FOOD PRESERVATIVES

Edited by N. J. Russell
and G. W. Gould

Blackie

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Food Preservatives

Preface

Long ago man discovered how to treat his food so that it was less susceptible to spoilage during the long winter months when fresh food was difficult to find. Many different chemical preservatives developed through centuries of common usage and these are generally the ones, such as salt, sugar and vinegar and other acids derived by fermentation, with which everyone is familiar. In more recent times, chemically-synthesized compounds have been added to the growing list of substances which not only prolong the storage and shelf-life of commodities and improve safety, but may also enhance the organoleptic and other desirable qualities of foodstuffs.

During the past decade, eating habits have changed to become what is popularly termed 'more healthy'. As part of this trend, the general public is much more concerned with the effects that preservatives and other substances might have on their well-being. This concern has been matched by a reduction in the levels of preservatives that are used in a range of commodities. It is suspected in some quarters that this could have contributed to increases in the numbers of reported cases of food poisoning, but no clear proof of cause and effect has yet been provided.

It is against this background that the present book was conceived. We believe that it is particularly appropriate at this time because it not only provides a long overdue update on chemical methods of food preservation but also provides guidance on the effective use of food preservatives in industry. The authorship comes from industry, food research institutes and academia. Most chapters are written by two authors who discuss the usage and underlying modes of action, including effects on target micro-organisms, of the most important preservatives. This unique feature of the book is designed to rationalize many of the rules and guidelines for practical use and to make them more easily understood. Furthermore, improved understanding of the basic modes of action should assist industry in the search for compounds with improved qualities in relation to preservation and acceptability.

The book covers the major antimicrobial food additives, including the use of salts, sugars and other solutes to lower water activity; acidification and the use of specific acidulants; organic acids such as propionic, sorbic and benzoic; esters such as the parabens; sulphite; nitrite; antibiotics such as

nisin and pimaricin; ethanol; carbon dioxide; antimicrobial antioxidants and glycerol esters. Although not strictly chemical compounds, starter cultures are covered in a separate chapter.

Two introductory chapters provide basic information about the properties of the major types of food-poisoning and food-spoilage micro-organisms, and the main factors that affect their growth and survival. These are followed by chapters on individual preservative compounds or groups of compounds, covering their practical use, effects on micro-organisms, and current ideas about their mechanisms of action. Next comes a substantial chapter which summarizes trends in legislation worldwide, with particular attention to the EEC, UK and USA. The final chapter looks to the future, considering alternative preservation systems that many believe will soon find use, including the natural systems that operate so effectively in many plants and animals.

The book is directed at those companies involved in food production, distribution and sales, particularly their development and quality control departments. It should appeal to those in the various government and industrially-sponsored food research institutes and associations around the world. In addition, the book should be a useful teaching aid for degrees in food science, home economics, microbiology and other courses supporting food-related research in universities, polytechnics and colleges.

We should like to thank all the authors for their contributions and for their patience during the preparation of this manuscript. As editors we have tried to retain as much individuality of style whilst blending the individual contributions of co-authored chapters into a unified whole. We trust that this multi-faceted approach to the topic will make the book particularly useful to all those who are concerned with food preservatives.

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1 Major food-poisoning and food-spoilage micro-organisms

G.W. GOULD and N.J. RUSSELL

1.1 Introduction

The various means available for combating the deleterious effects of micro-organisms in foodstuffs include, firstly, the prevention of their access to foods; secondly, inactivation, should they nevertheless be present; and, thirdly, the slowing or inhibition of their growth should they have gained access and not been inactivated (see Chapter 2). Food preservatives act principally in the third of these modes, operating predominantly by inhibition, although some preservatives additionally inactivate the inhibited micro-organisms at some rate or other as well.

Food preservatives are employed principally to prevent the spoilage of foods during storage and throughout distribution, retailing and use by the consumer. In this way they help to ensure that desired shelf-lives are met, that food products are convenient to store in the home, and that economic losses are avoided. Therefore, the targets of food preservatives are primarily those micro-organisms which can multiply in, and spoil, the various categories of foodstuffs. However, they also have a role in preventing the growth of pathogenic and toxinogenic micro-organisms which may contaminate foods, so that their influence on these food-poisoning micro-organisms is of importance as well.

In this introductory chapter we briefly indicate the major groups of food-poisoning and food-spoilage micro-organisms that are the targets of food preservatives.

1.2 Food-poisoning micro-organisms

Notwithstanding the tremendous advances that have taken place in food technology, distribution control, hygienic standards and education during the last few decades, food poisoning continues to increase in most developed countries of the world. In the UK the number of reported cases doubled between 1987 and 1988. The types of micro-organism that cause most of

the sporadic cases and outbreaks are not numerous, and are summarized in Table 1.1 They include infectious organisms, such as *Salmonella* and *Campylobacter* species, which cause by far the majority of cases of food poisoning, and toxinogenic organisms, such as *Staphylococcus aureus* and *Clostridium botulinum*, which cause far fewer. Their temperature minima for growth range upwards from near zero degrees Celsius, so that some of them are capable of slow growth in refrigerated, chill-stored foods. Their heat resistances range greatly from the low resistance of the most sensitive vegetative forms, with decimal reduction values (*D*-values) of <1 minute at 60°C, to the most resistant spores, with *D*-values of nearly 1 minute at 120°C.

Table 1.1 Food-poisoning micro-organisms of major concern.

Minimum growth temperature	Heat resistance	
	Low	High
	Vegetative cells	Spores
Low	*Listeria monocytogenes* (INF)*	*Clostridium botulinum* E and non-proteolytic B (TOX)†
	Yersinia enterocolitica (INF)	
	Vibrio parahaemolyticus (INF)	*Bacillus cereus* (TOX)
	Salmonella species (INF)	*Bacillus subtilis* and *licheniformis* (TOX)
Medium	*Escherichia coli* entero-pathogenic strains (INF)	*Clostridium perfringens* (INF)
	Staphylococcus aureus (TOX)	*Clostridium botulinum* A and proteolytic B (TOX)
High	*Campylobacter jejuni* and *C. coli* (INF)	

*INF, organisms that may contaminate foods, and may multiply in them, and which cause food poisoning by infection.

†TOX, organisms that may contaminate foods and multiply in them to form toxins that cause food poisoning by intoxication.

In addition to those organisms listed in Table 1.1, there are other, rarer, causative agents of food poisoning that are implicated, or are suspected of being implicated, in erratic problems: these organisms include *Shigella* species, *Aeromonas hydrophila*, *Plesiomonas shigelloides*, *Enterococcus* species, *Pseudomonas aeruginosa*, *Edwardsiella tarda*, *Vibrio vulnificus*, *Clostridium difficile*, *Cryptosporidium parvum*, viruses (e.g. 'small round' viruses and Norwalk virus) and mycotoxic fungi.

1.2.1 Salmonella

There are about 2000 different serotypes of *Salmonella.* Whilst some serotypes are more virulent than others, it is widely accepted that all are potentially infectious for man. Next to *Campylobacter* (see section 1.2.2) salmonellae cause the majority of food-poisoning cases in developed countries. Salmonellosis is substantially under-reported, so that estimations of the true incidence of the disease have to be made on the basis of assumptions derived from epidemiological data.

For example, it has been estimated that in the USA clinically significant infections may reach as many as 2 million per annum and, of these, up to about 2000 may be fatal (1, 2). By far the majority of human infections by salmonellae derive from man's association with animals. Most foods of animal origin can transmit salmonellae directly or indirectly to man and some, such as poultry, are particularly commonly implicated.

The organisms are Gram-negative, non-sporing rods which are not especially tolerant of any of the conventional food preservation techniques currently in use. Therefore, growth is possible in many non-acidified, high-water-activity foodstuffs if held above chill temperatures. Growth in foods is important because of its potential to raise numbers above the minimum infective dose, which ranges, depending on the stage of health and susceptibility of the host, from as low as about 10 cells for *S. typhi* to thousands of cells for the majority of salmonellae.

1.2.2 Campylobacter

Campylobacter jejuni and *C. coli* are common inhabitants of the intestinal tracts of a variety of animals, and consequently are found irregularly as contaminants on meat, and particularly on poultry (3). Raw milk is the vehicle most commonly implicated in large outbreaks. Whilst originally considered to be a pathogen solely of veterinary significance, causing abortion in sheep, *Campylobacter* is now considered to be responsible for more human cases of enteric disease than are salmonellae (4).

Campylobacters differ from most of the other food-poisoning micro-organisms in having a particularly high minimum temperature for growth of about 30°C. In addition, they are microaerophilic and do not compete well with other micro-organisms, so that their *growth* in foods is not regarded to be a problem. Rather, their ability to *survive* is important, but here again they are relatively sensitive to environmental factors such as high partial pressures of oxygen, drying, freezing, etc., but this may be offset to some extent by the fact that the infective dose for causing disease is probably as low as a few hundred organisms.

1.2.3 Listeria

Like the campylobacters, *Listeria monocytogenes* was, until the early 1980s, thought to be mainly of veterinary significance, causing encephalitis and abortion in sheep and cattle. Only the haemolytic species (*L. monocytogenes, L. seeligeri* and *L. ivanovii*) are pathogenic and, of these, only *L. monocytogenes* is regularly so. The numbers of human cases are $<1\%$ those of salmonellosis, and *very* few of these have proven food origins. Most instances of food-borne listeriosis have involved ingestion of raw milk or soft cheese (5). However, the high virulence of the organism for immunocompromised and pregnant humans has led to an increase in concern about its occurrence and potential for growth in foods. In particular, the ability of *L. monocytogenes* to grow at temperatures near to 0°C has focused attention on its presence in some chill-stored foods.

1.2.4 Yersinia

Yersinia enterocolitica causes severe though rare human infections, most characteristically affecting children and causing appendicitis-like symptoms. Avirulent strains are commonly isolated from animals and are found in foods, but pigs most often yield virulent strains. Chocolate milk, pasteurized milk and unchlorinated spring water have been associated with outbreaks but, oddly, pork meat has not been directly implicated in major outbreaks of yersiniosis (6).

Like *Listeria, Yersinia* species are psychrotrophic and are capable of multiplying slowly at temperatures near to 0°C.

1.2.5 Vibrio

Vibrio cholerae outbreaks are principally water-borne, but, of course, the organism may contaminate foods. *V. parahaemolyticus,* however, is an important food-poisoning organism, particularly in Japan, where substantial amounts of raw sea-food are eaten, causing 50% of the cases of enteritis in that country (7). The association of *V. parahaemolyticus* with fish and fish products is encouraged by its salt tolerance, some strains growing in the presence of up to 10% sodium chloride.

1.2.6 Escherichia

Outbreaks of food-borne disease attributable to enteropathogenic strains of *Escherichia coli* have increasingly been recognized recently (8). There are