FOOD MICROBIOLOGY

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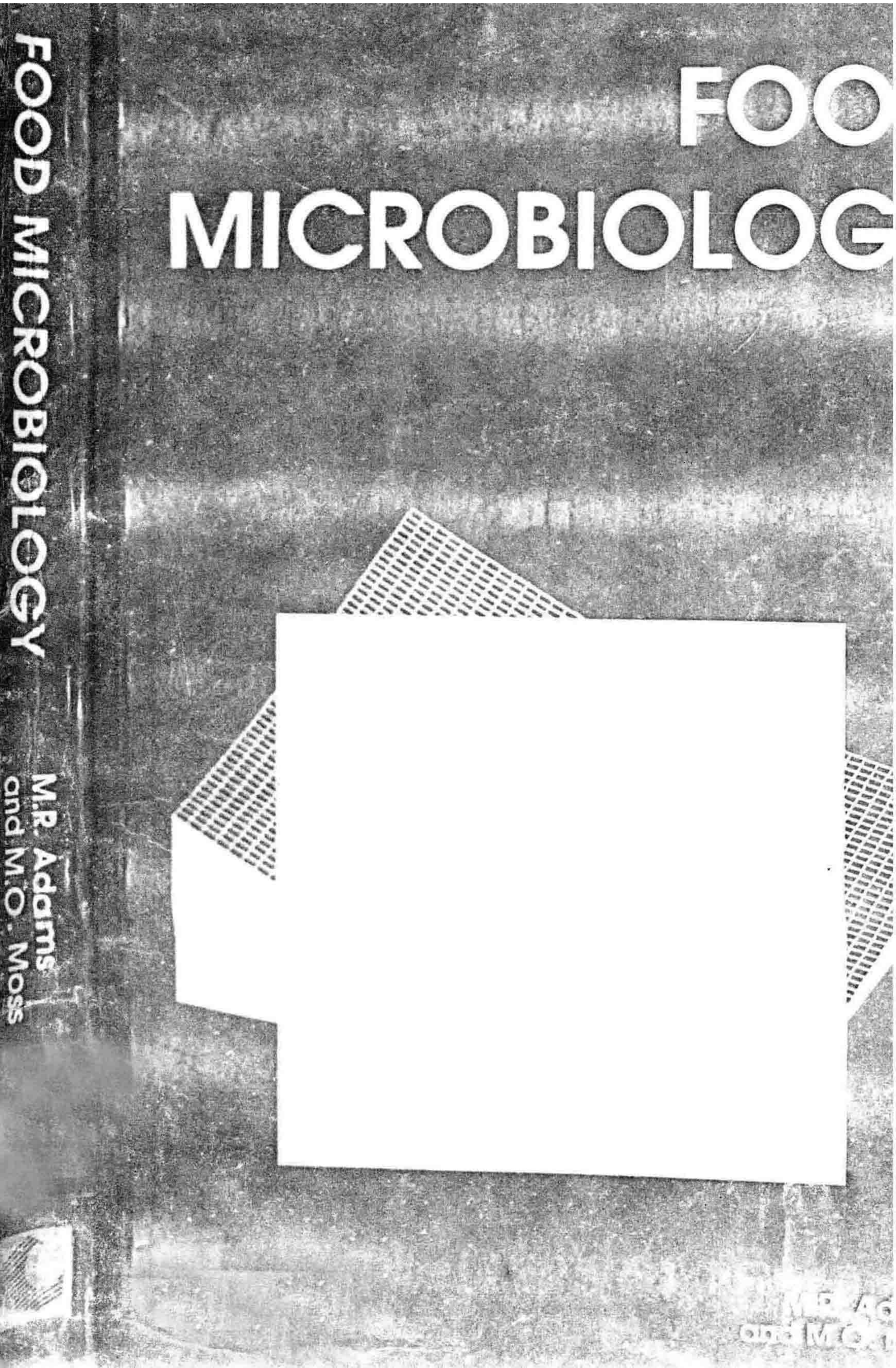
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Food Microbiology

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Preface

In writing this book we have tried to present an account of modern food microbiology that is both thorough and accessible. Since our subject is broad, covering a diversity of topics from viruses to helminths (by way of the bacteria) and from pathogenicity to physical chemistry, this can make presentation of a coherent treatment difficult; but it is also part of what makes food microbiology such an interesting and challenging subject.

The book is directed primarily at students of Microbiology, Food Science and related subjects up to Master's level and assumes some knowledge of basic microbiology. We have chosen not to burden the text with references to the primary literature in order to preserve what we hope is a reasonable narrative flow. Some suggestions for further reading for each chapter are included in Chapter 12. These are largely review articles and monographs which develop the overview provided and can also give access to the primary literature if required. We have included references that we consider are among the most current or best (not necessarily the same thing) at the time of writing, but have also taken the liberty of including some of the older, classic texts which we feel are well worth revisiting on occasion. By the very nature of current scientific publishing, many of our most recent references may soon become dated themselves. There is a steady stream of research publications and reviews appearing in journals such as *Food Microbiology*, *Food Technology*, the *International Journal of Food Microbiology*, the *Journal of Applied Bacteriology* and the *Journal of Food Protection* and we recommend that these sources are regularly surveyed to supplement the material provided here.

We are indebted to our numerous colleagues in food microbiology from whose writings and conversation we have learned so much over the years. In particular we would like to acknowledge Peter Bean for looking through the section on heat processing, Ann Dale and Janet Cole for their help with the figures and tables and, finally, our long suffering families of whom we hope to see more in the future.

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CHAPTER 1

The Scope of Food Microbiology

Microbiology is the science which includes the study of the occurrence and significance of bacteria, fungi, protozoa and algae which are the beginning and ending of intricate food chains upon which all life depends. These food chains begin wherever photosynthetic organisms can trap light energy and use it to synthesize large molecules from carbon dioxide, water and mineral salts forming the proteins, fats and carbohydrates which all other living creatures use for food.

Within and on the bodies of all living creatures, as well as in soil and water, micro-organisms build up and change molecules, extracting energy and growth substances. They also help to control population levels of higher animals and plants by parasitism and pathogenicity.

When plants and animals die, their protective antimicrobial systems cease to function so that, sooner or later, decay begins liberating the smaller molecules for re-use by plants. Without human intervention, growth, death, decay and regrowth would form an intricate web of plants, animals and micro-organisms, varying with changes in climate and often showing apparently chaotic fluctuations in populations of individual species, but inherently balanced in numbers between producing, consuming and recycling groups.

In the distant past, these cycles of growth and decay would have been little influenced by the small human population that could be supported by the hunting and gathering of food. From around 10 000 BC however, the deliberate cultivation of plants and herding of animals started in some areas of the world. The increased productivity of the land and the improved nutrition that resulted led to population growth and a probable increase in the average lifespan. The availability of food surpluses also liberated some from daily toil in the fields and stimulated the development of specialized crafts, urban centres, and trade – in short, civilization.

1.1 MICRO-ORGANISMS AND FOOD

The foods that we eat are rarely if ever sterile, they carry microbial associations whose composition depends upon which organisms gain access and how they grow, survive and interact in the food over time. The micro-organisms present will originate from the natural microflora of the raw material and those organisms introduced in the course of harvesting/slaughter, processing, storage and distribution (see Chapters 2 and 5). The numerical balance between the various types will be determined by the properties of the food, its storage environment, properties of the organisms themselves and the effects of processing. These factors are discussed in more detail in Chapters 3 and 4.

In most cases this microflora has no discernible effect and the food is consumed without objection and with no adverse consequences. In some instances though, micro-organisms manifest their presence in one of several ways:

(i) they can cause spoilage;
(ii) they can cause foodborne illness;
(iii) they can transform a food's properties in a beneficial way – food fermentation.

1.1.1 Food Spoilage/Preservation

From the earliest times, storage of stable nuts and grains for winter provision is likely to have been a feature shared with many other mammals but, with the advent of agriculture, the safe storage of surplus production assumed greater importance if seasonal growth patterns were to be used most effectively. Food preservation techniques based on sound, if then unknown, microbiological principles were developed empirically to arrest or retard the natural processes of decay. The staple foods for most parts of the world were the seeds – rice, wheat, sorghum, millet, maize, oats and barley – which would keep for one or two seasons if adequately dried, and it seems probable that most early methods of food preservation depended largely on water activity reduction in the form of solar drying, salting, storing in concentrated sugar solutions or smoking over a fire.

The industrial revolution which started in Britain in the late 18th century provided a new impetus to the development of food preservation techniques. It produced a massive growth of population in the new industrial centres which had somehow to be fed; a problem which many thought would never be solved satisfactorily. Such views were often based upon the work of the English cleric Thomas Malthus who in his 'Essay on Population' observed that the inevitable consequence of the exponential growth in population and the arithmetic growth in agricultural productivity would be over-population and mass starvation. This in fact proved not to be the case as the 19th Century saw the development of substantial food preservation industries based around the use of chilling, canning and freezing and the first large scale importation of foods from distant producers.

To this day, we are not free from concerns about over-population. Globally there is sufficient food to feed the world's population, estimated to be 5300 million in 1990. World grain production has more than managed to keep pace with the increasing population in recent years and the World Health Organization's Food and Agriculture Panel consider that current and emerging capabilities for the production and preservation of food should ensure an adequate supply of safe and nutritious food up to and beyond the year 2010 when the world's population is projected to rise to more than 7 billion.

There is however little room for complacency. Despite overall sufficiency, it is recognized that a large proportion of the population is malnourished. The principal cause of this is not insufficiency however, but poverty which leaves an estimated one-fifth of the world's population without the means to meet their daily needs. Any long-term solution to this must lie in improving the economic status of those in the poorest countries and this, in its train, is likely to bring a decrease in population growth rate similar to that seen in recent years in more affluent countries.

In any event, the world's food supply will need to increase to keep pace with population growth and this has its own environmental and social costs in terms of the more intensive exploitation of land and sea resources. One way of mitigating this is to reduce the substantial pre- and post-harvest losses which occur, particularly in developing countries where the problems of food supply are often most acute. It has been estimated that the average losses in cereals and legumes exceed 10% whereas with more perishable products such as starchy staples and vegetables the figure is more than 20% – increasing to an estimated 25% for highly perishable products such as fish. In absolute terms, the US National Academy of Sciences has estimated the losses in cereals and legumes in developing countries as 100 million tonnes, enough to feed 300 million people.

Clearly reduction in such losses can make an important contribution to feeding the world's population. While it is unrealistic to claim that food microbiology offers all the answers, the expertise of the food microbiologist can make an important contribution. In part, this will lie in helping to extend the application of current knowledge and techniques but there is also a recognized need for simple, low-cost, effective methods for improving food storage and preservation in developing countries. Problems for the food microbiologist will not however disappear as a result of successful development programmes. Increasing wealth will lead to changes in patterns of food consumption and changing demands on the food industry. Income increases among the poor have been shown to lead to increased demand for the basic food staples while in the better-off it leads to increased demand for more perishable animal products. To supply an increasingly affluent and expanding urban population will require massive extension of a safe distribution network and will place great demands on the food microbiologist.

1.1.2 Food Safety

In addition to its undoubted value, food has a long association with the transmission of disease. Regulations governing food hygiene can be found in numerous early sources such as the Old Testament, and the writings of Confucius, Hinduism and Islam. Such early writers had at best only a vague conception of the true causes of foodborne illness and many of their prescriptions probably had only a slight effect on its incidence. Even today, despite our increased knowledge, 'Foodborne disease is perhaps the most widespread health problem in the contemporary world and an important cause of reduced economic productivity.' (WHO 1992). The available evidence clearly indicates that biological contaminants are the major cause. The various ways in which foods can transmit illness, the extent of the problem and the principal causative agents are described in more detail in Chapters 6, 7 and 8.

1.1.3 Fermentation

Microbes can however play some positive role in food. They can be consumed as foods in themselves as in the edible fungi, mycoprotein and algae. They can also effect desirable transformations in a food, changing its properties in a way that is beneficial. The different aspects of this and examples of important fermented food products are discussed in Chapter 9.

1.2 MICROBIOLOGICAL QUALITY ASSURANCE

Food microbiology is unashamedly an applied science and the food microbiologist's principal function is to help assure a supply of wholesome and safe food to the consumer. To do this requires the synthesis and systematic application of our knowledge of the microbial ecology of foods and the effects of processing to the practical problem of producing, economically and consistently, foods which have good keeping qualities and are safe to eat. How we attempt to do this is described in Chapter 11.

CHAPTER 2

Micro-organisms and Food Materials

Foods, by their very nature, need to be nutritious and metabolizable and it should be expected that they will offer suitable substrates for the growth and metabolism of micro-organisms. Before dealing with the details of the factors influencing this microbial activity, and their significance in the safe handling of foods, it is useful to examine the possible sources of micro-organisms in order to understand the ecology of contamination.

2.1 DIVERSITY OF HABITAT

Viable micro-organisms may be found in a very wide range of habitats, from the coldest of brine ponds in the frozen wastes of polar regions, to the almost boiling water of hot springs. Indeed, it is now realized that actively growing bacteria may occur at temperatures in excess of 100 °C in the thermal volcanic vents, at the bottom of the deeper parts of the oceans, where boiling is prevented by the very high hydrostatic pressure (see Section 3.2.5). Micro-organisms may occur in the acidic wastes draining away from mine workings or the alkaline waters of soda lakes. They can be isolated from the black anaerobic silts of estuarine muds or the purest waters of biologically unproductive, or oligotrophic, lakes. In all these, and many other, habitats microbes play an important part in the recycling of organic and inorganic materials through their roles in the carbon, nitrogen and sulfur cycles (Figure 2.1). They thus play an important part in the maintenance of the stability of the biosphere.

The surfaces of plant structures such as leaves, flowers, fruits and especially the roots, as well as the surfaces and the guts of animals all have a rich microflora of bacteria, yeasts and filamentous fungi. This natural, or normal flora may affect the original quality of the raw ingredients used in the manufacture of foods, the kinds of contamination which may occur during processing, and the possibility of food spoilage or food associated illness. Thus, in considering the possible sources of micro-organisms as agents of food spoilage or food poisoning, it will be necessary to examine the natural flora of the food materials themselves, the flora introduced by processing and handling, and the possibility of chance contamination from the atmosphere, soil or water.