beyond mere nutrition to include waste management. The nutritional profile of SCP depends upon the drying, harvesting, and processing methods employed. These steps are crucial as they determine the quality of the final product. In the aquaculture industry, SCPs have been incorporated into diets as a sustainable alternative to fishmeal and as a means of fortifying rotifer and Artemia. Yeast SCPs, in particular, are gaining prominence due to certain strains like *Saccharomyces cerevisiae* and *Debaryomyces hansenii*, which exhibit probiotic properties (Suman *et al.*, 2015). These strains enhance larval survivability by colonizing the gut of fish, promoting early pancreatic maturation, or through the immunostimulatory effects of glucans derived from yeast cell walls.

Fungi and Yeast-based SCP are particularly rich in lysine, although they contain lower levels of methionine and cysteine. The balanced amino acid profile and high vitamin B-complex content make them suitable for poultry feed. Algal source of SCP contains healthy fats and a variety of vitamins, including A, B, C, D, and E. Notably, *Bacillus sp.* includes carotenoid pigments, which are recognized for their antioxidant properties. Algae contain β-carotene, tocopherols, and B vitamins, enhancing their nutritional value. Yeasts, another SCP type, are also rich in B vitamins. However, filamentous fungi have a lower vitamin content than their SCP counterparts. Bacterial SCPs differ from others in their protein makeup which is greater than 80%, with a minor amount of sulfur-containing amino acids and a high nucleic acid concentration. The nutritional and dietary properties of SCPs are inextricably tied to the microorganisms used in their creation.

8. General applications of SCP

Single Cell Protein (SCP) has a comprehensive nutritional profile that makes it useful for a wide range of businesses. It is an easy way to get energy and is great for keeping skin and eyes healthy. For undernourished youngsters, SCP is especially beneficial as a protein supplement since it provides a strong mixture of vitamins, minerals, and many important essential amino acids. SCP is used in therapeutic as well as natural remedies in the field of health and wellness to help control lower blood sugar levels in diabetic patients, reduce body weight, and cholesterol, reduce stress, and stop the body from accumulating cholesterol. SCP is also used in many personal care products to keep hair healthy and create a variety of herbal beauty products, like herbal face creams and Bio-lipsticks. Presently SCP is also commonly used in cattle feed, and feeds of birds, fish, and other agricultural animals in poultry and dairy farms, where it is a great and practical rich of proteins and other nutrients.

9. Significance of SCP in Aquaculture

Aside from serving as an alternate protein supply, single-cell protein (SCP) has a variety of applications in aquaculture. It acts as an immunostimulant and probiotic, improving the growth, health, disease resistance, and immune response of aquatic animals. Lactobacillus, a gram-positive bacterium, is used as a probiotic and is becoming an increasingly popular alternative to antibiotics in aquaculture disease management. SCPs generated from bacteria and yeast are high in nucleic acids, notably RNA, which promotes rapid protein synthesis. These bacteria' high protein production is due in part to their quick protein synthesis and low replication times. The inclusion of high-nucleotide SCP in fish meals can improve liver function and lipid metabolism.

SCP production also helps to ensure environmental sustainability by recycling agricultural and industrial waste, which bacteria may consume as nutrients. Furthermore, SCP can recycle feed-derived waste and ammonia excreted by aquatic animals. In the field of ornamental fish farming, fish size and pigmentation are important to success. SCPs from algae and bacteria, which are high in carotenoid pigments, can be used to change these characteristics. These microbial carotenoids are useful feed supplements for ornamental fish, promoting development and coloration.

10. Major issues related to the uses of SCP

Single Cell Protein (SCP) contains some anti-nutritional factors. The main concern is SCP's high nucleic acid content, which might result in elevated serum uric acid and kidney stones (Sharif *et al*., 2021). SCP is high in amino acids, but it also contains indigestible cell walls for some animals and birds. To avoid infection, nausea, and vomiting, live microbial cells must be inactivated before intake. Filamentous fungi and bacteria incorporated in SCP manufacture can be contaminated with endotoxins and other potentially dangerous compounds such as mycotoxins and cyanotoxins. However, these difficulties can be minimized by using the appropriate microbes and substrates, improving fermentation processes, and processing SCP to remove anti-nutritional components such as nucleic acids. Although algae is toxin-free, it grows slowly, which adds to the difficulty of producing SCP.

11. Conclusion

Single-cell protein is an important alternative protein source that reduces input costs by utilizing naturally occurring microbes in aquaculture systems or other waste substrates that serve as a nutrient source for growing microbes. Single-cell proteins are highly nutritious and support the growth and survival of cultured organisms by enhancing immune responses and disease resistance. Single-cell proteins serve as a source of β-carotene, which improves the color of ornamental fish. Using SCP supports one of the best and most convenient techniques for producing organic foods with low risk and high health benefits. Application of SCP in aquaculture therefore improves production in an economically and ecologically sustainable manner.

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