Microbial Biomass Proteins

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MICROBIAL BIOMASS PROTEINS

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MICROBIAL BIOMASS PROTEINS

PREFACE

This publication on 'microbial biomass proteins' (MBP) is the result of significant renewed interest in the subject matter. The title is chosen in an attempt to redress the historical anomaly whereby the term 'single cell proteins' (SCP), originally proposed in 1967 for these types of products, is no longer valid. Recent events have shown that the mass cultivation of multi-cellular fungi in addition to single-celled bacteria and yeasts is of commercial interest for the protein content of these microorganisms as animal and human food ingredients. Notable among these events is the introduction in 1985 of a fungal MBP product, 'mycoprotein', sold commercially for human consumption in England.

Microbial biomass proteins are potentially useful in supplementing the need for protein in animal and human nutrition. In addition, the production of MBP from waste residues and surplus raw materials could provide economic control of some forms of environmental pollution resulting from various industrial and agricultural operations and, concurrently, alleviate some of the global malnutrition and hunger problems. Governments and commercial enterprises are interested in all aspects of these potentials which could have far-reaching socio-economic benefits worldwide.

How safe are MBP products? What are their nutritional values? Are they economical to produce? How are government regulatory bodies involved in their commercialization? What are the market opportunities? These and other questions about MBP products are addressed in this book by some of the world's foremost experts in the field, including contributions from representatives of both developed and developing countries. The book is aimed at students, researchers and policy-makers in industry, government and academia who are interested in the resolution of problems in MBP commercialization.

The material, which ranges from basic scientific principles to practical engineering design and economic considerations, is treated in two sections:

Process Development and Economic Factors, and Product Safety and Nutritional Factors. Both these factors are crucial to the eventual commercial success of an MBP process as exemplified by the story of mycoprotein discussed in this work. This story marks a milestone in the history of the food industry which has been traditionally a very conservative one. In addition, this story draws attention to the importance of process engineering criteria; especially noteworthy is that a so-called toxigenic organism is 'controlled' in a continuous process to produce a safe, non-toxic, food-grade product. It is interesting to note that there are over one hundred MBP plants currently in operation in Eastern European countries, especially the USSR, and only a relatively few elsewhere.

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CONTENTS

Preface v

List of Contributors xi

Section 1: Process Development and Economic Factors

Technical, economic and market strategies for microbial biomass proteins. 1
J. H. LITCHFIELD

RayPro: a case history of single cell protein development . . 11
J. F. NOBILE

Microbial proteins and regulatory clearance for RHM mycoprotein 19
G. L. SOLOMONS

The Provesteen process—an ultra-high density fermentation . 27
D. O. HITZMAN

Microbial biomass protein grown on edible substrates: the indigenous fermented foods 33
K. H. STEINKRAUS

Techno-economic evaluations of various substrates for SCP production: a case study for Mexico 47
M. DE LA TORRE-LOUIS and L. B. FLORES COTERA

Economics of SCP based on lignocellulosic wastes: a case study for Canada 61
N. KOSARIC and P. C. BELL

Sexual cycle induction in the white rot fungus *Sporotrichum pulverulentum* 73
M. RAICES and O. R. CONTRERAS

Enzyme activities during *Pleurotus ostreatus* growth on wheat straw under controlled conditions. 79
G. GIOVANNOZZI SERMANNI, M. LUNA, M. FELICI, F. ARTEMI and M. BADIANI

Section 2: Product Safety and Nutritional Factors

Regulatory aspects of microbial biomass proteins as feed ingredients 93
S. K. HO

Evaluating the safety and nutritional value of microbial biomass. 97
J. N. UDALL and N. S. SCRIMSHAW

Genetic aspects and the possible hazard of mycotoxins in fungal products 103
J. D. BU'LOCK

Nutritional evaluation of inactive dried food yeast products . 107
G. SARWAR, R. W. PEACE and H. G. BOTTING

Thermophilic and thermotolerant fungi for industrial applications: mycology aspects 117
S. UDAGAWA, S. SEKITA and S. NATORI

Thermophilic and thermotolerant fungi for industrial applications: chemical aspects of mycotoxins 127
S. SEKITA, S. NATORI and S. UDAGAWA

Algal biomass production from wastewaters and swine manure: nutritional and safety aspects 141
J. DE LA NOUE, D. PROULX, R. GUAY, Y. POULIOT and J. TURCOTTE

Nutritive value of methane fermentation residue produced from cattle and swine wastes 167
D. N. MOWAT, C. R. JONES, J. G. BUCHANAN-SMITH and G. K. MACLEOD

Chaetomium cellulolyticum microbial biomass protein evaluation with rats, chicks and piglets 175
S. P. TOUCHBURN, E. R. CHAVEZ and M. MOO-YOUNG

TECHNICAL ECONOMIC AND MARKET STRATEGIES FOR MICROBIAL BIOMASS PROTEINS

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INTRODUCTION

What are the important technical, economic and market considerations in developing microbial biomass protein (MBP) products? To answer this question, we will discuss applications of MBP process factors including raw materials, product utility for food or feed applications, markets, economic and regulatory considerations, which are common to MBP products, from both photosynthetic and nonphotosynthetic micro-organisms although emphasis will be placed on nonphotosynthetic processes. Details on specific processes are covered in recent reviews (Batt and Sinskey, 1984; Litchfield, 1983a, b, 1984; Tanaka and Matsuno, 1985) and in other papers presented at this meeting, (Ban and Glanser-Soljan, 1985; Graille et al., 1985; Guiraud and Galzy, 1985; Moo-Young, et al., 1985, Nobile, 1985).

APPLICATIONS OF MBP

Table 1 summarizes MBP product values starting from raw materials and ranging from the primary product, microbial cells, to a variety of added value products. For the purpose of this discussion, we will consider food or feed uses of MBP. In the case of food, the products can be based directly on MBP or can be processed further to improve acceptability. The term "acceptability" includes sensory, nutritional, functional and safety aspects of the product in either human food or animal feed applications. Further processing includes texturization by addition of functional food additives, spinning into fibers, or extrusion, blending with flavorants, making protein concentrates and isolates by disrupting cells, removing cell walls and nucleic acids, or by preparing autolysates or hydrolysates to yield peptides and amino acids. MBP products designed for feed applications can be used to replace protein ingredients such as oil seeds or fish meal or as an additive to other plant or animal protein ingredients. We shall consider the performance of MBP in animal feeds subsequently

in this paper.

TABLE 1: Microbial biomass product values

Raw Materials	Primary Products	Added Value Products
Carbohydrate (Sugars, Starch, Cellulose Hemicellulose)	Dried Microbial Cells	Microbial Protein Concentrates
		Microbial Protein Isolates
Alcohols (Methanol, Ethanol)		Nucleic Acids
		Amino Acids
		Pigments
		Vitamins
		Polysaccharides
		Lipids and Steroids
		Enzymes

It is important to make a decision on the desired product application at the outset of the development program. In the United States, facilities for manufacturing food-grade MBP products must operate under the Food and Drug Administration's Good Manufacturing Practices regulations and the products must meet FDA requirements for safety. Similar conditions apply in most countries. Feed grade MBP products can be manufactured under less stringent conditions than food products, but must meet regulatory agency requirements for safety including freedom from microbial or plant toxins, heavy metals and toxic chemical residues. (Food and Drug Administration, 1984).

PROCESS CONSIDERATIONS

The major steps in typical MBP processes based on nonphotosynthetic microorganisms are: raw materials, treatment, bioreactor, product separation, and product purification. I shall discuss these steps from the standpoint of their impact on process economics.

Raw Materials

Raw materials requirements for MBP production are governed by the requirements for growth and product formation which usually include: carbon and an energy source, a nitrogen source, O_2, minerals and supplementary nutrients. At the Symposium on Biomass Conversion Technology held at the University of Waterloo in 1984, I presented some of the considerations in selecting raw materials for MBP production including availability, composition and physical characteristics, performance and costs(Litchfield, 1984).

Here, I shall emphasize the raw materials for MBP processes based on nonphotosynthetic micro-organisms. Table 2 shows materials requirements for selected classes of MBP processes based on bacteria, yeasts and fungi. Production media should be developed on the basis of cell composition. Haggstrom (1985) has shown that the elemental composition of typical growth media for bacterial cells reported in the literature often deviates widely from that of the cells themselves (Table 3).

TABLE 2: Materials requirements of microbial biomass protein processes

Material (Metric tons)	Quantity/Metric ton of MBP			
	n-Paraffins Yeast	Methanol Bacteria	Ethanol Yeast	Carbohydrate Yeast, Fungi
Carbon and Energy Source	0.87-1.05	2.0	1.4	2.00
Ammonia	0.14	0.13-0.16	0.09	0.09
Phosphoric acid (100% Basis)	0.05-0.08	0.095	0.05	0.06
Mineral Nutrients (Fe, K, Mg, Mn, Zn)	0.02	0.03	0.03	0.03

The values for carbohydrates given in Table 2 are based on the assumption that the carbohydrate supplied is in a form that is assimilated by the growing cells. Tanaka and Matsuno (1985) discuss pretreatment of lignocellulosic materials to make them suitable for MBP production. It is clear that only a portion of such substrates can be converted to utilizable form and amounts of these raw materials required per unit weight of MBP are considerably greater than that shown in Table 2.

Table 4 shows that prices for selected carbohydrate substrates for MBP production decreased markedly over the 1980-1985 period. As shown in Table 5, the price of anhydrous ammonia also decreased, but the price of 85 percent phosphoric acid increased over this same period. Current 1985 prices for ethanol and methanol (100 percent basis) are approximately $0.57/kg and 0.24/kg, respectively.

TABLE 3: Composition of bacterial cells and growth media

Elements	Cells	Media
N	100	100
P	23	176
K	14	201
S	8.9	59
Mg	4.9	15
Na	3.2	66
Ca	3.0	11
Cl	2.5	123
Fe	0.3	2.2
Zn	0.14	0.13
Cu	0.03	0.04
Mn	0.05	0.15
Co	0.003	0.02
Mo	0.002	0.09
B	0.006	0.01

Haggstrom, 1975

TABLE 4: Price trends for selected raw materials for microbial biomass production.

Raw Material	Price U.S. Dollars/kg 1980	1985
Glucose (Dextrose) Hydrate	0.64	0.53
Sucrose (Cane), raw		
U.S.	0.68	0.46
World	0.09	0.06
Molasses, Cane	0.18	0.07

TABLE 5: Price trends for supplemental nutrients for microbial biomass production.

Nutrients	Price U.S. Dollars/kg 1980	1985
Ammonia, Anhydrous	0.17	0.15
Phosphoric Acid 85%	0.52	0.74