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Production of Single Cell Protein by the fermentation biotechnology for Animal Feeding

Keywords: Kwashiorkor, single cell protein, food by-products, animal feeding, fermentation, biotechnology

1. SUMMARY

Background: **Fermentation is a sort of biotechnology that uses microorganisms to produce animal food through chemical process. In ancient times, wastes were treated with chemicals, but now companies convert wastes to valuable food, food ingredients or feed products such as single cell oils or single cell protein. The most used substrate is molasses and corn steep liquor which is a part of the fermentation process.**

Aim: **The aims of the manuscript is to provide an overview of the yeast strains and food by-products used in production of single cell proteins by fermentation process. Furthermore, the manuscript summarizes the role of single cell protein in animal feed.**

Methods: **Electronic searches were conducted on Google Scholar database Medline and PubMed. A further search was conducted on the Food and agricultural organisation FAO research article database.**

Results: **Single cell protein produced by these substrates and different microorganisms (algae, yeast, bacteria) play an important role in animal feeding. Furthermore, SCP is a high-quality protein, unsaturated fatty acids, vitamins and minerals sources for animals.**

Conclusion: **Production of single cell of protein through the fermentation has several significant benefits including sustainability, health and production efficacy.**

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2. Introduction

In ancient times, wastes were treated by various chemicals, but this method wasn't the best. As the worldwide population grows, over recent decades, both animal and dairy production have been increasing steadily. The world now produces more than 350 million tonnes of animal-derived protein, and this value will rise up to around 1250 million tonnes by 2050, to meet global demand for animal-based protein **[1]**. Now, a lot of company convert various wastes into useful food, food ingredients or feed products for human nutrition and animal feeding. These products are also environment friendly and healthy such as biogas, biofuels, bioenergy. Therefore, different methods and techniques are providing opportunity to develop these products as single cell oils, single cell protein, chemicals, enzymes and many others.

Following the carbohydrate and fat, protein is the major macronutrient, which the body requires in large amount. It is an essential factor for growth, repair of the body and maintenance of health. All of the proteins are made up of the 20 amino acids, and they determine the nutrition values of protein. Some of amino acids cannot be synthesized by humans but are still essential (valine, leucine, isoleucine, phenylalanine, tryptophan, lysine, histidine, methionine and threonine) and must be obtained from our diet. The general structure of amino acids is shown in the ***Figure 1***.

Protein digestion begins in the stomach and continues in the lumen of the intestine and so the proteins are degraded into mono and di amino acids. Those amino acids are absorbed by specific transporters in the intestines, and then released into the blood for use by other tissues, that are considered as the fundamental building blocks of proteins in the body, and they serve as the nitrogenous backbones for compounds like neurotransmitters, enzymes and hormones **[2, 3]**. Although, both the plant and animal proteins are similar in components, both contain the nearly the same amino acids, but the animal protein contains all the essential amino acids **[4]**.

In general, the human body needs between 1.0 g to 1.5g of protein for each kilogram of weigh in children and adults respectively **[5].** If there is insufficient protein in diet chronically that could cause kwashiorkor disease, which is a severe form of malnutrition **[6].**

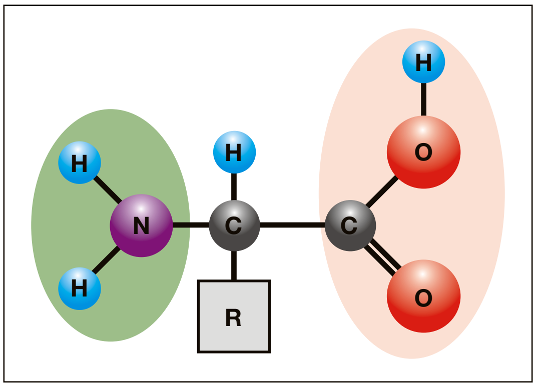

Figure 1. General formula for an amino acid:
amino group (-NH_2), carboxyl group (-COOH) and replaceable group (-R) ***[7]***

Single cell protein (SCP) is one of the high qualities and valuable dietary products from wastes **[8, 9, 10, 11, 12]**. SCP is a biomass which is produced by different microorganisms and it can also be termed as bio-protein, microbial protein or biomass. These microorganisms can be used as protein-rich ingredients in human and animal diet as well **[8]**. Furthermore, the SCP can be a good alternative to plant protein sources, and it can be produced throughout the year. In addition, they don't emit greenhouse gases. The most important thing is the selection of cheap and suitable substrates or agro-industrial by-products and valuable microorganisms to produce protein and reduce the production cost of single cell proteins **[8, 13, 14, 15, 16, 17]**. In order to achieve this, different substrates were used as apple pomace, yam peels, citrus pulp, potato peels, pineapple waste, papaya waste **[8].** However, the most used by-products are molasses and corn steep liquor. It is also important to choose microorganisms for research and industrial purpose as well.

This manuscript focuses on single cell proteins produced by microorganisms (algae, yeast, bacteria) as an alternative protein source. Due to the favorable content values of the single cell protein produced by fermentation (protein, vitamin, mineral), it can be used in digestible form for human nutrition, especially with vitamin supplementation and this contributes to the protection and treatment of malnutrition as a functional food and functional food ingredient **[10].**

3. Material and method

Electronic searches were conducted on Google Scholar database, Medline and PubMed. A further search was conducted on internet. The search items included, nutrition, dietary, protein, single cell protein, immune system. This review was conducted to analyse the recent literature to show the impact of nutrition, and single cell protein on the dietary system.

4. Result

4.1. Single cell protein produced by fermentation

Single cell protein (SCP) is a protein from cultivated microbial biomass and it can be used for protein supplementation. The SCP fermentation process can be seen in ***Figure 2***. Agricultural and industrial wastes used as substrate to yield SCP. Algae, fungi and bacteria are all the main sources of microbial protein that can be utilized as SCP (***Table 1***) **[18]**. In addition, the acceptability of species as food depends on the growth rate, substrate used, contamination, associated toxins. The produced biomass is rich in proteins, amino acids as lysine and methionine, unsaturated fatty acids, vitamins and minerals. Therefore, these are used as food, food supplements **[18]** and animal feed in the world.

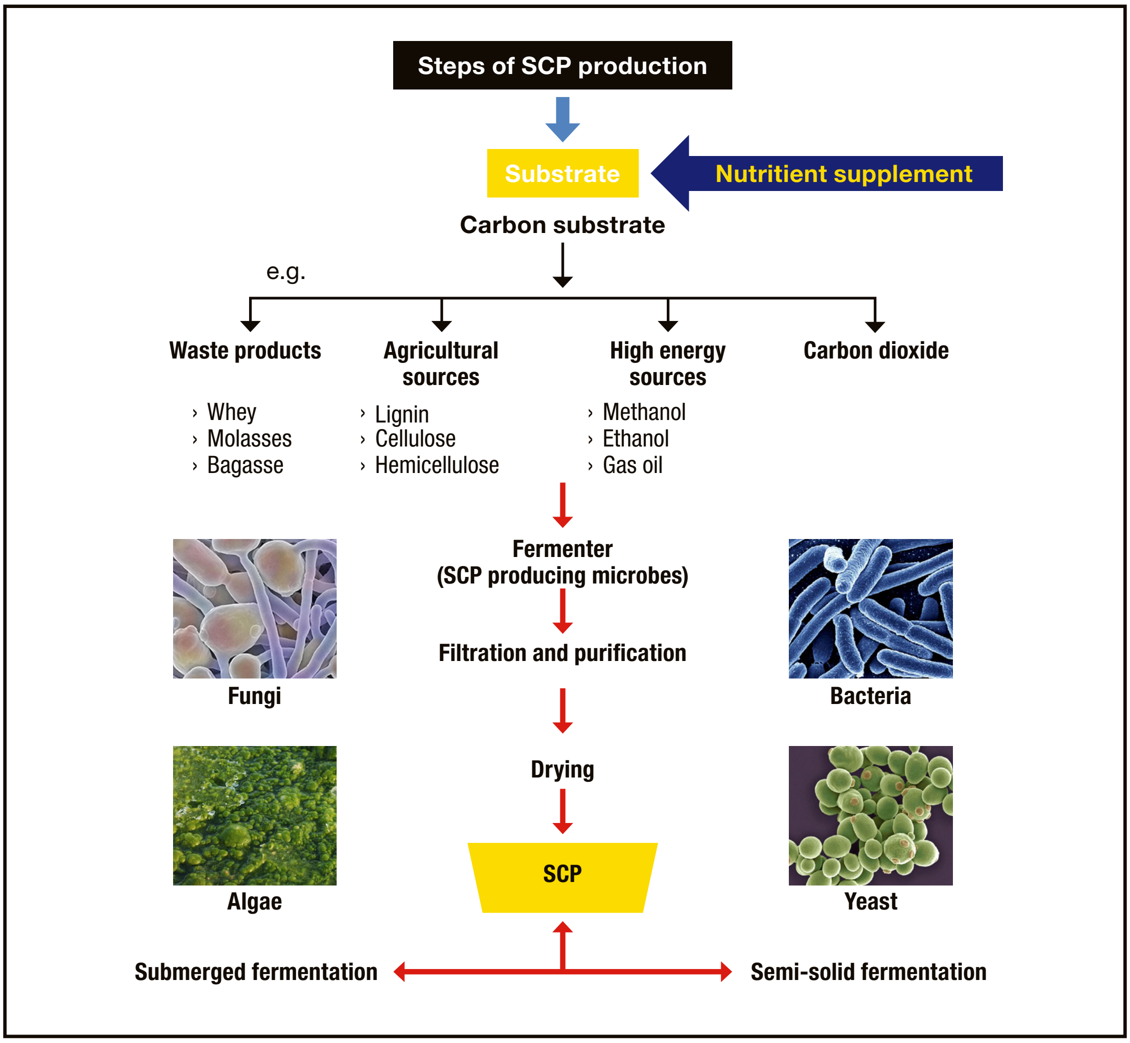

*Figure 2. Producing single cell protein by fermentation technology (Modified scheme **[8]**)*

Table 1. Single cell protein (biomass) production from microorganisms and different substrates

Microorganisms	***Substrate***	***References***
Trichosporon cutaneum LOCK 0254 Candida tropicalis LOCK 0007 Pichia stipitis LOCK 0047 Candida guilliermondii ATCC 6260 Saccharomyces cerevisiae LOCK 0132	Sugar beet pulp	**[19]**
Candida utilis	Molasses	**[20]**
Kluyveromyces fragilis	Fructose medium	**[21]**
Spirulina platensis	Beet vinasse	**[22]**
Saccharomyces cerevisiae KV-25	Molasses Corn steep liquor	**[23]**
Aphanothece microscopica Nägeli	Parboiled rice	**[24]**
Candida utilis	Rice	**[25]**
Kluyveromyces marxianus *Candida crusei*	Whey	**[26]**
Aspergillus niger *Trichoderma viride*	Lemon pulps	**[27]**
Saccharomyces cerevisiae	Virgin grape marc	**[28]**
Phaffia rhodozyma	Raw sugarcane juice Depolymerized bagasse	**[29]**

4.2. Use of food by-products for the production of biomass, in particular molasses and corn steep liquor

Food loss and waste reduction is an important way to reduce costs of production, increase the food system capacity and is also a way to join the environmental sustainability campaign. Food waste also contains several biodegradable components for pathogenic microorganisms that can cause communicable diseases. Thus, food loss and waste reductions also have a positive effect on the well-being and health of the consumers. Therefore, the European Union (EU) is promoting the reduction of food wastes and these food by-products from vegetables, fruits, beverages, sugar, meat, aquaculture and seafood also contain functional or bioactive components. The food by-products can be used in nutraceutical or pharmaceutical industries. These can be transformed by fermentation biotechnology into animal feed products **[30]**. One of the most used food by-products are molasses and corn steep liquor. Molasses (M) is a by-product of sugar cane and it contains several compounds for fermentation for example vitamins, minerals, sucrose and organic compounds. In addition, corn steep liquor (CSL) is a by-product of the corn wet milling industry and it is rich in several components such as vitamins, minerals, amino acids and proteins. Furthermore, the CSL is also an important source of nitrogen **[31].** The used molasses and corn steep liquor as a substrate in the fermentation process can be seen in ***Table 2***

Table 2. Summary of literature references of the beneficial effects of molasses and corn steep liquor

Substrate	***The topic of the publications***	***References***
Molasses	Characterization of molasses chemical composition	**[32]**
Molasses	Effect of molasses on the fermentation characteristics of mixed silage	**[33]**
Molasses	Molasses as by-product and raw material	**[34]**
Molasses	The water footprint assessment of ethanol production from molasses	**[35]**
Molasses	Effect of molasses products on productivity and milk fatty acid profile of cows	**[36]**
Corn steep liquor	Antidiabetic activity of corn steep liquor	**[37]**
Corn steep liquor	Effect of corn steep liquor of fresh rice straw silage	**[38]**
Corn steep liquor	Examination of corn dried steep liquor concentrate	**[39]**
Corn steep liquor	Studies of CSL in nutrition of lactic acid bacteria	**[40]**
Corn steep liquor	Microbiological assay of corn steep liquor	**[41]**

4.3. Role of single cell protein produced by fermentation in animal feeding

The high quality and high protein rich human food and animal feed important to increase with the global population grows. Single cell protein (SCP) products based on microbial biomass, have a potential ingredient to this need **[42].** The SCP contains high quality omega-3 fatty acids, vitamins, micronutrients, protein and other useful component for animal body. These valuable components can be seen in ***Table 3***.

*Table 3. Valuable components in single cell protein from different microorganisms **[42]***

SCP sources	***Protein content range***	***Special characteristics***	***Example of specific organisms***
Microalgae	60-70 %	Production of omega-3 fatty acids	*Chlorella vulgaris*
Yeasts	30-50 %	Production of vitamins and micronutrients	*Saccharomyces cerevisiae*
Bacteria	50-80 %	High protein content	*Methylococcus capsulatus*
Protists	10-20 %	Production of omega-3 fatty acids	*Schizochytrium limacinum*

Single cell proteins in animal feed supplement protein requirements well in addition to conventional feeds. This can also affect the quality of products of animal origin. The role of single cell proteins in animal feed is confirmed by several manuscripts, which are shown in ***Table 4***.

Table 4. The role of single cell proteins in animal feed

The tested animal	***Positive effect of single cell protein on the animal***	***References***
Largemouth bass (*Micropterus salmoides*)	Improved weight gain of Atlantic salmon	**[43]**
Cows	The positive effect during lactation is acceptable as part of a completely mixed ration	**[44]**
Broiler chicks	Improving feed consumption and weight gains	**[45]**
Norwegian Red cows	The microbial protein sources (*C. utilis*) has a positive effect of good quality of cheese	**[46]**
Abalone	The single cell protein increases the growth of abalone	**[47]**

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