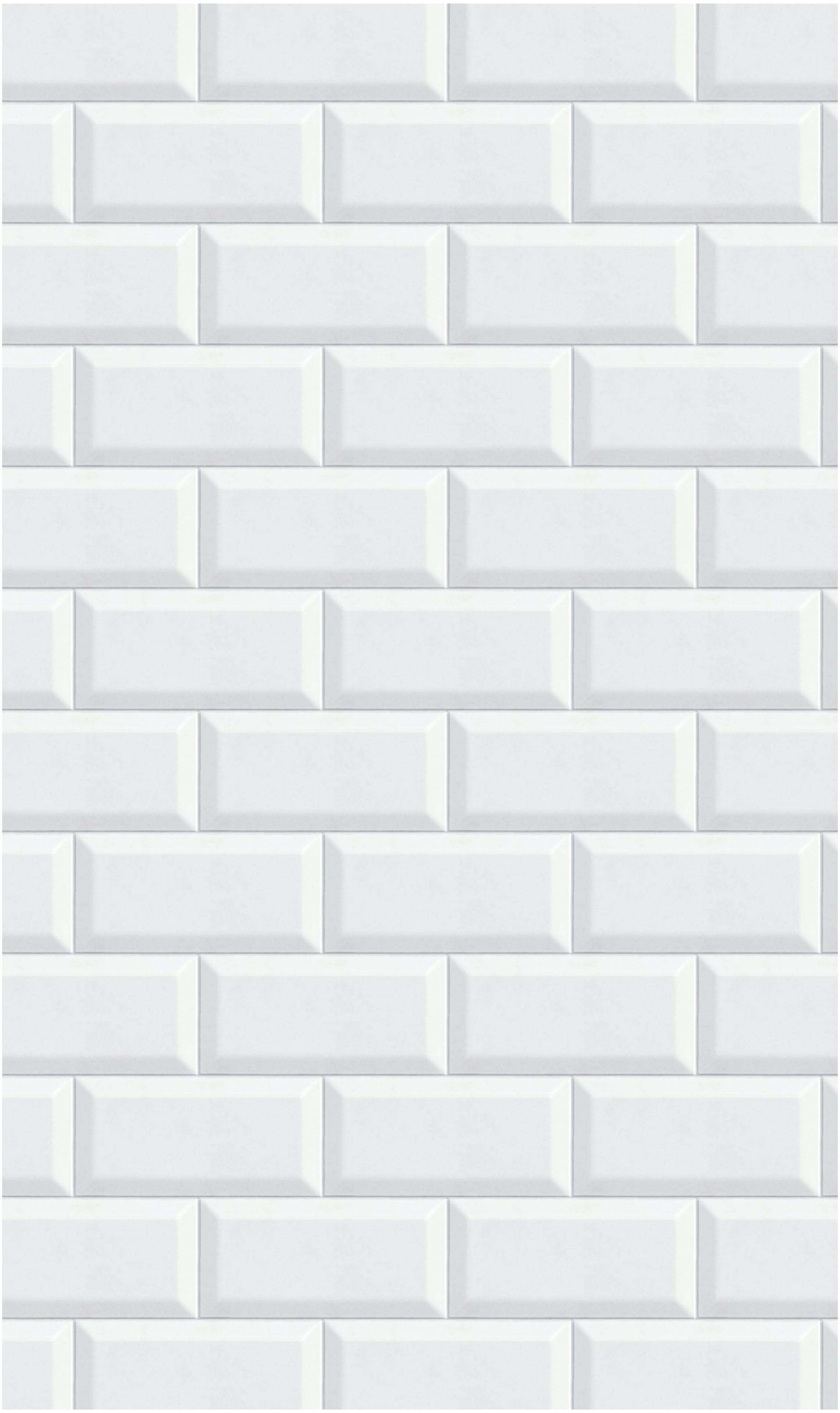

The Ice Cream Grammar

The complete guide to Gelato and Ice Cream making

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Preface

At the beginning of this year I, like many others, found myself suddenly confined at home as the global pandemic was flaring up. And because I work as Executive Pastry Chef, certainly my job cannot be performed from home or via videoconference. I so decided to keep myself busy studying and, almost as a joke, I uploaded a short educational video course about the ice cream balancing on an e-learning platform online. The video was appreciated and loads of messages started flowing in. In particular, a guy from Hong Kong reached out to me with interesting technical questions and we kept discussing this fascinating matter. He then asked me where did I study the world of ice cream and if there was a quality reading I could suggest. At that moment, I had an epiphany. I realized that, as far as I knew, there was no complete and professional book thoroughly discussing the artisanal ice cream and gelato making.
Several English books have been written about this extraordinary product. Most of them are meant to be simple cookbooks and collection of recipe perfect for home ice cream making, while others as opposite, are manuals written for the manufacturing industry, perfect if your production is measurable in hundreds of tons per day. No one seemed to be tackling the problem from an artisanal point of view.
I constantly meet ice cream professionals and pastry chefs who, while producing ice cream day in and day out, have a very loose grasp on the rules behind the ice cream functioning. They follow recipes blindly, the try adjustments "by heart", they have learned from the various products manufacturer or apply dogmas without questioning them. Equally common is to find recipes in books or specific magazines with ingredients clearly placed just to make the formulation look fancier and behind understanding, while these components do not have a technical reason to be or anyway, not in a certain dosage. These low-level gimmicks can only impress who cannot understand the mechanic of this formulations, whilst inducing a giggle in those who are deeply familiar with it.

In the same way that happens when learning a new language, initially, we will be more inclined to memorize some "survival" sentences and commonly used words. By the time, we might learn how to communicate with others using basic idiomatic expressions and a limited vocabulary. But to become proficient, to be able to

play with the words, read between the lines, and create complex sentences with different shades of meanings we have to first master the grammar.
I hope, after reading this manual, you will all be able to understand what lays beneath an ice cream recipe, why a specific ingredient has been chosen and why it is present in this specific amount. I hope you'll be able to analyse with a critical eye the job of others and correct it where needed, without being fooled by the (every day more common) self-proclaimed Chefs and ice cream experts.

This book is meant to fill up the gap of knowledge required to intimately understand the ice cream game rules, in fact, its grammar.

Contents

A bit of Ice Cream History ... 4

Some Chemistry Notion ... 17
pH and acidity ... 19
The alcohols ... 22
The sugars ... 24
Organic Acids ... 27
Fats and fatty acids ... 29
Proteins ... 32
Hydrocolloids ... 35

Some Physical Notion ... 39
Mixture ... 39
Solutions ... 40
Emulsions ... 43
Suspensions ... 44

Metric System vs Customary Units ... 47
Conversions ... 48
Kilograms to pounds ... 50
Volume conversions ... 51
Length Conversions ... 53

The Ice Cream Components ... 55
The air ... 56
The water ... 61
The fats ... 65
Partial coalescence of the fats ... *67*
Sources of the fat ... *69*
- *Milk* ... *69*
- *Butter* ... *73*
- *Cream* ... *77*
- *Mascarpone* ... *78*
- *Cream cheese* ... *79*
- *Vegetable whipping cream* ... *80*

The Lean Milk Solids ... 83
Dried skimmed milk ... *86*
Concentrated milks ... *88*
Whey products ... *91*
Special LMS products ... *92*
The sugars ... 93
Monosaccharides ... *94*
Disaccharides ... *94*

Oligosaccharides *95*
Polysaccharides *95*
Cellulose *96*
SP and AFP *96*
Sucrose *100*
Corn sugars *101*
DE: dextrose equivalence *102*
Dextrose.. *103*
Maltodextrin *104*
Inverted sugar.. *104*
Lactose *107*
Fructose *107*
Honey.. *108*
Sugar alcohols.. *109*
Xylitol *110*
Sorbitol *110*
Isomalt.. *111*
Erythritol *112*
Mannitol *112*
Maltitol *113*
Lactitol *114*
Inulin.. *114*
Polydextrose *114*
Trehalose *115*
High potency artificial sweeteners *116*
The Neutral Ingredients 121
Stabilizers.. *121*
- *Agar: E406*.. *123*
- *Alginate: E401* *123*
- *Carboxymethyl Cellulose (CMC): E460 & E469* *124*
- *Carrageenan: E407*.. *125*
- *Gelatin: E441* *126*
- *Gellan: E418* *126*
- *Guar Gum: E412* *126*
- *Pectin: E440*.. *127*
- *Starch* *128*
- *Xanthan Gum: E415* *129*

Emulsifier.. *130*
- *Egg Yolk* *132*
- *Lecithin: E322* *132*
- *Mono and Di-glycerides of the Fatty Acids: E471* *133*
- *Esters of the mono and di-glycerides: E472*.. *134*
- *Sucrose fatty acid esters: E473*.. *135*

- *Polysorbate 80: E433* *135*
- *Propylene Glycol Monoesters: E477* *136*

The Eggs 137
The Chocolate and Cacao Products 143
Cocoa powder *148*
Cocoa butter *150*
Cocoa mass (or cocoa liquor) *152*
Chocolate *152*
Nuts and Nuts Pastes 157
Hazelnut *159*
Pistachio *162*
Almond *165*
Walnuts *166*
Peanuts *167*
Pecan *169*
Pine nuts *169*
Other Vegetable Fats and Oils 172
Palm oil and PKO *173*
Coconut oil *175*
Margarine *176*
Other vegetable oils *177*

The Calculation and Balancing of the Mixes 179
Parameters 179
Sugars *181*
Fats *181*
LMS *182*
Other solids *182*
Standard reference parameters 183
Example problem 1 184
Example problem 2 189
Example problem 3 197
Example problem 4 199
The automated spreadsheets 203

The Ice Cream Technology and Manufacture 205
Dosing and Blending 205
Pasteurization 205
Homogenization 210
Ageing 212
Freezing / Whipping 213
Continuous freezers *215*
Batch freezers *219*

Hardening (packaging) 224
Storing and Holding 227

Food Safety and Hygiene 234
Chemical contamination 234
Physical contamination 236
Microbial contamination 237
Cleaning 240
Sanitizing 241
Allergenic contaminations 246

Food Allergens 248
The 14 allergens 250
Allergen labelling *251*
Cross contaminations *253*
Gluten 256
Vegan ice cream 259

Food Additives 263
A general view of food additives 268
Food additives classification 270

Theoretical Aspects of the Mix and Ice Cream Physic 273
Freezing point 273
Acidity 275
Rheology 276
Stability 277
Meltdown 281

The Ice Cream Defects 283
Body defects 285
Flavour defects 287
Meltdown defects 288
Colour defects 288

The Recipes 290
White Creams 292
White ice cream base *294*
Fiordilatte ice cream Petit Four recipe *295*
Espresso ice cream *296*
Gelato alla crema (Italian egg-custard) cheap recipe *296*
Gelato alla crema (Italian egg-custard) Petit Four recipe *297*
Gelato alla crema (Italian egg-custard) with condensed milk *297*
Gelato alla crema (Italian egg-custard) with condensed milk for restaurant *297*
Espresso ice cream Petit Four Recipe *298*
Original caramel ice cream *298*

Tea ice cream *298*
Rice pudding ice cream *299*
Yogurt ice cream *299*
Yogurt ice cream Petit Four Recipe *299*
Yogurt ice cream for restaurant *300*
White ice cream base for restaurant *300*
Ready mixed products 301
The pre-mixed dry compound made "in house" *304*
White ice cream base with premix 12% *304*
Strawberry & Cream ice cream with premix 12% *305*
Chocolate ice cream *306*
Using chocolate *307*
Chocolate ice cream rich recipe *311*
Using cocoa powder *312*
Chocolate ice cream with cocoa powder and egg yolk *313*
Chocolate ice cream with cocoa powder cheap version *314*
Chocolate ice cream Petit Four Recipe *314*
Milk chocolate ice cream *314*
White chocolate ice cream *315*
White chocolate ice cream for restaurant *315*
Gianduja ice cream rich recipe *316*
Nuts pastes *317*
Hazelnut ice cream *320*
Hazelnut ice cream Petit Four Recipe *320*
Hazelnut ice cream with condensed milk *321*
Hazelnut ice cream with egg yolk *321*
Hazelnut ice cream *321*
Hazelnut ice cream for restaurant *322*
Pistachio ice cream Petit Four Recipe *322*
Pralinèe ice cream *323*
Nougat ice cream *323*
The fruit *324*
Fresh fruit *327*
Frozen fruit *328*
Frozen fruit puree *329*
Lyophilized fruit *330*
Fruit juices *331*
Jam, concentrated pastes, compotes *332*
The fruit ice creams 333
Banana ice cream *336*
Banana ice cream for restaurant *336*
Blood orange ice cream *336*
Cantaloupe ice cream Petit Four Recipe *337*
Lemon ice cream *338*

Pineapple ice cream *338*
Strawberry ice cream for restaurant *338*
Strawberry ice cream *339*
Tangerine ice cream *340*
Tangerine ice cream for restaurant *340*
The fruit sorbet 327
Lemon sorbet *343*
Lemon sorbet for restaurant *343*
Banana sorbet *344*
Mandarin sorbet *345*
Passion fruit sorbet *345*
Peach sorbet *346*
Pistachio and rose sorbet *347*
Watermelon sorbet *348*
Raspberry sorbet for restaurant *348*
Raspberry sorbet *349*
Yuzu sorbet *349*
Basic sugar syrup 50% for sorbets *350*
Fruit sorbet with sugar syrup *351*
The alcohol in ice cream *352*
Beer ice cream *356*
Red wine ice cream *356*
Red wine and peach sorbet *357*
Strawberry and prosecco sorbet *358*
Sparkling sweet wine sorbet *358*
Whisky ice cream *359*
Zabaglione ice cream *359*
The savory ice cream *360*
Bell pepper sorbet *362*
Carrot sorbet *362*
Cooked carrot ice cream *364*
Fois gras ice cream *364*
Gorgonzola ice cream *364*
Guacamole ice cream *365*
Parmesan cheese ice cream *366*
Smoked salmon ice cream *366*
Tomato sorbet *367*
Dietetic ice cream 368
Labelling and regulation *368*
Formulations of sugar-reduced ice creams *376*
Sugar-free white ice cream *379*
Sugar-free white ice cream *379*
Formulations of fat-reduced ice cream *381*
Fat-free ice cream *367*

Low sugar / high protein ice cream ... *367*
Plant-based formulation ... 384
Vegan ice cream base ... *390*
Vegan coconut ice cream ... *390*
Vegan chocolate ice cream ... *390*
Granita ... 391
The freezing methods ... *395*
Almond granita ... *396*
Cocoa granita ... *396*
Coffee granita ... *397*
Lemon granita ... *397*
Real coffee granita ... *398*
Strawberry granita ... *398*
Sweet fruit granita ... *399*
Cocoa granita ... *399*
Icicles and molded stick ice cream ... 400
Fruit water ice bars ... *404*
White stick ice cream ... *405*
Toffee fudge bar ... *405*
Chocolate coating ... 406
Pacojet ... 409
Chocolate ice cream with Pacojet ... *411*
Vanilla ice cream with Pacojet ... *412*
Strawberry ice cream with Pacojet ... *412*
Hazelnut / Pistachio ice cream with Pacojet ... *413*
Yogurt and rosemary ice cream with Pacojet ... *413*
Fennel and lime ice cream with Pacojet ... *414*
Conclusions ... 416

The ice cream technology and manufacture

After the thorough study of the functional components, of the ingredients, and after having smacked our head on chart, tables, computation and equations, it is time to do some actual ice cream!
Now we know what must be inside the mix but we still have to turn the recipe in ice cream.
There are slightly different systems that can be encountered in ice cream manufacture, however, generally, they can be summarized in the following seven steps.

1. Dosing and Blending of the ingredients
2. Pasteurization
3. Homogenization
4. Ageing of the mix
5. Freezing / whipping
6. (Packaging) / Hardening
7. Storing, and holding of the finished product

Dosing and Blending

The first operation for the mix preparation is the dosing. The ingredient selected during the recipe design, are weighted separately, then usually all the powders are mixed together while the liquid ingredients go directly in the pasteurizing machine.
Nowadays no one still uses the direct cooking system in pots on heated stoves or fire, however, the principle is the same. Usually, cream, milk, condensed milk, water, glucose syrup and inverted sugar are poured directly into the pasteurizer tank while the latter is heating up. Once the mixture has reached around 35-50°C the other ingredients are added. Firs yolk or eggs, then all the powders and finally the butter, fats or other ingredients.
Once all the ingredients are into the tank we close the lid and the machine will blend the mix thoroughly while heating it up.

Pasteurization

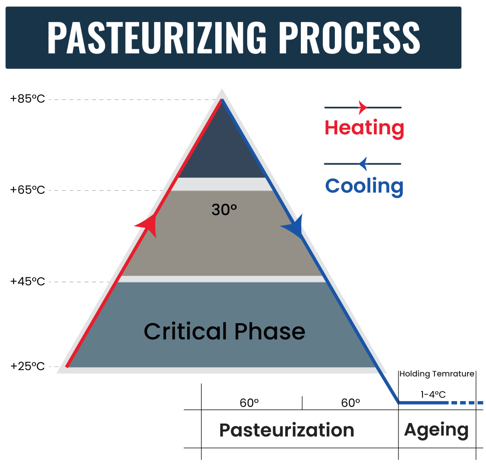
The pasteurization is a thermic treatment designed for the destruction of pathogenic bacteria, in order to safeguard the health of customers and reducing the microorganism responsible for spoilage. The heat also helps by destroying several enzymes, naturally occurring in raw milk and cream, that could lead to damages in the flavour and texture of the final product.

Furthermore, the elevated temperature of this process greatly enhances the hydration of hydrocolloids, and proteins (LMS, stabilizers) and allow to dissolve components like mono and diglycerides of the fatty acids and many other emulsifiers.
It is also very convenient that, at these temperatures, the homogenization can be carried out at its best.
The pasteurization process consists in quickly heating the mixture at a top temperature between 69°C and 85°C, maintaining it at this temperature for a given extend of time and then cooling the mix down as quickly as possible.
There are different types of pasteurization process. The most important subdivision must be made between *continuous pasteurization* and *batch pasteurization.*

The continuous pasteurization is largely used in big plant and industrial manufacturers.
According to the temperature reached and the speed at which the heat is exchanged to the mix, we can have HTST (high-temperature short time), HHST (high heat short time) or UHT (ultra-high temperature).

Pic. 1 Self-contained ice cream mix plant model 150 batch. Photo courtesy of © ROKK processing ltd

I will not go deep into the details of the process as this technique is used only by the large food industry, but to have an idea, it is carried out in large apparatus consisting in stacks of metal plate separated by thin gaps forming chambers. On one side of the plate, through all the chambers, runs the mixture pressurized by a pump. On the other side hot water or steam is pumped through. The mixture is then exposed at high temperature for a very short time, which anyhow depends on the temperature itself. The higher the temperature reached the lower the exposure time needed. All these parameters are fixed by law, and the manufacturer must be fully aware of all the norms and regulation that might apply oh the products in his specific area of competence. The regulations in this matter are different for each country and often for each state. Those parameters can refer to the obligatoriness of the treatment, time and temperature to be reached within the pasteurization process, maximum bacterial count before and after the process, etc.



The batch process is instead of great interest for the small ice cream maker and artisan. It consists of using a jacketed metal tank in which all the ingredients are mixed (see Dosing and Blending) and subsequently heated up while being kept in constant agitation. These containers can range from 60 to 2000 litres. Once again, time and temperature of the cycles are interrelated and limits are imposed by law. However, in artisanal production, ice cream parlours and shops practical and fully programmed pasteurizer are used, ensuring the perfect abidance to the rules on this topic.

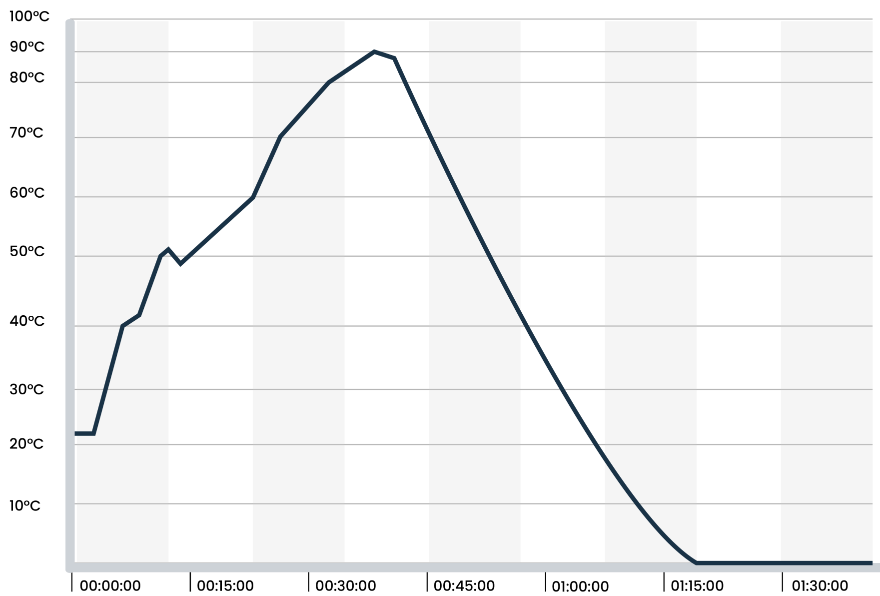
n these machineries, the temperature is monitored and controlled electronically. The operator only needs to set the chosen program and the machine will do the rest.
The program usually differs on the highest temperature reached, allowing to choose a delicate cycle when using materials particularly sensitive. The computer will then adjust the time accordingly.
At the end of the cycle, the machine will automatically stop and will immediately start cooling down the mixture by running refrigerated water through the jacket around the tank.
This is a critical aspect, it is crucial to ensure that the mix is quickly cooled and not held in temperature below the pasteurization and

above 5°C. It is very important to understand that, while the pasteurization process effectively destroys the vast majority of the microorganisms within the mix, it DOES NOT sterilize it. This means that, at the end of the cycle, there will still be (few) microorganisms cells alive and capable to thrive and multiply if given chance to.
Bacteria grow most rapidly in the range of temperatures between 4°C (40 °F) and 60°C (140 °F), doubling in number in as little as 20 minutes. This range of temperatures is often called the "Danger Zone."
Simplifying, pasteurization consists of heating the mixture to 85°C and cooling it down right after to 4°C. The process must be completed in no more than 2 hours and, more importantly, the cooling time must be less than an hour.

Pic. 2 Modern ice cream mix pasteurizer model Pastomaster 60. Photo courtesy of © Carpigiani

Once the mix inside the thank has reached 4°C the cooling system stops, and the mixture is held within the machine tank until the moment of its use. The pasteurizer will keep the mix at 4 °C mixing from time to time to ensure homogeneity and temperature dispersion of the mixture.
By keeping the mix close into the pasteurizer thank, we minimize the handling of the product and therefore the contamination it might be exposed to.

Pasteurization Curve

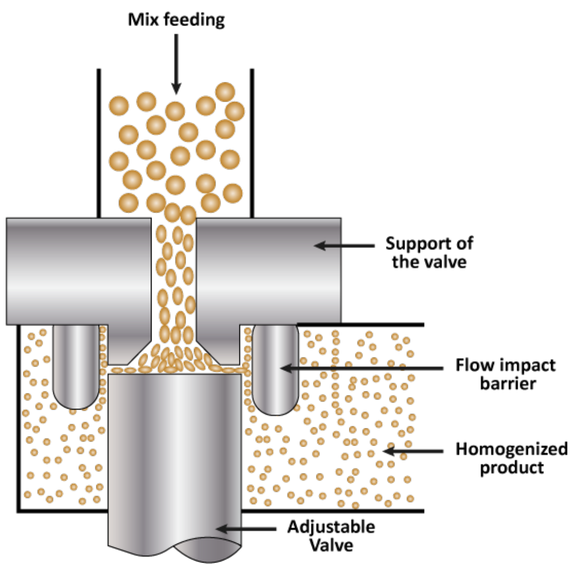


This working method is the most commonly used, and consist in preparing large batches of "white cream base" that undergoes pasteurization and then is stored directly within the equipment. The day after the ice cream maker will simply tap the needed amount of white base, add it with the chosen flavouring ingredient or paste, and proceed to freeze it into ice cream.

Homogenization

The ice cream mixture is a complex matrix composed by solutions (sugars, salts…), colloidal systems (proteins, stabilizers…), suspensions (fibre, particulates…) and emulsions (fat and oils).

We know that milk fat is arranged in globules of varying dimensions throughout the dairy portion of the mix. These globules are kept separated from one another by a coating membrane made of phospholipids, to which proteins and other fats are adsorbed.
By reducing the volume of the fat globules, the surface is increased dramatically, and with it the amount of substances that can be bonded to it. Thus the more we reduce the size of the globules, the more material will be captured on the surface of the globules and therefore the more stable the emulsion (and all the mix system) will be.
The purpose of the homogenization is then to reduce the size of the fat globules to 1 – 2 μm, producing a stable and uniform suspension of the fat.
If the fat is properly homogenized there will no fat separation on the surface and the ice cream will have a pleasant mouthfeel, a smooth and dry appearance. Also, the resistance against melting will be improved.
This process is always beneficial but must be considered paramount when in the mix are present fats prone to generate unstable emulsions (vegetable oils above all).
Homogenization consists in forcing the (hot) mix through very small valve orifice under extremely high pressure. The pressure of these pistons can be adjusted from 500 to 2500 psi, according to the composition of the mixture and the process is often carried out in two stages.



Pic. 3 Detail of a homogenization nozzle

Particular attention must be paid when homogenizing mixes with a high amount of fibre cocoa or undispersed solids since these substances are prone to damage the delicate equipment valves.

Homogenization of the mix should take place ate the pasteurization temperature, since this process exert its maximum efficiency at around 80°C (175°F). The high temperature eases the fat globule breaking up.

Pic. 4 Full ice cream production line including (from the right): Pasteurizer, Homogenizer, Holding and Ageing device, two batch freezers. Thank to---

Pic. 5 Laboratory size homogenizer. Photo courtesy of © ROKK processing ltd.

Pic. 6 Turbomix emulsifier / homogenizer machine. Photo courtesy © Carpigiani

When dealing with a larger amount of production, the homogenizer is strongly recommended and should be placed between the pasteurizer and the cooling/ageing tanks (see pic). In fact, the industrial manufacture requires the incorporation of a larger amount of air into ice-cream compared to the artisanal process.
In commercial production, type of fat such as hydrogenized fats are more commonly used, making more difficult their dispersion than milk fat, used by small premium ice cream makers.

Due to the high cost of proper homogenization apparatus, often the small artisanal ice cream maker, or pastry chef, resources to smaller and inexpensive blender instead. These blenders can be handheld or standing (see pic), however, they cannot be classified as actual homogenizer but rather emulsifier machines. Modern pasteurizers often have a homogenization system that while not capable of a real homogenization, is sufficient to allow the incorporation of the amount of air needed for artisanal ice creams, which we have seen to be around 35%. Small ice cream makers can absolutely do without this machine by using products that are normally partly homogenized such as milk and cream, a good balance of the mix, using proper emulsifier and stabilizers and an adequate production process.

Ageing

This phase of the ice cream manufacture is often underrated above all by the artisanal ice cream makers and chefs. It is indeed one of the most important moments of the production process.
During the pasteurization of the mix, several physical changes occur: the hydrocolloids expand while getting soaked in water, the emulsifiers start to bound with water and fats, and the fat melts easing the homogenization of all these components.
However, we need to maintain these conditions stable in the mix, and we do so by cooling the mix down at below 5°C (<40°F). When the mix is cooled below this temperature the fats start to crystalize. This crystallization is important to ensure a correct destabilization of the fat globules during the freezing process, thus ensuring a proper partial coalescence.
Fat crystallization rate depends on several factors, nonetheless, an ageing period of a minimum of 4 hours at less than 4°C (<39°F) will suffice for all the possible mixes.
The best practise is, beyond any doubt, ageing the mix overnight at the lowest possible temperature without freezing it, at anyway always below 5°C (<40°F). Best results are obtained with mixture

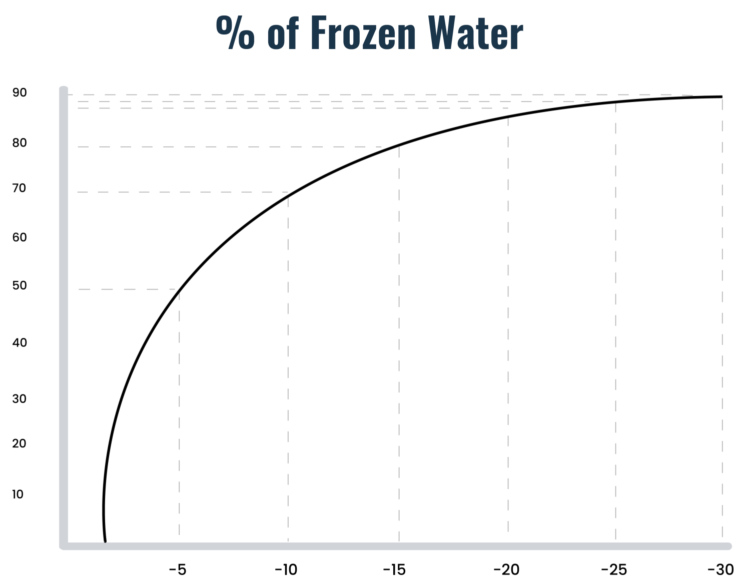
cooled at 0 - 2°C, where fat crystallization is at its best, freezing process is quicker (due to the smaller temperature differential), and the highest microbiological stability is obtained.
The ageing process is performed in insulated, refrigerated storage tanks, in food container od buckets stored in the fridge or directly within the pasteurizer machine.
A "green" under-aged mixture is generally easily recognisable during the freezing process, with an irregular texture, less overrun, and wet appearance.

Pic. 7 Pasteurizer ageing vat model Age 60+60 XPL. Photo courtesy by © Carpigiani.

Freezing/whipping

Here we finally came to the heart of the ice cream processing. In this phase, we pass from the liquid mix to the creamy ice cream.
This phase, while seeming straight-forward, holds several variabilities and being able to produce consistently high-quality ice cream is not a simple task.
This part of the freezing process is called dynamic freezing and it consists of the quick removal of heat from the mix while the latter is kept in constant agitation inside a cooled cylinder. As we are going to see, there are different types of dynamic freezers, but they basically all have in common general design. An ice cream freezer consists of a stainless steel cylinder (arranged in horizontal or vertical position) fitted with an external jacket through which coolant runs at negative temperature. This coolant is usually refrigerant gas, R502, R448, R134A or others, is pumped by powerful compressor working within a refrigeration system. The heat extracted from the mixture is then exchanged through proper dissipater to the water coolant system or air.
Meanwhile, the mixture inside the cylinder (barrel), is continuously agitated by scraper blades and dashers that rotates at various speed (from 50 to 200 rpm) forcing the frozen portion of the mix out of the barrel wall and into the unfrozen mass.
The aim of this process is multiple. In first place freezing the mix generate ice crystals which, due to the constant agitation, are formed in the smaller size possible. In second place, the mix is whipped up and incorporates a certain percentage of air (overrun).
The amount of air a give ice cream will incorporate depends primarily by the freezing equipment design, as well as by the mix

characteristics. Last but not least during the dynamic freezing also the fat undergoes important changes. The fat globules are destabilized causing the (desired) partial coalescence and generating bigger fat clusters responsible for the stabilization and air-trapping in the ice cream.
Gradually the liquid mix becomes solid; we can say that the ice cream is ready when it is "dry", meaning that is sufficiently consistent and full-bodied not to appear wet on the spatula. At the end of the freezing process, the water frozen in the mass exceeds 50 - 60% and the ice cream is extracted from the machine at a temperature of approximately -5 / -9 ° C.
One of the most important characteristics we are after is the finest structure possible. This, as we have seen, is achieved by reducing the size of water crystals, and to do so the mixture must be cooled as fast as possible while constantly churning and agitating.
At the beginning of the freezing process, the temperature alights down to -5 / -6°C, at this moment the viscosity increases and 55 – 60% of the water is frozen while the remaining is still liquid.



Freezing Curve of an ice cream mix. The % of frozen water depends of the reached temprature.

Due to the presence of sugars, to further freeze a larger percentage of water, a proportionally lower temperature will be required. The more water gets frozen, higher the concentration of sugars and salts will result in the remaining liquid part, and therefore more difficult will be freezing this part.

The mix temperature at the moment of introduction in the freezer is therefore crucial to ensure the best ice crystal formation.
A too high temperature can result in a slower heat extraction rate thus allowing the growth of larger ice crystals.
On the other hand, introducing a partially frozen mix (temperature below -2°C) will cause the introduction in the machine of ready-grown ice crystal. Those will act as germs of crystallization promoting the formation of large crystals and giving an icy texture to the final product.
Furthermore, the whipping process must start in the freezer at a temperature between 5°C and 0°C because in this specific range the incorporation of air is maximized.

The freezing equipment may come in a variety of different designs. The first distinction to be made is between continuous freezer and batch freezers.

<u>Continuous freezers</u>

The continuous freezer is typically a large and costly piece of equipment, mostly used by industrial large manufacturer.
The base principle is the same, with the only difference that in the continuous freezer the mix is pump-fed into the freezing barrel. Here the dashers and scarpers whip it up while the freezing process takes place. The frozen ice cream is then extruded from the other end of the cylinder into pipes to be packaged or to feed other processing machines.

Pic. 8 Continuous freezer model RFE400A / 2 (twin barrel). Photo courtesy of © ROKK processing ltd.

The chamber is pressurized and a define ratio mix/air is pumped in to ensure a controlled (and usually high) overrun. Continuous ice cream freezers may have production capacity ranging from 60 to 4500 litres/hours. This amount is multiplied by the number of freezing cylinders the machinery is equipped with; some freezer can 2 or 3 of them running simultaneously.

Pic. 9 Large production facility featuring 4 single cylinder continuous freezer

Nowadays, those types of machinery are computer-controlled and fully automatized. The computer controls the amount of air and mixture to be pumped in, the pressure of the cylinder and the stiffness of the product inside the barrel. The viscosity of the ice cream is monitored by measuring the torque required by the dasher motor to rotate. Higher the stiffness higher the needed amperage to operate the electric motor.
By monitoring and controlling all these parameters, the machine PLC (programmable logic controller) can ensure a constant overrun and texture of the product, mirroring what is designed in the formulation phase.
These machines are usually employed only in large production because, besides their challenging cost, they require a large amount of wastage at the beginning of the production before stabilizing the temperature of cylinders, pumps and pipes. Also, the cleaning and sanification of those machines require large volumes of hot water and proper detergents.
Among the continuous freezer, I must mention also the soft-serve ice cream machines.

0 Model Super Tre B G EVO High Volume soft-serve ice cream machine. Photo esy of © Carpigiani.

The soft-serve machine is indeed a miniaturized version of the big brother continuous freezer in use in large production plants. The only difference is that soft-serve ice cream machines can operate intermittently over an extended operation time. Upon demand from the operator, the machine will instantly extrude a small amount of soft ice cream on the cone and then will be capable, once the drawing is completed, to remain in standby mode without getting jammed or stuck because of ice formation.

This is achieved by clever design of the freezing chamber and electronic controls.

In soft-serve ice cream machines, the mixture can be pumped into the cylinder or enter it just by the action of gravity or forced in by the void generated by the product drawing.

The ration mix/air is adjustable by the operator and the stiffness is monitored by measuring the motor load (amperage of the phase).

These machines are equipped with a refrigerated holding tank to store the liquid mix for days.

The machine must be disassembled in all its food-contact parts, those can be then washed in a washing machine or with hot water and soap. The parts must then be sanitized and properly lubricated before reinstalling them.

These machines are widely used in the US as well as in many other European countries. They are cheap and easy to operate and maintain, thus often employed in fast food, take away restaurants, ice cream parlours, cafés, etc.

<u>Batch freezers</u>

The king of all the artisanal and medium-small ice cream manufacturers. Its functioning is simpler than any other kind of freezing machinery. A given amount of cold mixture is introduced into the freezing drum through the proper opening after the loading the machine is started and the program runs. The program duration is determined by timers and by sensor measuring the torque needed for the electric motor to rotate the blades.

New machinery nowadays, to evaluate the right consistency (i.e. when the ice cream has the optimal structural quality, given by the correct percentage of crystallized water), regardless of the mix load contained in the cylinder, are not based on control of amperage, but on an electronic system. The system measures the migration of ions in the water. The conductivity of the mixture changes when the water crystallizes. The measurement is entrusted to probes and a microprocessor processes the data indicating when the ice cream is ready.

Pic. 11 Typical Italian style ice cream batch freezer model Maestro HE 3. Photo courtesy of © Carpigiani.

Once the wanted stiffness is achieved the program ends and the operator can extract the ice cream. This is easily propelled out from a purposely designed extraction port in the lower part of the cylinder and can be collected in the chosen containers.
Traditionally the batch freezers produce ice cream with a lower overrun than continuous freezers. This is due to the shape of the scraping blades and above all to the fact that batch freezers operate at atmospheric pressure as opposed to the continuous freezer in which a certain positive pressure is forced into the barrel. For this

reason, particular attention must be paid in the ice cream formulation, ensuring proper emulsification and whipping properties. Nonetheless, is possible to adjust the overrun ratio by introducing less or more mixture in the freezing chamber at each cycle. A lower amount of mixture will allow more air to be whipped into the mix because of the increased contact surface air/mix. On the contrary, a fuller drum will generate a harder and more compact ice cream with less overrun. However, equipment manufacturer instructions must be followed concerning the proper loading of each machine.
The cycle duration depends on the amount of mixture loaded and on the machine specifications, on average takes somewhere between 6 and 12 minutes.
In these machineries, the ice cream is extracted at a temperature of -5 -6°C, slightly higher than with continuous freezers.

Commonly the mix is added with flavouring ingredient right before being inserted into the batch freezer. Other ingredients might be incorporated through the upper hopper while running the freezing program towards the end of it, just before the ice cream extraction. Other recipes instead require some ingredients to be added in the extraction moment, directly mixing the ice cream in the container (stracciatella for example).
A properly balanced ice cream will easily extrude through the discharge port in a ribbon flowing down in the container below. The operator will guide the ribbon using a hard plastic spatula to obtain an even distribution in the tub. When pieces of nuts, dried fruit or chocolate morsels are added into the freezing chamber, a complete dismantling of the blades is necessary in order to allow complete cleaning. It is recommendable to plan a proper sequence of production to minimize those operations and to reduce the risk of allergens cross contaminations.
Although today the vast majority of ice cream maker opt for the most convenient horizontal batch freezers, vertical batch freezers are still available on the market albeit mostly employed in show-laboratories where the customer can see the production operation. This because these types of machinery are the heritage of the past in tradition Italian gelato making, and therefore are capable to evoke a special "handcrafted" romanticism.
Vertical batch freezers produce an Italian style ice cream with a typically lower overrun and a stiffer consistency. They allow easier insertion of particulate materials such as chocolate pieces, cookie crumbs, dry fruit, etc. but have as cons a longer production cycle, a difficult completely manual extraction and the more difficult cleaning.

Pic. 12 Vertical batch freezer model Effe 6 for production Italian-style gelato. Photo courtesy of ® Ice Team 1927

It is important to mention that are available on the market combined machines that include in one piece of equipment both pasteurizer and batch freezers.

These machineries are extremely convenient when dealing with limited floor space, allowing the condensate an entire ice cream lab in single machinery.

Pic. 13 Combined machine capable of mixing, pasteurizing, homogenizing, cooling down and batch freezing. Photo courtesy of © BRAVO spa.

In this combined machinery we find two discrete cylinders. The upper one is heated and serves as mixer/pasteurizer. All the ingredients are inserted raw in it and an automatic program will proceed to agitate, the mixture while bringing the temperature up to the needed pasteurization point. Once the pasteurization program is completed (usually take 10-15 minutes), the mixture still hot is transferred into the lower cylinder. In here the mix is rapidly cooled to 4°c and seamless the freezing process starts. Once the mixture is dumped in the freezing chamber and therefore the boiler is freed, another pasteurization program can be simultaneously run, optimizing the production times. We can notice that the boiler cylinder is smaller compared to the freezing chamber, this is due to the fact that a larger contact surface is needed during the freezing process to ensure a correct overrun.

Pic. 14 Combined machine model Compacta VariO 12 Elite. We can see the above cylinder used for pasteurization, the pouring mechanism and the lower part for the batch freezing. Photo courtesy ® Ice Team 1927.

These machineries have great perks. First of all, albeit expensive the cost less than buying two distinct machines (pasteurizer and batch freezer). The second advantage is the extreme simplicity of use jointed to the very high food safety (no storage of the mixture). Another pro of this system is that the ice cream maker can produce

every single flavour by using a different and specifically balanced recipe, enhancing the best of each ingredient.
On the other hand, this method neglect completely the ageing of the mix, thus affecting coalescence, fat crystallization, overrun and texture. For this reason, specific stabilization/emulsion profile must be designed when using this machinery. Furthermore, the extemporaneous scaling - boiling – cooling – freezing of small batches one after another can slow down dramatically the production. All pros and cons must be taken into consideration and weighted according to the specific production need.
Alternative systems are on certain occasions used to prepare a very small quantity of ice cream. Some example can be the production of ice cream with liquid nitrogen or using powerful specific appliances capable to blend frozen product directly into a sort of ice cream (see www.pacojet.com).
Those systems, though convenient in certain specific applications such as small restaurants, cannot be classified into the ice cream production process.

Hardening (Packaging)

When drawn from the freezer, the ice cream will be -6 -10°C with 60 – 65% of frozen water. At this point, the ice cream is soft enough to be easily packaged to be commercialized in plastic tubs or buckets or to be graciously arranged in the stainless steel container for the showcase. These operations must take place immediately and as quickly as possible to prevent thawing. In case of continuous freezers, the extraction pipe must be as short and as straight as possible to minimize the distance between freezer and packaging area and reduce heating of the ice cream in the pipes.

Pic. 15 Filling machine model RU3S. Photo courtesy of © ROKK processing ltd.

Specific automatic equipment is then used to fill up or to form and fill up proper containers in the designated shape, size and material.

Pic. 16 Detail of a small tubs filling apparatus. The pipe is fed by a continuous freezer.

These machines may range from a semi-automatic system functioning with the aid of an operated to large scale industrial fillers capable of forming, filling, labelling and sealing up to hundreds of gallons' tubs per hours.
Alternatively, the soft ice cream can be fed in complex machines and lines to produce ice cream novelties, moulded ice creams, mono-portion cups, cookies sandwiches and popsicles.
In these conditions the ice cream is unstable and prone to collapse in its structure, losing its shape and melt. Is then needed a further freezing phase to harden it in its final shape and texture. The freeze-hardening must be carried out in the quickest possible way in order to prevent the still liquid water from generating large ice crystals. The target is reaching temperatures below -18°C, and usually, -23 -30°C are considered ideal.
It is crucial to harden the packaged products as well as the ice cream in tubs for direct selling to customers, ensuring a proper air circulation around each packet/tub. A non-readily performed hardening will lead to superficial melting causing water or sugar crystallization, discolouration and loss in shape. To ensure a fast rate hardening, the ice cream is placed in powerful blast freezers chambers capable to reach temperatures as low as -30°C or -40°C. Larger packaging, obviously, pose major challenges, nonetheless, the target of this operation should be reaching a core temperature

of at least -18°C in less than 4 hours. Home size container (half-gallon or smaller) take just a few minutes.
In commercial large scale manufacturing plants, the hardening is commonly performed in large spiral cold wind tunnels. In these large chambers (rooms), the ice cream packages run on spiral-shaped conveyor belts while air at -40°C is blasted by powerful fans reaching homogeneously all the sides of each container.

Pic. 17 Hardening line for ice cream on stick.

In smaller scales, like in artisanal production and ice cream parlours, the hardening is performed following the exact same principle, obviously without sourcing to large equipment, blast freezers are used instead.
A blast freezer is basically a fridge equipped with a powerful refrigerating compressor system and strong air fans.
They are available in an array of sizes and shapes, generally, the artisanal ice cream maker uses medium size blast freezer units, to harden the ice cream in metal tubs for selling. This machinery can perform a satisfactory hardening in few minutes (15-30 minutes), allowing the operator to quickly free the hardening chamber and place the frozen ice cream in storage freezer units at -22 -24°C. So doing the blast freezer is immediately available to receive a new load of ice cream tubs.

Pic. 18 Blast freezers of various sizes used for the hardening of ice cream in tubs and ice cream pieces. Photo courtesy of ® Ice Team 1927

Storing and holding

Once the ice cream, either packaged for shipping or in metal containers for direct lose selling, is hardened can be finally stored in proper storage freezers. The ideal storage temperature for ice cream is around -22 -24°C.
In small artisanal reality, must be always preferred to reiterate daily a limited production in order to be able of selling the freshest ice cream possible, rather than bulk produce large amounts and store it over long periods. However, it is clear that to avoid the risk of running out of a certain product, some degree of storage is always maintained in the freezers. A properly balanced, frozen and hardened ice cream can theoretically last months if well preserved and covered. Nonetheless, I believe that professional ethic and pride should guide the artisanal ice cream maker in aiming to a higher

degree of quality, capable of setting him apart from the large industrial manufacture.
Generally speaking is always recommendable to store the ice cream at the lower possible temperature, well covered to avoid air-burn, discolouration and unpleasant tastes.
Besides that, any sudden temperature change must be avoided (door opening, moving from fridge to fridge, cleaning operation of the freezer, etc.).

However, storing the ice cream in containers for the selling at so low temperature (- 23°C) poses a clear obstacle to its spoonability and degustation. At – 22°C the ice cream will be stone-hard and impossible to serve. Certainly, a permanence period in the showcase at -11°C will eventually soften it, but this passage would take too long and will be gradual from the outside first and slowly towards the core of the mass. It is then desirable to set a third storage freezer at an intermediate temperature for example – 16°C. The ice cream exiting the colder storage freezer (-22 -24°C) will be passed into the higher temperature one at -16 -17°C in order to "temperate" throughout all its mass. Only then will be transferred into the selling showcase at -11 -12°C where it will climb the remaining 4 or 5°C to reach the perfect service temperature.
All the above-mentioned phases of the storing, holding and exposing process must be performed respecting the FIFO (first in first out) order.
Once the ice cream is moved from the colder freezer to the “warmer” one must never return to the firs. Following a one-way direction only ensure to minimize the large ice crystal formation. In the same way, the remaining ice cream resulting at the end of the day from the showcase shall never be re-frosted at -22 -24°C. This ice cream instead will be stored in the -16°C freezer and should be consumed within the following day.

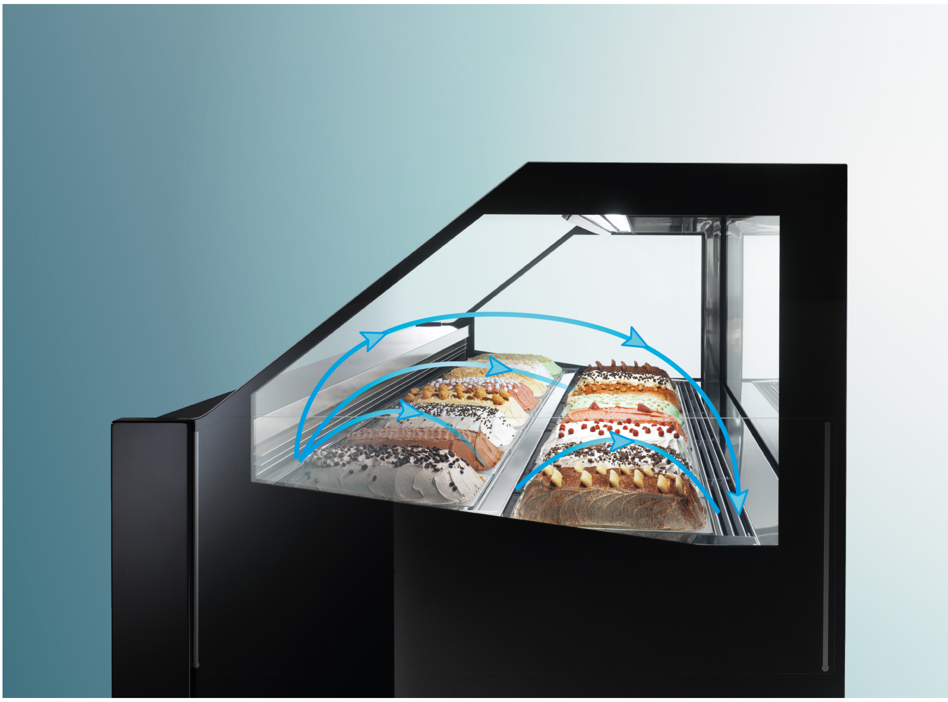
It is also possible the case where an ice cream production laboratory produces to supply more than one shop or sell to external bars, restaurants or bakeries. In this case, the transportation of the ice cream must be analysed in every single step in order to avoid any disruption in the cold chain. Depending on the volume of products to be moved, different solutions may apply. Ideally, the best way to transport ice cream while preserving all its qualities is by mean of properly fitted and refrigerated vehicle. The smallest of these are obtained by modification of a common car or van. In alternative, properly designed insulated boxes are available on the market, those might come equipped with refrigeration compressor or without for passive cold holding.

However, before starting any business involving the transportation of food and above all of the ice cream the entrepreneur should be fully aware of all the laws and regulation regarding that matter. These may differ from country to country and often from county to county.
For what concerns the displaying in showcases for direct selling, the products should be arranged in order to attract and appeal the customers. All the containers should look fresh and never more than half empty. The most popular ice cream will be the easiest to get a hand on and often doubled. The double displays allow to have 2 tubs for each flavour so the first (closer to the operator) will be the softer, the farer one will be just drawn from the conservation freezer at -16°C thus will have all the time to acclimatise and soften at the showcase temperature. Display cabinets may come in different designs, shape and size.

Pic. 19 Modern ice cream counter. Photo courtesy of Frigomeccanica SRL

Nowadays the most common design is the air-cooled showcase in which the ice cream tubs sit on metal racks "hanging" in an under chamber through which cooled air is forced by mean of fans. This

system is cheaper and lighter than other older design but let capable to withstand temperature surges and more prone to ice packing.
It is however good practice defrost, wash and sanitize every night the display cabinet and recover all the ice cream tubs in the -16°C freezer.



Pic. 20 Refrigerated air flow circulation through ice cream counter. Photo courtesy of Frigomeccanica SRL

Another possible design is the well counter freezer. This “old school” system is lately regaining popularity due to several advantages.

- It allows a perfect temperature holding with less excursion than traditional display cabinets
- It has a more "authentic" and "old-style quality" look, appealing modern and aware customers
- It allows the ice cream maker to sell until the last spoon of ice cream because the customer cannot see inside the well. In comparison an empty tub would look awful in a traditional display, this allows a dramatic wastage reduction, thus cost-saving.
- The ice cream is less subject to air burning or surface discolouration.

On the other hand, because the customer cannot see the product it might lead to a less compulsive buying, and to a slight time waste for the operator whom then have to explain or show the customer each scoop of the different flavours.

Pic. 21 Modern designed "well" counter for ice cream in vertical tubs. Photo courtesy of Frigomeccanica SRL

Whichever mean of storing and preservation is used, we must keep in mind that ice crystals are unstable by nature. Throughout the storage period, ice crystals change in size, number and shape and undergo recrystallization. Recrystallization occurs each time ice cream is exposed to higher temperature leading to partial defrost of the water contained in its serum. Once the ice cream is then put back in freezer at low temperature, the serum recrystallizes aggregating to pre-existing ice crystal and therefore forming larger new ones. This phenomenon is the most significant issue leading to quality losses in ice cream.
Ice cream may be exposed to high temperature in several moments of its "life". Rarely important temperature fluctuations occur within the production site, rather they take place during the shipping, handling and transporting. The ice cream maker that sell packaged ice cream or serves other location through shipping must ensure the correct cold chain maintenance throughout all the process. It is

important to understand that, regardless where and when temperature fluctuation occurred, leading to quality loss, the customer will always associate the bad quality of the product to the manufacturer instead of blaming other factors. The ice cream manufacturer image will be reflected in the quality of the delivered product. The ice cream maker, when engaging in a business requiring delivery and shipping, should monitor the process in every step to avoid mishandling and temperature fluctuation throughout storage, shipping and distribution. In this case, particular attention must be paid also in regard to the stabilizers profile. A correctly formulated stabilizing blend is probably one of the best assets to ensure proper control in ice crystals growth. When designing a recipe meant for shipping, the I cream maker must remember that a mix with lower total solids will be more difficult to stabilize, and also that high sugar content, lowering the freezing point, eases the melting of water destabilizing the ice cream.