

## Chapter 2

# Technology and Chemical Features of Frozen Vegetables

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**Abstract** The aim of this study has been the description of the current state of the art of frozen vegetables. One of the most promising food and beverage categories in the current market is represented by frozen products, although the modern food industry is officially born in 1928 in the United States of America. Before this date, previous freezing systems were based on the production of ice, with the use of refrigerating machines and the development of storage rooms. At present, the evolution of this sector can be briefly identified with the improvement of freezing techniques, the notable demand of food supplies worldwide, and the increasing number of frozen food typologies, including fruits and vegetables. Basically, frozen foods are very similar to original products when speaking of sensorial features. On the other side, some defects have been observed and correlated with freezing techniques and blanching treatments. The most used systems—air blast, plate and immersion freezers—are discussed with the description of correlated advantages and risks, including economic evaluations.

**Keywords** Air blast freezer • Cryogenic freezing • Frozen vegetable • Immersion freezer • Individual quick freezing • Plate freezer • Texture

### Abbreviations

IQF Individual quick freezing

INRAN Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione

## 2.1 Introduction

One of the most promising food and beverage categories in the entire food market worldwide is represented by frozen products (Mallett 1993). Actually, it should be highlighted that the modern food industry is officially born in 1928 in the United States of America (Persson and Londahl 1993) with the introduction of double-belt contact freezers. Before this date, previous freezing systems were based on the

production of ice, the use of refrigerating machines and the development of storage rooms (slow freezing techniques). Because of technological limitations related to the first technological procedures, only three main food categories—meat, butter and fish—were frozen. The real difference between old freezing systems and the current situation may be easily identified (Arthey 1993; Cortellino 2016; Fellows 2009; Hui 2006; James and James 2016; North and Lovatt 2006; Parreño and Torres 2016) as follows:

- (a) The improvement of freezing techniques, with the introduction of multi-plate freezers, individual quick freezing systems and cryogenic methods
- (b) The remarkable demand of food supplies worldwide without seasonal variations, differently from the past
- (c) The increased request of readily available foods in different regions of the industrialised world
- (d) The increasing number of food typologies which can be treated with freezing techniques.

With relation to the last point, it should be considered that fruits and vegetables are one of the most important categories of frozen foods at present. Probably, this reflection may reveal the real difference between past and present times, when speaking of frozen technologies. Moreover, fruits and vegetables are considered with great favour when speaking of good nutritional advices and the necessity of supplying a good amount of vitamins, minerals, fibres, and other healthy principles with anti-oxidant properties (Delgado et al. 2017). As an example, Italian Guidelines for a Safe Nutrition recommend five portions of vegetable products per day: in other terms, 600–800 g of vegetables should be consumed daily (INRAN 2003). On the other side, certain food processing technologies may cause peculiar damages to vegetable tissues and other foods (Parisi 2002). For all these reasons, the necessity of long-durability foods such as vegetables and fruits is ‘mandatory’ in globalised markets (Parisi 2016). Finally, the perishability of food commodities—all food commodities—should not be forgotten. Parisi has enunciated recently his Law of Food Degradation: in brief, there are not foods or beverage which could remain unmodified during time; chemical, physical, microbiological and structural properties are always subjected to modifications, without exceptions (Parisi 2002; Volpe et al. 2015).

## 2.2 Frozen Foods: Chemical and Physical Modifications

Basically, frozen foods are similar to original products when speaking of sensorial features. In some situation, frozen foods may exhibit similar or ameliorated organoleptic features (Lisiewska and Kmiecik 2000), although other authors signal different properties (Le Bail et al. 2016). Anyway, basic sensorial properties are judged satisfactory in the most part of situations; sometimes, these results are

correlated with good or excellent raw materials (Senesi 1984), the use of particular additives such as maltodextrins (Specter and Setser 1994) and the reduction of lipidic oxidation in peculiar foods (Erickson 1997). On the other side, the modification of chemical parameters for frozen foods during storage could give some unexpected surprise when speaking of fish products (Arannilewa et al. 2006).

In general, chemical features and sensorial properties of frozen foods can suffer the following modifications:

1. The formation of ice crystals into foods under freezing processes is well known and extensively studied. The problem correlated with ice crystals is not dependent on the crystallisation of aqueous molecules, but with the destruction of tissues because of large ice crystals and the possible emersion of ice needles from food surfaces, similar to the situation observed in deep-frozen cheeses (Parisi et al. 2016). This phenomenon should be carefully discussed in detail in terms of kinetics (Belitz et al. 2009; Bevilacqua and Zaritzky 1982; Donhowe et al. 1991; Lévy et al. 1999). By the microscopic viewpoint, it could be affirmed that the obvious removal of liquid water molecules is cause of partial protein dehydration with consequent spatial modifications of lipoproteins. With particular reference to meat products, the formation of large ice crystals (and consequent macroscopic damages) is inhibited on condition that freezing is very rapid. With relation to physical modifications, a certain variation of rheological properties in intermediate liquid masses can be observed (Belitz et al. 2009). The problem is correlated with the amount of non-freezing water even at  $-30^{\circ}\text{C}$ , the high viscosity of the remaining liquid medium, and the consequent slowing of freezing (Walstra 2003)
2. Should large ice crystals be formed because of too slow freezing in meats, myofibrillar proteins could be irreversibly modified because of the increasing salt amount (Belitz et al. 2009). Anyway, volumetric increase has to be expected (Walstra 2003)
3. Certain food products may be concentrated with freezing techniques on condition that the initial moisture amount is remarkable. The resulting product is a network of glassy compounds with dispersed ice crystals. The process can give very stable foods on condition that the 'special glass transition temperature' is kept continually (Walstra 2003). This thermal value is generally between  $-10$  and  $-40^{\circ}\text{C}$ : should freezing be carried in this thermal range, deep-frozen foods would not show physical or chemical variations with some negligible exception (Walstra 2003)
4. The diminution in solubility of fish proteins has been reported during frozen storage in certain situations involving Maillard reactions. In addition, deep-freezing techniques inhibit proteolysis in fish and may cause some colorimetric variation and textural changes in certain products such as whale meat (Belitz et al. 2009). Consequently, should proteolytic reactions be observed in frozen fish, the reason would be easily found in the quality of original fish
5. Some decrease in vitamin amounts has been observed in cooked and drained frozen products

6. The possible loss of aroma in certain frozen meat and fish products has been observed and ‘amended’ by means of the addition of monosodium glutamate. This correction can be also used when speaking of processed and canned fish and meat products.

These chemical and physical modifications concern all possible food typologies in general. With concern to vegetable products, it has been reported that blanched vegetables may exhibit a certain loss of chlorophylls because of their transformation in pheophytins even at  $-18^{\circ}\text{C}$  (Belitz et al. 2009). The same thing can be told when speaking of certain vitamins such as vitamin C. Reasons for lowered amounts are not linked with incorrect freezing methods, but with blanching treatment and storage. However, the most important problem for these products concerns always irreversible textural modifications (Belitz et al. 2009) and general damages to plant tissues after defrosting (Aked 2000): decrease in vitamins; flavour modifications (caused by residual enzymatic activity); discoloration; and microbial spreading by yeast (if thermal values are different from expected values). The next section discusses main technological solutions for vegetable and other food products.

## 2.3 Frozen Foods: Main Technological Processes

In general, freezing techniques can be carried out with the use of two different freezers types (Senesi 1984):

- (a) Mechanical freezers
- (b) Cryogenic freezers.

Actually, the modern industry is accustomed to use three main freezers typologies (Senesi 1984):

1. Air blast freezers
2. Plate freezers (also named contact freezers)
3. Immersion freezers (also named spray freezers).

A brief description of these systems is now provided in the following sections.

### 2.3.1 Air Blast Freezers

The most used freezer system appears to be the ‘air blast freezer’ type (Johnston et al. 1994). Briefly, this system is based on the forced convection of cold air into rooms of various dimensions by means of fans. In this way, regularly or irregularly shaped foods can be frozen with good results. Moreover, there are not peculiar failures linked to ‘critical’ dimensions or shapes, although a pre-determined air blast freezer is not easily modifiable after installation and initial trials. In other words,

different shapes could require different freezers, and the preliminary design of air blast freezers is surely critical. Normally, air speed values could be 5 m/s although larger industries may prefer higher values (10–15 m/s) with the aim of reducing freezing times in continuous processes (Johnston et al. 1994).

On the other side, main risks depend mainly on the presence of physical obstacles. Packaging materials and other non-food materials have to be removed. For this reason, Individual Quick Freezing (IQF) systems are available at present. These machines can easily freeze unpackaged foods, and the frozen product can be immediately packaged just before IQF. Actually, the IQF system may show a notable problem when speaking of economic results: the possible superficial dehydration of products. For this reason, a correct design is critical; economic evaluations should be taken into account (Senesi 1984).

Anyway, air blast freezers can be defined as discontinuous- or continuous-flow machines, depending on excessive ‘dead times’ in production. Batch-continuous freezers are widely used nowadays; products are uploaded on proper belts (Johnston et al. 1994; Senesi 1984).

### **2.3.2 Plate Freezers**

Differently from air blast freezers, contact freezers are not ‘customisable’ systems. Only regularly shaped foods can be treated with these machines (Johnston et al. 1994).

The real difference between available types is substantially the vertical or horizontal arrangement of freezing plates into the freezer. For this reason, available machines are named horizontal or vertical plate freezers. Basically, the heat removal is realised by means of the contact between food products and cold plates: a refrigerant fluid can flow into plates and maintain constant cold conditions. In addition, plates may be moveable during the process (Johnston et al. 1994). Unfortunately, the presence of packaging materials and excessive air amount into ‘open spaces’ between food products may delay freezing times.

### **2.3.3 Immersion Freezers**

Differently from above-mentioned systems, immersion freezers are based on the direct contact of food products with a refrigerant fluid: nitrogen gas (temperatures:  $-50$  to  $-196$  °C) or liquefied carbon dioxide (temperature range:  $-50$  to  $-70$  °C). Apparently, this approach is excellent and should be recommended because of the limited size of freezers and the rapidness of freezing processes. On the other hand,

1. Supplies of refrigerant fluids such as required nitrogen or carbon dioxide may be a real problem in certain Countries

2. Carbon dioxide can be really dangerous; consequently, should a similar system use this material, adequate safety countermeasures (example: ventilation) would be mandatory
3. Frozen products could be easily damaged because of high freezing speed
4. Anyway, economic costs are convenient on condition that discontinuous productions are considered.

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The Chemistry of Frozen Vegetables

Steinka, I.; Barone, C.; Parisi, S.; Micali, M.

2017, VI, 41 p. 3 illus. in color., Softcover

ISBN: 978-3-319-53930-0