METHODS IN INDUSTRIAL MICROBIOLOGY

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Table of contents

List of symbols

A	medium component
c	positive non-zero constant
D	dilution rate, h^{-1}
F	flow rate, $l\ h^{-1}$
K_s	saturation constant, $g\ l^{-1}$
m	specific maintenance rate, h^{-1}
N	number of cells in unit volume, l^{-1}
r_A	rate of formation of medium component A
S	concentration of limiting substrate
t	time, h
τ	doubling time, h
V	medium volume, l
X	cell mass concentration, $g\ l^{-1}$
Y	yield coefficient
μ	specific growth rate, h^{-1}

Indices

c	critical value
max	maximal value
n	n-th stage (continuous cultivation)
O	initial value

1 Introduction

Applied microbiology, which is also called industrial microbiology, microbial technology or fermentation processes, is a part of a broader field of science called biotechnology. Schmidt – Kastner (1978) defined biotechnology as production, isolation, modification and application of bioproducts from microorganisms, plants, animals, and humans on a technological scale. Applied microbiology is sometimes viewed as a discipline encompassing also food microbiology, microbiology of water and microbial corrosion.

Industrial microbiology entails in essence an understanding of four disciplines: microbiology, biochemistry, organic chemistry and engineering (Fig. 1.1). The closer individual disciplines interlace, the better is their

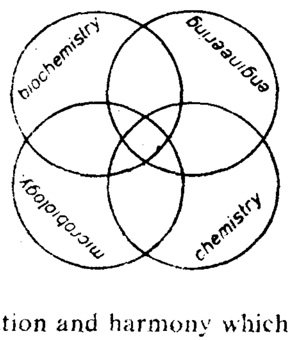

Fig. 1.1 Science branches involved in applied microbiology

cooperation and harmony which is of crucial importance for the solution of any challenging problem. In an ideal case the four circles representing the four disciplines merge into one.

Any group investigating microbial processes must comprise biologists and engineers, with the biologists as dominant partners. Consequently, in a process team comprising a microbiologist, biochemist, chemical, control and mechanical engineer, the first two have to formulate and carry out long-term planning whilst the third, fourth and fifth have to translate this into large-scale practice.

The history of microbial technology over the last fifty years has convincingly demonstrated this thesis. For example, due to Waksmann's basic microbiological work the organism *Rhizopus nigricans* was isolated in 1939 to produce fumaric acid. Subsequently he had to overcome chemical engineering problems such as continuous neutralisation of acid as soon as it was formed, sterilisation of mash, aeration and agitation during fermentation, and control of foaming. These were all practical problems which could only be solved after the microbiology and biochemistry had been successfully developed.

1.1 IMPORTANCE OF INDUSTRIAL MICROBIOLOGY

In industrially advanced countries microbial industry plays an important part in national economy, contributing several per cent to the overall gross national product. Table 1.1 lists products manufactured microbially and their applications. The summarized facts indicate clearly that applied microbiology is important in therapy of humans, animals and plants (pharmaceutical industry, manufacture of vaccines), in food industry, agriculture, procurement of new sources of raw materials and energy, protection of the environment, and in a number of other fields such as chemical, leather and tanning, pulp and paper and textile industries, ore and oil mining; others could be added to this list.

1.2 THEORETICAL BACKGROUND OF INDUSTRIAL MICROBIOLOGY

All branches of industrial microbiology have a common theoretical basis which considerably affects their development. The two main disciplines which determine the trends of industrial microbiology are theoretical microbiology (including microbial genetics, physiology and biochemistry) which forms the theoretical cornerstone, and microbial engineering which creates the basis for the application of engineering aspects in microbial processes.

Intensive development of theoretical microbiology has recently markedly affected applied microbiology as a whole. In its beginning this effect was hardly perceptible owing to the overwhelming traditions and long empirical history of major microbial processes. Among these, procedures such as brewing have been empirically brought to a high

Table 1.1

Application of microbial processes to products, by industry (Da Silva *et al.*, 1978)

Application processes of microbes	Application industry
Production of fermented foods Soya sauce, miso-paste, natto pickled vegetables, cheese, yoghurt, lactic acid (sour) drinks, dried bonite, etc.	Fermented food industry, livestock industry, fishery food industry
Production and utilisation of microbial cells Baker's yeast, food or fodder yeasts, nori (laver), chlorella and other algae, single-cell protein (CSP)	Food industry, fodder and feed industry
Utilisation of ribonucleic acid, protein and other cellular components	Food industry, bio-pharmaceutical industry, chemical industry
Utilisation of microbes for the preparation of microbial (bacterial, fungal, viral) insecticides and pesticides and for production of bio-fertilizers	Agricultural industry
Cultivation of microbes for preparation of vaccines, e.g. preparation of vaccines (poliovirus) by tissue culture	Medical industry
Brewing Sake, beer, wine, other fruit wines, white liquor, whisky, brandy, other spirits and distilled beverages	Brewing industry
Production of industrial solvents	
Industrial ethanol	Chemical industry
Additive ethanol	Brewing industry
Production of organic acidulants Citric, lactic, fumaric, itaconic acids, vinegar	Food and chemical industry
Production of macromolecular polysaccharides	

Table 1.1

continuation 1

Application processes of microbes	Application industry
Dextran, levan, xanthan, mannan, caragheenin	Food industry, mining industry
Production of antibiotics	
Penicillin, synthetic penicillins, streptomycin, kanamycin, bleomycin, actinomycins	Medical and pharmaceutical industry
Blasticidin S, kasugamycin	Agriculture, medical industry
Thiostrepton, thiopeptin	Feed industry
Production of physiologically active substances	
Vitamin B_2, B_6, B_{12}, C, ergot alkaloids, enzyme inhibitors; microbial transformation of steroids, sugars, alkaloids	Medical and bio-pharmaceutical industries
Gibberellins and other auxins (plant growth hormones)	Agro-medical industry
Production of amino acids	
Glutamic acid, glutamine, lysine, aspartic acid, arginine, ornithine, threonine, valine, tyrosine, phenylalanine, leucine, tryptophan, hydroxytryptophan	Food and feed industries, chemical industry
Production of mononucleotides and related compounds	
5′-inosinic acid, 5′-guanylic acid, 5-amino-4-imidazole-carboxyamide (AICA)-riboside, ATP, cyclic AMP	Food industry, medical industry
Production and utilization of enzymes	
Amylases, proteases, milk-clotting enzyme (rennin), lipase, cellulase, asparaginase, glucose isomerase, glucose oxidase, aspartase, melibiase, naringinase, and other insoluble enzymes	Brewing, food and fodder industries, fibre, leather and tanning industries, laundry and washing industries

Table 1.1

continuation 2

Application processes of microbes	Application industry
Penicillinase, glucose oxidase	Medical and chemical industries, medical therapy and diagnosis, chemical analyses
Treatment of sewage and industrial wastes and waste waters, disposal of waste matters, recovery and recycling of biodegradable utilizable wastes and waste waters	Conservation of natural environment
Bacterial leaching of ores, recovery of copper, uranium, zinc, manganese from mining and colliery wastes	Mining industry
Utilization of microbial probes for oil deposits	Petroleum industry
Utilization of bagasse (sugar cane residue), production of silage, utilization of nitrogen-fixing algae and rhizobia, amendment of peat-bogs	Feed and agricultural industries
Various fermentation products from hydrocarbons	

technological level, although they are based on a complex interaction of biochemical, enzymic and chemical processes. This development of a purely empirical nature continued for centuries and represents the effort and skills of generations of brewers. Until recently, genetic and physiological manipulations with industrial microorganisms were carried out without any knowledge of fundamental genetic and regulatory mechanisms. Increasing knowledge of microbial biochemistry and genetics is at present shedding light on the significance and role of these mechanisms; modern microbial processes involving the biosynthesis of primary products such as amino acids, vitamins and nucleotides have therefore evolved on a rational basis. On the other hand, the development of technology for