Chocolate and couvertures: applications in ice cream

D. J. Cebula and A. Hoddle, Unilever R&D, UK

Abstract: We describe the combination of ice cream and chocolate as a complement of contrasts in physical and sensory properties and show how these are addressed in the manufacturing process of chocolate-coated ice cream products. Each material has distinctive features of texture, melting characteristics and flavour and, to the manufacturer, the combination presents significant technical challenges to making good products. We introduce the various different formats (sticks and cones etc.) and describe different formulations, comparing and contrasting chocolate and couverture. The evolution of manufacturing is discussed and how new technologies provide a source of product innovation. Lastly we consider the consumer drivers for products to be more nutritionally sound.

Key words: application process, chocolate-coated ice cream, chocolate coatings, chocolate-filled ice cream, couverture coatings, enrobing, ice cream, spraying.

9.1 Introduction

For the consumer, the combination of ice cream and chocolate is highly desirable and derives from the complement of contrasts in the physical and sensory properties of the two materials. Both ice cream and chocolate are essentially sweet and both have ‘body’ and smooth mouthfeel and, in those respects, are similar. Both materials are constructed from lists of ingredients, require significant processing, and result in a structure that confers unique sensorial properties. However, each material has very distinctive features and there are outstanding differences in their texture, their melting characteristics and their flavour. Ice cream is soft, creamy and cooling to eat. Chocolate is firm, often brittle, smooth and warm in the mouth.
Nevertheless the differences conspire and result in irresistible products. In this chapter we will examine the origins and nature of the differences in texture and melting behaviour and we will address the challenges consequently faced by the manufacturer in assembling products, often with highly complicated structures. For the classical formats (such as sticks and cones etc.) we will describe details of the different formulations and the demands placed on the manufacturing processes. Lastly we will reflect on how manufacturing is evolving and indicate the emergence of new technologies that are providing a source of product innovation. We will also consider the drivers from the consumer side with particular reference to the requirement for products that are both perceived to be and actually are more nutritionally sound.

9.2 Features of ice cream and chocolate

It would seem that the first (industrial) use of the combination of ice cream and chocolate was in the 1920s. Several citations are possible such as choc ices on the price card from Lyons Maid (2008), Eskimo Pie’s (2008) block of vanilla ice cream covered in chocolate and also the tale (Shilling, 2006) of how Good Humor launched stick products:

‘It was 1920. Harry Burt had just created the Jolly Boy Sucker, a lollypop on a stick. Later, while working in his ice cream parlor, Burt developed a smooth chocolate coating that was compatible with ice cream. Unfortunately, the new combination was too messy to eat. Burt’s young son, Harry Jr, suggested that his dad take some of the wooden sticks used for the Jolly Boy Suckers and freeze them into the ice cream. The first ice cream on a stick was born from the resourceful tip by a son to his dad’.

Today, significant use is made of chocolate (and related cocoa-based products) in ice cream on the scale of thousands of tonnes per year.

The two basic components, ice cream and chocolate, are both composed of ingredients from which complex structures are created. In the case of ice cream, four phases are present (in varying proportions): ice, air, fat (as droplets) and ‘matrix’ which comprises the unfrozen concentrated aqueous solution of sugar, milk solids and so on. Chocolate too is multi-phase comprising a dispersion of sugar crystals, cocoa and milk solids in a continuous phase of fat (cocoa butter, milk fat etc.) which itself is largely solid.

9.2.1 Ice cream

Ice cream is a material that truly operates on a range of spatial scales (see Fig. 9.1). On a macro scale the sensory properties of the texture are perceived; these are determined by the microscopic details of the structure which, in turn, are determined by complex molecular interactions. The main aim is to generate the correct microstructure in the ice cream to achieve the desired organoleptic characteristics
Fig. 9.1 Typical ice cream microstructure by scanning electron microscope.

so that the product can breakdown and melt away in the mouth thus delivering the consumers’ preferences for taste. However, the structure needs to be sufficiently robust to withstand transportation and storage, so that quite a balancing act must be performed to reconcile these simultaneous and often conflicting requirements. Therefore, in achieving the optimum microstructure, there are tradeoffs between the formulation (levels and types of ingredients and actives such as process aids and stabilisers) and the processing regimes (heat transfer rate, temperature of freezing etc.). A general description of the science of ice cream is given by Clarke (2004). Increasingly, as consumers demand healthier products, nutritional aspects of formulation become significantly more important and whereas, for example, reduction of both saturated fat or sugar are desirable, they may not be immediately possible since these are crucial components for both the process conditions and the microstructure per se.

A typical microstructure is one that consists of ice crystals and air bubbles in the size range 20 µm to about 100 µm, and fat droplets in the size range from 1 µm to 0.1 mm. These fine entities are embedded throughout a viscous solution of sugars, polysaccharides and milk proteins known as the ‘matrix’. At another order of magnitude lower in scale, it is possible to identify the location of the fat. Fat droplets of size <1 µm can be seen which exist as clusters located on the surface of the air cells as well as distributed throughout the matrix. Not visible in the figures here, milk protein is also partially located on the air interface and together fat and protein both help to stabilise the air. Fat has an incredibly important role in the microstructure which relates directly to the sensory properties like mouthfeel, creaminess and flavour delivery but it is also critical to the stability of products such as meltdown. It can be appreciated that reducing the fat by 50% or more, to
enable healthier products, may not only compromise the sensory quality but may put the stability, specifically of the air phase, at considerable risk.

As mentioned previously ice cream is thermodynamically unstable and even under ideal storage conditions the structure, specifically the ice and the air phases, will coarsen over time resulting in loss of quality and loss of stability. This situation is exacerbated by upward temperature fluctuations and by pressure changes which affect the air phase. In addition, stability becomes a real problem when distributing products across different altitudes when the ice cream expands in response to a lower pressures then shrinks to lower volume as normal pressure is restored. Low fat or reduced nutritional energy products are particularly susceptible to variations in ambient conditions.

The structure is created by preparing the ‘mix’ of the ingredients forming an emulsion of fat droplets. After homogenisation (at high pressure) the size of the droplets is significantly reduced. Aeration (under pressure) and freezing occur in a single step in a scraped surface heat exchanger. This produces air bubbles and ice crystals dispersed throughout the continuous phase. The resulting architectured structure is held in place largely through kinetics rather than thermodynamics, the presence of interfaces and structural stability achieved by formation of crystals of ice. Storage of the structure is effected at low temperature until consumption, whereupon the structure rapidly breaks down by melting of the ice which gives a distinct mouth cooling with definite creaminess provided by the fat droplets and the very small air bubbles.

9.2.2 Chocolate

For chocolate, the principal phases are given by the ingredients namely cocoa powder and milk solids as particles, and tiny crystals (ca. 25 µm) of sugar all dispersed throughout a continuous phase of fat. The fat is present as a mixture of liquid and solid depending on the composition of the fat and the temperature. Figure 9.2 shows a scanning electron microscope image across the fractured surface of chocolate which reveals, at least, the spatial scale of granularity of the microstructure of a typical chocolate.

The microstructure is obtained by a series of processing steps from grinding the beans, mixing with sugar and refining to reduce the particle size. Then extra fat is added (cocoa butter and milk fat, in the case of milk chocolate) and milk solids and natural emulsifiers (lecithin) to facilitate easy flow. The conching stage, at elevated temperature, drives off unwanted volatiles and helps to develop the distinct flavour. The chocolate is stored until use, that is crystallising the fat and solidifying the chocolate (often with a tempering step to ensure the presence of specific polymorphic forms of the fat). This is necessary to achieve equilibrium of the fat and prevent recrystallisation, a process that leads to bloom formation spoiling the product’s appearance. As a solid, chocolate is quite hard but readily melts in the mouth. The exact melting temperature depends largely on the fat composition of the chocolate (particularly the level of milk fat) and the degree to which tempering has been effected (most ambient chocolate melts at around 30 °C whereas
untempered chocolate, usually employed in combination with ice cream and already much softer, melts at around 17 °C).

9.2.3 Chocolate and couvertures

Forsaking many of the exact details that can be found elsewhere (Marshall et al., 2003), several types of chocolate formulation are employed in combination with ice cream. For simplicity chocolate can be real chocolate (containing only cocoa butter and dairy fat, no vegetable fat except in certain countries where this is permitted) or couverture (or compounds) which includes products in which some or all of the cocoa butter has been replaced by other vegetable fats, such as coconut oil or fractions of palm, see Fig. 9.3 for typical compositions. Depending on the application (moulding, enrobing or spraying etc) greater levels of fat are required to facilitate that particular coating process. Since cocoa butter is a very expensive ingredient, in application for ice cream, cocoa butter is often replaced by vegetable fat. However, both chocolates and couvertures must possess specific properties to suit the application in the ice cream sector.

Whereas the properties of chocolate can mainly be changed by altering the fat content (cocoa butter, milk fat) the couverture properties can be varied over a very wide range by using different fat levels and fat types (cocoa butter, milk fat, vegetable fat). Therefore it is possible to get couvertures with specific advantages in respect of processing, functional properties and oral response.
9.2.4 Differences between ambient chocolate and chocolate for ice cream

Chocolate coatings for the ice cream sector have generally higher fat levels (40–60%) than their ambient counterparts (28–35%). This is in order to obtain a more fluid chocolate allowing it to flow across the whole product. Even in the short time during which chocolate is applied, the higher fat level counteracts the fast rates of setting on the cold surface of the ice cream. Higher fat levels tend to make the chocolate more expensive than its ambient counterpart. The chocolate for the ice cream sector generally contains higher milk fat levels to obtain a less brittle structure. In many countries, the standard couvertures for the ice cream sector are usually based on coconut oil at levels of 45–60%. Other vegetable fats could be added to achieve variations in texture and melting characteristics. For example, to make it softer, sunflower oil and soft fractions of palm oil are added but, to make it harder, hardened palm oil is used. Premium couvertures contain cocoa mass and therefore (some) cocoa butter.

In terms of sensory delivery, owing to the cooling effect of ice cream in the mouth, chocolate in ice cream products should have a lower melting point than in ambient chocolate (melting point: 21–23 °C vs. 32–34 °C). For this reason, the normal tempering process that is applied to ambient chocolate ensuring crystallisation into one of the high polymorphic forms of cocoa butter, leading to good mould release, surface sheen, and so on, is not required for ice cream-coated products and would actually be counterproductive as the chocolate would taste waxy.

**Fig. 9.3** Variation of fat content and type for typical chocolates and couvertures.
### Table 9.1 Differences between chocolate and couverture as ice cream coatings

<table>
<thead>
<tr>
<th>Properties</th>
<th>Chocolates (based on cocoa butter)</th>
<th>Couvertures (based on coconut oil, for example)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formulation</td>
<td>Narrow Confined to palmitic, oleic and stearic acids (chocolate legally defined)</td>
<td>Wide Many fatty acid types The composition can be changed to obtain special properties</td>
</tr>
<tr>
<td>Viscosity</td>
<td>High Requires optimisation by emulsifier concentration adjustment</td>
<td>Low • Low pick-up weight • Easier to spray than chocolate</td>
</tr>
<tr>
<td>Crystallisation rate</td>
<td>Fast Melts over a wider temperature range (21 to –23 °C). Higher degree of after cooling required.</td>
<td>Fast Melts over a narrow temperature range (12 to –3 °C).</td>
</tr>
<tr>
<td>Drying times</td>
<td>ca. 30 s</td>
<td>ca. 10 s</td>
</tr>
<tr>
<td>Melting</td>
<td>6 crystal forms.(^a) Melting range 18–23 °C when fresh and rises to 23 °C after long storage</td>
<td>2 crystal forms ((\alpha) and (\beta)) (\alpha) hardly survives and (\beta) melts at around 23 °C both as fresh and after storage</td>
</tr>
<tr>
<td>Texture on storage</td>
<td>Plastic to brittle</td>
<td>Brittle (no change)</td>
</tr>
</tbody>
</table>

\(^a\)The traditional view is that cocoa butter has six crystal forms. More recent work has modified this view (see Chapter 4.2). Tables 4.2 and 4.3 compare these two views.

#### 9.2.5 Key properties of coatings in ice cream applications

Each application and final product demand different and specific attributes from its coating. There can be a conflict between the fat properties required for a particular couverture attribute (e.g. with respect to processing) and those required for another attribute (e.g. in the final ice cream product). In these cases, an optimum balance must be found. The advantages and disadvantages of each couverture or chocolate must be weighed up before choosing which to use for a particular application. The key considerations are listed in Table 9.1.

#### 9.2.6 Challenges in processing ice cream and chocolate together

Their basic characteristics define that ice cream is cold and hydrophilic but chocolate is warm and hydrophobic. The interplay of the characteristics lead to challenges in processing.

Ice cream must be kept cold during application of hot liquid chocolate; it is deep frozen to ensure that ice does not melt leading to the release of air bubbles. It thus presents a rigid ‘former’ of specific shape around which the chocolate must flow thinly and then set. In a coating process, for example, attention must be paid to the dynamics of heat flow and viscosity change because these affect the rates of
solidification, drying and melting of the materials. Balance is required between the depth of ice cream temperature and the ‘pick-up’ of chocolate achieved; lower temperature causes a faster crystallisation rate in the chocolate and a subsequent increase in viscosity. That increase prevents efficient drainage and results in a thick and uneven layer. Overall adhesion is a perennial problem but is achieved largely by encasement of the ice cream piece and from the mechanical integrity of the coating, rather than a specific bond between ice cream and chocolate.

For ice cream bars or mono-bite products that pass through a bath of liquid chocolate, buoyancy becomes the source of a problem. The low density ice cream simply floats in the chocolate and so incomplete coating is achieved. Mechanical arrangements are required to keep ice cream portions submerged to achieve good coating but not for long enough to allow any melting of the ice cream. As time goes on, inevitably, ice cream is melted into the chocolate reservoirs. The release of water has a dramatic affect on the viscosity of the chocolate causing it to thicken to a paste. For the enrobing process, ingress of water can lead to serious alteration of viscosity and loss of stability in the chocolate curtain.

When in combination with ice cream, chocolate is required to melt at about 17 °C for good sensory delivery in the final product. Flavour release for chocolate is better at higher temperatures but the low temperature required to preserve ice cream structure and delivery of its sensory offering is a limitation. Therefore the chocolate must be cooled rapidly by the ice cream. Immediately on drying, the chocolate has a rather plastic and leathery texture and it requires further storage at low temperature to prevent higher order polymorphic transitions from occurring. Even during processing this can present a range of problems related to the ease with which products ‘slide’ efficiently into packaging sleeves. This stabilisation process is very slow and it can take days in cold store to achieve formation of the brittle crack features which are particularly associated with chocolate.

Ice cream products with an external moulded chocolate surface are also very difficult to achieve. In general, successful moulding is largely determined by the density increase (and hence volume reduction) attained in chocolate as the confectionery fat undergoes polymorphic transition. Efficient release from the mould is crucial to the surface quality. A special tempering process arranges for crystallisation into one of the high melting point forms for ambient chocolate and achieves melting around 28–30 °C. For ice cream products, however, special cryogenic conditions are required to achieve the best mould release and these have been codified by Cebula and Rayet (1997).

9.2.7 Examples of requirements for these properties in ice cream

Oral response is a very important parameter. The required properties depend on the final ice cream product. For example:

- The flavour is very important in dipped stick products or in enrobed products such as bars.
- In layered architectures, the texture contrast is of paramount importance between the ice cream and the ‘chocolate’.
In cone products the main purpose of couverture is to make sure that the cone remains crisp on eating. Here the couverture is used as a waterproof layer between the aqueous ice cream part and the dry wafer.

Chocolate or couverture in contact with ice cream or other products will change its flavour. Since some of the chocolate flavour moves into the ice cream during storage time, the sensory attributes of the product should not be tested until at least one week after production.

9.3 Application processes, formats, requirements, defects

9.3.1 Dipping

Ice cream products carried on sticks can be easily dipped into chocolate to achieve a good coating. There are a number of process options for manufacturing and dipping stick products and two examples are shown in Figs 9.4 and 9.5. The two routes involve different ice cream temperatures, ice cream densities (and therefore thermal mass), timescales and complexity.

The first route, shown in Fig. 9.4, is for premium products where a good quality, thick coating can be obtained. In this example, sticks are inserted into an ice cream flow (typically –6 °C) as it is extruded through a shaped nozzle, then cut into thin sections before dropping onto plates. The products are passed through a hardening tunnel and the ice cream is cooled to approximately –25 °C. The sticks are gripped by mechanical dipping racks and the plates are struck sharply to release the ice creams. The ice creams are dipped for a very short time (<1 s) into chocolate coating which is held at 40–45 °C. The ice creams then pass over a drip tray on the way to wrapping. Wrapping is carried out when the coating surface is sufficiently dry to prevent smearing on the wrapper (typically within 90 s). Packing is normally done fairly quickly, before the coating is brittle, in order to prevent products being damaged or cracked. The chocolate normally sets in an unstable polymorph, which is fixed owing to the low temperature. The freshly dipped chocolate can remain plastic or leathery for a number of days before full brittleness is achieved. The liquid chocolate typically has a Casson viscosity of 0.3–0.6 Pa s and Casson yield value of 1–3 Pa at 40 °C.

The second example is normally for standard grade products, typically coated in couvertures which have much more suitable setting properties for this process. Ice cream is extruded at much higher temperatures (typically –3 °C) and is filled into metal pockets (moulds) on a turntable over cold brine. At this temperature the ice cream is quite fluid and fills the pockets without trapping large air voids. The ice cream is then further frozen from the outside towards the middle. For some product types, some ice cream can be removed before complete setting and replaced with a core to provide flavour or texture contrast. Just before freezing is complete, sticks are inserted. After freezing is complete, the turntable passes over a warm brine section and the ice cream in contact with the metal is melted sufficiently to allow products to be removed from the pockets. Products are
transferred to a dip tank and dipped for a short time (<1 s) in couverture which is held at 35–40 °C (see Fig. 9.5). The reason for the cooler dip with this process is that the ice cream is typically –17 °C at this stage and can be easily melted. The products then pass over a drip tray on the way to wrapping. Wrapping is carried out after the coating surface is sufficiently dry to prevent smearing on the wrapper (typically within 60 s). Packing is done carefully, since the coating becomes fully brittle within 2 min and products can be easily damaged or cracked. At this point the ice cream has warmed to approximately –5 °C and the products are very delicate. The couverture typically has a Casson viscosity of 0.1–0.2 Pa s and
Casson yield value of 0.1–0.3 Pa at 40 °C. This gives a much thinner coat than chocolate but is therefore less likely to melt the ice cream and cause pinholes.

Depending on several factors the ice cream density chosen is typically between 0.5 and 0.7 g cm⁻³. This allows for ease of ice cream processing such as ability to retain overrun during freezing, extraction from moulds and preservation of cutting equipment, and achieving the desired texture contrast of the coating with the ice cream core.

The factors affecting the pick-up weight and quality of coating include:

- number of dips
- temperature of the ice cream
- temperature of the chocolate
- length of time of submersion
- viscosity and yield value of the chocolate
• mechanical vibration or shuddering
• setting rate of the chocolate.

It is important that the coating should dry quickly (e.g. less than 90 s) so as not to smear the wrapper. It is also important that the coating remains slightly plastic for a reasonable time (e.g. 3–4 min) so that any mechanical impact during the packaging does not cause cracks.

The main defects in dipped products are drips and pinholes. Drips can form at the bottom of the product caused by drainage of the coating whilst it is still drying. Mechanical vibration or shuddering may shake off the drip as the product is moved from the dipping tank to the wrapping station. The drip can also be forcibly removed by a de-tailing wire set at the required height. Pinholes are caused either by too high a coating temperature or by too high an ice cream temperature. Ice cream is melted during the dipping and entrapped air (as overrun) which is released from the molten ice cream then forces its way through the coating before it sets.

9.3.2 Enrobing
Bars and other ice cream products which do not contain sticks are most easily coated by enrobing. The enrober design for coating ice cream products is similar to that used for enrobing ambient confectionery products. For example, most ice cream enrobers feature a bottoming section (flood), a means of providing curtains, air blowers to remove excess coating and a detailer for removing any tails (see Fig. 9.6). Additional features may include a hill, overhang or series of separate belts to lift products and prevent adhesion to the wire mesh belt. Another difference between ice cream and ambient product enrobing is the belt speed. Ice cream enrober belts are much faster and typically travel at 1–2 m s⁻¹ and the residence time of products on the belt is <10 s. This is to prevent adhesion of products (or coating) to the wire mesh belt which leads to melting of the ice cream. This is vitally important as the coating can begin to set within seconds of being applied to cold ice cream. In the enrobing process, the formation of solid chocolate ‘tails’ or ‘feet’ can be a major problem along the base of, say, the ice cream bar.

Ice creams to be enrobed are typically extruded from shaped nozzles onto a flat conveyor belt, before being cut to length and passed through a hardening tunnel. When the ice cream has been cooled to approximately −25 °C it is passed through single or multiple curtains of 40–45 °C chocolate or 35–40 °C couverture. Each curtain can be created by filling a trough which then overflows or by pumping coating through pipes at speed which spreads out after hitting angled deflector plates. The deflector plate method can be more effective at coating products with vertical sides. Curtains applied directly from above may deflect over the edges of vertically sided products leaving gaps in the coating. Bottoming can be carried out before, during or after top coating. The coating typically has a Casson viscosity of 0.2–0.8 Pa s and Casson yield value of 0.5–3 Pa at 40 °C. For enrobing, ice cream usually has a density of around 0.7 g cm⁻³ when applying chocolate and 0.5 g cm⁻³ for couverture enrobing, according to the needs of texture contrast between the
coating and the core. As with dipping, couverture coatings are normally much thinner than chocolate. Downstream processing and packing of enrobed products is much gentler than dipped products since products are transported on belts rather than carried on and released from stick-grippers. This means that impact damage during wrapping or post wrapping is less likely.

The quality and quantity of pick-up is affected by:

- number of curtains
- bottoming depth and duration
- temperature of the ice cream and overrun (determines thermal properties)
- temperature of the chocolate
- length of time under the curtain
- viscosity and yield value of the chocolate
- setting rate of the chocolate
- air knife or other devices for removal of excess coating
- detailing rods
- transfer from enrober mesh belt to post enrobing belts (with height and speed synchronisation).

In most cases it is desirable to have a low yield value to keep the pick-up weight low, but a higher yield value and an air blower can be used to introduce a ripple pattern on the top surface. It is important to match belt speeds and heights during transfer from the enrober belt to avoid either the front or back end from being ripped from the bottom of the product. It is preferable to have a product that has a shape or orientation which is wider at the bottom than the top as it is difficult to coat below overhangs.

9.3.3 Spraying
Couverture can be sprayed into or onto ice cream products with great control over
dosage and positioning. One such application is as a moisture barrier in cones. Here the coverage of the wafer needs to be complete and even to prevent moisture transfer from ice cream to wafer. It is essential that the coating is complete where the rim of the wafer is in contact with the sleeve as this is where moisture normally first enters the wafer. Temperature control for spraying is vital since the couverture needs to atomise easily, yet not drain after application. A degree of firmness needs to be achieved rapidly, before ice cream filling, to prevent the barrier being scoured, reducing its thickness and therefore effectiveness (see Fig. 9.7).

The plug which can form at the bottom of the cone, caused by drainage, is not effective at preventing moisture transfer and if needed (to satisfy appreciative consumers!) can be added directly. Couvertures for spraying typically have a Casson viscosity of 0.35–0.45 Pa s and a Casson yield value of 1.5–3 Pa at 40 °C.
Spraying is normally done at 40–45 °C. Various spray equipment is available, the most important parameters being spray height and width to give appropriate coverage.

Couverture can also be sprayed into layered fluted products to give a multiplicity of thin brittle layers (see Fig. 9.8). These products have immense texture contrast, giving the consumer a clearly audible cracking experience when cutting through the product. The application of thin layers means the couverture sets quickly, avoiding the risk of being squeezed out of the product after the addition of the next layer of ice cream. In this application, couverture and air flow rates, spray height and spray width are important to control distribution and thickness of sprayed layers. Alternatively it is possible to dribble couverture to form layers using air-knives to spread the coating evenly and thinly before addition of the next ice cream layer. In this case a higher viscosity couverture (or chocolate) can be used, which would not atomise sufficiently during spraying.

9.3.4 Co-extrusion
A further alternative to place chocolate within a product is the method of co-extrusion. Here, chocolate is rapidly cooled, using a scraped surface heat exchanger and, whilst still in a plastic state, is extruded alongside ice cream. An example of this is shown in Fig. 9.9, where a plastic sheet of chocolate is formed and it follows the flow contour of an ice cream wave as the wave is formed. The relative viscoelastic properties of the two materials are critical to the stability of the process and, in particular, to the solidification kinetics of the chocolate and the melting characteristics of the ice cream. Another format example is where cylinders of ice cream are simultaneously formed and coated with chocolate, where the chocolate is extruded through an annular nozzle around a stream of ice cream. For this application chocolate is held at 45 °C before rapid cooling to 25 °C immediately prior to application. Recirculation is vital, to ensure that chocolate is not held without shear at the point of extrusion long enough for complete solidification to occur. In this application, the chocolate is crystallised into an unstable low melting polymorph. This is different to the high pressure cold extrusion of tempered chocolate (Beckett et al., 1994) used to form shaped chocolate direct from the solid state.

9.3.5 Chocolate aeration
Chocolate in ice cream can be perceived as very hard, especially where used as a large proportion of a product. This is due to the combination of high solid content and low consumption temperature. There are a number of routes to reducing this hardness, one of which is consuming the product at warmer temperatures, however this is largely impractical as the ice cream will become extremely soft. Another route is the use of high butterfat levels or use of couvertures where the solid fat content is reduced. An alternative method is the addition of large amounts of water, such that an aqueous phase of sugar solution is formed, reducing the solid phase
volume. A further method of reducing the solid phase volume is incorporation of air, a simple expression being the use of ‘flake’. The use of ‘flake’, even in a relatively warm (typically –5 °C) freshly extruded whippy ice cream is much more acceptable than a solid lump of chocolate of the same dimensions. Chocolate can also have gas incorporated in the form of bubbles to reduce the overall solid phase level. There are two ways of incorporating gas, one of which is whipping gas, for example air, into the chocolate before application into a product. More recently it was discovered that certain gases, for example carbon dioxide, could be dissolved in the fat phase of the chocolate under excess pressure and that this gas would come out of solution as the chocolate is returned to atmospheric pressure. Use of this discovery was applied in a product called ‘Sky’, where aerated chocolate was extruded into the core of a spirally extruded outer cylinder of ice cream (see Fig. 9.10). The CO₂ was dissolved into the chocolate at 40 °C under 4 bar pressure during shear. It was cooled to approximately 30 °C whilst being pumped to the point of extrusion before exiting the pipe work at atmospheric pressure. At this point the chocolate is rapidly cooled by the ice cream and an aerated structure becomes fixed. The gas volume of the chocolate core of Sky was typically 50% and this enabled a large volume core with the right degree of texture contrast where a pure chocolate core would have been excessively hard.

### 9.4 Inclusions in ice cream

Chocolate can be used within products as inclusions, where they provide flavour, texture contrast and visual contrast with ice cream. In these applications the chocolate is normally prehardened, usually tempered, unlike chocolate toppings, coatings or the plug within a cone, where the chocolate is rapidly cooled into a low melting polymorph. For this reason inclusions are usually quite small or thin, to avoid perception of excessive hardness. Examples of inclusions are chunks, chips, drops and curls. For a more visual treat, some manufacturers use premoulded inclusions, for example fish, animals and other entertaining shapes. Where the
inclusions are made with tempered chocolate, or stable couvertures, they can be stored, under suitable conditions (in a cool, dry place free from sources of taints) for months before use. They can be fed into a stream of ice cream between the scraped surface heat exchanger and product container (usually pot or tub). A fruit feeder can be used to disperse the inclusions evenly and minimise damage to the inclusions during incorporation. The ice cream needs to be reasonably firm to prevent inclusions from settling at the bottom of the container after filling. With certain inclusions, however, the ice cream needs to be reasonably soft to avoid damage to the inclusions, for example curls or thin flakes where the thickness can be less than 1 mm. It is extremely fortunate that although these shapes are particularly vulnerable to damage, they also resist settling! It is important to minimise downstream shear after feeding delicate inclusions in order to prevent disintegration. This usually means wide, preferably flexible, pipe work and an avoidance of sharp bends and valves.

Inclusions normally preclude ‘extrude and cut’ products for two reasons. First, wire cutters employed for cutting ice cream between −5 °C and −12 °C could be snapped when encountering hard particles which are firmly embedded in the ice cream. Second the cutter could drag particles across or out of the surface where they are not firmly embedded, leaving an uneven surface. For hand-held products, an alternative method for manufacture is the use of cold rollers, where inclusions are incorporated into the ice cream stream shortly before moulding between very cold rotating rollers with shaped depressions. Products made in this manner can have a much higher volume of inclusions since they are not cut. Also, since the mould surface is solid, the product surface is rendered smooth and easily released by the very cold surface of the mould giving excellent surface definition. Unlike the example given earlier of lolly manufacture, where sticks are inserted into ice
Fig. 9.11 Cold stamping on the surface of chocolate.

cream, inclusions prevent this owing to resistance during stick insertion, with the inherent risk of stick breakage within the products. Use of cold rollers allows stick insertion at the nip point when the product halves are compressed together.

9.5 Future trends

To date, the preponderance of chocolate use in ice cream is for coatings on stick and bar products applied by dipping or enrobing and inclusion of pieces into the bulk. However, as with all product types that are susceptible to innovation, this situation is evolving. This evolution is driven by several factors. First, the needs of consumers is at the heart of growth in a business and the clear demand in the emerged markets (of Europe and North America) is for increases in sophistication, quality, novelty and convenience. Increasingly the concern to have nutritious food (including that in the ice cream and confectionery sector) is a major factor contributing to trends. Progressively there is a greater overlap between chocolate confectionery containing ice cream with ambient confectionery and this too stimulates the initiatives in cross-over products.

Ice cream and chocolate, both being technically based, in that they require elaborate manufacturing processes, will make progress towards satisfying consumer demand and trend through the evolution and purposeful development of technology. There are new initiatives in transferring ambient chocolate manufacturing technology to chocolate-coated ice cream in terms of shaping and making small format products (such as mono- and duo-bites) and this will continue apace. A major hurdle has been the development of high stroke rate machinery utilised in
a very low temperature environment. Advances in the manipulation of chocolate into a solid form, yet still as an unstable polymorph, have really allowed this. Cold moulding of chocolate is now possible, using cryogenically cooled tools to decorate surfaces by ‘branding’ (Dyks et al., 2007), see Fig. 9.11. Methods in cold extrusion of chocolate which may emerge on an industrial scale in the coming years are also available. In this way chocolate-coated ice cream products will emulate their ambient confectionery counterparts. Examples of these are now starting to appear on the market (see Fig. 9.12).

To supply the consumer need for more healthy options, further manipulation of chocolate (particularly the fat phase) and emphasis on its purported health benefits will appear. Greater interest is being placed on the functional actives, such as polyphenols for heart health, in chocolate. Nevertheless the conundrum of how to deliver such important actives on which to base health benefits in conjunction with the natural features of sugar and saturated fat of chocolate will remain a challenge. Arguably it might fuel an increase in consumer acceptance of vegetable-based ‘chocolate’ in which fats and oils offering more unsaturated components are substituted for modern nutritional benefits.

9.6 Sources of further information and advice

- NIIR Board of Engineers (2005), *The Complete Technology Book on Cocoa, Chocolates, Ice Cream and Other Milk Products*, National Institute of Industrial research, Delhi, India.

Trade Journal: *Manufacturing Confectioner*.


Publications from major chocolate manufacturers, such as Barry-Callebaut.

Books such as:


9.7 References


REINDERS, P (1999), *Licks Sticks and Bricks, A World History of Ice Cream*, Unilever, Rotterdam.