CHILLED FOODS: THE STATE OF THE ART

CHILLED FOODS

The State of the Art

Edited by

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There have been rapid developments in the chilled food area over the last five years. Consumers perceive chilled foods as fresh, and the food industry promotes the sale of chilled foods, including a wide range of combination products, aggressively. There is, therefore, an urgent need for factual and practical information on chilled foods in terms of

- ease of temperature abuse
- synergistic effects with other treatments such as modified atmosphere packaging
- combination products
- high quality shelf life
- overall safety

This book brings together a wealth of European expertise in the chilled food area and the 15 chapters will be of considerable benefit to all involved in the production, distribution and retailing of chilled foods. Considerable emphasis has been placed on the safety and quality of chilled foods and the chapters on microbiology, combination foods and the chill chain pay particular attention to this feature. There are chapters dealing with all the main food commodities and attention is also focused on economic aspects of food chilling. The nutritive aspects of chilled food are considered as are modern systems and equipment used for the wide range of chilling functions found in the modern food industry.

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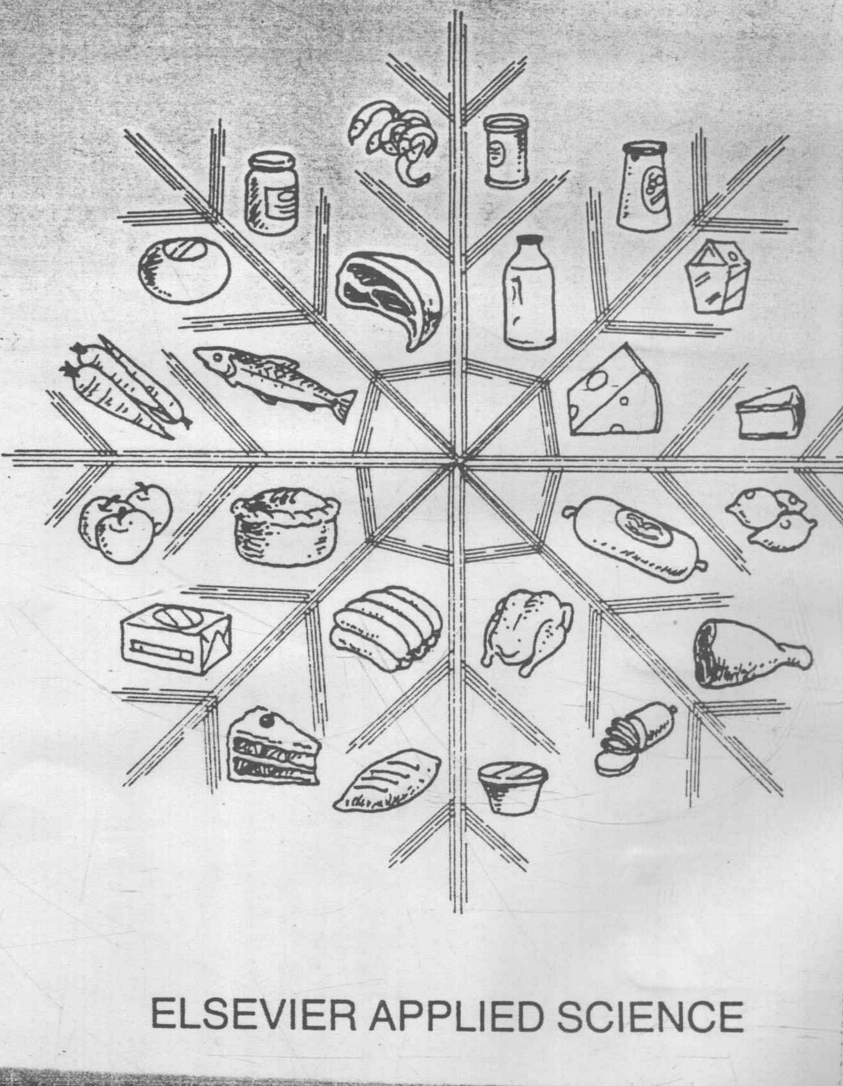

ELSEVIER APPLIED SCIENCE

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The State of the Art

Prepared under the auspices of the chilled foods subprogramme of the European COST 91 (Cooperation in Science and Technology) programme on the quality and nutritive value of foods.

Foreword

There is unprecedented interest at present in the convenience, quality and safety aspects of chilled foods and the decision in 1984 to include chilled foods as one of the sub-programme areas for the European COST 91 (Cooperation in Science and Technology) programme on the quality and nutritive value of foods has been fully vindicated. While chilling has long been used as a method to extend the shelf life of foods the recent developments in sophistication of the chilled food industry—brought about to a great extent by consumer demands for differentiation, freshness, convenience and shelf life—have led to many breakthroughs but also to problems.

It was decided during the course of the COST 91 bis programme to invite experts to prepare a series of reviews on a number of key aspects of chilled foods and hence this volume. The data are aimed not only at researchers who are specifically interested in food chilling, but also at the mainstream of the European food industry involved in food chilling, at equipment manufacturers, and at those involved in the distribution and retailing of chilled foods.

This book is one of three major publications on chilled foods emanating from the COST 91 bis chilling programme. The others are *Chilled Foods: The Revolution in Freshness* (part of the three-volume proceedings of the final Symposium of COST 91 bis held in Gothenburg in 1989 and entitled *Processing and Quality of Food*), and a booklet entitled *Chilled Foods: The Ongoing Debate* which is based on the proceedings of the nine chilled food workshops held during the course (1985–1989) of the chilling programme. Both are published by Elsevier Science Publishers Ltd.

For the information of the reader, the COST 91 bis programme also contained two other sub-programme areas, i.e. food biotechnology and HTST. These were chaired, respectively, by Professor C. Eriksson (SIK, Sweden) and Dr K. Paulus (Bund fur Lebensmittelrecht und Lebensmittelkunde, FRG).

Finally, as project leader of COST 91 and COST 91 bis I would like to thank sincerely all those who contributed to this volume. Special thanks are extended to Dr T. R. Gormley for his chairmanship of the chilling programme and for editing the book and to the late Professor M. Jul for his inspiration and foresight in conceiving the COST 91 bis programme on chilled foods.

PETER ZEUTHEN

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Chilling Systems for Foods

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ABSTRACT

Primary and secondary chilling are discussed under the headings principles, rapid chilling, including batch and continuous air chillers, hydro/immersion cooling, plate and vacuum cooling, and cryogenic cooling. Details of cooling liquids and solid/liquid mixtures are also given. The area of chilled storage is treated under the subsections bulk storage rooms, CA rooms and jacketed cold store. The use of mechanical units, eutectic plates and liquid nitrogen in the over-land transport of foods is outlined as are key elements in air and sea transport of chilled foods. Retail display cabinet design is also considered and it is concluded that the complete cold chain for chilled foods contains many specific unit operations that are often considered in isolation. Consumer requirements for safe high quality chilled food will only be achieved via integration of all the components of the chill chain.

1. INTRODUCTION

Chilling systems for foodstuffs contain many if not all of the following unit operations:

1. Preparatory treatment; conditioning, waxing, cooking, pasteurising, etc.
2. Chilling; primary or secondary.
3. Chilled storage.

4. Transportation
5. Retail display.

These five types of unit operation fall into three different temperature categories: (a) during the preparatory treatment there can be a range of temperature responses from a large gain to a small decrease in the temperature of the foodstuff, (b) chilling results in a substantial decrease in the mean temperature of the product, and (c) within a correctly designed chill chain there should be an insignificant rise in mean product temperature during storage, transport or retail display.

The initial and final temperatures, and the maximum and minimum desirable rates of temperature reduction during the chilling operation depend on the food being processed. In all cases the final product temperature must, by definition, be above the initial freezing point of the food, but in a number of products other biological factors dictate higher storage temperatures. For example tropical fruits such as bananas suffer discoloration at temperatures below 12°C, whilst salad vegetables such as cucumbers lose their textural properties at temperatures below 6°C. In red meats (pork, beef and lamb) slow rates of temperature reduction can result in high drip losses following cutting, but high chilling rates immediately post slaughter can produce tough meat.

The choice of a chilling system for a particular foodstuff must take into account many factors including the required throughput of product and the limitations placed by thermodynamic or quality restrictions and economic considerations, e.g. capital and running costs of the chilling cycles. The following sections indicate the principles behind the various unit operations required in a complete chilling system and describe a selection of the available equipment. Data are provided on the relationship between the controllable factors associated with each operation. The practical advantages and limitations of each system are described for a number of different food products.

2. PREPARATORY TREATMENTS

2.1. Meat

The main slaughtering operations applied to red meat (beef, lamb and pork), i.e. sticking, bleeding, evisceration, washing and dressing are independent of the chilling operation. However, with poultry the scalding and chilling method must be matched to obtain the desired final appearance of the product. After semi-scalding, 60–180 s at 51–54°C, the poultry skin remains intact and air blast chilling can be used without subsequent discoloration. Sub-scalding, 40–100 s at 56–60°C, results in a completely feather-free carcass after plucking with standard equipment, but the epidermis will generally be damaged. To achieve an acceptable appearance the birds must be chilled under conditions of excess moisture and a low temperature to avoid blotching.

2.2. Fish

Fish is a very perishable product and the initial handling operations, i.e. sorting, gutting, beheading and washing need to be carried out as rapidly as possible but do not interact with the chilling system used.

2.3. Dairy products

Raw milk is not normally pretreated before chilling but treatments such as pasteurisation and sterilisation of milk and other dairy products are often followed by secondary chilling. In the three main pasteurisation systems; low temperature (LT); high-temperature short-time (HT) and ultra-high temperature short-time (UHT), the rate of cooling is an integral part of the process.

With fermented dairy products, e.g. yogurt and buttermilk, temperature control is important during incubation which must be followed by controlled rates of chilling to achieve the required texture and flavour characteristics. In general, higher viscosity products, e.g. thick set yogurt, require slower cooling cycles.

2.4. Fruit and vegetables

In addition to the usual sorting, washing and packaging operations pretreatments may also include fungicidal, scald inhibiting or hormone sprays, but these do not affect the chilling systems.

3. PRIMARY AND SECONDARY CHILLING

3.1. Principles

The main factors which control the rate of heat and mass transfer during cooling are independent of the foodstuff. Heat can be lost from the surface of a body by four basic mechanisms: radiation, conduction, convection or evaporative cooling. To achieve substantial rates of heat loss by radiation large temperature differences between the surface of the product and that of the enclosure are required. Such differences are not normally present during food cooling operations except in the initial chilling of bakery products. However cooling rates have been increased by radiation during the later stages of carcass cooling by suspending low temperature refrigerated plates between the rails [1].

Physical contact between the product and the source of refrigeration is required to extract heat by conduction. The irregular shape of most foodstuffs precludes this mechanism in many applications. Plate conduction coolers are used for quick cooling of some packaged products and highly perishable products such as mechanically recovered or hot boned meat [2]. In these cases they usually form the first stage of a freezing operation. They also have possible application in the cooling of pasteurised ready meals [3].

The heat lost in the evaporation of water from the surface of the product is a minor component of the total heat loss for the majority of foodstuffs. However in a number of specific cases (detailed below) it can be the primary cooling agent.

Most food chilling systems rely on convection as the principal means of heat removal. Heat is transferred from the surface of the product into a cooling medium which passes over the product. The most common media are air or water, although salt solutions, sugar brines and other refrigerants have been used. The rate of heat removal from the product depends on the surface area available for heat flow, the temperature difference between the surface and the medium, and the surface heat transfer coefficient. Each combination of product and cooling system can be characterised by a specific surface heat transfer coefficient. The value of the coefficient depends on the shape and surface roughness of the foodstuff, but not its composition, and to a much greater degree on the thermophysical properties and velocity of the medium. Typical values range from 5 $W/m^2\,°C$ for slow moving air to 500 $W/m^2\,°C$ for agitated water.

However, the rate at which heat can be conducted away from the surface is not the sole criterion that governs the time taken to cool a product. Heat must also be conducted from within the product to its surface before it can be removed. Most foodstuffs are poor conductors of heat and this imposes a severe limitation on attainable chilling times for either large individual items or small items cooled in bulk. In practice most food cooling operations fall into one of these two categories. Animal carcasses, and many fish, are large individual items whilst fruit, vegetables and grain are cooled in bulk in silos or pallets. The few exceptions (soft fruit, tomatoes, etc.) that are not stored or transported in bulk containers, are often wrapped and placed in cartons before cooling. The combined effect of the wrapping and the static air enclosed in the carton considerably limit the rate at which heat can be extracted from the product.

3.2. Rapid chilling

It is clear from the above discussion that attempts to increase chilling rates are complicated by many factors, but there are a number of clear advantages in production economics if faster cooling can be achieved. Most foods are of high value and any increase in rate of product throughput will improve cash flow and utilise expensive plant more efficiently. Rapid reduction in surface temperature also retards microbial growth and consequently extends shelf life. This is especially important when chilling cooked products that will eventually be consumed cold or in a warm reheated state. Cooking rarely eliminates all food poisoning organisms and a number survive as spores which will germinate and grow if cooling rates are slow. Minimum cooling rates for cook chill meals are defined in the UK [4] and for cooked products in the USA [5].

Different foodstuffs exhibit particular quality advantages as a result of rapid chilling. In meat the pH starts to fall immediately after slaughter and protein denaturation begins. The result of this denaturation is a pink proteinaceous fluid, commonly called 'drip', often seen in prepackaged joints. The rate of denaturation is directly related to temperature and it therefore follows that the faster the chilling rate the less the drip. Investigations using pork [6] and beef [7] muscles have shown that rapid rates of chilling can halve the amount of drip loss. Fish passing through *rigor mortis* above 17°C are to a great extent unusable because the fillets shrink and become tough [8]. A relatively short delay of an hour or two before chilling can demonstrably reduce shelf life. In a different commodity/area, Fig. 1 shows the relationship between sugar loss and temperature in freshly harvested sweet corn [9]. Prompt cooling is clearly required if this vegetable is to retain its desirable sweetness. Similarly, the ripening of fruit can be controlled by rapid cooling, the rate of ripening declining as temperature is