TECHNOLOGY OF REDUCED-ADDITIVE FOODS

Edited by J Smith

Blackwell Science

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Preface

The food industry for many years reacted to consumer demand for more appealing and convenient food products by using additives. More recently the demands of consumers have grown to include still higher performance products but with less additives. The industry has responded accordingly. There are often significant scientific and technical obstacles to be overcome to make a product with less additives. It is these technical challenges that this book is intended to address.

The approach taken in this book is to examine specific aspects of the industry where important contributions are being made to avoid or reduce additive use or to create new, natural and more acceptable additives which can replace the old ones. There is a tremendous amount of work underway in this field and to cover it comprehensively would fill many volumes. This volume addresses the areas where there has been a considerable amount of recent activity and published results.

Chapter 1 covers starter cultures in dairy products, meat products and bread. The author is Professor Gunnar Mogensen, the Director of Research and Development for Chr. Hansen's Laboratorium, the foremost suppliers of starter cultures in the world. He examines developments in starter culture technology and illustrates ways in which starter cultures are replacing traditional additives in foods.

Chapter 2 was contributed by Paul Whitehead and Nick Church, both Senior Scientists with Leatherhead Food Research Association and Malcolm Knight, formerly of Leatherhead Food Research Association and now with Griffith Laboratories. They are at the forefront of meat research and have provided a review on new animal-derived ingredients. This includes meat surimi, fractionation of meat and blood and techniques for production of new ingredients.

Chapter 3 addresses new marine-derived ingredients and was contributed by Torger Børresen of the Fiskeriministeriets Forsøgslaboratorium in Denmark. The characteristics of marine foods and specific marine-derived compounds are addressed.

In Chapter 4, Philip Voysey and John Hammond of the Flour Milling and Baking Research Association in Chorleywood, England cover reduced-additive breadmaking technology. The two major areas of development in this area are bread improvers and antimicrobial additives.

Novel food packaging is reviewed in chapter 5 by Michael Rooney, Principal Research Scientist with CSIRO Food Research Laboratory in Australia. The scope for avoidance of additives is covered first, followed by properties of packaging materials and packaging processes.

Chapter 6 on antimicrobial preservative-reduced foods by the editor, Jim Smith of the Prince Edward Island Food Technology Centre in Canada, addresses the control of microorganisms in foods and various strategies for producing preservative-reduced or preservative-free foods. This includes evaluating the processing environment, processing methods and the use of various alternative preservatives.

Nazmul Haq of the Department of Biology, University of Southampton, England (and until recently the Director of the International Centre for Underutilised Crops at the University of London) has reviewed new plant-derived ingredients in chapter 7. A wide variety of ingredient plants and food plants are identified. These plants will be invaluable over the years ahead as resources in their own right and as genetic sources for new varieties.

Food from supplement-fed animals is reviewed in chapter 8 by Cameron Faustman of the Department of Animal Science at the University of Connecticut, USA. The use of feed supplements is a growing area of research for improvement of the quality of meat. Supplementation with vitamin E, carotenoids and vitamin C is addressed. Cholesterol reduction, alteration of fatty acid profiles and competitive exclusion are also covered.

Chapter 9 by Creina Stockley (Information Manager), Nigel Sneyd (Manager, Extension) and Terry Lee (Director) of the Australian Wine Research Institute reviews reduced-additive brewing and winemaking. Antimicrobial agents and antioxidant agents are the two major concerns facing the industry and these are covered with particular emphasis on reducing the use of sulphur dioxide.

My thanks are extended to the authors for their contributions and for their hard work in helping to complete the book within the required schedule.

Finally, I would like to thank my wife Valerie and children Jemma, Graeme and Calum for helping me to keep things in perspective!

J.S.

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Contents

1 Starter cultures

G. MOGENSEN

1.1 Introduction

Microorganisms in food production have been associated mainly with fermented dairy products, wine and beer. They are of equal importance, however, in fermented meat, bread and vegetables, and it is only recently that the potential of using starter cultures in such products has been fully recognised.

There are many reasons for using starter cultures in food production. In fact, recent research has turned the use of starter cultures into 'high technology' by which it is possible to govern flavour development, texture and viscosity as well as the keeping quality of foods. Research in starter cultures has been increasingly focused on the further added value that may be achieved by using these bacteria. This includes improvement of the dietetic and health-benefit properties of foods.

The increasing understanding of the genetics and physiology of food microorganisms has opened the door for strain improvements through the use of classic biotechnology (mutagenesis and selection). By using such technologies it has been shown possible to suppress undesirable and express desirable properties of starter strains and combine such strains into tailored starter cultures for the food industry. In the future, modern biotechnology involving direct genetic engineering will extend these possibilities even further.

From the beginning, the natural occurrence of lactic acid bacteria and yeast has reduced our need for using additives. The natural presence of these organisms in foods has directed research to exploit further the possibilities in utilising biotechnology instead of chemistry.

1.2 Dairy products

1.2.1 Additives used in dairy products

1.2.1.1 Preservatives. Generally, great efforts are taken to avoid preservatives in dairy products. Even so, preservatives have been and are being used in the dairy industry to avoid microbial spoilage. Use of preservatives is mainly restricted to cheese products. To avoid mould spoilage of cheese products, organic acids like sorbic acid and benzoic acid have been used. During recent years, microorganism-derived fungicides like Natamycin and Pimaricin have been widely used, although this is forbidden in several countries.

Nitrate is used to a great extent as a preservative for the prevention of unwanted gas formation from coliforms and clostridia. Nitrate acts as a hydrogen acceptor for coliforms as it is reduced to nitrite. Formation of gaseous hydrogen is thus prevented and this avoids early blowing of the cheese. Nitrite, in turn, inhibits the outgrowth of clostridia bacteria and therefore late blowing of the cheeses is prevented.

The addition of nitrate is becoming increasingly unpopular due to possible formation of carcinogenic nitrogen-containing compounds in the cheese. In the production of cheese spreads and other processed cheese products, the problem has been solved by the addition of nisin (an antimicrobial compound produced by certain strains of *Lactococcus*).

1.2.1.2 Stabilisers and emulsifiers. Stabilisers and emulsifiers are widely used as additives in the production of certain dairy products. In products such as UHT milk, chocolate milk and ice cream, the use of stabilisers and emulsifiers is a technological necessity.

For fermented milks, for example yoghurt, acidophilus milk and bifido products, stabilisers are widely used in many countries to improve viscosity and prevent wheying-off. Several types of stabilisers (e.g. gelatins, starch, pectins, carrageenans and cellulose derivatives) are used. The choice depends on the characteristics wanted and the technology used. The main parameters to be considered in the choice of stabiliser for fermented milks are heat stability and sensitivity towards low pH and salts. The effect of stabilisers on the activity of starter cultures must also be taken into consideration (Kalab *et al.*, 1983).

1.2.1.3 Enzymes. Enzymes are of great importance to the dairy industry as they play a key role in various processes, such as the production and ripening of cheese. Rennets are the giants in milk processing enzymes but other enzymes such as proteases, lipases, lysozyme and β-galactosidase have shown their applications in dairy processing.

1.2.1.3.1 Proteases. Milk-clotting enzymes are classified as proteases. Apart from causing coagulation of the milk, milk-clotting enzymes contribute greatly to the flavour and texture formation during cheese ripening.

In special cheese types where a specific flavour development or a shorter ripening time is wanted other proteolytic enzymes may be used.

1.2.1.3.2 Lipases. The major application of lipases in the dairy industry is in the production of Italian cheeses, for example, Romano and Provolone. These cheese varieties have a characteristic piquant flavour due to short-chain fatty acids liberated from the milk fat by lipases. The lipases used are mainly from oral tissues because these have a higher specificity than those from microbial sources. A considerable amount of information (Shahani, 1975) has been accumulated on the characteristics of lipolytic systems.

1.2.2 Starter cultures for dairy products

Starter cultures used in the production of dairy products comprise a great variety of lactic acid bacteria. Most common are species within the genera *Lactococcus*, *Streptococcus*, *Lactobacillus* and *Leuconostoc*. Non-lactic acid bacteria of the genera *Bifidobacterium* and *Propionibacterium* are commonly used in Swiss-type cheeses and so-called 'health cultures'.

Traditionally, commercial starter cultures were only specified on genus or species level, therefore the composition of starter cultures, i.e. number of strains and strain variety, was generally unknown. Recently, cultures composed of pure, single strains have been introduced to the market. This avoids strain dominance and greatly stabilises performance.

1.2.2.1 Purpose of using starter cultures. Preservation of food by fermentation is one of the oldest methods known to humankind. Products and microorganisms from ancient times are the predecessors of the variety of fermented milk products and cultures we have today.

Nowadays most fermented milks are manufactured under controlled and sanitary conditions. As in the past, the main purpose of using starter cultures is to preserve the milk, but other reasons for using starter cultures in modern dairy industry are diverse and may be summarised as follows:

(a) Preserve due to production of organic acids and secondary metabolites.
(b) Contribute specific sensory properties.
(c) Contribute specific textural properties.
(d) Contribute dietetic properties.

1.2.3 Starters as substitutes for additives

1.2.3.1 General preservative effect of starter cultures. Lactic acid bacteria have traditionally been used in food fermentation and preservation. The preservative effect of the starter culture is considerable due to the acids produced. The acids (mainly lactic acid) lower the pH and inhibit most spoilage and pathogenic organisms. In addition to lactic acid, other antimicrobials, e.g. acetic acid, propionic acid, diacetyl, CO_2 and bacteriocins, may be produced by some lactic acid bacteria.

Hydrogen peroxide (H_2O_2) is known as an antimicrobial agent. In the presence of oxygen, H_2O_2 is produced by some lactic acid bacteria. In fresh milk, H_2O_2 can also potentiate the lactoperoxidase antibacterial system in which oxidation products of thiocyanate rapidly kill Gram-negative bacteria (Ahrne and Björck, 1985; Gilliland, 1985; Daeschel, 1989; Adams, 1990).

1.2.3.2 Preservative effect of primary metabolites. Conversion of carbohydrates to lactate by the lactic acid bacteria may well be considered as the most important fermentation process employed in food technology. The three major pathways of hexose fermentation occurring within lactic acid bacteria are schematically depicted in Figure 1.1. In the homolactic fermentation, glucose is converted mainly to lactate. The facultatively heterofermentative lactic acid bacteria also convert glucose mainly to lactate, but some species are able to utilise pentoses during limitation of glucose. The pentoses are converted to equimolar amounts of lactate and acetate without any gas formation. The heterofermentation of hexose results in formation of equimolar amounts of CO_2, lactate and acetate or ethanol. The ratio of acetate to ethanol depends on the redox potential of the system (Kandler, 1983; Kandler and Weiss, 1986).

Propionic acid is produced by *Propionibacterium* from lactic acid. Ripe Swiss and Jarlsberg cheese may contain up to 1% of propionic acid (Blom and Mørtvedt, 1991).

The antimicrobial effect of an organic acid is not simply due to the ability to decrease pH (Abrahamsen, 1989; Adams, 1990). Weak organic acids only dissociate partially in aqueous media, and because of the lipophilic character of the undissociated form it freely penetrates the bacterial cell membrane. In the cell, the acid dissociates due to higher pH, acidifying the interior of the cell and releasing potentially toxic anions, which appear to be the most important factors in the antimicrobial activity of the organic acids.

1.2.3.3 Preservative effect of secondary metabolites. Secondary metabolites such as diacetyl and bacteriocins can have preservative effects as follows:

1.2.3.3.1 Diacetyl. In many dairy products, citrate-utilizing lactic acid bacteria play an important role as they are responsible for the formation of the flavouring compound diacetyl. Much of the literature describing the antimicrobial activity of diacetyl has been reported by Jay (1982). It is active against a broad spectrum of microorganisms including *Bacillus*,

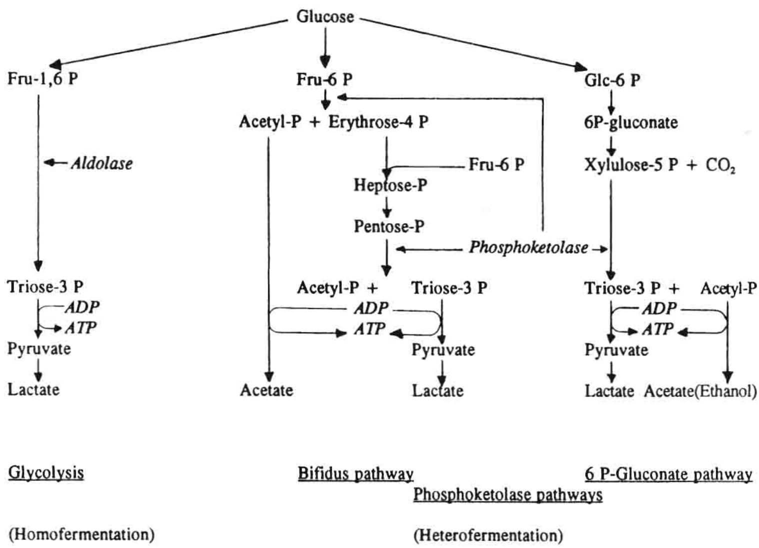
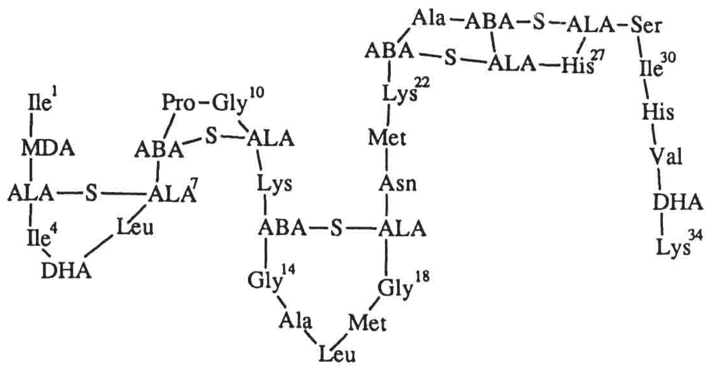


Figure 1.1 Main pathway of hexose fermentation in lactic acid bacteria (after Kandler, 1983).

Pseudomonas, *Escherichia coli*, *Staphylococcus aureus* and *Yersinia enterocolitica*. In fermented products, diacetyl is normally produced in very low concentrations (<10 ppm); however, in combination with other factors, e.g. the presence of organic acid, bacteriocins, H_2O_2 and nutrient depletion, the total inhibitory effect may be substantial.

1.2.3.3.2 Bacteriocins. Bacteriocins are proteins or protein complexes with bactericidal activity against microorganisms usually closely related to the producer organism. Production of bacteriocins by lactic acid bacteria has been extensively investigated. Reviews by Klaenhammer (1988), Hillier and Davidson (1991) and Stiles and Hastings (1991) describe bacteriocins produced by the lactic acid bacteria. These bacteriocins are heterogeneous and vary in spectrum of activity, mode of action, molecular weight, genetic origin and biochemical properties.

The best known and studied bacteriocin is nisin, produced by *Lactococcus* spp. Nisin is commercially available and has been approved for use in certain foods in more than 45 countries, including the UK and the USA (Stiles and Hastings, 1991). It belongs to a group of bacteriocins termed lantibiotics. Nisin differs from most other bacteriocins in having a relatively broad spectrum of activity against Gram-positive bacteria, including the outgrowth of *Bacillus* and *Clostridium* spores. It is a polycyclic peptide with a high proportion of unsaturated amino acids (e.g. dehydroalanine, dehydrobutyrine) and thioether amino acid (e.g. lanthionine [Ala-S-Ala], β-methyllanthionine [Aba-S-Ala]) as shown in Figure 1.2. Nisin is gener-



MDA = β-methyldehydroalanine
DHA = dehydroalanine
ALA-S-ALA = lanthionine
ABA-S-ALA = β-methyl-lanthionine

Figure 1.2 Structure of nisin.

ally considered to be non-toxic to humans. It is digested by α-chymotrypsin, an enzyme produced in the pancreas and released into the small intestine. These properties in particular have led to the extensive use of nisin as a food preservative.

1.2.3.4 Sensory properties. Lactic acid bacteria also produce volatile substances, for example, diacetyl and acetaldehyde, that contribute to the typical flavour of cultured buttermilk and yoghurt. Starter cultures also possess some proteolytic and lipolytic activity, which, especially during the maturation of cheeses, contributes to their characteristic flavour.

1.2.3.5 Dietetic properties. In 1908 the Russian biologist Metchnikoff put forward the theory that certain lactobacilli have a positive influence on digestion; however, the influence depends on their ability to survive the passage through the stomach and resist the bile salts in the small intestine. Only recently has it been possible to produce commercial quantities of specific dietetic cultures based on selected strains of *Bifidum infantis*, *Bifidum longum*, *Lactobacillus acidophilus* and *Lactobacillus casei*.

1.2.3.6 Polysaccharides. When producing fermented milk products, it is often desirable to increase the viscosity, improve the texture, increase the firmness and reduce the susceptibility to syneresis. This can be done by increasing the total solids in the milk before fermentation, using, for