

Single Cell Protein

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Abstract

As aquaculture production is witnessing a good increase it is further expected to increase in future at a good rate. Single cell protein refers to a protein procured from microbiological source in a dried form such as bacteria, fungi, yeast, unicellular algae or the total protein acquired from cell culture. The production of SCP is limited to human consumption, however, for animal nutrition the source of SCP are extensive. The demand for high quality, protein rich food will continue to increase as global production grows. Aquaculture is the fastest animal protein growing industry. Aquaculture diets have larger crude protein levels ranging from 35-60%. SCP finds its advantage in aquaculture in terms of high protein levels as SCP has almost all the essential amino acids present in it. SCP can be a key ingredient in feed as a source of protein. The use of SCP in aquaculture will enhance cellular development and co-product yields in an effective and economic way. SCP finds its use as immune stimulants and probiotics in aquaculture industry. The use of probiotics in aquaculture reduces incidents of diseases resistance caused by antibiotics. Also, for ornamental aquaculture practices the color and size of the fish is an important point for success. This can be improved using SCP products derived from algae, bacteria having high levels of carotenoid pigments. Therefore, the SCP use in aquaculture industry would prove to be beneficial in many ways in a cost effective way.

Introduction

The issue of providing adequate food supplies is increased by the world's fast growing population. Protein supply, in particular, is a challenge since necessary amino acids cannot be substituted. Protein deficiency is becoming a big issue for humanity around the globe (Suman *et al.*, 2015). In fact, aquaculture has developed at a higher rate than any other animal protein sector during the last two decades, with a compound annual growth rate of 7% compared to

4% for poultry (Ritchie and Roser, 2019). Aquaculture diets have a larger crude protein level, ranging from 35-60 wt%, than terrestrial cattle diets, which have a crude protein value of 12-26 wt% (Jones *et al.*, 2020)

As a result, in 1996, novel sources of protein biomass, namely bacteria, yeast, fungi, and algae, were employed to make Single Cell Protein (SCP). Carol L. Wilson invented the term SCP in 1966. Single cell proteins are produced using a range of microbes and substrates. Because of its exceptional nutritional quality, yeast is ideal for the generation of single cell proteins. Cereals that have been supplemented with single cell proteins, particularly yeast, are as good as animal proteins (Huang and Kinsella, 1986). Single Cell Protein refers to a protein derived from a microbiological source. SCP is expected to play a key role in its long-term success.

Single Cell Protein organisms

Microalgae, yeast and other fungi, and bacteria can all be used to make SCP products. All have concentrated the attention of researchers and now are also being developed, and each has its own set of benefits and challenges.

Microalgae

Microalgae can be a SCP source with a reasonably high crude protein content, as (Tibbetts, 2018) recently evaluated. However, potential production of omega-3 fatty acids (i.e. eicosapentaenoic acid and docosahexaenoic acid) (Tocher *et al.*, 2019) and carotenoids, namely astaxanthin — an antioxidant, immune stimulant (Shah *et al.*, 2018), and pink pigment for salmon and shrimp (Hu *et al.*, 2018) by the strain *Aurantiochytrium* species appears to be more poignant.

Yeast and other fungi

Yeasts and fungi have long been used in animal feed, especially for terrestrial livestock and direct human consumption, such as Quorn. *Saccharomyces cerevisiae*, different *Aspergillus*, and *Fusarium venenatum* are the most well-known species, but *Candida utilis* and *Kluyveromyces marxianus* are getting popular as protein replacement strains (Overland *et al.*, 2013). However, in most cases, the purpose is to provide additional benefits, such as *Rhodotorula mucilaginosa* (Chen *et al.*, 2019) biomass, which has immunomodulation and

antioxidant properties, and *Yarrowia lipolytica*, which produces EPA and was previously marketed as Verlasso salmon (Tocher *et al.*, 2019) by DuPont and AquaChile.

Bacteria

Bacterial SCP strains may produce high crude protein content (>80 wt%) and EAA values, as well as vitamins, phospholipids, and other valuable compounds, from a variety of feedstock (Suman *et al.*, 2015). The variety of feedstocks has stimulated more research into bacteria that use methane, methanol, syngas, carbon dioxide and hydrogen, as well as second generation sugars.

Protists

Labyrinthulomycetes are heterotrophic marine protists that are divided into three groups: thraustochytrids, aplanochytrids, and labyrinthulids (Leyland *et al.*, 2017). Because of their potential to generate omega-3 fatty acids, Thraustochytrids like *Schizochytrium limacinum* (*Aurantiochytrium limacinum*) are of particular interest (Ganuza *et al.*, 2019).

Table: Summary of SCP sources with current examples

SCP sources	Protein content range	Special characteristics	Example of specific organisms	Challenges	Current commercial activities
Microalgae	60–70% (Ritala <i>et al.</i> , 2017)	Phototrophic growth. Production of omega-3 fatty acids	<i>Chlorella vulgaris</i> <i>Desmodesmus sp.</i>	Economical scale-up Cell disruption to release nutrients	Cellana Pond Technologies BioProcess Algae
Yeasts	30-5-% (Ritala <i>et al.</i> , 2017)	Use of a variety of feedstock	<i>Saccharomyces cerevisiae</i> <i>Candida utilis</i>	Improve protein and EAA content	ADM Alltech Flint Hills Resources

		Production of vitamins and micronutrients			ICC Brazil Pacific Ethanol
Bacteria	50-80% (Ritala <i>et al.</i> , 2017)	High protein content Growth on C1 substrates	<i>Methylococcus capsulatus</i> <i>Cupravidus nectar</i>	Palatability issues	Calysta Kiverdi KnipBio NovoNutrient White Dog Labs
Protists	10-20% (Moran <i>et al.</i> , 2017)	Production of omega-3 fatty acids	<i>Schizochytrium limacinum</i>	Improve protein content	Veramaris

Source: Jones *et al.*, 2020

Nutritional Value of SCP

Almost all essential amino acids are found in single-cell protein from bacteria and fungi, which may not be found in plant derivatives. Amino-nitrogen accounts for 70-80% of total nitrogen in microbial cells. Algae are abundant in lipids and numerous vitamins such as A, B, C, D, and E. Antioxidant carotenoid pigments are found in *Bacillus* species. β -carotene, tocopherols, and B vitamins are all found in algae. B vitamins are also found in yeast; however filamentous fungi have a low vitamin concentration (Bharti *et al.*, 2014).

Table: Average Composition of the Main Group of Microorganisms (% dry weight)

Nutrients	Fungi	Algae	Yeast	Bacteria
Protein	30-45	40-60	45-55	50-65
Fat	2-8	7-20	2-6	1.5-3

Ash	9-14	8-10	5-9.5	3-7
Nucleic acid	7-10	3-8	6-12	8-12

Source: Miller and Litsky (1976)

Production Processes

The purpose of SCP production is to maximize cellular development and co-product yields in cost-effective ways, and the feedstock has a notable impact on the costs.

Table: SCP production processes

Cultivation Operation	Growth modality	Capital & operational considerations	Emerging commercial examples
Aerobic Bioreactor	Heterotrophs Mixotrophs	<ul style="list-style-type: none"> • High cell mass yield • High capital costs • High energy consumption • Sterile operation • Significant installed industrial capacity 	<ul style="list-style-type: none"> • Methanol, glycerol or ethanol – KnipBio • Glucose – Veramis • Cellulose – Arbiom & Menon
Anaerobic Bioreactor	Heterotrophs Mixotrophs	<ul style="list-style-type: none"> • Low cell mass yield • Low capital costs • Low energy consumption • Requires metabolite production and valorization 	<ul style="list-style-type: none"> • Glucose or glycerol – White Dog Labs • Yeast separation – Fluid Quip Technologies & ICM

		<ul style="list-style-type: none"> • Non-sterile operation • Most installed industrial capacity 	
Gas Bioreactor	Methylotrophs Chemoautotrophs Mixotrophs	<ul style="list-style-type: none"> • Variable cell mass yield • High capital costs • High energy consumption • Could require metabolite production and valorization • Sterile & non-sterile operation • Limited installed industrial capacity 	<ul style="list-style-type: none"> • Methane – Calysta, Unibio, & String Bio • CO₂, H₂ & O₂ – Kiverdi, NovoNutrients & Solar Foods • CO₂ & H₂ – LanzaTech • Glucose & syngas – White Dog Labs • CO₂ & light – BioProcess Algae & Pond Technologies
Photosynthetic Bioreactor	Photoautotrophs Mixotrophs	<ul style="list-style-type: none"> • High cell mass yield • High capital costs • High energy consumption • Sterile operation • No known installed industrial capacity 	<ul style="list-style-type: none"> • Brewing by-products – iCell Sustainable Nutrition • Open photosynthetic system – Cellana
Open Cultivation Systems	Photoautotrophs Heterotrophs Mixotrophs	<ul style="list-style-type: none"> • Variable cell mass yield • Low capital costs 	

		<ul style="list-style-type: none"> • Low energy consumption • Non-sterile operation • Limited installed industrial capacity 	
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Source: Jones *et al.*, 2020

Advantages of SCP production

Single Cell Proteins are becoming increasingly popular as a result of their ability to grow on a little area of land while also helping in waste recycling (Hojaosadati *et al.*, 2000).

1. To begin with, it is a potential industry because the raw ingredients are free, or can be purchased at a low cost, but the products to sell are quite expensive. Not only that, it contributes to the reduction of pollution and the promotion of recycling.
2. It is rich in protein and low in fat. SCP organisms grow quicker and produce huge quantities of SCP from a limited amount of land and time. Genetic engineering allows the scientist to change the amino acid components of SCP.

Disadvantages of Single Cell Protein

There are certain drawbacks to use microorganisms or microbial biomass as a dietary supplement or as a single cell protein.

1. Many different types of microbes release substances that are hazardous to both humans and animals. As a result, it must be ensured that the microbial biomass produced does not contain any of these toxic elements.
2. When used as a dietary supplement, microbial biomass can cause indigestion and allergic reactions in humans.
3. Many kinds of microbial biomass have a high nucleic acid content, which can cause poor digestion, gastrointestinal problems, and skin reactions in humans.
4. Single cell protein production is an extremely expensive technique since it requires a high level of sterility control in the manufacturing unit or laboratory.
5. Single cell protein produced as animal feed on agricultural wastes will benefit developing nations' economies in the future.



Further research and development will ensure that microbial biomass is used in developing countries as a single cell protein or as a diet supplement.

Importance of Single Cell Protein in Aquaculture

SCP acts as an immunostimulant and probiotic that significantly improves the growth, health, disease resistance, and immune system of cultured organisms, in addition to serving as an alternative protein source for aquafeeds. One of the most effective ways to control disease recurrence in intensive aquaculture is to use probiotics (Ige, 2013). *Lactobacillus* (gram-positive bacteria) as a probiotic has proven a viable alternative to antibiotics in aquaculture disease management (Kolndadacha *et al.* 2011).

Single-cell proteins from bacteria and yeast contain a significant amount of nucleic acid in the form of RNA. Microorganisms' increased amounts of RNA allow rapid protein synthesis (Adedayo *et al.* 2011). Rapid protein synthesis and rapid multiplication times are important characteristics in single-cell organisms with high protein content. Aquafeeds with a high nucleotide content increase hepatic function and lipid metabolism in fish.

Because these compounds can be used as nutrition sources by bacteria, single-cell protein synthesis recycles waste from agriculture and industry. SCP can also recycle feed-derived wastes and ammonia released by cultured organisms.

Fish size and colour are essential aspects in the success of ornamental fish aquaculture. Both can be modified by using SCP produced from algae and bacteria, which have high levels of carotenoid pigments. Microbial carotenoids can be used as a feed addition to promote ornamental fish growth and Colour.

Conclusion

Single-cell protein is an important alternative protein source that reduces input costs by utilizing naturally occurring microorganisms in aquaculture systems or other waste substrates that act as nutrition sources for growing microorganisms. Single-cell protein has a high nutritional value, promoting the growth and survival of cultured organisms through improving immune response and disease resistance. Single-cell protein can be a source of β -carotene, which can be used to improve the colour of ornamental fish. The use of SCP promotes one of the best and most convenient methods for producing low-risk, high-health-

benefit organic food. Thus, the use of SCP in aquaculture increases production while being economically and environmentally viable.

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