INSTITUT INTERNATIONAL DU FROID
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IIR Refrigeration News

Is an *'isochoric freezing'* revolution really in the offing?

1. Introduction

A refrigeration technique named *'isochoric freezing'* [1], previously tested for preserving biomaterials, has recently been publicised worldwide and claimed to be a superior alternative to the classical freezing throughout the entire food cold chain [2]. The method has been advocated as a revolution in food preservation [3,4], a *'panacea'* for most problems of food storage [5] or a break-through solution to both energy- and quality-related problems of global frozen food industry [4,6,7].

The trick is in hindering the phase transition of food's water into ice by means of high pressures (e.g. within the range of approx. 30-180 MPa when the targeted final temperature of food is between –2.5 and –18 °C) [8]. Such a great pressurisation can occur under isochoric thermodynamic conditions by lowering the temperature inside robust constant-volume containers, where a sufficient amount of auxiliary aqueous solution, filled around foods, freezes and expands in volume [8].

Favourable *'isochoric freezing'* effects on food quality are associated with reduced structural damage because of the inhibited phase-change in food [8]. Thanks to the minimised or prevented ice crystallisation, developers report enormous potential energy savings [4,6,7].

A team of food refrigeration experts, serving as IIR commission officers or executive committee members (namely K. Fikiin, S. Akterian, A. Le Bail, J. Carson and T. Eikevik), assessed the actual state of play in *'isochoric freezing'* and identified **several major points** which **need to be scrutinised or critically re-examined** [9]:

2. Terminology

Method's proponents believe that the phrase *'isochoric freezing of food'* is *'the most rigorous thermodynamic descriptor'* [10], though the process aims to keep food unfrozen. By contrast, the expert group [9] considers the latter incompatible with a science-based terminology [11,12], but possibly admissible as a commercial tradename.

Thus, *'isochoric pressure-aided supercooling'* or *'isochoric pressurised supercooling'* is deemed a more adequate term [8,9,13]. *'Isochoric freezing'* proponents disagree with such a formulation, arguing that the spontaneously supercooled state is metastable [10]. However, the established international terminology defines supercooling as *'cooling a substance below the normal freezing point without solidification'* [11,12], which is not necessarily relevant to thermodynamic stability. As is known, artificial supercooling for useful purposes can be achieved by using different physical means (pressure, electrical and/or magnetic fields, structural modifications, etc.).

3. Plausibility, resource efficiency and safety

As the long-lasting preserving effect of freezing is primarily due to the conversion of water into ice, rather than to the low temperatures, the claimed method's advantages need to be verified during long-term food storage against the conventional modes. At present, no replicable data is available on the useful shelf life of isochorically supercooled products. For delicate and highly porous foods, the tissue-damaging impact of high pressures might be no less severe than the destructive effect of phase change. Thus, isochoric preservation is a largely unexplored topic, whose capabilities still need to be investigated and hopefully proven in a sufficiently representative real-life environment.

To reach and maintain the required high pressures along the cold chain for freezing, frozen storage and distribution, massive pressure-resistant containers are necessary [2-7,10,14]. This complicating circumstance substantially increases the consumption of energy and resources to produce, refrigerate, transport and handle at home such bulky containers (given also the hazardous pressures inside them might accidentally cause explosions). From this viewpoint, *'isochoric freezing'* appears to be more resource-intensive than the conventional isobaric freezing at atmospheric pressure.

4. Energy demand and efficiency

Enormous energy benefits claimed [4,6,7] are debateable as it remains unclear how and where the energy consumed to cool the pressurised container and to freeze the expanding substance is taken into account. In particular, the claim for up to 70% energy savings [6], as compared with the classical isobaric freezing, remains unsupported. Method's proponents [6] claimed such huge savings after comparing the calculated cold energy expenditure of an isochoric system with that of its isobaric counterpart by using the assumption depicted in Fig. 1.

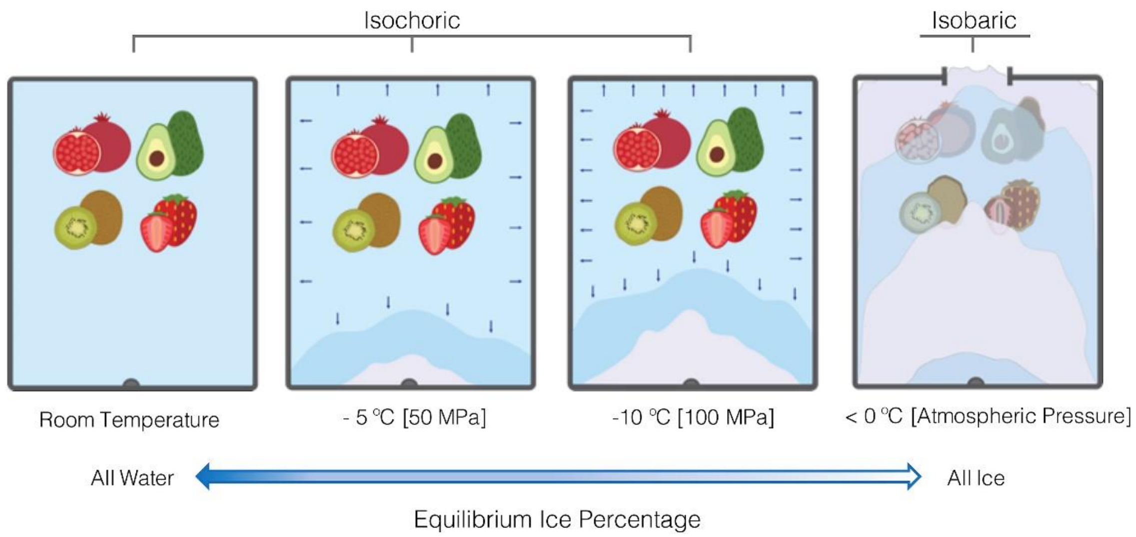

Fig. 1. Fictitious scenario for traditional isobaric freezing to be compared with *'isochoric freezing'* [6].

However, presenting classical isobaric freezing at atmospheric pressure as per the right-most image of Fig. 1 is fictional and unrealistic, because no technology freezes food in this way. Unlike *'isochoric freezing'*, classical freezing requires neither special robust containers, nor pressurising substances, given that a direct or close contact between the product and the refrigerating medium is normally present [9]. Energy comparisons can only be objective under realistic conditions and per unit of useful end product (frozen food), without arbitrarily attributing any imaginary energy wastage to the classical freezing. The alleged *'isobaric system'* (Fig. 1) does not really exist in food freezing practices and cannot serve as a reference.

To date, no experimental data and explicit quantitative information can be found on the energy expenditure for a *'workable industrial configuration'* [10], while energy assessments [8] based on lab tests [14] disfavour the employment of *'isochoric freezing'.*

5. Conclusion

A number of thermophysical phenomena and engineering issues related to *'isochoric freezing'* require further clarification. The spectacular energy efficiency claims [6,7] need to be objectivised. Determining the energy usage for unit of useful product or useful effect is a *'conditio sine qua non'* – irrevocable prerequisite for any credible technology assessment.

Potential energy savings might result from carrying out the refrigerated warehousing and distribution of *'isochorically pre-frozen'* products at a higher temperature (e.g. –5 °C instead of the standard −18 °C) [9]. Nevertheless, it is unlikely that the latter could compensate for the resource- and cost-inefficiency in processing, packaging and transport, given also the safety hazard of high-pressure operations for personnel and consumers [9].

The expert group concluded that despite the significant aspirations and associated claims, *'isochoric freezing'* cannot presently be regarded as a competitive alternative to classical freezing and the frozen food cold chain at atmospheric pressure [9].

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