What are we planning to learn?

The purpose of this manual is to provide a basic understanding of freezing processes as they are used in the food industry and in various sectors of the agricultural industry.

In Course 1, Part 1 we will examine the reasons for freezing food, introduce some definitions and then look on the range of produce/products suited for freezing and the conditions for storing major product groups under freezing regimes.

In Course 1, Part 2 freezing is being discussed as a Unit Operation process.

In Course 2, Part 3 details regarding technical equipment are in the focus of the considerations.

In Course 2, Part 4 the entire chain of operations are being addressed.
Part 1:

1. Produce and Products suited for Chilling and Freezing

1.1 Background

1.1.1 Definition of Chilling and Freezing

Chilling and freezing as food preservation processes are technically rather simple operations and have been applied since centuries wherever the environmental conditions offered appropriate possibilities. In the Northern parts of Europe, Asia and America and in the high altitudes of the Andes people chilled or even did freeze their food surpluses and supplies for shortage periods. A better understanding of the physiological processes involved, new technological insight and modern materials like film materials for packaging allow for improvements for both processes.

In general chilling and freezing are carried out in order to:

- Create special processing conditions, e.g. meat/sausage processing, to churn butter or margarine,
- Create special structures, e.g. ice-cream, protein solutions
- Create special conditions for shelf-life extension/improvement

To create special processing conditions food products are chilled to temperatures ranging from 8°C to 1°C or they are partially frozen at temperatures just below the freezing point i.e. to −5°C to -8 °C which is also considered as “deep chilling”.

For the creation of special structures various freezing regimes are applied, e.g. ice cream is usually frozen rather fast during the initial phase to −15/-18 °C and then brought to lower temperatures during subsequent storage.

For shelf life extension food products are frozen to temperatures ranging from −12 °C (Frozen Storage) to −18 °C and lower (Deep Frozen Storage). In special cases the storage temperature is lowered to −70 °C (sensitive fish products).

Besides arranging optimal temperatures for various food processes and the creation of special product properties the extension/improvement of shelf life is from an economic and industrial point of view the most important application of the freezing process.

Fig. 1 Chilling and Freezing Temperatures

1.1.1 Chilling

Chilling of foods is a process by which the product temperature is reduced to the desired lower temperature normally just above the freezing/melting point of the product. This statement is especially true for any type of processed food e.g. precooked meals, pasta or potato products etc. moreover for meat and marine products. Fresh vegetable and fruits however do not always tolerate temperatures close
to the freezing point, if their temperature is lowered for a longer period of time below a tolerance temperature they will suffer so called “physiological disorders”, through which the taste and/or the general appearance is being affected. As a rule of thumb it can be stated that vegetable and fruits originating from areas with a moderate climate usually tolerate chilling temperature just above the freezing like apples or pears which can be stored around 0°C whereas vegetable and fruits originating from areas with a sub-tropical or even a tropical climate usually do not tolerate chilling temperatures below +5°C like potatoes or banana which should not be chilled below ~14 °C for longer periods of time.

In certain countries the temperatures at which temperature sensitive products have to be transported and stored are strictly regulated. Examples are fresh milk, fish, meat or poultry which must be chilled for safe storage conditions to temperatures around +4 °C.

Commercial chilling operations are mostly carried out at temperatures between +10 °C and +2 °C, household refrigerators are usually operated at temperatures between +4 °C and +8 °C.

For obtaining best results by chilling, the produce should be processed immediately after harvesting. The individual processing steps comprise independent of the nature of the produce, if liquid or solid, adequate measures like trimming, cleaning or washing and if required cutting. In most chilling operations the produce are chilled after the preparative steps and then packaged, in certain cases it might be just the other way round. The chilled and packaged produce should, from now on, i.e. during distribution and retail storage as well as during transportation, be kept without any interruption in a cold environment before being consumed. For produce where the respiration continues after harvesting it is advisable to package the material in containers which allow for a control of the storage atmosphere. Such practices are called Controlled Atmosphere storage (CA-Storage) or Modified Atmosphere storage (MA-Storage). In both cases it is important that the accumulation of gases in the storage atmosphere is controlled and that the concentration of certain gases, especially CO₂, does not exceed pre-defined levels. The chilling, storage and transport operations are mostly carried out in specifically designed equipment; details will be discussed in Part 3 of this manual.

1.1.1.2 Freezing

In food processing freezing is defined as a process by which the product temperature is lowered below the freezing point of the product. Depending of the nature of the product this temperature lies between −0.7 °C for milk/meat products and −7 °C for fruit juices with a high sugar content. In principles three types of freezing have to be considered Because of the complex composition of food materials in case of freezing three, resp. four situations have to be considered, freezing of

- pure water
- a solution containing low molecular solutes (salts and /or sugars, organic acids)
- a solution containing macro-molecules which are partially water soluble (proteins, starches
- a solution containing low molecular solutes and macro-molecules which are partially water soluble

**Pure Water**, freezing point at 0 °C. The temperature drops only below 0°C to
the final product temperature once all water is frozen.

Solutions with (low molecular) solutes like salt and/or sugar; a typical example is a clear fruit-juice. The freezing point is lowered below the freezing point of pure water, the extent depends on the concentration of the solutes.

Solutions with proteins, starch, and celluloses (macromolecules, this are large molecules), the freezing point is not lowered; it is however expanded over a wide temperature range because a fraction of water is bound to the macro-molecules; this type of solutions is very rare.

Solutions with proteins, starch, and celluloses and salt or sugar, typical examples are meat, bread and fruit-pulps. The freezing point is lowered; the freezing process is also expanded over a wide temperature range.

Similar to chilling, products which have been earmarked for freezing should be processed immediately after harvesting in order to preserve the original high quality.

The processing steps are also quite similar to chilling, vegetable however have to be heat treated before freezing in order to inactivate enzymes (blanching). For best quality retention the frozen products should be kept in the freezing chain which should not be should not be interrupted at any time.

The freezing, storage and transport operations are mostly carried out in specifically designed equipment; details will be discussed in Part 3 of this manual

1.1.1.3 Definitions around the chilling and freezing process:

Chilling/Freezing Time (h)
The chilling/freezing time is defined as the time elapsed from the start of the operation until the final temperature is reached at the thermal centre of the product. The chilling/freezing time depends not only on the initial and final temperature of the product and the quantity of heat to be removed, but also on the dimensions (especially the thickness) and shape of the product unit as well as on the heat transfer process and its temperature.

Chilling/Freezing Rate (°C/h)
For a product or a package, the chilling/freezing rate (°C/h) is the difference between the initial and the final temperature divided by the chilling/freezing time. In a given part of a product, the local chilling/freezing rate is equal to the difference between the initial temperature and the desired temperature divided by the time elapsed until the moment at which the latter temperature is achieved in this particular part.

Speed of Movement of the Temperature Front (cm/h)
The chilling/freezing rate may be evaluated by the speed of movement of a specific isotherm through a product. This speed is faster near the surface and slower towards the thermal centre. As a result, reported chilling/freezing rates from different sources are not necessarily comparable.

Thermal centre
The thermal centre of unit to be chilled/frozen is the location within the unit which has the warmest temperature during the chilling/freezing process.

Storage Life
The physical and biochemical reactions which take place in chilled/frozen food products lead to a gradual, cumulative and irreversible reduction in product quality. The period
during which the product is suitable for consumption is considered as storage life.

**High Quality Life (HQL)**
The High Quality Life is defined as the time elapsed between the chilling/freezing of an initially high quality product and the moment when, by sensory assessment, a minor quality difference can be established.

**Practical Storage Life (PSL)**
The practical storage life of a product is the period of chilled/frozen storage after chilling/freezing during which the product retains its characteristic properties and remains suitable for consumption or the intended process.

### 1.2. Historical Development

The development of the freezing industry is very closely related with the technical ability to create low temperature independent of the environmental conditions. At the beginning of the 18th century the slowly growing food industry developed an increasing demand for ice to control and improve various processing steps (beer brewing, shelf life extension etc.). These demands were at first covered through the use of natural ice which was produced in the cold regions of Europe and North America, from there it was exported to warmer areas, e.g. from Norway to Mexico. When temperatures below 0°C were required “cold mixtures” i.e. mixtures of ice and salts were prepared. The first ideas and technical concepts for the construction of refrigeration equipment with which it was possible to create low temperature independent of the environmental conditions were discussed at the middle of the 18th century. The real success story of the freezing industry started with closed cycle ammonia-absorption system. The absorption refrigeration system became the most widely used method of cooling for a long period of time. Absorption machines in sophisticated design are still widely used in the industry wherever cheap thermal energy is available.

![Diagram of an Absorption Refrigeration Machine](image)

Fig. 2. Flow Sheet of an Absorption Refrigeration Machine

The absorption technology was improved by developing the closed cycle compression process and the use of ammonia as refrigerant. Today compression machines in various forms are the dominating design in the refrigeration industry.
A Compressor, B Condenser, C Throttle valve D Evaporator

Fig. 3 Flow Sheet of an Compression Refrigeration Machine

According to the available records the first industrial unit for freezing food (meat) was opened 1861 in Darling Harbor/Sydney. The first documented long distance transport of a frozen product (again meat) was carried out by a steamer from Argentine to France in 1876. The further development of the refrigeration equipment to the present high standards was supported to a large extend by the needs of the brewing industry and the meat industry in the Southern Hemisphere and the United States.

1.3. Reasons for Chilling and Freezing

The processes impeding product quality and shelf life normally commence right after harvest and/or production, those processes are of a chemical (including biochemical /microbial) and a physical nature. Through lowering the product temperature into the chilling or freezing range or heat-processing of the product chemical and biochemical reactions are reduced in their rate or even inactivated. This is not only true for enzymatic/non enzymatic reactions but also for microbial processes. In the case of chilling especially of fresh produce (vegetable and fruit) the rate of quality losses can also be influenced by modifying the composition of the atmosphere of the storage facility: Relative humidity $\phi$, and the composition of the gases surrounding the product have an impact on desiccation and maturation/microbial spoilage.

1.3.1 Spoilage Reactions

1.3.1.1 Chemical reactions

Chemical reactions which have to be encountered after harvest and also after processing with regard to quality losses are (examples):
- browning reactions (fresh produce),
- losses of sugars through respiration (fresh produce),
- changes in the fat fraction (Oxidation) and losses of Vitamins and coloring substances (Carotenoids, Anthocyanins).

The chemical reactions which take place in harvested and also processed products are not always of detrimental nature, some of these processes improve the quality of the products like (examples):
- maturation of meat and fruits and wine/beer

With regard to bio-chemical reactions two groups of enzymes (lipases and lipoxigenasis) are of special concern because they attack any type of fats and may develop a considerable activity even at temperatures below $-20$°C down to $-40$ °C. Fats are converted or broken down into unpleasant smelling/tasting compounds. The storage time of fat
containing products e.g. fatty fish, pork meat, peas is therefore considerably limited compared to non fat containing products. It is therefore important, that especially vegetable are heat treated before freezing.

### 1.3.1.2 Microbial processes

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+45°C</td>
<td>Danger Zone!! Optimal growing conditions for many pathogenic and food spoiling microorganisms</td>
</tr>
<tr>
<td>+10°C</td>
<td>Limit of vegetative growth of Staphylococcus, Clostridium perfringens, Salmonella spp.</td>
</tr>
<tr>
<td>+6.5°C</td>
<td>Limit of toxin formation by Clostridium Botulinum Type E</td>
</tr>
<tr>
<td>+3.3°C</td>
<td>Limit of vegetative growth of Yersinia enterocolitica</td>
</tr>
<tr>
<td>0°C</td>
<td>Limit of growth of Bacteria</td>
</tr>
<tr>
<td>-10°C</td>
<td>Limit of growth of Yeasts and Moulds</td>
</tr>
</tbody>
</table>

Fig. 4 Growth Conditions for Micro-Organisms at Chill/Freeze Temperatures

Most pathogenic and food spoiling micro-organisms grow and reproduce in the temperature range between +45°C and +10°C quite actively. If possible any type of food should therefore not be exposed to the temperature range between +45°C and +10°C longer than necessary. Below +10°C the growth rate of most pathogenic and food spoiling micro-organisms slows down or comes to its limits depending on the species. Below -10°C bacterial growth is completely ceased whereas the growth limit for yeasts and moulds is -18°C; the lower temperature limits are only reached by specialists.

During freezing the number of living and reproducible microbial cells is reduced.

There are however always some micro-organisms that survive low/freezing temperatures. Therefore: lowering product temperatures even to the extremes (-190°C) cannot be considered as a sterilization process.

### 1.3.1.2 The General Rule

As a rule of thumb, lowering the product temperature by 10°C, results in doubling the shelf-life.

If, in the case of chilling, the shelf-life of a product at 20 °C is 2 days, then it is at 10 °C 4 days and at 0 °C 8 days.

In case of freezing the starting temperature is usually -10 °C, at this temperature most of the freezable water is frozen out and reasonable shelf-life can be achieved.

In case the Shelf Life of a product (fatty fish) at -10 °C is 2,5 months, then it is at -20 °C 5 months and at -30 °C 10 months.

### 1.4 Products suited for Chilling and (Deep) Freezing and Frozen Storage

When food products are prepared for chilled or frozen storage it should always be kept in mind: Best quality can only be achieved with raw materials suited for chilling or freezing, harvested at optimal conditions of maturity, processed immediately after collection under utmost hygienic conditions, packaged, stored, distributed and retailed at lowest possible/feasible temperatures and shortest possible/feasible times.

#### 1.4.1 Chilling

The list of produce/products which are chilled in industry and private households comprises almost all types
of edible produce/products. Properly
treated chilled food materials maintain
their quality characteristics during
storage to a high degree; therefore
chilling has to be considered as the
perfect preservation method in case
relatively short periods of time have to
be bridged between harvest/production
and consumption.

Major groups of chilled foods are:
- Fresh vegetable and fruit
- Meat and meat-products
  including poultry
- Marine products including fish
- Dairy products including milk,
cream, dressings etc.
- Ready meals and recipe dishes,
pasta, rice, sauces
- Bakery products including
  pastry

1.4.2 Freezing

When Freezing is being discussed very
often the question is being raised:"can
this or that product be frozen". The
answer is a very simple one; every
product containing “free” water can be
frozen (Walnuts with a water content of
about 4% can not be “frozen” because
the entire water is bound to the protein
and carbohydrate fraction, Walnuts can
only be chilled!). The correct question
should be: “is this, or that product
suited for freezing and thawing”.
The answer now is:
Animal tissue is well preserved by the
process whereas
Plant tissue in most cases is severely
damaged by the freezing process.
Heat processed food/bakery products
etc. can be frozen and thawed with
very good results.

Major deep frozen/frozen products are:
- Ready prepared meals: All kind
- Meat: Beef, Pork, Lamb, Rabbit
- Poultry: Chicken, Duck, and
  Turkey
- Fish: All kind of lean (e.g. Cod)
  and fatty (e.g. Salmon) Fish
- Fruit: Strawberry, Raspberry,
  Cherry, Citrus Juices
- Vegetable: Peas, Spinach,
  Broccoli, Brussels Sprouts
- Potato Products: French Fries,
  Dumplings, Pre-Fried Potato
- Bakery Products: All types of
  Bread, Rolls, Pretzel, Croissant,
  and Cakes/Tarts, Short Cake
- Ice Cream/Sherbet: All types
  and varieties

Ready prepared meals
Ready prepared meals are lifestyle
products and reflect to a high degree
consumer demands for convenience
and quality. Ready prepared meals
help to reduce the time consumers
have to spend in kitchen; they allow
also addressing consumer concerns
regarding health issues with special
products targeted towards health
problems like heart disease or
diabetes. The components of frozen
ready prepared meals are in general
similar to those used for preparing
meals which are not frozen, certain
components like starches have
however special properties e.g. being
freeze stable. Also the application of
particular spices has to be modified in
case of frozen ready prepared meals.
Bakery products require to some
extent special types of processing..

Meat/Fish and Meat/Fish Products
Meat and fish and meat- and fish-
products are very much suited for
freezing, frozen storage and thawing. If
properly processed (frozen with
minimum freezing rate of ~ 1cm/h, well
packaged and stored at sufficient low
temperatures for appropriate times) the
thawed products are of high quality
and suited for any consecutive process
step.
Like other meat products, chicken are processed in large quantities as frozen products in the form of whole chicken and chicken parts e.g. chicken breast, drumsticks or wings. In general, chicken are slaughtered, scalded, eviscerated, packaged and then immediately frozen. Since many chicken flocks are highly contaminated with Salmonella in their digestive system, the whole process from slaughtering to freezing has to be carried out with great care and under extreme hygienic conditions.

Most fish and fish products are frozen on board directly after being caught in floating factory units. This allows longer catching journeys and optimises the quality of the products.

Vegetable
In the case of vegetable and fruits, the situation is different from meat products. In the course of the freezing process, plant cell membranes are damaged in a way that the cell compartments are destroyed so that already in the frozen state chemical reactions amongst the components of the cells are possible. Those reactions lead especially in the case of vegetable to unfavourable quality symptoms like off-flavour, changes in colour, and loss of vitamins. Vegetable therefore has to be blanched before freezing and frozen storage. Once blanched, the freezing rate does not play a major role for quality retention, it is however recommended to freeze with rates of ~1 to 2 cm/h.

Deep Frozen Potato Products
Processed potato products are especially suited for deep freezing. The potato industry has developed a large variety of products for all types of meals. Those products are mostly based on classical recipes e.g. French fries, tumbling, hash potato etc. Cassava and yam tubers can be prepared and frozen in a similar way.

Fruits
Fruits are frozen in general without pre-treatment like blanching, they are less susceptible to quality losses during frozen storage because of a low pH and frequently high sugar contents. Freezing of fruits should be carried out with freezing rates of ~2 to 3 cm/h.

Bakery Goods
Bread
Bread like any other food product can be frozen in the finished baked form. Such products are available on the market. Their quality is however inferior to the quality of fresh products and basically they cannot compete with the fresh product form. These products lack of almost all volatile aroma components, the acid content is reduced and the crust usually is extremely fragile and lacks coherence with the crumb.

In case bread is prepared from frozen-thawed dough, the final products contain all the quality characteristics of good bread and are in any sense comparable with products made up of fresh dough.

1.5 Storage and Storage-Life of chilled and frozen produce/products

1.5.1 Storage of Chilled products

Fresh vegetable and fruit
The storage life of chilled fresh vegetable (including tubers) and fruit may last from a few weeks to several months depending on the cultivar, variety and the state of maturity of the chilled produce. As already mentioned, the storage temperature has to be adjusted to the requirements of the produce, in case of tropical vegetable and fruits the “critical” temperature has to be observed. It has to be understood
that fresh vegetable and fruit are living organisms that means that even under a low temperature regime the metabolic processes persist producing heat and degrade carbohydrates. By modifying and controlling the storage atmosphere those processes can be slowed down and the shelf life of most vegetable and fruits extended.

**Meat and Fish**

Protein rich materials like red meat and fish of any kind are very susceptible to microbial contamination; if possible they should be kept close to their freezing point. Optimal hygienic conditions should be observed when handling this type of food!

**Milk and dairy products**

The storage life of chilled dairy products like milk, cream and cheese varies very much with type of product. The storage temperature of milk and to some extent also of cream is, as already mentioned, regulated in many countries. Because of its high water-content the shelf-life of fresh milk, cream and soft cheese is much shorter than that of hard cheese, butter and margarine.

**Prepared Meals and related products**

The storage life of prepared meals, bakery products depends on the type of the product. The preparation of those products have to be carried out under utmost hygienic conditions (HACCP). In certain cases special care has to be devoted to seasoning, because some condiments may loose their flavour faster than others causing an imbalanced product flavour.

<table>
<thead>
<tr>
<th>Produce</th>
<th>Optimal Temperature °C//Tolerance Temperatures °C</th>
<th>Mod. Atmosp. O2%/CO2 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avocado</td>
<td>10//5/13</td>
<td>2/5//3/10</td>
</tr>
<tr>
<td>Banana</td>
<td>14//12//16</td>
<td>2/5//2/5</td>
</tr>
<tr>
<td>Mango</td>
<td>13//10//15</td>
<td>3/5//5/10</td>
</tr>
<tr>
<td>Papaya</td>
<td>12//10//15</td>
<td>2/5//5/8</td>
</tr>
<tr>
<td>Pineapple</td>
<td>10//8/13</td>
<td>2/5//5/10</td>
</tr>
<tr>
<td>Cherimoya</td>
<td>10//8/15</td>
<td>5/5/10</td>
</tr>
<tr>
<td>Lychee</td>
<td>7/5/12</td>
<td>5/3/5</td>
</tr>
<tr>
<td>Strawberry</td>
<td>0/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Apple*</td>
<td>0/-1/5</td>
<td>3/5/8/12</td>
</tr>
<tr>
<td>Pear*</td>
<td>-1/-2/6</td>
<td>3/5/8/12</td>
</tr>
<tr>
<td>Ch.Cabbage**</td>
<td>0/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Cassava</td>
<td>3/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Carrots**</td>
<td>0/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Corn</td>
<td>0/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Paprika</td>
<td>8/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Pea</td>
<td>0/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Potato**</td>
<td>5/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Spinach</td>
<td>0/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Tomato</td>
<td>10/-/-/-</td>
<td>--/--</td>
</tr>
<tr>
<td>Yam*</td>
<td>--/--13/15</td>
<td>--/--</td>
</tr>
<tr>
<td>Fish***</td>
<td>0 (on ice)</td>
<td>--/--</td>
</tr>
<tr>
<td>Meat***</td>
<td>-1,25/-0,75</td>
<td>--/--</td>
</tr>
<tr>
<td>Meat</td>
<td>-1,25/-0,75</td>
<td>--/--</td>
</tr>
<tr>
<td>Prepared Meals***</td>
<td>-1,25/-0,75</td>
<td>--/--</td>
</tr>
</tbody>
</table>

*) Extended storage-life up to 5 months
**) Reduced storage-life 1 week
*** Reduced storage-life 2 weeks

Table 1 Recommended storage conditions for various groups of chilled produce/products

**1.5.2 Storage of Frozen Products**

Storage of frozen produce and products is certainly the most effective method to preserve larger amounts of materials over longer periods of time
without noteworthy quality losses. Besides the criteria for obtaining satisfactory results, already mentioned, it is important that the storage temperatures are always kept at a constant level, this is especially important for rather elevated storage temperatures (e.g. ~ -10°C to ~ -18°C); independent if the material is kept in small or large storage facilities. In order to avoid weight losses and partial desiccation (freezer burn) and pronounced fat oxidation during storage it is advisable to package the stored materials in water-vapour and air-tight cold tolerant plastic films. An alternative to plastic films is glazing i.e. covering the product with a thin layer of ice.

Major product groups which are frozen and stored as frozen/deep frozen products are:
- Meat and meat-products including poultry
- Marine products including fish
- Vegetable
- Fruits and fruit juices
- Potato products including Chips
- Ready meals and recipe dishes including pizza
- Bakery products including pastry

**Meat and meat products**
Meat and meat products are traditionally the products which are traded and stored as frozen or deep frozen products. Beef, pork, lamb/mouton, game, and poultry and related products show very good quality when properly frozen and stored. Nutritional studies demonstrate that frozen meats are in certain cases easier to digest than fresh meat, a further beneficial effect of frozen storage the destruction of parasites e.g. parasitic protozoa, cestodes, cysts of tapeworm and nematode larvae causing trichinosis; the minimum storage time for disinfection is about 21 days at -25°C.

**Marine products**
Similar to meat, fish and other marine products are well suited for frozen storage. Since the connective tissue of fish muscle is rather weak, the fish muscle tends to disintegrate after thawing. For exceptional good quality retention fish like tuna, which is frequently eaten raw, is kept at temperatures as low as -70°C for the East Asian market. In this context it should be mentioned that, like in the case of meat fish can be disinfected by exposing to freeze-store conditions. Freezing/storing at -20°C or below for 7 days or -35°C for about 20 hours will kill parasites e.g. nematodes. Many species of nematodes are known to occur worldwide and some species of marine fish act as secondary hosts. Among the nematodes of most concern are Anisakis spp., Capillaria spp., Gnathostoma spp., and Pseudoteteranova spp. which can be found in the liver, belly cavity, and flesh of marine fish. An example of a nematode causing disease in man is Anisakis simplex; the infective stage of the parasite is killed by freezing (-20°C for 24 hours in the thermal center of the fish).

**Vegetable**
The quality of frozen-stored and thawed vegetable compare favorably with fresh products especially when those products have been kept after harvest even for a short time under rather unfavorable conditions. As already mentioned it is advisable to blanch vegetable after cleaning and trimming before freezing. During storage the products have to be protected against oxygen penetration and water vapor losses.
Fruit
Fruits have to be protected during storage against oxygen penetration and water vapor losses. For high quality products it is frequently recommended to add sugar or fructose for better quality retention. Fruits with a weak/soft cellular structure suffer in general pronounced cellular damage especially in case of unfavorable freezing and storage conditions, after thawing in most cases a trip loss is observed. The products are therefore with regard to sensorial properties e.g. consistency or mouth feeling only in limited cases comparable to unfrozen fresh products, flavor and taste are however retained by the freezing process.

<table>
<thead>
<tr>
<th>Product</th>
<th>Temperature °C</th>
<th>Possible Storage Time Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>-12</td>
<td>5 ./. 8</td>
</tr>
<tr>
<td></td>
<td>-15</td>
<td>6 ./. 9</td>
</tr>
<tr>
<td></td>
<td>-18</td>
<td>9 ./. 12</td>
</tr>
<tr>
<td></td>
<td>-24</td>
<td>./. 18</td>
</tr>
<tr>
<td>Ground Meat</td>
<td>-12</td>
<td>3 ./. 6</td>
</tr>
<tr>
<td></td>
<td>-18</td>
<td>4 ./. 8</td>
</tr>
<tr>
<td>Lamb</td>
<td>-12</td>
<td>3 ./. 6</td>
</tr>
<tr>
<td></td>
<td>-18/. -20</td>
<td>6 ./. 10</td>
</tr>
<tr>
<td>Pork</td>
<td>-12</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>-18</td>
<td>4 ./. 6</td>
</tr>
<tr>
<td></td>
<td>-23</td>
<td>8 ./. 10</td>
</tr>
<tr>
<td></td>
<td>-29</td>
<td>12 ./. 14</td>
</tr>
<tr>
<td>Ham (Uncured)</td>
<td>-18/. -23</td>
<td>4 ./. 6</td>
</tr>
<tr>
<td>Offal</td>
<td>-18</td>
<td>3 ./. 4</td>
</tr>
<tr>
<td>Lard</td>
<td>-18</td>
<td>9 ./. 12</td>
</tr>
<tr>
<td>Rabbit</td>
<td>-18/. -23</td>
<td>./. 6</td>
</tr>
<tr>
<td>Chicken</td>
<td>-18</td>
<td>8 – 10</td>
</tr>
<tr>
<td>Turkey</td>
<td>-18</td>
<td>4 – 6</td>
</tr>
<tr>
<td>Duck</td>
<td>-18</td>
<td>4 – 6</td>
</tr>
<tr>
<td>Geese</td>
<td>-18</td>
<td>6 – 8</td>
</tr>
<tr>
<td>Pheasant</td>
<td>-18</td>
<td>8</td>
</tr>
<tr>
<td>Fish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lean Fish</td>
<td>-18</td>
<td>3 ./. 5</td>
</tr>
<tr>
<td></td>
<td>-25</td>
<td>6 ./. 8</td>
</tr>
<tr>
<td></td>
<td>-29</td>
<td>8 ./. 10</td>
</tr>
<tr>
<td>Fatty Fish</td>
<td>-18</td>
<td>2 ./. 3</td>
</tr>
<tr>
<td></td>
<td>-25</td>
<td>3 ./. 5</td>
</tr>
<tr>
<td></td>
<td>-29</td>
<td>~ 6</td>
</tr>
<tr>
<td>Vegetable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>-18</td>
<td>15</td>
</tr>
<tr>
<td>Green Beans</td>
<td>-18</td>
<td>18</td>
</tr>
<tr>
<td>Brussel sprout</td>
<td>-18</td>
<td>15</td>
</tr>
<tr>
<td>Carrots</td>
<td>-18</td>
<td>18</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>-18</td>
<td>15</td>
</tr>
<tr>
<td>Corn on the cob</td>
<td>-18</td>
<td>12</td>
</tr>
<tr>
<td>Peas</td>
<td>-18</td>
<td>18</td>
</tr>
<tr>
<td>Potato Chips</td>
<td>-18</td>
<td>24</td>
</tr>
<tr>
<td>Spinach</td>
<td>-18</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 2  Recommended Storage Times for various groups of frozen product
(Source International Institute of Refrigeration, Paris)
1.6 Supporting Literature

RECOMMENDED INTERNATIONAL CODE OF PRACTICE
GENERAL PRINCIPLES OF FOOD HYGIENE
CAC/RCP 1-1969, Rev. 4-2003

RECOMMENDED INTERNATIONAL CODE OF PRACTICE FOR THE PROCESSING AND HANDLING OF QUICK FROZEN FOODS.
Codex Alimentarius, (CAC/RCP 8-1976)

RECOMMENDED INTERNATIONAL CODE OF PRACTICE FOR PACKAGING AND TRANSPORT OF FRESH FRUIT AND VEGETABLES
(CAC/RCP 44-1995, AMD. 1-2004)

RECOMMENDED INTERNATIONAL CODE OF HYGIENIC PRACTICE FOR THE PROCESSING OF FROG LEGS (CAC/RCP 30-19831)

CODE OF PRACTICE FOR FISH AND FISHERY PRODUCTS (CAC/RCP 52-2003)

CODE OF HYGIENIC PRACTICE FOR PRECOOKED AND COOKED FOODS IN MASS CATERING (CAC/RCP 39-1993)

CODE OF HYGIENIC PRACTICE FOR THE PREPARATION AND SALE OF STREET FOODS
CAC/RCP 43-1997, Rev.1-2001

CODE OF PRACTICE FOR FISH AND FISHERY PRODUCTS (CAC/RCP 52-2003)

STANDARD FOR SALTED ATLANTIC HERRING AND SALTED SPRAT CODEX STAN 244-2004

<table>
<thead>
<tr>
<th>Quick Frozen Foods</th>
<th>Codex Standard (CODEX STAN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAW SQUID</td>
<td>191 - 1995</td>
</tr>
<tr>
<td>PEAS</td>
<td>41-1981</td>
</tr>
<tr>
<td>RASPBERRIES</td>
<td>69-1981</td>
</tr>
<tr>
<td>BILBERRIES</td>
<td>76-1981</td>
</tr>
<tr>
<td>FINFISH, UNEVISCERATED AND EVISCERATED</td>
<td>36-1981, Rev. 1 – 1995</td>
</tr>
<tr>
<td>LOBSTERS</td>
<td>95 - 1981</td>
</tr>
<tr>
<td>FISH FILLETS</td>
<td>190 – 1995</td>
</tr>
<tr>
<td>STRAWBERRIES</td>
<td>52-1981</td>
</tr>
<tr>
<td>FROZEN BLOCKS OF FISH FILLET, MINCED FISH FLESH AND MIXTURES OF FILLETS AND MINCED FISH FLESH</td>
<td>165-1989 (REV. 1 - 1995)</td>
</tr>
<tr>
<td>FISH STICKS (FISH FINGERS), FISH PORTIONS AND FISH FILLETS - BREADED OR IN BATTER</td>
<td>166 – 1989</td>
</tr>
<tr>
<td>SHRIMPS OR PRAWNS</td>
<td>92-1981, Rev. 1 - 1995</td>
</tr>
<tr>
<td>LEEK</td>
<td>104-1981</td>
</tr>
<tr>
<td>SPINACH</td>
<td>77-1981</td>
</tr>
<tr>
<td>BROCCOLI</td>
<td>110-1981</td>
</tr>
<tr>
<td>CAULIFLOWER</td>
<td>111-1981</td>
</tr>
<tr>
<td>BRUSSELS SPROUTS</td>
<td>112-1981</td>
</tr>
<tr>
<td>GREEN BEANS AND QUICK FROZEN WAX BEANS</td>
<td>113-1981</td>
</tr>
<tr>
<td>FRENCH FRIED POTATOES</td>
<td>114-1981</td>
</tr>
<tr>
<td>WHOLE KERNEL CORN</td>
<td>132-1981</td>
</tr>
<tr>
<td>PEACHES</td>
<td>75-1981</td>
</tr>
<tr>
<td>CORN-ON-THE-COB</td>
<td>133-1981</td>
</tr>
<tr>
<td>FROZENCARROTS</td>
<td>140-1983</td>
</tr>
</tbody>
</table>

Codex Alimentarius Standards for Quick Frozen Foods