3

Fats

3.1 What are the critical properties of fats for making bread, cakes and pastries?

To answer this question it is first necessary to be clear about the definition of a fat. In the bakery this is usually the term given to a material that is a blend of liquid oils and solid fats from different sources, usually vegetable in origin. Podmore (1997) provides a comprehensive review of the nature and structure of fats. The basic building blocks of fats are the fatty acids, of which there are three. The fatty acids of the triglyceride may be the same as one another or different. All natural oils and fats are mixtures of glycerides and the properties of the individual fats and oils depend on the quantity and distribution of the different glycerides that may be present.

Since fat properties are related to the glycerides present a detailed knowledge of the composition of a compound fat can be useful. This is commonly obtained using gas chromatography (GC) or high-performance liquid chromatography (HPLC). However, such analytical techniques require expensive and specialised equipment that is not within the scope of many laboratories. The fatty acid composition is related to other more readily measurable properties of fats and oils.

A readily known measurement is the *iodine value* which measures the proportion of double carbon bonds in the fat and indicates the degree of saturation present. In some fatty acids adjacent carbon atoms in the chain may be joined by a double bond so that fewer hydrogen atoms are attached than theoretically possible and so they are called ‘unsaturated’. In ‘saturated’ fats two bonds form between two carbon atoms in the chain while the two remaining bonds are formed with two individual hydrogen atoms.

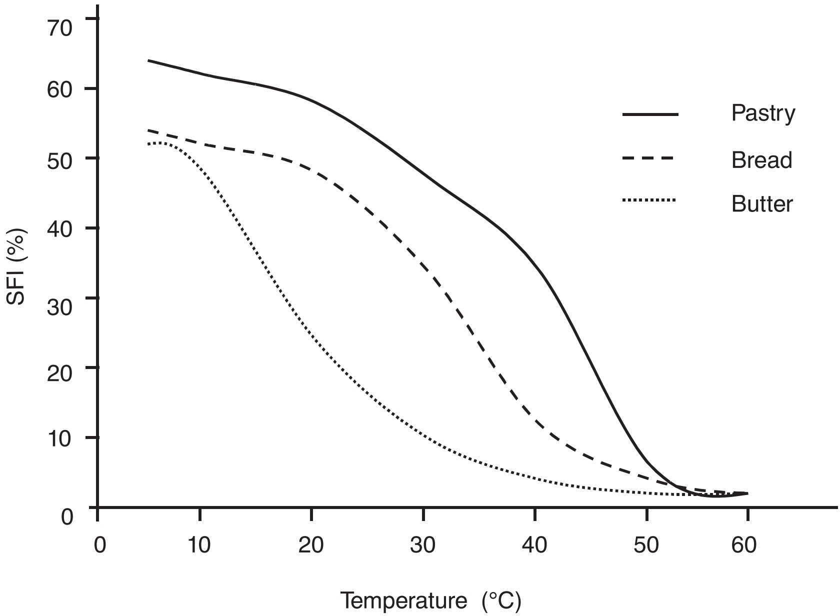

Fig. 7 Examples of fat solid fat index profiles.

Traditionally the ‘slip’ or ‘melting point’ of a fat was used to characterise its performance in baking. However, since many commercial fats are compound mixtures of triglycerides the melting point is often spread over a wide range of temperatures and so has limited value. It is now more common to refer to the Solid Fat Index (SFI) of a fat which considers the proportion of a compound fat which is solid at a given temperature.

Fat SFIs are commonly measured using nuclear magnetic resonance (NMR) and sometimes NMR values for fat are quoted rather than the SFI. Whichever nomenclature is used the temperature at which the measurement is made should be quoted, e.g. NMR_{20} indicates the percentage of solid fat present at 20 ºC (see Fig. 7).

In the past measures of fat firmness using cone penetrometry have been used to indicate the characteristics of given fats, e.g. ‘C’ values (Haighton, 1959). The firmness of a fat at a given temperature is strongly influenced by the proportion of oil to solid; however, this is not the only relevant property of fat to be considered. Solid fats may exist in different crystalline forms depending on their temperature history in production and use. The size of the fat crystals also affects their functionality. Small crystals have a larger surface area relative to large ones and so are more able to retain large quantities of liquid oil within the crystal matrix. The crystalline form of a fat is not usually assessed or measured even though it may affect the fat performance.

References

HAIGHTON, A.J. (1959) The measurement of the hardness of margarines and fats with cone penetrometers. *Journal of the American Oil Chemical Society*, **36**, 345–348.

PODMORE, J. (1997) Baking fats, in *The Technology of Cake Making* (ed. A.J. Bent), Blackie Academic & Professional, London, UK, pp. 25–47.

3.2 Our bread doughs prove satisfactorily but they do not rise in the oven. On some occasions they may even collapse and blisters may form on the dough surface in the corners of the pans. What is the cause of these problems?

A lack of oven spring or collapse of the dough in the oven usually signifies a lack of gas retention in the dough. This may arise for a number of different reasons but your comment on the formation of blister on the dough surface in the corner of the pans strongly suggests that your problem comes from a lack of fat or other suitable lipid (e.g. emulsifier) in your improver or bread formulation. The problem can be too low a level or an inappropriate character of the ingredient.

In modern, no-time breadmaking systems, e.g. the Chorleywood Breadmaking Process (CBP), the addition of a fat or emulsifier is important in ensuring adequate gas retention in the dough (Cauvain, 1998). It has been known for quite some time that it is only the solid portion of the fat that can affect dough gas retention and in no-time doughmaking processes it is important that a proportion of any added fat should remain as solid in the dough at the end of final proving. Since typically final proving is carried out at around 40–45 ºC, the fat melting point must be above 45 ºC.

The necessary level of solid fat to achieve the required effect at 45 ºC can be quite small and values as low as 0.02% flour weight have been quoted. However, it is known that the minimum level of fat required varies with flours. In general higher levels of fat appear to be required with stronger white flours and a general recommendation of 0.7% of a compound bakery shortening was the original blanket recommendation in the CBP because this ensured that a sufficiently high level of solid fat remained in the dough at the end of proving.

Improved gas retention with wholemeal and brown flours requires considerably higher levels of added fat than white flours. Cauvain (1998) provides an example for wholemeal bread made by the CBP where maximum bread volume was obtained when added fat levels reached 4% of the flour weight. It is also known that the loss of gas retention which comes from prolonged storage of flour can be compensated with the addition of high levels of a suitable fat.

It is most likely that the fat confers improved gas retention in bread dough by helping to control gas bubble size and stability. Composite bakery shortenings are a mixture of oil and solid fat at dough temperatures but it is only the solid fat portion that can play the necessary gas bubble stabilising role. The molecules of the solid fat portion align themselves at the interface of the gas bubble and the liquid dough phase and play a part in determining the size of the gas bubbles as well as their stability. As the temperature rises in the dough some of the fat molecules melt and lose their ability to stabilise the gas bubbles. Eventually all the fat melts and other materials, principally the gluten, are left to maintain gas bubble stability. A key role for fat may be the prevention of coalescence of gas bubbles in the dough in the early stages of baking.

Emulsifiers are commonly used to replace fat in bread doughs on the basis that they can be used at lower levels. In simplistic terms they may be considered as specialised fats with a high melting point. They play a similar role to fats in stabilising gas bubbles in the dough. However, their melting profile is quite different from that of fats in that they remain solid to much higher temperatures in the dough, typically around 60 ºC.

The blisters observed on the dough are gas bubbles that have become excessively expanded but are unstable. When the dough reaches the oven the gluten network is unable to cope with the gas bubble expansion and individual bubbles become over-expanded, perforate and collapse. Collectively they lead to total dough collapse. The addition of a suitable level of a high melting point fat should overcome this problem.

Reference

CAUVAIN, S.P. (1998) Breadmaking processes, in *Technology of Breadmaking* (eds S.P. Cauvain and L.S. Young), Blackie Academic & Professional, London, UK, pp. 18–44.

3.3 What is the role of fat in the manufacture of puff pastry?

In the manufacture of puff pastry, fat may added to the paste in two ways: as part of the base dough formulation and as fat layers formed between two adjacent dough layers. The latter is by far the more important of the two uses and contributes most to the formation of the characteristic layered structure and flaky eating character.

It is not common to add aerating agents to puff pastry yet considerable expansion of the structure occurs as the dough layers are forced apart during baking. The pressure for the expansion comes from the water present in the dough layers as it turns to steam. As the steam tries to escape to the atmosphere, the melting fat acts as a barrier to its progress and the dough layers move apart (Cauvain and Young, 2000).

In order to obtain maximum pastry lift it is important that the fat layers remain separate and discrete from the dough layers for as long as possible, so careful attention should be paid to the processing temperature for the paste. For example, butter has a low solid fat index at 20 °C and pastes made with all butter benefit from processing at temperatures around 12–14 °C, which gives workable fat layers but ones that will not be so brittle as to break during sheeting.

Since the aeration mechanism involves the fat it is reasonable to assume that the characteristics of the fat play a part in the degree of lift during baking. Telloke (1991) showed that the pastry lift depended on the following fat characters:

- The level of added fat, with higher fat levels giving greater lift.
- The solid fat index, with higher SFI giving greater lift.
- The firmness of the fat at point of use, with greater firmness giving greater lift.
- The crystalline form, with smaller crystal size giving greater lift.

While pastry lift benefits from a higher solid fat index there may be some loss of eating qualities as fats with very high melting points tend to give a greasy mouth-feel and ‘palette cling’. The addition of fat to the base dough has a small adverse effect on pastry lift and gives a more tender eating quality to the final product.

The impedance of steam by the fat layers also plays a part in the aeration of Danish pastries and croissant, though in these cases lift is affected by the activity of the yeast which contributes to the expansion of the dough layers (Cauvain and Telloke, 1993).

References

CAUVAIN, S.P. and TELLOKE, G.W. (1993) Danish pastries and croissant. *FMBRA Report No. 153.* CCFRA, Chipping Campden, UK.

CAUVAIN, S.P. and YOUNG, L.S. (2000) *Bakery Food Manufacture and Quality: Water control and effects*, Blackwell Science, Oxford, UK.

TELLOKE, G.W. (1991) Puff pastry II: Fats, margarines and emulsifiers. *FMBRA Report No. 146*, CCFRA, Chipping Campden, UK.

3.4 What is the optimum level of fat to use in the production of puff pastry?

The level of fat that is used in the manufacture of puff pastry depends on a number of factors including the degree of lift and flakiness of eat that you are seeking in the baked product. Puff pastry and other laminated products are characterised by the formation of a relatively thin dough sheet, part of which is covered with fat and subjected to a series of folding and further sheeting steps, with the objective of forming alternate and discrete layers of fat and dough.

Traditionally there are three types of puff pastry characterised by the level of laminating fat used in the formulation. They are commonly designated as **full**, **three-quarter** and **half** puff in which the laminating fat is used at an equal weight to the flour, $\frac{3}{4}$ and $\frac{1}{2}$ respectively. The level of laminating fat has a direct effect on the thickness of the fat layer in the laminated paste and thus a direct impact of the degree of separation of the dough layers. The higher the level of laminating fat, the greater the pastry lift but also the greater the pastry shrinkage (Telloke, 1991). With an increase in laminating fat levels the baked pastries became more tender eating.

There is no absolute optimum level of fat for use in the manufacture of puff pastry, the choice depends on a number of different criteria which may be required in the final product, such as lift, eating quality and flavour. The level of laminating fat is also linked with the number of laminations (folds or turns) given to the paste. In general the lower the laminating fat level, the lower will be the number of laminations required to achieve maximum lift or optimum quality. Telloke (1991) suggested that optimum quality with half paste came with 128 theoretical fat layers (see 8.3) while with full paste the optimum was achieved with 256.

The base dough may also have a small addition of fat (5%) which confers a more tender eating quality to the baked product but does decrease pastry lift. Because of the latter effect we recommend that you avoid using levels of added dough fat greater than 10% of the flour weight.

Similar effects of changing fat levels may be observed in the production of Danish pastry and croissant, though the numbers of laminations are fewer than with puff pastry and the maximum laminating fat level lies around 65% of the flour weight (Cauvain and Telloke, 1993).

References

CAUVAIN, S.P. and TELLOKE, G.W. (1993) Danish pastries and croissant. *FMBRA Report No. 153*, CCFRA, Chipping Campden, UK.

TELLOKE, G.W. (1991) Puff pastry II: Fats, margarines and emulsifiers. *FMBRA Report No. 146*, CCFRA, Chipping Campden, UK.

3.5 Our puff pastry fails to rise sufficiently even though we believe that we are using the correct level of fat. Are we using the correct type of fat?

The lift in laminated products can be affected by two properties of the laminating fat; the solid fat index and the size of the crystals in the solid fat portion, and the degree of work softening of the fat during preparation for use.

The laminating fat plays a significant role in the aeration mechanism in puff pastry by impeding the movement of steam from the dough layers to the surrounding atmosphere (see 8.1). Solid fat layers form a greater barrier than liquid ones and so the proportion of laminating fat that remains solid as the pastry begins to bake is an important characteristic. We can measure the solid fat to liquid oil ratio in a given fat using a number of techniques, for example NMR. The SFI represents the proportion of fat that is solid in the mixture at a given temperature. Such measurements are typically made at three of four different temperatures to establish the solid fat profile.

The higher the solid fat index, the greater the puff pastry lift will be (see Figure 8) but the increase in solid fat may lead to an unacceptable change in eating characteristics (Telloke, 1991). It is particularly important that the proportion of solid fat at 40 ºC is restricted because it does not melt in the mouth and confers an unpleasant waxy eating quality commonly described as ‘palate cling’. We suggest that any laminating fat you use should not have more than 5% solid fat at 40 ºC.

Reference

TELLOKE, G.W. (1991) Puff pastry II: Fats, margarines and emulsifiers. *FMBRA Report No. 146*, CCFRA, Chipping Campden, UK.

Fig. 8 Effect of large (left) and small (right) fat crystals on puff pastry height.

3.6 What is the role of fat in cakemaking?

The main function of fat in cakemaking is to assist with the incorporation of air into the batter during mixing. It also affects the air bubble size in the batter and the bubble stability during before and during the early stages of baking.

Cake batters are essentially a 'foam', that is a system in which air bubbles are trapped and held in an aqueous phase. Foam systems are characterised by the fact that all the air bubbles are separated from one another by a thin film of stabilising material. During baking the foam changes to a sponge (in the generic sense), that is a system in which all of the air cells are interconnected and vapours and liquids can move through the matrix. The moment at which the foam in a cake batter makes the conversion to a sponge has much to do with the recipe formulation (Cauvain and Young, 2000) and the stability of the air bubbles while the temperature is rising makes a major contribution to final cake volume.

The protective film that forms around the gas bubbles may come from a number of sources. Fat can contribute to the protective films in the batter foam. Telloke (1984) used light microscopy to show that fat crystals in high ratio cake batters were located at the interfacial film between the air bubbles and the sucrose solution. The crystalline form of the solid portion of the fat is important in determining the functionality of the fat in cakemaking, of the three fat polymorphs encountered the volume of air which could be incorporated into the batter. Telloke (1984) showed that it was greatest with the β', less with the α and least with the β form.

As the batter temperature rises in the oven the solid fat turns to liquid oil and the natural buoyancy of the air bubbles causes them to try to move upwards and escape. The longer the bubbles are retained in the batter the greater the cake volume will be. This means the fat must have a high melting point. However, dispersion of the solid fat crystals is important if they are to be effective and a liquid oil component is necessary to achieve ready dispersion.

Fats and oils contribute to the soft and tender eating properties required for cakes. In part this benefit comes from the effect on batter aeration and in part from the lubricating effect that fat has in the mouth.

References

CAUVAIN, S.P. and YOUNG, L.S. (2000) *Bakery Food Manufacture and Quality: Water control and effects*, Blackwell Science, Oxford, UK.

TELLOKE, G.W. (1984) The mixing of cake batters. *FMBRA Report No. 114*, CCFRA, Chipping Campden, UK.

3.7 We are making 'all-butter' cakes but find that after baking they lack volume and have a firm eating character. Why is this and is there any way to improve the cake quality?

Butter is often chosen in cakemaking because of its quality attributes related to flavour and mouthfeel, and its potential marketing value through the association with 'naturalness' and 'quality'. However, while a 'natural' product, butter can be the subject of natural quality variations and has characteristics that are not always best suited to cakemaking.

Butter is a mixture of butter oils, water and salt. The level of water must not exceed 16% and salt levels do not exceed 2% of the total butter weight. Thus if butter is used to replace an oil or bakery shortening then the level of addition should be increased to about 1.2 times the recipe shortening level. A weight for weight replacement of shortening with butter will therefore result in a lower fat level in the recipe which will reduce batter aeration and cake volume. Butter oils and butterfats are available which can be used on a one for one replacement basis because they do not contain water (Rajah, 1997).

Generally the ability of butter to contribute to batter aeration and thus cake volume is inferior to bakery shortenings or cake margarines . This is because the SFI at 20 ºC for butter is lower than that generally recommended for use in cakemaking; typically around 24% of a fat should be solid at 20 ºC. Butter SFIs at 20 ºC vary according to the butter's source, in part because of differences and changes in feeding habits of the cows.

The tempering of butter can improve its functionality in cakemaking. We suggest that you hold the butter between 28 and 30 ºC for 18–20 h before use. This tempering period permits a beneficial increase in the crystal size of the solid fractions in the butter. You should ensure that full equilibration of temperature has taken place because often the slabs of butter may be stored on a pallet or in a large block which slows down the rate of heat penetration to the centre of the stack.

Considerable improvements in cake volume, softness and eating quality can be obtained by adding a low level of glycerol monostearate (GMS) to the batter. GMS is more effective than butter at stabilising the foam structure of a cake batter. We suggest the addition of a level of 1% (GMS solids) of the total batter weight. The GMS should be in the *alpha* form and may be added as a stabilised gel.

Reference

RAJAH, K.K. (1997) Cream, butter and milk fat products, in *The Technology of Cake Making* (ed. A.J. Bent), Blackie Academic & Professional, London, UK, pp. 48–80.

3.8 We have been using oil in the production of our sponge cakes but we wish to change to using butter. How can we do this?

There are two courses of action open to you: either melt the butter and add it as a warm oil or add it in the solid form.

The practice of melting fats to incorporate them into sponge batters has been known for some time. The traditional 'butter sponge' utilises a basic sponge recipe to which the melted butter is added after all of the other ingredients at the end of the mixing process. The butter should be heated only until it is just liquid, otherwise the hot oil may increase the batter temperature high enough to cause a premature reaction of the baking powder. You may find some benefit in using a little more baking powder in the formulation to compensate for any losses that may occur. If you are not already doing so you may find some advantage in the addition of a suitable emulsifier to the formulation.

If you are going to use the butter in the solid form we certainly recommend the addition of an emulsifier to the formulation otherwise you will not achieve the product volume that you are seeking. You may experience some difficulty in dispersing the butter and so it may be better to use an all-in mixing method. You may also wish to adjust the baking powder level in the formulation.

If you wish to make any claim regarding the use the term 'butter' as part of the baked product descriptor you will need to ensure that the level of added butter conforms to the following Code of Practice in the UK:

- At least 5% butterfat for the claim 'contains'.
- 100% for the claim 'made with butter' or the descriptor 'butter sponge'.

3.9 We wish to produce a softer eating sponge cake and have been trying to add fat or oil but cannot get the quality we are seeking. Is the addition of fat to sponge batters possible and what do we need to do to achieve the quality we are seeking?

In a traditional sponge recipe composed of flour, sugar and egg the mixing action of the whisk draws small air bubbles into the batter during mixing. The egg proteins, principally the lipoproteins, align themselves at the interface of the air bubbles with the aqueous phase. At the interface they provide stability to the air bubbles and prevent them from rising to the batter surface and escaping to the atmosphere.

This bubble stabilisation of the batter ‘foam’ is particularly important in the early stages of baking when the increase in temperature increases the tendency of the air bubbles to rise. Later, during baking, the solid part of the foam begins to set, the gas bubbles begin to burst and the gases diffuse out leaving behind a sponge structure (here the term ‘sponge’ is used in the generic sense, referring to a structure in which the individual cells are interconnected and gases and liquids may diffuse through the matrix).

When oils or solid fats are added to a traditional sponge batter they inhibit the inclusion of air into the batter and displace the egg proteins at the gas bubble/aqueous phase interface. This change allows many of the gas bubbles to escape from the batter, especially during baking when any solid fat is turning to liquid oil. The result is that the mechanical aeration is much reduced and the resultant cake volume is small. For these reasons many traditional methods of producing sponge cakes encourage the scalding of the mixing bowl to remove any traces of fat before the start of mixing.

Oils or fats may be added to sponge cakes to improve the eating quality by carefully blending them into the batter towards the end of mixing. In the case of fats which are solid at bakery temperature it is advisable to heat the fat until it is liquid.

Alternatively you can add an emulsifier, such as GMS, to the sponge formulation to take over the main air bubble stabilising role from the egg proteins. The level of addition needs to be sufficiently high to ensure that bubble stability is maintained during baking up to the point of conversion from foam to sponge (Cauvain and Cyster, 1996). Oils are more suitable for the production of enriched sponges though the addition of solid fat is possible but sponge cake volume and texture are less satisfactory (Cauvain and Cyster, 1977).

References

CAUVAIN, S.P. and CYSTER, J.A. (1977) The effect of fat on sponge cake quality. *FMBRA Bulletin No. 5*, October, 171–176, CCFRA, Chipping Campden, UK.

CAUVAIN, S.P. and CYSTER, J.A. (1996) Sponge cake technology. *CCFRA Review No. 2*, CCFRA, Chipping Campden, UK.

3.10 We are making a non-dairy cream cake and find that after some days a 'soggy' layer forms at the interface of the cake and the cream. We have balanced the water activity of the cake and cream but still see the problem and so we believe that this comes from fat migration from the cream. Are we correct?

There are two possible causes for the formation of a soggy layer at the interface of the cake and cream: one is related to moisture migration and the other as you correctly assume comes from fat migration. Both moisture and fat migration can occur and so we must consider that your problem may be related to a combination of the two effects. However, since you have balanced water component activities we can assume that most of the seepage comes from the migration of fat.

The mobility of a composite fat or shortening depends on its oil content at any given temperature since only the liquid component can flow downwards under the influence of gravity. Thus, we would expect that the problem would be worse when using fats with lower solids contents. To minimise the problem we suggest that you use a fat with a higher solids fat content provided that this does not give you problems with aeration of the fat during whipping or an unacceptably greasy mouthfeel.

Fat seepage is affected by the product storage temperature (see Fig. 9). The higher the storage temperature, the greater the proportion of a given fat that is

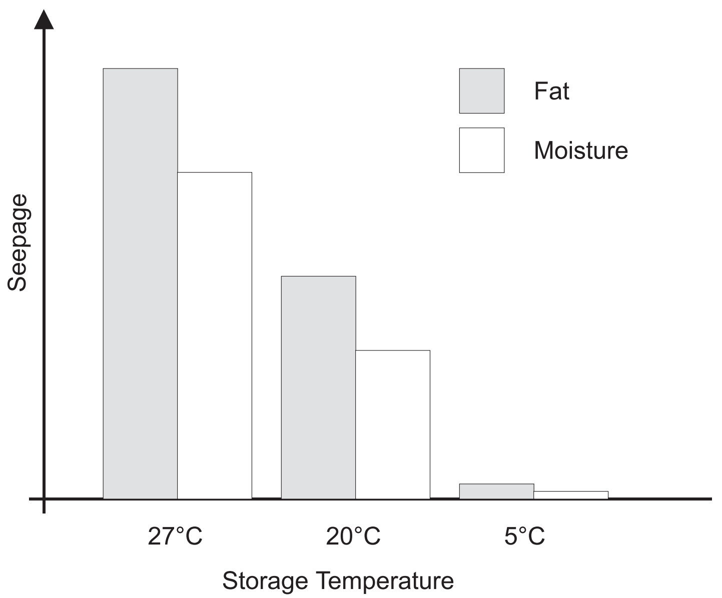

Fig. 9 Fat and moisture seepage in non-dairy cream cakes.

liquid and so the greater the risk of seepage. Variations in storage humidity on the other hand have very little effect on fat seepage though small increases have been observed as the storage humidity increases (Cauvain and Young, 2000).

Fat seepage is affected by the degree to which the cream has been aerated with seepage being greater as the cream specific volume increases (Cauvain and Young, 2000). You may wish to limit your cream specific volume or reduce your overall fat content.

Reference

CAUVAIN, S.P. and YOUNG, L.S. (2000) *Bakery Food Manufacture and Quality: Water control and effects*, Blackwell Science, Oxford, UK.