DEVELOPMENTS IN FOOD PRESERVATION—5

Edited by

STUART THORNE

*Department of Food and Nutritional Sciences,
King's College, University of London, UK*

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PREFACE

We have entered a period of consolidation and subtle improvement in food preservation. No completely new processes have been introduced for some time and it seems unlikely that we will see any in the foreseeable future. Instead, attention is turning towards subtle improvements to existing processes, aimed at improvements in product quality and process efficiency. Perhaps most important of all, research is increasingly directed at an improved understanding of the fundamental behaviour of foodstuffs and food processing systems; thermal and physical properties, heat and mass transfer, the behaviour of micro-organisms and deteriorative chemical reactions. An increasing knowledge of all of these and the relationships between them is reducing the empirical content of food preservation operations and effecting a steady improvement in the quality of preserved foods.

Increasing consumer resistance to food additives has forced change on the Food Industry. Whilst we must resist the 'all additives are bad' brigade, the food industry is increasingly considering additives by need as well as legality. The use of additives should be based on ratio of benefit to possible detriment that they effect. Additives are not our primary concern here, but, as fundamental knowledge of processing operations improves, we are able to reduce additive use. For instance, there are many examples in this volume of how careful selection of processing conditions can reduce colour loss in foods; if we can reduce colour loss then we need add less synthetic colouring materials. I do not believe that synthetic additives are inherently less desirable than natural ones, but, because the safety of no food component, either natural or synthetic, can be proved absolutely, the fewer the components the safer the food.

The chapters in this volume represent much recent work on fundamental aspects of food preservation and demonstrate how proper application of this knowledge can result in better product quality and safety and improved process efficiency. And this is in the best interests of both the consumer and ourselves.

A problem with which we have to contend is consumer suspicion; our final customers often do not believe that the food industry always acts in their best interests. This is at least partly due to consumer ignorance. The popular media talk of 'scientific proof' when, of course, science is concerned with disproof and probability. Often 'proof' and 'disproof' are interchangeable; we are almost completely sure of our conclusions. But with food safety this is not so. We can never prove that a food will never harm a single consumer; we can only have proof that it can cause harm. So we have to be honest and admit that 'as far as we can ascertain the product is not harmful'. But this is not enough for our non-scientific customers, who have been led to believe in scientific proof. Better customer relations are needed; we must put aside our arrogance and attempt to explain to the public what we are doing, how we do it and why. Then, perhaps, we will have customers who have faith in us and our products.

Those of us in the European Economic Community have an exciting time ahead. The abolition of all trade barriers within Europe means that we have to have coherent European food legislation by 1991. It will also give us a market of some 300 million customers. But there will be immense problems. Every European nation has workable food legislation that permits production of safe food, but to agree to a single set of legislation is difficult; we all have our own national products and processes, which are not compatible with the requirements of other European nations. The British, for example, allow cereal fillers in sausages and non-dairy fats in ice cream and all of us have different regulations for the use of additives. I am sure that the problems will be solved, but we must ensure that they are solved in a way that permits national variation. As far as food is concerned, we must not all end up as identical Europeans, losing our national identities. Imagine the horrors of the Euroloaf or Eurowine. It may seem far fetched, but bureaucrats are capable of curious behaviour in their enthusiasm for unification. When problems of legislation are solved satisfactorily, the vast European market will be a challenge to the food processing industry. Those who are prepared with quality products will thrive and expand, but I fear that many, smaller firms will fall by the wayside. Unfortunately, it will not always be their own fault if they fail through lack of expertise in the vast new market. And the firms that lose their market to the large international companies will often be the suppliers of the national variations in foodstuffs that we need. The great attraction of a 'Common Market' is that we can be a great political and economic power whilst retaining our national identities and what we eat and drink are a major part of these national identities. Let us all ensure that a tariff-free Europe does not become a Europe of identical eaters and drinkers.

STUART THORNE

LIST OF CONTRIBUTORS

M. Bennasar

Centre de Genie et de Technologie Alimentaire, Universite des Sciences et Techniques du Languedoc, Place E. Bataillon, 34060–Montpellier, France

W. Canet

Instituto del Frio (CSIC), Ciudad Universitaria, 28040 Madrid, Spain

C. Guizard

Laboratoire de Physico–Chimie Matériaux, E N S C M, 8 Rue de l'ecole Normale, 34075 Montpellier, France

J. R. Heil

Department of Food Science and Technology, University of California, Davis, California 95616, USA

H. G. Kessler

Institute for Dairy Science and Food Process Engineering, Technical University Munich, D–8050 Freising–Weihenstephan, FRG

G. M. Rios

Centre de Genie et de Technologie Alimentaire, Universite des Sciences et Techniques du Languedoc, Place E. Bataillon, 34060–Montpellier, France

Sudhir K. Sastry

Department of Agricultural Engineering, The Ohio State University, 590 Woody Hayes Drive, Colombus, Ohio 43210, USA

John N. Sofos

Department of Animal Sciences and Department of Food Science and Human Nutrition, Colorado State University, Fort Collins, Colorado 80523, USA

J. Succar

Research and Development Center, Beatrice/Hunt–Wesson Inc, 1645 West Valencia Drive, Fullerton, California 92633–3899, USA

B. Tarodo de la Fuente

Centre de Genie et de Technologie Alimentaire, Université des Sciences et Techniques du Languedoc, Place E. Bataillon, 34060–Montpellier, France

Stuart Thorne

Department of Food and Nutritional Sciences, Kings's College London (KQC), Campden Hill Road, London W8 7AH, UK

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Chapter 1

QUALITY AND STABILITY OF FROZEN VEGETABLES

W. CANET

Instituto del Frio (CSIC), Ciudad Universitaria, Madrid, Spain

SUMMARY

Freezing is widely acknowledged as the most satisfactory method of preserving vegetables over long periods. This chapter reviews and discusses technological innovations in the field of freezing during the past ten years; primarily on the effects of freezing on the quality of the final product.

Topics considered include basic aspects of freezing itself, the physical and chemical alterations taking place in the product during storage, and the combined effect of storage time and temperature (TTT factors), with a discussion of the relative importance of the freezing rate and storage temperature.

The effect on quality of product–related factors, processing (in particular blanching, in view of the greater importance of technical developments in this area as compared to those relating to freezing per se*), pre–freezing treatments, and packaging (PPP factors).*

Lastly, future research priorities are summarized. A combination of more basic knowledge, technological development, and optimization of the many PPP and TTT factors would all help achieve the higher levels of final product quality increasingly demanded by consumers.

1. INTRODUCTION

Looking back over the historical development of quality requirements for processed foods,[1] freezing is undoubtedly the most satisfactory method for the long-term preservation of vegetable produce. The low temperature commonly recommended for frozen foods (−18°C) inhibits the activity of microorganisms and slows the biochemical reactions which, together with the reduction in water activity due to freezing, can maintain the initial quality and nutritive value almost unchanged, with differences only in texture between frozen and fresh vegetable products.

The economic importance and continuous growth of frozen vegetable consumption in Europe are reflected in Table 1. The data show that in 1984 the UK, Federal Republic of Germany, and France were the three countries with the highest overall consumption of frozen foods (poultry products not included), while Sweden, France, and Denmark enjoyed the highest per capita consumption. The increase in consumption in 1984 with respect to 1983 ranged between 5 and 10% in all countries except Sweden (2%) and Holland (3·1%).

The proportion of frozen vegetables (including potato products) in total frozen food consumption ranged from 34% in Sweden and Norway to 61% in Italy. Frozen vegetables were, in volume, by far the largest sector of frozen food sales in all countries. The data on total frozen vegetable consumption in 1985 show the UK in first place, followed by the Federal Republic of Germany and France, with the highest increase in consumption over 1984 being recorded in France (28·9%) and the lowest in Holland (2·8%) and Finland (3%).

The importance of freezing and the scientific and technological development of this method of food preservation is highlighted by the considerable attention afforded to it in all the countries of the EEC in recent years. In 1977, it was included as a research priority in food science and technology under the first Intra-European Collaborative Research Programme; the COST 91 Project on the Effects of Thermal Processing on Quality and Nutritive Value of Foods.

In the three-year period 1981–3, a subgroup for collaborative work on the influence of freezing, distribution, and thawing on the quality and nutritive value of foods existed under this project, culminating in new and interesting scientific findings in the field of freezing in general and with respect to frozen vegetables in particular.

Vegetable produce is characterized by its seasonal and highly perishable nature, with extremely rapid deterioration in quality at ambient temper-

TABLE 1

FROZEN FOOD CONSUMPTION IN EUROPE IN 1984 AND 1985[a]

	Total frozen food consumption[b] *(Tm) 1984 A*	*Per capita consumption (kg) 1984*	*% difference over 1983*	*Total frozen vegetables consumption*[c] *(Tm) 1984 (B)*	*% frozen vegetables/total frozen foods (B)/(A) 1984*	*Frozen vegetables*[c] *consumption (Tm) 1985*	*% difference over 1984*
Denmark	94·769	17	9·1	35·509	37·46	39·355	10·8
Finland	38·511	10·1	5·4	17·754	46·1	18·290	3
France	669·817	18·5	9	313·764	46·8	404·421	28·9
Germany (FR)	692·219	7·5	9·2	390·130	56·3	428·846	9·9
UK	880·000	11·2	5·4	444·000	50·4	493·000	11
Italy	229·030	3·7	10·2	140·640	61·4	154·240	9·6
Holland	205·691	19·3	3·1	109·450	53·2	112·500	2·8
Norway	53·817	11·9	9·7	18·979	34·8	21·777	14·7
Sweden	172·688	20·1	2	59·009	34·2	61·864	4.8
Switzerland	76·982	11·8	7·9	42·065	54·6	46·056	9·5

Tm, metric tons.

[a] Elaborated with values obtained from Elman[2] and Halique.[3]

[b] Frozen poultry products not included.

[c] Including frozen potato products.

atures after harvesting. Freezing under optimum conditions and storage at temperatures of −18°C or lower can maintain initial quality for between twelve and thirty-six months. The final quality of frozen vegetables is dependent upon a large number of factors, such as product type and variety, degree of ripening, initial quality, harvesting methods, elapsed time between harvesting and processing, pre-freezing treatments, freezing procedures, packaging, storage time and temperature. All these factors and their interactions, combined with possible deficiencies in storage conditions during the freezer chain, point out the difficulty in optimizing the process as a whole and thus in satisfying consumer quality expectations.

The main objective of this chapter will be to review the fundamental aspects and technological features of the main stages of the freezing process and storage and their effects on the quality and stability of frozen vegetables, focussing on the state of the art and future research goals.

1.1. Historical Notes on Vegetable Freezing

The modern era of frozen foods began in the 1930s, with the appearance of frozen vegetables in the United States market.[4] Intensive research efforts in the field had commenced during the previous decade and have continued up to the present day, giving rise to an extensive scientific literature on the quality and stability of frozen vegetables. The first review of the literature was made by Tressler and Evers.[5] Initially, research concentrated on the search for solutions to the problems posed by changes in colour and the development of off-flavours during storage. In 1929 Joslyn and Cruess[6] demonstrated that blanching (brief heating of the product) increased the stability of frozen vegetables over prolonged periods of storage. Onslow[7] studied and discussed, for the first time, the phenomena underlying oxidative browning in frozen fruit, relating it to the action of certain oxidases on phenols. In 1941 Joslyn[8] showed that ascorbic acid could act as an inhibitor of the oxidation reactions causing browning.

At the same time, scientists also turned their attention to the effect of the freezing rate on the quality of frozen vegetables. Woodroof[9] described physical changes in vegetable tissues during freezing, showing the advantages of rapid freezing. Morris and Barker[10] confirmed these results for fruits, recording considerable organoleptic differences between fruits subjected to rapid or slow freezing; nevertheless, the differences disappeared after storage. Lee *et al.*[11,12] were of the opinion that there was no advantage in using faster freezing rates than those commonly employed by the food industry at the time.

In order to maintain product quality and stability after freezing, it was necessary to select a storage temperature appropriate to the probable duration of storage and distribution until consumption. At the end of the 1940s scientific opinion concerning the most suitable storage temperature was still divided, though −18°C (0°F) had become the most widely used temperature industrially; more from technical and cost considerations than on any sound scientific basis. Today −18°C is regarded as the target temperature, but it is not always maintained, particularly during transportation and distribution. At the request of the US frozen food industry, in need of scientific 'facts' on which to base quality preservation during the storage and distribution of frozen products, in 1950 the USDA Western Regional Research Laboratory at Albany, California designed and implemented a research programme aimed at studying the combined action of storage time and storage temperature on the quality and stability of frozen foods, the so-called 'TTT Project' (time, temperature, tolerance). Such concepts as 'high quality life' and 'practical storage life' were first defined by this project, and instrumental and sensory measures of quality were designed and put into practice. The scientific methodology developed under the project is still in use today. The results of this programme were published by van Arsdel *et al.*[13] Particular attention was addressed to the quality and stability of frozen vegetables, with extensive studies of such vegetables as green beans, peas, spinach, and cauliflower[14] and fruits like strawberries, peaches, raspberries, and cherries.[15,16]

Together with this applied research, more basic theoretical work was performed in an attempt to study and explain the structural changes occurring in different vegetable tissues associated with freezing, thawing, and blanching.[17] More recently, similar work has been carried out, directed specifically at cauliflower,[18] green beans,[19] and peppers.[20] There has been a comprehensive review by Reeve[21] and significant work by Brown[22] on green beans, Rahman *et al.*[23] on carrots, and Mohr[24] on peas, spinach, and green beans. All these authors underlined the beneficial effect of fast freezing rates on quality by reducing structural damage. Losses in quality that are chemical in nature, caused primarily by enzymatic reactions, gave rise to basic, general papers like those by Joslyn,[25] Lee *et al.*,[26] Leeson,[27] and a review of blanching by Lee.[28] Interesting work was also carried out by Esslen and Anderson[29] and Zoueil and Esslen[30] for peroxidase and by Sapers and Nickerson[31] for catalase on the degree of thermal destruction of enzymes at high tempratures and possible regeneration during frozen storage. Other work by Dietrich *et al.*[32] and Pinsent[33] for peas, by Dietrich and Newmann[34] for Brussels sprouts, by Rosoff and Cruess[35] for cauliflower, and by Resende *et al.*[36] for green beans and spinach was aimed at determining optimum conditions for blanching and the possible repercussion of blanching on quality. Aylward and Haisman[37] published an interesting review on fruit, summarizing the knowledge and results obtained up to that time with regard to oxidative systems and their effect on the quality of processed vegetables.

There are other factors in addition to the freezing process itself and to frozen storage that exert a sizeable influence on quality, e.g. product type and variety, degree of ripening, initial quality, pre-freezing treatments, and packaging. Dalhoff and Jul[38] listed these, which they termed PPP factors (product, processing, packaging), stressing their relative importance—in some cases more important than freezing rate and storage time and temperature themselves. Such factors have been reviewed by Gutschmidt,[39] Olson and Dietrich,[40] and Pointine *et al.*[41]

Some works dealing with frozen food processing, whose chapters on vegetables are an excellent compendium of scientific information, are essential to any list of reference works: Fennema *et al.*,[42] Cioubanu *et al.*,[43] Desrosier and Tressler,[44] and the International Institute of Refrigeration.[45]

This summary of the considerable scientific literature available, of necessity incomplete, emphasizes topics with a bearing on the quality and stability of frozen vegetables that were the main areas of interest to research workers between 1930 and 1970.

In line with the main objective of the present review, attention will focus on these main subject areas: the effect on quality of the initial freezing process, the frozen storage period, the TTT factors, and, finally, product-related factors, processing (in particular blanching), pre-freezing treatments, and packaging (PPP factors).

2. INFLUENCE OF FREEZING

2.1. The Freezing Process

The freezing process in itself consists of lowering the product temperature to $-18°C$ at the thermal centre, resulting in crystallization of most of the water and some solutes.

A knowledge of the temperature changes undergone by the different parts of the product during freezing (Fig. 1) is essential in order to be able to understand the process. Three separate stages are distinguishable.[46] First there is a pre-freezing stage, in which the product is cooled from its initial temperature to the freezing point. Ice crystallization occurs only after