

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 food-stuffs.

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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Contents

1 Major food-poisoning and food-spoilage micro-organisms	1
G.W. GOULD and N.J. RUSSELL	
1.1 Introduction	1
1.2 Food-poisoning micro-organisms	1
1.2.1 <i>Salmonella</i>	3
1.2.2 <i>Campylobacter</i>	3
1.2.3 <i>Listeria</i>	4
1.2.4 <i>Yersinia</i>	4
1.2.5 <i>Vibrio</i>	4
1.2.6 <i>Escherichia</i>	4
1.2.7 <i>Staphylococcus</i>	5
1.2.8 <i>Clostridium botulinum</i>	5
1.2.9 <i>Clostridium perfringens</i>	6
1.2.10 <i>Bacillus cereus</i>	7
1.3 Food-spoilage micro-organisms	7
1.3.1 Gram-negative, catalase-positive, oxidase-positive rods	7
1.3.2 Gram-negative, catalase-positive, oxidase-negative rods	9
1.3.3 Gram-positive, catalase-positive, non-sporing rods	9
1.3.4 Gram-positive, catalase-positive cocci	9
1.3.5 Gram-positive, catalase-negative, non-sporing rods and cocci	10
1.3.6 Gram-positive, catalase-positive, spore-forming rods	10
1.3.7 Gram-positive, catalase-negative, spore-forming rods	10
1.3.8 Yeasts and moulds	11
1.4 Conclusions	11
References	11
 2 Factors affecting growth and survival	 13
N.J. RUSSELL and G.W. GOULD	
2.1 Introduction	13
2.2 Basis of food preservation	14
2.3 Major food preservation techniques	14
2.3.1 Low temperature	15
2.3.2 Reduction in water activity	16
2.3.3 Vacuum and modified-atmosphere packaging	17
2.3.4 Acidification	18
2.3.5 Use of preservatives	19
2.3.6 Compartmentalization	19
2.3.7 Heat	20
2.4 Conclusions	20
References	21

3 Acidulants and low pH	22
M.H. BROWN and I.R. BOOTH	
3.1 Introduction	22
3.2 The effect of pH on growth and survival	23
3.2.1 Growth	23
3.2.2 Survival	24
3.3 Effects of acidification on different types of bacteria	25
3.3.1 Non-sporing bacteria	25
3.3.2 Sporing bacteria	25
3.3.3 Yeasts and moulds	26
3.3.4 Food-borne pathogens	26
3.4 Acidification of foods	26
3.4.1 Types of acid	27
3.4.2 The use of weak acids in food preservation	27
3.4.3 Methods of altering the pH of foods	28
3.5 Practical examples	29
3.5.1 Canning	29
3.5.2 Mayonnaise	30
3.5.3 Egg albumen	30
3.6 Mechanisms of action	31
3.6.1 General aspects	31
3.6.2 Mechanisms of the effects of external pH on growth and survival	32
3.6.3 Cytoplasmic pH and growth	35
3.6.4 pH homeostasis in micro-organisms	36
3.6.5 Sensing external and internal pH	39
References	41
4 Organic acids and esters	44
J.J. KABARA and T. EKLUND	
4.1 Introduction	44
4.2 Fatty acids as antimicrobial agents	47
4.3 Monoesters as antimicrobial agents	50
4.4 Phenolic esters as antimicrobial agents	53
4.5 Application of fatty acids and monoesters in food products	57
4.6 General mechanism of action	60
4.7 Specific modes of action	64
4.7.1 Acetic acid	64
4.7.2 Propionic acid	65
4.7.3 Lactic acid	65
4.7.4 Sorbic acid	65
4.7.5 Benzoic acid	67
4.7.6 Esters of <i>p</i> -hydroxybenzoic acid (parabens)	67
References	69
5 Sulphite	72
G.W. GOULD and N.J. RUSSELL	
5.1 Introduction	72
5.2 Uses in food	72
5.3 Mode of action	75
5.3.1 Chemistry of sulphite	75
5.3.2 Reactions of sulphite	77
5.3.3 Uptake of sulphite by micro-organisms	79
5.3.4 Metabolism of sulphite by micro-organisms	81

5.3.5	Antimicrobial action of sulphite	83
5.4	Postscript	86
	References	87
6	Nitrite	89
	T.A. ROBERTS, L.F.J. WOODS, M.J. PAYNE and R. CAMMACK	
6.1	Introduction	89
6.1.1	Meat as a source of pathogenic bacteria	89
6.1.2	Factors affecting growth	90
6.2	Cured meats	91
6.2.1	Raw cured meats	94
6.2.2	Comminuted cured meats	94
6.2.3	Heated cured meats	95
6.3	Nitrite in combination preservation	96
6.4	Nitrosamines	97
6.5	Nitrite alternatives	98
6.6	Risk analysis	99
6.7	Mechanisms of action	100
6.7.1	Inhibition of bacteria by nitrite	100
6.7.2	Nitrite in the preservation of meat products	101
6.7.3	Inhibitory compounds produced from nitrite	102
6.7.4	Electron spin resonance of iron-nitrosyl-thiol species	105
6.8	Conclusions	108
	References	108
7	Solutes and low water activity	111
	L. LEISTNER and N.J. RUSSELL	
7.1	Introduction	111
7.2	Influence of water activity on micro-organisms	112
7.2.1	Multiplication	112
7.2.2	Metabolic activity	113
7.2.3	Resistance	114
7.2.4	Survival	115
7.3	Foods	115
7.3.1	Adjustment	116
7.3.2	Products	116
7.3.3	Traditional foods	117
7.3.4	Novel foods	118
7.4	Microbial response to low water activity: basic mechanisms	119
7.4.1	Accumulation of compatible solutes	119
7.4.2	Osmoregulation of compatible solute uptake	122
7.4.3	Molecular properties of compatible solutes	124
7.4.4	Gram-negative bacteria and osmoregulation of the periplasm	125
7.4.5	Membrane lipid changes in response to low a_w	127
7.5	Combined factors	129
7.5.1	Hurdle effect	130
7.5.2	Practical applications	130
	References	131
8	Antibiotics—nisin	135
	G.G. FOWLER and M.J. GASSON	
8.1	Introduction	135
8.2	Background to the use of nisin in food preservation	135

8.3	Practical applications of nisin in food preservation	136
8.3.1	Definition of nisin activity and potency	136
8.3.2	Relationship between nisin concentration in food and numbers of potential spoilage bacteria and spores	137
8.3.3	First uses of nisin	137
8.3.4	Development of nisin applications	138
8.4	Mode of action	146
8.5	Structure and biosynthesis of nisin	146
8.6	The genetic determinant for nisin biosynthesis	149
	References	150
9	Ethanol as a food preservative	153
	D.A.L. SEILER and N.J. RUSSELL	
9.1	Introduction	153
9.2	Early studies	153
9.3	Studies with foods	155
9.3.1	Prevention of microbial growth	155
9.3.2	Anti-staling effects	160
9.3.3	Organoleptic effects	162
9.4	Antimicrobial mode of action	163
9.4.1	Background	163
9.4.2	Pleiotropic effects of ethanol	163
9.4.3	Ethanol action on membranes	164
9.4.4	Are membranes the primary target for ethanol?	167
9.5	Legal considerations	168
9.6	Conclusions	169
	References	169
10	Modified atmospheres and vacuum packaging	172
	C.D. GILL and G. MOLIN	
10.1	Introduction	172
10.2	Factors other than packaging affecting spoilage development	173
10.2.1	Initial contamination	173
10.2.2	Temperature	173
10.2.3	Product composition	174
10.3	Non-microbial product deterioration	175
10.3.1	Colour	175
10.3.2	Odour and flavour	176
10.3.3	Tenderness and texture	176
10.3.4	Exudate	177
10.4	Packaging materials	177
10.5	Preparation and use of preservative packagings	179
10.5.1	Vacuum packs	179
10.5.2	High-oxygen modified-atmosphere packaging	180
10.5.3	Low-oxygen modified-atmosphere packaging	182
10.5.4	Controlled atmosphere packaging	183
10.6	Mode of action	185
10.6.1	Gas phase	185
10.6.2	Biological effects	186
10.6.3	Oxygen limitation of carbon dioxide inhibition?	189
10.6.4	Microbial ecology	191
10.7	Conclusions	197
	References	198
11	Phenols and chelators	200
	J.J. KABARA	
11.1	Introduction	200

11.2 Phenolic antioxidants as antimicrobial agents	200
11.3 Application of antioxidants in foods	203
11.4 Chelating agents as potentiators for preservatives	206
References	212
12 Starter cultures	215
F.-K. LÜCKE and R.G. EARNSHAW	
12.1 Introduction	215
12.2 Preservation of various food commodities with the aid of starter cultures	216
12.2.1 Milk and dairy products	216
12.2.2 Meat and meat products	218
12.2.3 Foods of plant origin	221
12.3 Mechanisms of action	222
12.3.1 Competition for nutrients and space	222
12.3.2 Formation of organic acids	223
12.3.3 Formation of other products of catabolism	224
12.3.4 Bacteriocins	226
12.3.5 Other antimicrobial products of starter cultures	229
12.4 Practical aspects of detecting and quantifying antimicrobial processes mediated by starter cultures	230
12.5 Culture development and strain improvement	230
12.6 Conclusions	231
References	231
13 Legislative aspects	235
J.A. POLLARD	
13.1 Introduction	235
13.2 Role of preservatives	235
13.3 Legislation of preservatives	238
13.3.1 EEC legislation	238
13.3.2 UK legislation	244
13.3.3 Other European countries legislation	250
13.3.4 USA legislation	252
13.3.5 Other major countries legislation	256
13.3.6 Codex Alimentarius Commission	260
13.4 Future trends in preservatives legislation	262
References	265
14 Future prospects	267
R.G. BOARD and G.W. GOULD	
14.1 Introduction	267
14.2 Food ecosystems	268
14.3 Predictive mathematical modelling of microbial growth and survival in foods	272
14.4 Future prospects	275
14.4.1 Principles	275
14.4.2 Natural antimicrobial systems	277
14.5 Conclusions	282
References	283
Index	285

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	<i>Listeria monocytogenes</i> (INF)*	<i>Clostridium botulinum</i> E and non-proteolytic B (TOX)†
	<i>Yersinia enterocolitica</i> (INF)	<i>Bacillus cereus</i> (TOX)
	<i>Vibrio parahaemolyticus</i> (INF)	<i>Bacillus subtilis</i> and <i>licheniformis</i> (TOX)
	<i>Salmonella</i> species (INF)	<i>Clostridium perfringens</i> (INF)
Medium	<i>Escherichia coli</i> enteropathogenic strains (INF)	<i>Clostridium botulinum</i> A and proteolytic B (TOX)
	<i>Staphylococcus aureus</i> (TOX)	
High	<i>Campylobacter jejuni</i> and <i>C. coli</i> (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