Iowa Science Teachers Journal

Volume 19 | Number 2 Article 13

1982

Single Cell Protein: The Future Food

D. O. Hitzman
Phillips Petroleum Company

SINGLE CELL PROTEIN — THE FUTURE FOOD

Dr. D.O. Hitzman
Research Center
Phillips Petroleum Company
Bartlesville, Oklahoma 74004

The population of the world is now over 4 billion, with approximately two-thirds of this population being in regions characterized as being underdeveloped. Today there are 200,000 more people than there were yesterday, with about 10,000 persons estimated as dying each week from lack of food. By the year 2000, it is estimated that 6 to 7 billion persons will live in the world. Current global surveys measuring food supply per person indicate severe undernutrition (too few calories) and an unbalanced diet (too little protein). The most critical single shortage in the world food supply is protein, vital to the human diet. Many nations cannot produce or import enough for their minimum needs. Others face serious shortages and prohibitive costs. Today, millions suffer protein malnutrition. Tomorrow, as populations continue to rise, the problem will grow far worse unless new protein sources emerge. Single cell protein (SCP) is a new food source that will help alleviate this protein deficiency.

Proteins are made up of about 20 amino acids, of which eight are essential for human life. These essential acids cannot be synthesized by our bodies and must be ingested. The body can only use these essential amino acids to the extent of the one that is there in the smallest amount. It is like a chain in which the chain is only as strong as its weakest link. All proteins are rated by comparison to a standard and are given a protein score which reflects the concentration of the limiting amino acid. The protein is only as good as this limiting amino acid. SCP has a high protein score and would complement many other foods such as the cereals, which are limited in some essential amino acids. Different types of SCP may have different amino acid compositions. Thus, while the composition of grains and animals cannot be easily altered, the range and opportunity to select different enriching SCP to complement and improve other foods is possible.

SCP is a giant stride forward in simplifying and improving the efficiency of the protein food chain. Grains and cereals fed to animals convert to meat on the table at extremely low efficiencies. SCP converts at greater magnitudes. A cow weighing 1,000 pounds creates perhaps one pound of effective protein per day. In contrast, 1,000 pounds of cells can grow to 100,000 pounds of protein in a day. By using SCP instead of grain in animal feeds (later, SCP will play a role in direct human consumption) there will be an important "domino effect." By such means vast amounts of grain and legumes now fed to animals would be released for direct human use.

SCP refers to many microorganisms rich in protein that can be grown rapidly when fed various nutritive substrates. The final SCP products are the whole or extracted parts of yeast or bacteria cells. Besides protein the cells contain other valuable nutrients: carbohydrates, fats, vitamins, minerals and growth factors — all important in a balanced diet. Similar-type yeasts and bacteria are now being consumed in foods such as bakers' yeast, yogurt, cheeses, etc.

SCP is made by continuous fermentation, a process in which the optimum microorganism grows on a selected substrate of minerals (potassium, phosphorus, calcium, magnesium) and trace elements (manganese, copper, zinc, iron, etc.). For some organisms, the addition of trace amounts of growth factors such as vitamins may also be required. A wide range of substrates can be selected for microbial growth. Some of the substrates currently used are sugars, molasses, whey, etc. However the idea of using non-food substrates to make a food product is what makes the new generation of SCP products most intriguing and versatile. Examples of such non-food substrates which are being used are n-paraffins, gas oil, or hydrocarbon gases such as methane. Currently one of the most interesting substrates for SCP production are alcohols, such as methanol and ethanol, derived from hydrocarbons.

Many bacteria and yeasts have been discovered that can use such alcohols for growth. In this process the culture is inoculated into the fermenter where it multiplies at a rapid rate. For bacteria, doubling times of one to two hours are reasonable, while yeast requires about twice this time for one cell to become two, thus essentially doubling their number and weight. Since two thus become four within the same time interval, the process has enormous potential for growth. Once high-cell numbers are achieved the continuous addition and withdrawal of nutrient solution is begun in which the same number of cells are withdrawn at each time interval as are produced during that time interval. A steady state condition of continuous propagation of cells is thus maintained with the volume of the fermenter remaining constant. Thus, once inoculated, no further cells need be added. Product, the cells themselves, is harvested continuously as long as fresh nutrient is supplied. The system must be agitated continuously since the cells require a great deal of oxygen to reproduce. In larger fermenters the oxidation of these substrates by the cells release heat (exothermic reaction) which requires that the fermenters be cooled to maintain a constant temperature (for yeasts about 30°C; for bacteria about 40°C). The basic process involves the continuous addition of feed medium to the fermenter; the recovery of the cell product by separation, washing and pasteurization to kill the cells; and the drying of the product as shown in Figure 1.

The cells are washed to remove any residual nutrient solution and to produce a pure product. Since the purity of the final product is important, the substrate must be pure and any residual that could be present must be removed. The use of alcohols is particularly favored in this

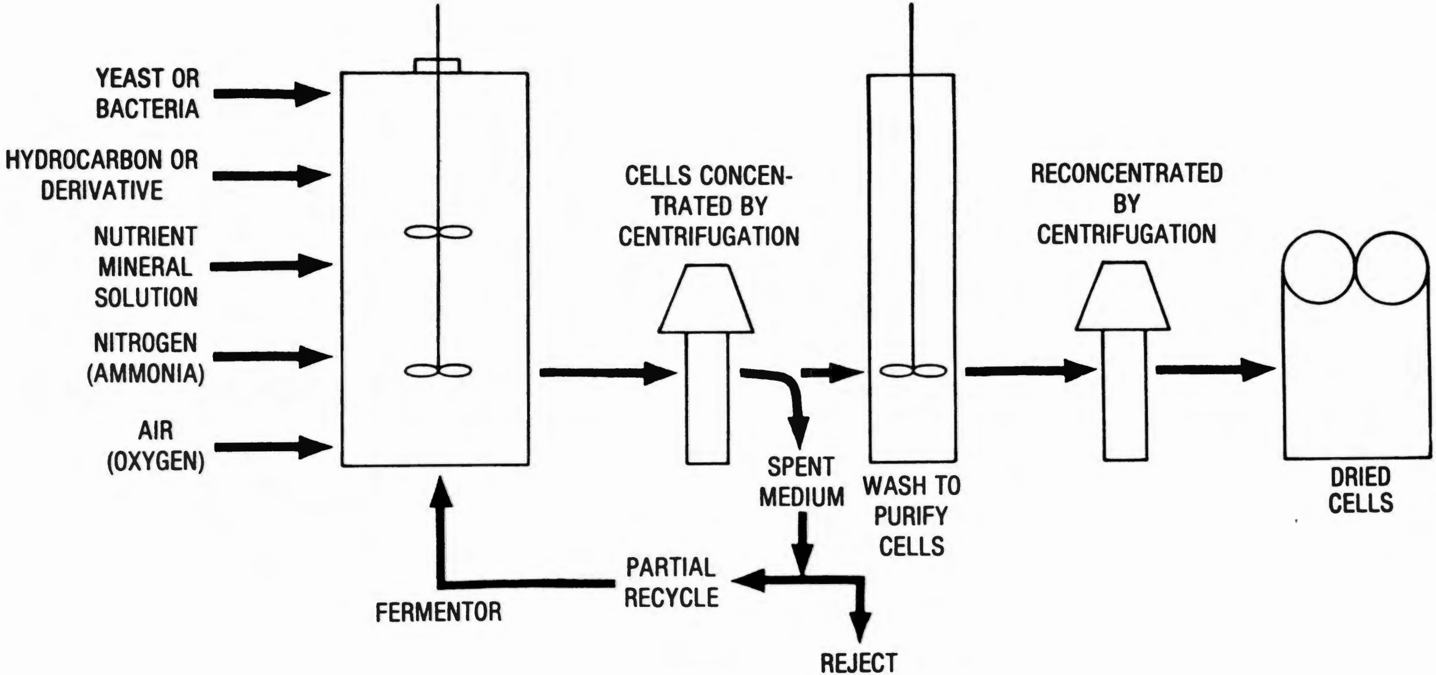

Fig. 1. The process of producing cellular protein.

regard since the alcohol is totally consumed during fermentation or, being water soluble, is removed during washing and drying. The product so treated consists only of the cells themselves and is a dry free-flowing powder that is usually white or tan in color and has the appearance of flour. It is relatively odorless with little or no taste and consists of about 50 to 55 percent protein in the case of yeast and about 70 to 75 percent protein with bacteria. The dry powder as recovered would not be consumed in this concentrated form but would be added in small amounts (5 to 25 percent) to feeds or foods low in protein.

The magnitude and timing of SCP on the world protein supply — at first mainly in animal feeds, later increasingly in human foods — cannot be accurately predicted because of many influencing factors. Governments working together could elect to create economic incentives that would stimulate early large scale commercialization. New technologies that produce SCP efficiently and rapidly using hydrocarbon derivatives can do so utilizing only a small fraction of the world petroleum reserves. What could be a better utilization of such petroleum products than the direct production of food for the hungry? However SCP is not a panacea that by virtue of its greater efficiency will displace conventional agriculture and animal sources of protein. Instead SCP will only add to and supplement such much needed conventional food production. Improvement of the old ways and adoption of the new SCP will go hand in hand, complementing each other, thereby better serving mankind in its urgent quest for protein.

Instructional Implications

The study of SCP is essentially a study of enormous cell populations and rapid growth rates under controlled conditions. Using the following information there are a number of questions that can be posed and studied that show the potential for producing this novel new food. It is instructive to make the calculations and compare to the given answer.

Bacteria are usually very small, a common value being about 1/50,000 inch in diameter (0.6 microns) and weighing about 4×10^{-12}, or four ten-trillionths of one gram. In spite of their small size bacteria can double in number as often as every 20 minutes.

If these bacteria cells double every hour, and assuming the original number (inouclum) was 1×10^{6} cells per liter in the fermenter, how many cells would be present after 24 hours in a volume of 50,000 liters? (Answer: 8.4×10^{17} cells) If the cell concentration was maintained at this concentration level by new feed being added at the rate of 10,000 liters per hour, and an equal volume was removed to keep the volume constant, how many pounds of SCP could be produced daily? (Answer: 35,524#/day)

By considering the ramifications of such values concerning fermentations and populations, other questions can be raised that could be pursued in further studies.

Suggested References

1. Tannenbaum, S.R. and Wang, D.I.C. 1975. Single Cell Protein The MIT Press, Cambridge, Mass. 707 pp.
2. Watts, H. 1976. Single Cell Protein: A New Source of Food from Hydrocarbon Fermentation. *Chemistry and Industry 13* (London July 3) 537-540.
3. U.S. Department of Agriculture 1974. The World Food Situation and Prospects to 1985. *Foreign Agriculture Economic Report No. 98*. U.S. Government Printing Office, Washington, D.C.
4. Food: Economics, Politics, and Social Structure. 1975. *Science*, 188 (4188) 503-650.
5. Malick, E.A., Hitzman, D.O., Wegner, E.H., Case, N.L. and Hawkins, H.M. Single Cell Protein: Its Status and Future Implications in World Food Supply. A Phillips Petroleum Company presentation at Second Arab Conference on Petrochemicals in Abu Dhabi, March 15-22, 1976.

***

Metric Poster Series Available for Testing

NSTA has developed a series of six posters which will be distributed as centerfolds in *The Science Teacher* magazine. The poster series is a product of the NSTA's International System of Units Material Development Project, which is funded by the United States Department of Education. The major objective of the project is to offer teachers and students materials which will enhance the understanding of six derived units and their use in common scientific applications. There is a poster and background information on each of the following SI derived units: pascal (Pa), joule (J), watt (W), newton (N), volt (V), and hertz (Hz). These posters are now ready for field testing. If you would be willing to test these materials with your classes and provide feedback to the project staff, you may write to: Helenmarie Hofman, Project Director, 1742 Connecticut Avenue, N.W., Washington, D.C. 20009.