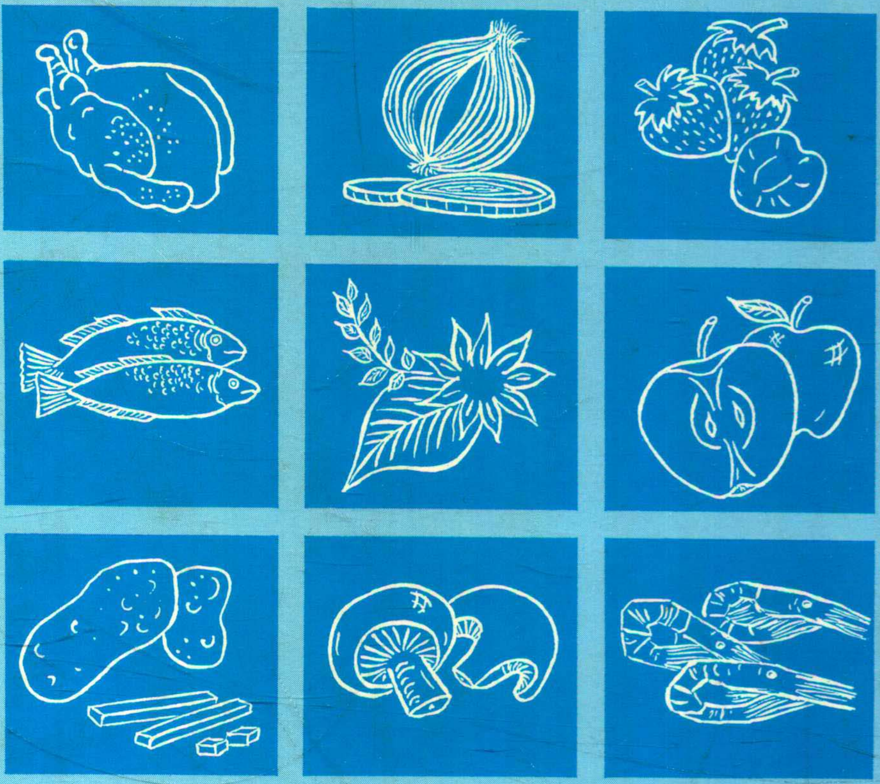
FREEZE-DRYING FOR THE FOOD INDUSTRIES

J. McN. DALGLEISH



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FREEZE-DRYING FOR THE FOOD INDUSTRIES

To both our families

Preface

In a multi-basic-disciplined field such as food technology, in order to visualise a process better, one tends to simplify it by imagining a *model* system, in form having likeness or reference to things already known.

Foods then are pictured as 'foodstuffs', and popularly recognised as 'starchy foods', or 'plenty-of-vitamins foods' or 'fresh foods' or other common conceptions, quite adequate for the most part in persuading people to balance their diet and enjoy the prospect of intake and the functions, social or survival, of eating. The complication of enquiring into the means by which we build and maintain our bodies on what has already proved useful and integral to *other* forms of life rarely is considered a subject warranting more than superficial scrutiny from a well-established and secure society.

Retail presentation of preserved foodstuffs is an ancient art, and the general public, provided they are assured of hygienic supply lines, seem singularly un-curious regarding the complexity or otherwise of the highly technical system at their service.

Consequently when, perhaps as a snippet of wrapper news, the public are introduced behind the scenes and asked to accept a phrase describing a preservation process such as 'freeze-drying', they may well be satisfied with the notion that something familiarly edible is actually rather like a honeycomb inside, the combs containing mostly water with a variety of 'nutrients' in suspension, and the whole is first frozen but then dried, after which it is unnecessary to keep it frozen, just dry.

Their model may be amplified with the information that the drying part is the changing of the ice into steam without being melted, and further that atmospheric pressure must be vacuumised in special machines, all of which makes the process slow, elaborate and somewhat expensive, but the resultant quality, when the water is restored perhaps many years later, makes it all worthwhile.

For the layman, such a model is sufficient for everyday visualisation, albeit scant on technical detail. Why should it be contradicted—it has the necessary elements of comfort, assurance of skill, marvel and more than a hint of justified cost.

Alas, for the technically aware, there is much that is glib in this descriptive outline. We know that the chemical composition of any cytoplasm is highly intricate, and that separating out H_2O molecules as ice crystals or in any form is a drying or dehydrating action in itself; that the whereabouts of these molecules within the 'honeycomb' matrix is dependent on the striated fibril layers forming the cell wall boundaries and interconnections; that the nutriments themselves are mobile, but enmeshed in a gel-propertied structure, and their relation to that structure alters depending on the liquidity of their environment. We know moreover that the extraction of the 'moisture' as vapour from the ice phase is dependent more on the partial pressure of water vapour than on the total pressure, and that the phenomenon can take place on a winter's clothesline, in a cold store, or indeed upon the exposed living tissue of an Arctic explorer or a micro-organism, and can render them dead or dormant depending on the conditions.

For the jibe of 'elaborate' one may choose to read 'elegant', for 'slow' substitute 'careful' and for the relative term 'expensive' respond with 'not necessarily'. We are led to explain a much more elegant model, having parameters that fit the constraints of physics and chemistry as we can apply them. The quality then is a measure of the care we have taken, and the cost rests on the engineering skill and the benefits of scale.

Explanation of the construction of such a model for this fascinating foodstuff process, from which to plan optimum performance, is the purpose of this book.

This then is a book dealing with an involved process, of commercial use to a large number of diverse companies in a wide-ranging food industry. It is important, therefore, especially when mathematical treatments of parameters are discussed, to have a concept that is understandable by all parties. Such a vision is not always immediately provable—indeed many of those concepts reported are *dis*provable—but at least the present intention, as no doubt all others, is to conjure a mental picture around which one can argue the practical sense of what is happening in reality.

When a problem has to be programmed to fit the memory or capacity of an available computer (say), then sometimes constraints are applied to the program parameters which cut the problem down to convenient size, without recall. Eventually the workable program may bear insufficient resemblance, in its simplistic form, to the original to enable the operator to use the solution in the real world. Increasingly this is unlikely nowadays, for vast memories are tappable, but (computer) programs are still often built around sub-routines that themselves have crept into common usage, not because of memory size, nor even because of simplicity, but in an endeavour to frame the solution to the 'new' problem in a satisfying familiarity of context.

Thus it has become assumed, almost taken for granted, that one must perform a freeze-drying operation within a hermetically sealed chamber of great strength, from which all gases have been removed to a near vacuum, and that the capital cost of achieving the inherent conditions is high, not to mention the running costs. This need not be!

Dictionary definitions have in their nature to be universal. So it is not surprising to find that Webster explains freeze-drying as 'a process by which heat sensitive materials . . . can be dried by freezing and then converting the frozen solvent to gas in a high vacuum at a low temperature'!

The treatment of blood plasma or antibiotics in medical laboratories is readily pictured by this definition. But what about the classic illustration of the frozen clothes drying on the washing line, without ever thawing? They are still in a vacuum, one might accept, since the whole world is in a near-vacuum, and the temperature profile (compared with the sun) is not all that high. What happens to the vapour? Is it enticed to a colder *surface* to condense again as ice, as many laboratory freeze-driers arrange?

It is not too difficult a coloured concept then to view the Earth perhaps as a gigantic shuttle freeze-drier, or at least a heat pump of reversible type, where the polar cap nearer the sun sublimes to the other, mountain peaks blanch in the wintry wind, and Nature's changing apparel signifies senescence.

Geophysical studies tend to be concentrated at the pole that is Southern, where the landmass, staked out but as yet uncarved, protrudes to point ominously at the sky. Until lately it was mineral content that held the various settler nations' attention, rather than the

(CFC-gathering) hospitality of the heavens (North Pole '89 has also a reported 'ozone gap').†

There it is a delicate balance. The size and amount of minute dust in the outer layers of the atmosphere, where such vapours are super-cooled and invisible, may become enough to permit ice crystals to form and grow before that vapour can reach its ultimate or penultimate destination. Not for it the high peaks of the polar region or even the Himalayas; the crystals are bound for the lower, warmer, higher vapour pressure of the clouds, there to add to the greenhouse effect, urged on by the occasional volcanic eruption or nuclear explosion.

In freeze-drying for the food industry, world-wide, one has to ensure that the ice is not diverted.

J. McN. DALGLEISH

† The Natural Environment Research Council plans (1989) to develop a UK Universities' *Global* Atmospheric Modelling Project, euphemistically shortened to UGAMP, perhaps modestly to signify the Dickens of a large umbrella! In such hands and the data-crunching age, some spin-off on the Spin-Off should prove the adroitness of the move.

Author's Note

When absolute pressure is discussed in this book, it will generally be referred to in mm Hg. This is because a number of other publications, endeavouring to standardise reported observations in Pa or kPa to concede *derived* SI units, have merely converted data in easily visualised *round* numbers, based on scale divisions of 760 mm, into obscure decimal-fractionated numbers that convey little hint of the real accuracy. Thus 0·2 mm Hg has appeared as 26·7 Pa, 20 mm Hg has become 2·7 kPa, and so on. The finesse of quoting a reading on a scale to the nearest mark is lost, and an accuracy is implied which not only was not there but may be misleadingly precise. The ratios 760 mm Hg = 1·01325 bar = 101·325 kPa are given with this proviso in mind (Fig. 1).

A number of non-orthodox but graphic terms have been used in technical contexts. These layman's words are intended deliberately to conjure up more vivid mental pictures for the serious student, perhaps prompting him or her to explore some of the features reported, of which this process has traditionally been embarrassed, and thus to branch into quasi-associated territory previously dismissed as a side-track of assumed less rewarding economical significance.

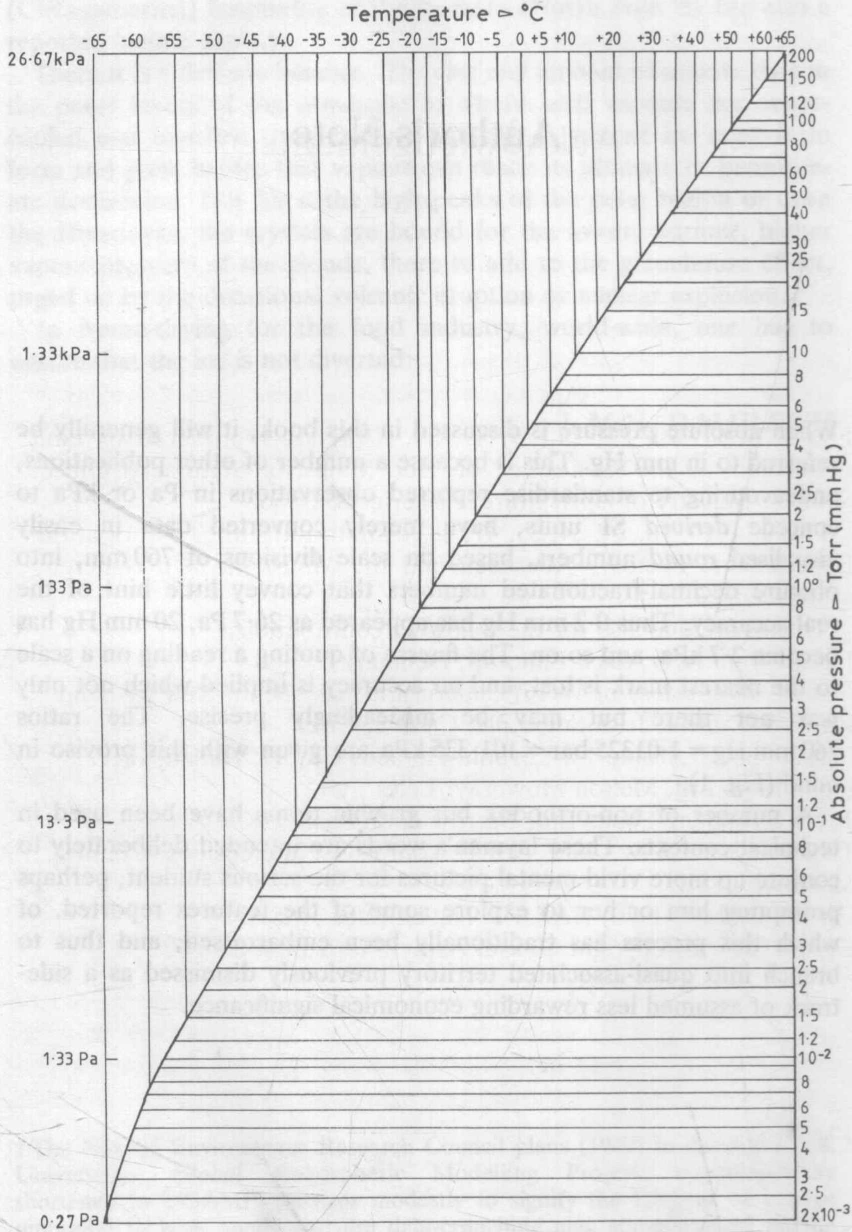

FIG. 1. Pressure/temperature relationship for water and ice.

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Fig. 9 Mars Ltd, Melton Mowbray, Leics., UK

Table 5 Haldane Foods Ltd, Barrow upon Soar, UK

Table 6 Science & Life (1985) courtesy "Intercosmos Council", Moscow, USSR.

Fig. 55 Table 7 (1970) NASA & Natick Labs., USA.

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Part I

HISTORICAL BACKGROUND

(EVOLUTION OF COMMERCIAL FOOD FREEZE-DRYING)

Chapter 1

The Role of the Aberdeen Experimental Factory

The second half of this century has seen considerable emphasis placed on foods that are quick and easy to prepare, whether the feeding pattern was in famine relief, or in combat zones, or in highly urbanised societies. Tastiness, wholesomeness, variety of diet, reasonable cost, with no waste and with ready availability, outline the consumer demand to which industry has responded by increasing preparation *within* the factory of top quality ingredients and materials, and stressing the subsequent convenience at the point of consumption—the pickling and canning stories all over again, perhaps, but both public and food industry were shaking off the fetters of Second World War rationing. A new look was sought. As with all forms of food presentation, assurance had to be inherent of freedom from bacterial spoilage and off-putting enzymatic changes, while flavour and mouth-feel, original or acquired, had to be acceptable and enticing. Preservation had to start at the farm gate, distribution chains within and without Great Britain were primitive, motorways in their infancy, grocery shops still small and multi-outlet.

Freeze-drying came near to being dismissed out of hand as inordinately expensive by the food industry, not the general public. They in fact were demonstrably eager, in post-austerity, to try all things new, from instant soups to TV dinners. To the entrepreneur processor, unaided capital outlay appeared too high for this process, which for a start had a long production time. Commercial quality tight-roping for a just-adequate packaging form was unknown, and some considerable extra marketing effort, compared with (say) frozen foods, was deemed likely. Many socio-economic factors were at work. Government, commerce and public had different attitudes.