

Independent advice on possible reductions for saturated fat in products that contribute to consumer intakes

Summary Report

Prepared for
Food Standards Agency

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The views contained within this report reflect those of the author and do not necessarily
represent the views of the Food Standards Agency

EXECUTIVE SUMMARY

This report was commissioned by the Food Standards Agency (FSA) to assist in achieving their target of reducing the average saturated fat intake (for everyone in the UK from age 5 upwards) from current levels of 13.4% to below 11% of food energy by 2010.

Approach

Information was collected from two main sources:

- (a) Published literature in journals and patents to give a background as to what the scientific and technical problems are and how, in some instances, these have or could be overcome. This information is collected and summarised in sections relating to the main product categories where saturated fats make a significant impact on diet. Full references are given to this information.
- (b) Within the limited timescale of this project discussions were held with leading contacts in industry, trade and research associations and academia. Their (anonymous) views are summarised, segmented into the same product categories as above.

From a combination of the published literature and the views of industry and academia, suggestions were formulated for where reductions in saturated fats could be made and what the barriers are likely to be to further reductions in various food areas.

Main Findings

- i) The main food product categories that provide saturated fat to the diet are: milk, cheese, ice cream, butter, margarine and fat-based spreads, meat, pastry products (pies, tarts etc), bakery products (buns, biscuits, cakes), chocolate and chocolate confectionery, snacks.
- ii) Although there has been no National Diet and Nutrition Survey since 2002 it is possible that *trans* fatty acids from partially hydrogenated oils have been partly replaced by saturates.
- iii) Potentially there are three main replacements for saturated fat in foods - (a) *cis*-unsaturates, (b) carbohydrates, (c) 'healthier' saturates. Purely from a nutritional point of view the first option is preferred but product functionality (the need for some solid fat to be present) may mean that the other two options need to be considered.
- iv) Milk. Approximately 65% of milk fat is saturated and about 3% of dietary energy is from dairy products making this a major target. Indeed, it makes such an impact on saturates in the diet that if all consumers were to switch to skimmed milk there would be a reduction of over 1% in dietary energy from saturates. This is about 40% of the FSA's target. Changes in cattle feed can also have a sizeable impact on the amount of saturates in milk. Literature sources suggest that reductions in saturates ranging from 16% to 30% are possible. If this were to mean that, say, a 25% reduction in saturates in milk could be made then this would give a reduction of about 0.75% in dietary energy from saturates. If some consumers also change to skimmed milk or semi-skimmed milk then the reduction could be even greater.
- v) Cheese. Reduced-fat cheese has a rubbery texture making it unacceptable to many consumers. It could, however, be potentially

used in some products where the cheese is melted (e.g. pizza toppings). There is also some scope for fat reductions of up to 10% in hard cheeses such as cheddar to be made whilst still remaining within the Food Labelling Regulations.

- vi) Ice cream. Traditionally this has a very high saturated fat phase (about 65% in dairy ice cream and 80-90% in non-dairy ice cream). Reduction in saturates in milk would carry through to dairy ice cream but there are also (patented) possibilities to reduce saturates to about 35% in non-dairy ice cream.
- vii) Butter. Once again, changes in the saturated fat content of milk would carry through to changes in butter. An alternative is to promote the use of 'spreadables', i.e. blends of butter with a vegetable oil, which are products that are both spreadable from the fridge and also lower in saturates, whilst maintaining the buttery flavour notes.
- viii) Margarines and spreads. Large reductions in the saturates and total fat content of these products have already been made over the past few years, coupled in many cases with the removal of hydrogenated fats from the formulation. Plant sterol and stanol esters which are used in some spreads as cholesterol-lowering ingredients can also function as part of the spread's 'hardstock' and in so doing help to further reduce saturates. These ingredients are, however, more expensive than standard saturate-rich hardstocks.
- ix) Meat. Changes that have taken place in animal breeding and feeding coupled with changes in butchery have resulted in the fat content of carcass meats being reduced from 25-30% to about 4-8%. It is difficult to see this being reduced much further because the remaining fat is mainly intramuscular and difficult to remove by butchery methods. There may be some scope for saturates reduction by making the same changes to animal feed as would be needed to change milk fat composition. Reduction in fat in processed meats, especially sausages and mince, whilst possible, does start to have adverse effects on the texture and succulence of the meat product.
- x) Pastry and bakery products. This is a very difficult area and although there is the potential to make reductions in both total fat and saturates this would mean the use of additives such as emulsifiers to get the correct texture and structure and preservatives to ensure sufficient microbiologically stable shelf-life if water activity is increased as a result of fat reduction. Significant research is needed to define ways of reducing saturated fat in these types of product.
- xi) Chocolate and chocolate confectionery. The need for a very solid material at ambient temperatures coupled with one that melts in the mouth mean that only very specific fats can provide this. These are essentially cocoa butter and cocoa butter equivalents, both of which contain 60-65% saturates. The current EU regulations on chocolate also limit any major changes that could be made to enable any kind of saturate reduction. There is scope for small changes either by changing the nature of or reducing the level of the vegetable fat used in chocolate but these could result in textural changes in the chocolate which would need to be compensated for by other modifications. There is potentially more scope in confectionery fillings but here there is an increased risk of fat migration and fat bloom formation if liquidity (by saturates reduction) is increased.
- xii) Snacks. There have been significant changes in frying oil over the past 2-3 years, some of which have been prompted by moves away from

partially hydrogenated oils. This has meant that, in terms of the saturated fat content of the fat phase of these products, they now fall into two groups - those containing about 40-50% saturates and those containing 10-20% saturates. A wholesale switch to a lower-saturates frying oil would reduce saturates in these and other fried products. Such a switch, however, may not be completely possible in the short-term because of availability of the lower-saturated oil (high oleic sunflower oil).

- xiii) Fats and oils. In some products it may simply be impossible to replace a 'solid' fat with a more 'liquid' oil and so we would then need to identify potentially more 'healthy' forms of the solid fat. This may mean focusing on particular types of saturated fatty acid or particular structures of triglyceride. The technology available within the oils and fats industry today is such that most products of this type could be produced. The constraints, however, are cost (both development and material costs), the need to use some technology which may be considered 'unacceptable' (e.g. complete hydrogenation), and the use of fatty acids and glyceride structures not normally found in nature (and hence the need to go through a novel foods procedure).

Recommendations

All of the interested parties from the farmer to the consumer have a role to play in reducing saturated fat in the diet.

- i) The Agri-Food industry. Many barriers have been identified, both in past research work and in this current work, to total fat reduction and saturated fat reduction. Much of the work that will need to be done has to be focused towards overcoming these barriers (some of which are outside the control of the agri-food industry). The following, however, are some of the points that the agri-food industry will need to address:
 - a. Reduction of saturated fatty content in milk by changes in cattle feed, possibly even using rumen-protected cattle feed.
 - b. Development of low-saturated whipped cream analogues
 - c. Reduction of fat in full-fat cheeses (e.g. cheddar) down to about 30%. This will give a reduction in total and saturated fat of about 10% whilst allowing the cheese to stay within the scope of the Food Labelling Regulations, i.e. still labelled as 'cheddar cheese', for example.
 - d. Development of texturally-acceptable reduced fat cheeses; blending of vegetable oils into processed cheeses (but unable then to label as 'cheese'); inclusion of reduced-fat cheese in those products where current textural issues are not a problem.
 - e. Consider a greater use of plant sterol and stanol esters in spreads to replace further quantities of saturates.
 - f. Reduce saturated fat in meat by changes in animal feed.
 - g. Reduce saturates in processed meats such as mince and sausages - research will be needed into how to do this while still maintaining textural characteristics
 - h. Significant research into how to reduce both total fat and saturated fat levels in bakery and pastry products without compromising texture and, ideally, without the use of chemically-sounding additives.

- i. Move to lower-saturates frying oils in snacks and par-fried ready meal components.
- j. Make changes to some of the compositions of ready meals to reduce the level of saturates, e.g. less saturated carrier of garlic in 'Kiev' products, replacement of highly saturated coconut cream by a lower-fat milk and, if necessary, added vegetable oil in Asian dishes, increase the thickness of French fries in foodservice outlets.
- k. Portion control can also play a big role in saturates reduction as well as overall calorie reduction. At present, there are big differences across producers as to portion sizes in similar products.
- ii) The Ingredients Industry. There is a need for more functional ingredients that will allow reductions in saturated fat in many of the above applications. This will mean that ingredient suppliers and food manufacturers will need to work very closely together in order to solve the problems that exist in many food sectors with regard to saturated fat reduction. This will apply particularly to suppliers of oils and fats and to suppliers of emulsifiers.
- iii) Machinery manufacturers. Differences in the way food products 'handle' as fat is reduced (e.g. reduced fat bakery doughs) may mean that machinery manufacturers also have to work alongside the food industry to develop machinery specifically tailored for production of lower-fat products.
- iv) Consumers. At the present time there are many options available to the consumer in terms of low-fat and reduced-fat alternatives to full-fat products. In some instances the consumer perceives the lower-fat options as not being as good quality and therefore only to be used if absolutely necessary. This is often a false perception - the lower-fat alternatives are, in many cases, every bit as good as the full-fat options. It should be recognised that consumers have as much responsibility for their own well-being as does the food industry and government, but perhaps they need to be given more detailed, understandable and, above all, accurate information about the levels of saturated fat they should be consuming and exactly what that comes down to in portion sizes. Some of the responsibility for reducing saturates then rests with the consumer choosing appropriate alternatives to the products they currently use.
- v) Government. Government has a role to play in two major areas:
 - a. Education. This links into helping the consumer make better choices about what they eat and drink. It means educating the consumer into what saturated fats (and other fats) are and the effect they have on health and well-being. It may mean re-educating them about hydrogenation if this is seen as a possible route to getting very specific saturated fatty acids with the formation of *trans*. It may also mean educating them about additives and assuring them that many emulsifiers (e.g. lecithin, mono- and di-glycerides) are also found naturally in the food chain. And, it may mean educating them about better ways to choose and cook foods so that they use minimal amounts of saturated fat.
 - b. Help to the food industry. The food industry, in discussions, highlighted a number of areas which would be considered barriers to reductions in saturates. Some of these barriers could be lowered if government relaxed some of the limits on being able to make claims. For example, in most food products it will be very difficult to, at a single stroke, make a 25% reduction in saturates (the level needed to

be able to make a claim). If claims could be made about lower levels of reduction there would be a greater incentive for the industry to invest in the development needed to make such reductions. Other areas of legislation were also identified - these are discussed in detail in the main report.

- vi) Research. Many areas have been highlighted where further research is needed. Some of this will be very fundamental research carried out in universities (e.g. research into food structure and texture, research in satiety and how ingredients in the diet can affect this). Other research is more application-orientated and would focus, for example, on the functionality of saturated fat in products such as bakery, pastry and processed meats and what the limitations are on reducing saturates in these products. Such research could be carried out either in universities or in research institutes and associations with links to these sectors of the food industry.
- vii) Retailers. The major retailers also have a big role to play because, to a large extent, they decide exactly what goes on sale - and at what price. So, whilst they may not directly be manufacturers, they do have a large responsibility to work together both with their suppliers and with government to ensure that lower-saturate products are developed and are available to consumers.

Conclusions

What, then, is possible? If the recommendations listed above are carried out successfully then the level of reduction being targeted by government and the Food Standards Agency ought to be possible. The 'big hit' areas are dairy, meat and bakery products so the ability to meet the target does depend very much on (a) significant changes being achieved in the fatty acid composition of both milk and meat as a result of feeding changes and (b) the ability of the bakery industry to find ways of reducing saturates in their products.

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1 Introduction

This report was commissioned by the Food Standards Agency (FSA) to assist in achieving their target of reducing the average saturated fat intake (for everyone in the UK from age 5 upwards) from current levels of 13.4% to below 11% of food energy by 2010.

Information was collected from two main sources:

(a) Published literature in journals and patents to give a background as to what the scientific and technical problems are and how, in some instances, these have or could be overcome. This information is collected and summarised in sections relating to the main product categories where saturated fats make a significant impact on diet. Full references are given to this information.

(b) Within the limited timescale of this project discussions were held with leading contacts in industry, trade and research associations and academia. Their (anonymous) views are summarised, segmented into the same product categories as above.

The current figure of 13.4% of food energy is taken from the 2002 National Diet and Nutrition Survey (NDNS) which showed that men and women (aged 19-64) obtained the following levels of energy from total and specific types of fat (Table 1). Because respondents in the survey were asked to weigh everything, including any leftovers, the survey was an accurate reflection of actual consumption and would account for both losses during cooking and any fat which was trimmed off during consumption and left on the plate.

Table 1 Energy intake from fat (NDNS, 2002)

Type of Fat	Men	Women
Total	35.8	34.9
Saturated	13.4	13.2
<i>trans</i>	1.2	1.2
<i>cis</i> monounsaturated	12.1	11.5
<i>cis</i> n-3 polyunsaturated	1.0	1.0
<i>cis</i> n-6 polyunsaturated	5.4	5.3

Fat plays a major role in defining the sensory characteristics of many food products. Simply reducing fat levels in foods can, therefore, affect the consumer's perception of the taste, texture and quality of the food. All of these aspects need to be taken into account when reducing fat contents. This report, however, is aimed at reducing saturated fat levels, not total fat levels *per se*.

To a large extent, however, the comments made about the role that fat plays in food can also be made about the levels of solid fat in a food. To have solid fat, at ambient temperatures at least, means having a fat phase containing either saturated fat or *trans* fat. As the industry has spent the past few years removing much of the *trans* fat resulting from partial hydrogenation, this leaves saturated fat as the main means of achieving the

desired level of solid fat in some products. It is inconceivable, for example, to imagine a product such as chocolate without the degree of structure and solidity that we are used to. It is equally extremely difficult to achieve that degree of structure and solidity without using a fat phase containing a significant level of saturated fat. Similar comments can be made about many food products which rely on fat in the solid phase, however that might be achieved, to provide structure and texture to the product.

Although the main concern with regard to saturated fat is its effect on blood cholesterol levels and thence on the risk of cardiovascular disease (and this will be considered in more detail later in the report) it can also have adverse effects on insulin sensitivity which can lead to the onset of diabetes. There is some evidence to suggest that different types of saturated fatty acid behave differently with regard to their effect on blood cholesterol. At present, however, there are no clinical results to show or suggest that different saturates have different effects on insulin sensitivity.

It is becoming more and more accepted that there is an interaction between several risk factors which are collected together under the term 'metabolic syndrome'. These risk factors are high blood cholesterol and blood triglyceride levels, hypertension and insulin resistance.

The EU Sixth Framework Integrated Programme, LIPGENE, has been set up to look at what are the influences on metabolic syndrome resulting from an interaction between dietary fats and variations in the human genome. The factors being examined in the LIPGENE project are discussed further in chapter 12.

1.1 Saturated fat intake from different food groups

The NDNS 2002 report allows us to list both total fat intake and saturated fat intake broken down into various food categories (Table 2).

These figures would suggest that the product categories to be concentrating on in terms of saturate reduction should be:

- Milk (including ice cream)
- Cheese
- Butter, margarine and fat-based spreads
- Meat (including eggs)
- Pastry products - pies, tarts etc
- Bakery products - buns, biscuits, cakes
- Chocolate and chocolate confectionery
- Snacks

As long ago as 1973 Stare was writing that, in the United States, 'the fact that approximately 60% of our total fat intake comes from "invisible" fat, particularly in meat and dairy products emphasises the difficulty in bringing about marked changes in the P/S¹ ratio of diets on a large scale.' The contribution of these food groups to our total fat intake now is such that this comment could equally well apply today.

¹ P/S = polyunsaturated/saturated

Table 2 Contribution of food groups to total and saturated fat intake

Food group	Contribution to daily total fat intake (%)	Contribution to daily energy intake from total fat (%)	Contribution to daily saturated fat intake (%)	Contribution to daily energy intake from saturated fat (%)	Saturate intake as % of total fat intake
Cereals and cereal products:	19	6.4	18	2.3	36%
Pizza	2	0.7	2	0.3	43%
White bread	2	0.7	1	0.1	14%
Biscuits	3	1.0	4	0.5	50%
Buns, cakes and pastries	4	1.3	4	0.5	38%
Milk and milk products:	14	4.7	24	3.0	64%
Whole milk	3	1.0	4	0.5	50%
Semi-skimmed milk	3	1.0	5	0.6	60%
Cheese (incl cottage cheese)	6	2.0	10	1.3	65%
Eggs and egg dishes	4	1.3	3	0.4	31%
Fat spreads:	12	4.0	11	1.4	35%
Butter	4	1.3	6	0.8	62%
Margarines	1	0.3	1	0.1	33%
Reduced fat spreads	5	1.7	3	0.4	24%
Low fat spreads	1	0.3	1	0.1	33%
Meat and meat products:	23	7.7	22	2.8	36%
Bacon and ham	2	0.7	2	0.3	43%
Beef, veal and dishes	3	1.0	4	0.5	50%
Lamb and dishes	1	0.3	1	0.1	33%
Pork and dishes	1	0.3	1	0.1	33%
Coated chicken and turkey	1	0.3	1	0.1	33%
Chicken, turkey and dishes	4	1.3	3	0.4	31%
Burgers and kebabs	2	0.7	2	0.3	43%
Sausages	3	1.0	3	0.4	40%
Meat pies and pastries	4	1.3	4	0.5	38%
Other meat and meat products	1	0.3	1	0.1	33%
Fish and fish dishes:	3	1.0	2	0.3	30%
Coated and or fried white fish	2	0.7	1	0.1	14%
Oily fish	1	0.3	1	0.1	33%
Vegetables (excl potatoes)	4	1.3	2	0.3	23%
Potatoes and savoury snacks:	10	3.4	7	0.9	26%
Chips	5	1.7	3	0.4	24%
Other fried or roast potatoes	1	0.3	0	0.0	0%
Savoury snacks	3	1.0	3	0.4	40%
Fruit and nuts	2	0.7	1	0.1	14%
Sugars, preserves and confectionery:	3	1.0	5	0.6	60%
Chocolate confectionery	3	1.0	5	0.6	60%
Drinks	0	0.0	1	0.1	
Miscellaneous	5	1.7	3	0.4	57%

It is, however, interesting to note the changes that have been made in our diet since a previous Dietary and Nutritional Survey in 1986/87. Energy intakes from each of the main fatty acid groups are shown in Table 3. It is clear from these data that there has been a significant reduction in food energy intake from fat in total as well as in saturated fat (3.1% energy reduction for men and 3.8% energy reduction for women). This does at least show that reduction of food energy from saturates is possible, although it has to be said that every further incremental reduction of 1% becomes more and more difficult to achieve.

Table 3 Changes in energy intake from fat between 1986/87 and 2002

Type of Fat	Men		Women	
	1986/87	2002	1986/87	2002
Total	40.4	35.8	40.3	34.9
Saturated	16.5	13.4	17.0	13.2
<i>trans</i>	2.2	1.2	2.1	1.2
<i>cis</i> monounsaturated	12.4	12.1	12.2	11.5
<i>cis</i> n-3 polyunsaturated	0.8	1.0	0.8	1.0
<i>cis</i> n-6 polyunsaturated	5.4	5.4	5.3	5.3

One of the major changes which have taken place since Stare (1973) made his comments is that the range and variety of foods on offer to consumers has greatly increased. Whilst this increase in consumer choice obviously has tremendous benefits to both consumer and manufacturer it could be considered to contribute to a greater caloric intake. Recent research (Raynor and Wing, 2006) has shown that when volunteers were fed the same snack (a crumb cake) over a period of four days their liking of the cake decreased and therefore consumption decreased. On the other hand, volunteers fed a variety of different snacks on each of the four days resulted in a small increase in the liking of the cake. As variety in foods available to the consumer has undoubtedly increased between 1986/87 and 2002, there does not appear to have been a related increase in energy from fat or from saturates. Indeed as is apparent in Table 3, the opposite is the case. One further comparison, however, would be useful and that is whether there has been significant change in either fat intake or saturated fat intake from different food types. These data are compared in Table 4.

The biggest changes in saturated fat consumption have been in the areas of milk and milk products and fat spreads. The contribution of both total fat and saturated fat from whole milk has dropped significantly in the period between the two surveys while semi-skimmed milk which was not even reported separately in 1986/87 was more important in terms of energy contribution than whole milk by the time we get to 2002. Interestingly, however, as a percentage, the contribution of milk products as a whole has hardly changed.

The other big area where changes have been seen is in fat spreads where not only has the contribution of both total fat and saturated fat in the sector dropped significantly so has the contribution from butter itself. This has been accompanied by a decrease in importance in terms of contribution

Table 4 Contribution of food groups to total and saturated fat intake

Food group	Contribution to daily total fat intake (%)		Contribution to daily saturated fat intake (%)	
	1986/87	2002	1986/87	2002
Cereals and cereal products:	19	19	18	18
Pizza		2		2
White bread		2		1
Biscuits	4	3	4	4
Buns, cakes and pastries	6	4	6	4
Puddings and ice cream	3		4	
Milk and milk products:	15	14	23	24
Whole milk	7	3	11	4
Semi-skimmed milk		3		5
Cheese (incl cottage cheese)	6	6	9	10
Eggs and egg dishes	4	4	3	3
Fat spreads:	16	12	17	11
Butter	6	4	10	6
Margarines		1		1
Reduced fat spreads		5		3
Low fat spreads	1	1		1
Polyunsaturated marg.	4			
Other marg and spreads	6			
Meat and meat products:	24	23	23	22
Bacon and ham	4	2	3	2
Beef, veal and dishes	4	3	4	4
Lamb and dishes		1		1
Pork and dishes		1		1
Coated chicken and turkey		1		1
Chicken, turkey and dishes		4		3
Burgers and kebabs		2		2
Sausages		3		3
Meat pies and pastries	5	4	4	4
Other meat and meat products		1		1
Fish and fish dishes:	3	3	2	2
Coated and or fried white fish		2		1
Oily fish		1		1
Vegetables (excl potatoes)	11	4	6	2
Potatoes and savoury snacks:		10		7
Chips	5	5		3
Other fried or roast potatoes		1		0
Savoury snacks	2	3		3
Fruit and nuts	1	2	0	1
Sugars, preserves and confectionery:	3	3	4	5
Chocolate confectionery		3		5
Drinks	0	0	0	1
Miscellaneous	3	5	3	3

of fat and saturated fat from (full-fat) margarines these having been replaced to a large extent by reduced-fat spreads.

1.2 Effect of changes in *trans* consumption

Since the publication of the 2002 NDNS report the UK food industry has made significant changes in terms of the use of partially hydrogenated fats in food products. This has been mainly in response to pressure from the media, nutritionists and consumers to replace fats containing *trans* fatty acids with non-*trans* alternatives.

The Dietary Reference Value (DRV) for *trans* fatty acids as proposed by the Department of Health (1991) is an average of no more than 2% of food energy intake. The actual intakes of *trans* fatty acid from the NDNS report (2002) are well below the DRV suggesting that there was no real need to reduce *trans* intake below the levels found in 2002. These levels have reduced significantly since the 1986/87 survey. Further confirmation of *trans* intake comes from the TRANSFAIR study of 1999 (Hulshof et al, 1999). This was a study across all Western European countries of fatty acid intake. This study found that average daily intake of *trans* fatty acids in the UK across both men and women was 1.3% of energy.

Some of the *trans* fatty acid intake will be from 'natural' sources such as milk, butter, cheese and meat from ruminant animals such as cows and sheep. Most of the rest will be from the use of partially hydrogenated vegetable fats in processed foods. Only *trans* from the latter source will have been affected by removal or reduction of partially hydrogenated fats. In many cases the *trans* fatty acids that have been removed will have been replaced by saturated fatty acids. This is because the original hydrogenated fat was used to give some structure or stability to the food product which can only be achieved by the use of solid fat. If *trans* cannot be used then the alternative, in many cases, is to replace with saturates.

Since many of these changes will have taken place since the 2002 NDNS it is possible that the intake of saturated fat in the UK has increased slightly over the levels shown in Table 1. This aspect is explored more fully in chapter 1.3. On the other hand replacement of partially hydrogenated, *trans*-containing fats has, in most cases, not only increased saturates but it has also increased the levels of the nutritionally beneficial *cis*-unsaturates. The question then is - is the balance of fatty acids in the non-hydrogenated fat phase 'better' in overall health terms than the original *trans*-containing system, even though there has been an increase in saturates?

1.3 Fatty acid composition of common oils and fats

The fatty acid compositions of the oils and fats commonly used in food and food manufacture are shown in Table 5.

This information coupled with estimates of consumption of particular oils can be used to get an indication of the fatty acid consumption in the UK over the past five years. This approach has been described by Gunstone (2005) in which he took oil consumption data on a global basis, subtracted from this estimates of industrial as opposed to food uses and then

Table 5 Fatty acid compositions of common food oils and fats

Acid	Cocoa Butter	Coconut	Corn (Maize)	Cotton-Seed	Ground-nut	Lard	Olive	Palm	Palm Kernel	Rapeseed	Soya	Sunflower	High-oleic Sunflower	Tallow Beef
C6:0		1.3							1.0					
C8:0		12.2							3.0					
C10:0		8.0							4.0					
C12:0		48.8	0.1			Tr		0.2	49.0					Tr
C14:0	0.1	14.8	0.2	0.8		2.0		1.0	16.0			0.1	0.1	2.5
C16:0	26.0	6.9	13.0	27.3	12.5	27.1	11.1	45.0	8.0	4.0	11.0	5.5	3.6	27.0
C16:1	0.3			0.8		4.0	0.7	0.1		2.0	0.5	0.1	0.1	10.8
C18:0	34.4	2.0	2.5	2.0	2.5	11.0	2.5	4.6	2.5	56.0	4.0	4.7	4.9	7.4
C18:1	34.8	4.5	30.5	18.3	37.9	44.5	74.1	37.7	14.0	26.0	22.0	19.5	80.6	47.5
C18:2	3.0	1.4	52.0	50.5	41.1	11.4	9.4	10.6	2.5	10.0	53.0	68.5	8.4	1.7
C18:3	0.2		1.0	Tr	0.3	Tr	0.2	0.2		Tr	7.5	0.1	0.1	1.1
C20:0	1.0	0.1	0.5	0.3	0.5	tr	0.4	0.3		2.0	1.0	0.3	0.4	Tr
C20:1			0.2		0.7		0.2			Tr	1.0	0.1	0.3	
C22:0					2.5		0.1			tr		0.9	1.2	
C22:1					1.0									
C24:0					1.0		0.4					0.2	0.3	
Others							0.9	0.3						2.0

(source: Loders Croklaan)

calculated the intake of individual fatty acids based on typical fatty acid compositions of each oil.

Oil World Annual (2006) publishes information on opening stocks, imports, exports and ending stocks of the major global oils and fats. From this can be calculated the 'domestic disappearance', i.e. the amount of each oil which has been used in a specific country. For the UK, information is published each year from 2001 to 2005 for soyabean oil, cottonseed oil, groundnut oil, sunflower oil, rapeseed oil, corn oil, olive oil, palm oil, palm kernel oil, coconut oil, butteroil, lard, fish oil, linseed oil, castor oil and 'tallow and grease'. Not all of these oils are used in food and, of course, there are other oils which are used in food which are not on the list. Nevertheless, this does allow us to calculate useful information on fatty acids intake in each of these five years.

Gunstone (2005) in his calculations assumes no food use for castor oil, linseed oil or fish oil and that only 50% of tallow, 85% of soyabean oil, 80% of palm oil, 80% of canola oil and 90% of sunflower oil are used in food. Doing this gives the proportion of total production which is used in food to be 79.7-80.9% - this is close to the generally recognised level of 80%.

This calculation then gives us overall fatty acids consumption in the UK in each of the past five years as shown in Table 6.

Table 6 UK Average fatty acid consumption (2001-2005)

Acid	2001	2002	2003	2004	2005
C12:0	3.2	2.9	3.2	2.9	2.5
C14:0	2.3	2.2	2.4	2.3	2.3
C16:0	19.8	21.6	22.5	23.2	23.4
C18:0	4.6	4.6	4.7	4.7	4.8
C18:1	39.7	39.4	38.7	39.7	38.8
C18:2	21.6	21.1	20.2	19.2	20.2
C18:3	4.2	4.0	3.7	3.7	3.6
Total SAFA	29.9	31.3	32.9	33.1	33.0

Three clear trends are obvious from this data:

- total saturates have increased significantly, mainly between 2001 and 2003 (from then on they have remained constant)
- palmitic acid levels have increased significantly from 2001 to 2004
- linoleic acid levels have decreased significantly from 2001 to 2004 and then recovered slightly in 2005.

The increase in saturates, therefore, is mainly due to an increase in palmitic acid consumption. This, in turn, can be attributed to an increased consumption of palm oil by over 50% in 2005 compared to a 2001 base. A total saturates level of 31.3% of all fatty acids in 2002 would equate to a saturates intake of 11% of dietary energy (assuming that 35% of dietary energy came from fat in total). As the NDNS (2002) survey indicates that over 13% of dietary energy was from saturates this is clearly not the total picture. The reason for that is that Table 6 does not include saturated fatty acids (a) from non-oilseed sources such as meat or dairy products (other

than butteroil, tallow or lard themselves), (b) from other fats not included in the above list such as cocoa butter, (c) produced as a result of hydrogenation. Adding these in could well bring the total saturates intake up to the level found in the NDNS (2002). What is perhaps of even greater concern is the increase in saturates consumption after 2002 - a further 1.7% increase in saturates (expressed as a percentage of total fat) would equate to an increase in about 0.6% of dietary energy from saturates. If this is the case then the starting point for saturates reduction may not be 13.4% of dietary energy but nearer to 14% of dietary energy - an increase of 0.6% of dietary energy. Since this is close to the level of dietary energy identified in the TRANSFAIR study as resulting from industrially-produced *trans* fatty acids, it is highly likely that one of the main causes of this higher degree of saturates consumption since 2002 is the replacement of *trans* fatty acids from partially hydrogenated vegetable oils by the saturated fatty acids needed to maintain functionality in products.

2 What should saturates be replaced with?

On the assumption that replacement of saturates with *trans*-unsaturates is not an option there are three possible answers to this question:

- Replace with *cis*-unsaturates
- Replace with carbohydrate
- Replace with 'healthier' saturates

Replacing saturates with carbohydrates will result in a lower total fat intake as well as a lower saturated fat intake, and a higher carbohydrate consumption. Studies on the effects of low-fat diets have shown that they can increase blood triglycerides and lower HDL cholesterol without having any effect on LDL cholesterol (Abbasi et al, 2000). Because of this German and Dillard (2004) have questioned the wisdom of recommending carbohydrate as a replacement of saturated fat. The type of carbohydrate used as a replacement is also a factor to be taken into account. In an environment in which the food industry is being encouraged to reduce sugar as well as fat any carbohydrates being used to replace fat ought ideally to be complex carbohydrates rather than simply replacing by more sugar.

This view has been further emphasised by Willett (2000) who found that replacing saturated fat with a *cis*-unsaturated fat gave a large reduction in coronary heart disease risk. There was no association between total fat intake and coronary heart disease risk and the use of carbohydrate as a replacement for saturates as opposed to using *cis*-unsaturates as a replacement arguably increased the risk of coronary heart disease. Corr and Oliver (1997) express an even greater scepticism by saying that 'dietary advice to reduce saturated fat and cholesterol intake, even combined with intervention to reduce other risk factors, appears to be relatively ineffective for the primary prevention of coronary heart disease and has not been shown to reduce mortality.' They add to this by saying that increasing intake of both omega-6 and omega-3 polyunsaturates is more effective.

The overall consensus, therefore, is that, where possible, it would be sensible from a nutritional point of view to replace saturates with *cis*-unsaturates, without necessarily reducing total fat content. However, if we

consider the edible oil quality triangle as defined by Lui (1999) then such an approach is not always possible. Such a triangle has three points - oxidative stability, functionality and nutrition. The ideal oil should have a high oxidative stability at both ambient temperature and temperatures up to those used in frying, together with enough solid fat to give the required functionality to spreads, bakery fats, confectionery and chocolate, and have a minimum of saturates and high levels of *cis*-unsaturates. Sadly, such an oil does not exist and so, depending on the food application, there will need to be compromises. In frying, for example, the compromise may be on oxidative stability by accepting that, whilst not as stable as a more saturated oil or a partially hydrogenated oil, an oil rich in monounsaturates will, nevertheless, have enough stability to perform well in industrial frying yet still be low in saturates.

In other applications it may be necessary to compromise to some extent on nutrition by accepting that the presence of some saturates may be necessary. This, then, prompts the question as to whether some saturates are nutritionally better than others.

The reason that a recommendation has been made to reduce saturated fatty acid intake from 13.2-13.4% of dietary energy down to 11% has been based on the evidence that saturated fats increase blood cholesterol levels. However, there are some suggestions that saturated fats are of value in nutrition. Firstly, human milk fat contains over 42% of saturated fatty acids yet is necessary for the growth and development of human babies. Secondly, it has been suggested (Lawson and Kummerow, 1979) that saturated fatty acids are the preferred fuel for the heart. Finally, if the body has insufficient dietary fat it synthesises this from carbohydrate. Palmitic acid is the main fatty acid produced in this way.

Saturated fatty acids appear to be different in their effects on blood cholesterol and the generally accepted view is that fatty acids with less than ten carbon atoms are neutral in this respect as is stearic acid (C18:0), while lauric (C12:0), myristic (C14:0) and palmitic (C16:0) increase blood cholesterol, with myristic acid being the most potent of these. However, as with many things in nutrition, even these generalities are not clear cut. Sundram et al (1994) found that palmitic acid lowered blood cholesterol levels in comparison with a mix of lauric and myristic acids. On the other hand, Mensink et al (2003) found that while lauric acid increased total cholesterol levels it reduced the ratio of total:HDL cholesterol (a parameter which they considered to be more important in defining cardiovascular disease risk). In the same paper, stearic acid reduced this ratio slightly more than did myristic or palmitic acids although the 95% confidence intervals show a degree of overlap. The effects of individual saturated fatty acids on blood cholesterol levels are considered in more detail in chapter 11.1.

These types of studies have resulted in a number of equations relating changes in blood cholesterol levels to the different fatty acids in the diet. Perhaps the oldest and most well-known of these is the Keys equation (Keys, 1965) which is:

$$\Delta TC = 0.031 \times (2D_{SAT} - D_{PUFA}) + 1.5/D_{CHOL}$$

where ΔTC is the change in total blood cholesterol level, D_{SAT} is the change in percentage of dietary energy derived from saturates, D_{PUFA} is the change in percentage of dietary energy derived from polyunsaturates, and D_{CHOL} is the change in dietary cholesterol intake (Marshall, 2000).

Using the Keys equation Marshall (2000) calculated the effect on the incidence of coronary heart disease of isocalorically replacing 50% of the saturated fats in the most commonly consumed sources of these acids with saturate-free alternatives (either unsaturates or carbohydrates). He found that such an action would give a reduction in heart disease of between 7.6% and 10.9%.

Blood cholesterol, however, is not the only factor of importance in defining cardiovascular disease risk. The ratio of thromboxane to prostacyclin in blood plasma is an indicator of thrombogenesis. Ng et al (1992) found that replacing lauric and myristic acid with palmitic and oleic acid had a beneficial effect on this ratio. Fibrinogen, the central protein of the blood coagulating system was raised more by a diet enriched in stearic acid than one rich in palmitic acid (Baer et al, 2004). This was claimed to increase the risk of a myocardial infarction by about 7%. After initially claiming that stearic acid consumption produced more beneficial effects on cardiovascular risk factors than did consumption of palmitic acid (Kelly et al, 2001) a later paper by the same authors (Kelly et al, 2002) concluded that there was no difference in effect on platelet aggregation and other risk factors.

There have also been claims that stearic acid had adverse effects on blood lipids and blood coagulation factors in the few hours immediately after a meal. Sanders and Berry (2005) have concluded that there is no evidence to support this view. Indeed the opposite may even be the case - that oleic acid-rich fats can increase blood lipids after eating more than do stearic acid and palmitic acid. This was also confirmed by Tholstrup (2005) who concluded that 'dietary stearic acid was not more thrombogenic than unsaturated FA, including *trans* FA, in the postprandial state'.

3 Dairy Products

Milk and milk products provided almost one quarter of the daily intake of saturated fatty acids in the 2002 NDNS survey and so is perhaps a good place to start. This section covers, milk, cheese, yoghurts, ice cream and desserts. Although ice cream coatings may more logically come within the scope of chocolate type confectionery they are included in this section instead as a sub-section of ice cream. Although a dairy product, butter is included in the section on fat-based spreads rather than in this section.

3.1 Milk

Background

3.0% of daily energy comes from the saturated fat in milk and milk products (including cheese and ice cream). 64% of the fat we ingest from milk and milk products is saturated making it a food category where saturated fat reduction may be a possibility.

Clearly, moving consumption away from whole milk to either semi-skimmed milk or, better, skimmed milk will not only reduce intake of saturated fat but will also reduce intake of total fat. To achieve a large-scale shift in this direction, however, requires a will on the part of the consumer to want to make the change. Many consumers prefer the full-fat creaminess of whole milk either as a drink or when consumed with, for example, breakfast cereals. Others who have made the change to skimmed milk become used to it and then consider whole milk to be too rich.

If all whole milk consumers changed to skimmed milk then the average daily energy from saturated fat would reduce by 0.5%. If, in addition, all semi-skimmed milk consumers changed to skimmed milk then a further 0.6% reduction in saturated fat could be achieved. Such a large-scale migration from whole or semi-skimmed milk to skimmed milk is, however, very unlikely to happen. With enough of a publicity campaign about the saturated fat content of milk it is possible that some consumers would move to a lower-fat alternative.

There are, however, possible ways of retaining the current level of fat in the milk while replacing some saturates with unsaturates. However, it needs to be remembered that milk is not simply used as milk itself but many other products are produced from the milk (butter, cream, cheese etc) and that reducing the saturates in the milk can have functional implications for these products.

For example, the less saturated fat there is in butter the lower will be its melting point. This could be considered a functional advantage making it potentially easier to spread the butter directly from the fridge. Reducing the saturates level could, however, give a functional disadvantage to cream making it more difficult to whip and aerate.

Changes to cattle feed

Pantoja et al (1996) investigated the effects of changes to cows' diet on the fatty acid composition of their milk. By moving from a control diet to one containing 5% animal-vegetable fat, 60% forage and no soyahulls they were able to reduce saturated fat in the milk from 74.8% to 56.4% (25% reduction). As the diet changed the myristic and palmitic acids in the milk decreased significantly while the stearic acid and oleic acid contents increased.

Working on the basis that myristic and palmitic acids are negative in terms of their effects on blood cholesterol levels and that stearic acid is neutral (see, however, chapter 2 for further comments on this), Grummer (1991) showed that feeding whole canola, sunflower or high oleic sunflower gave reductions in saturates up to and including palmitic acid in milk of 20-40% coupled with increases in stearic and oleic acids of 55-80%.

Schingoethe et al (1996) found that feeding cows with a diet in which soyabean meal was replaced with extruded soyabeans (complete replacement of soyabean meal) or sunflower seeds (partial replacement of soyabean meal) resulted in milk with a lower level of saturates. The diet containing extruded soyabeans gave milk with saturates of 59.9% (16% reduction); the diet containing sunflower seeds gave milk with saturates of

61.2% (15% reduction). In both cases the myristic and palmitic acid contents of the milk decreased while the stearic acid content increased.

Feeding linseeds or linseed oil to sheep resulted in a reduction in saturates of about 5% in the ewes' milk (Bouattour et al, 2006). There is also a recent report (Vanhatalo, 2006) that feeding red clover to cattle reduced the saturated fatty acid content of their milk.

There are also significant seasonal differences in the fatty acid composition of milk fat. For example, summer milk fat in Slovenia contained 64.2% saturates compared with 70.1% saturates in winter (Levart et al, 2006). Although some of this difference could be attributable to feed it is also probably that some is attributable to ambient temperatures since it is a trend that has been seen in other countries also.

Rumen-protected oils

In the rumen of animals such as cattle and sheep a process of biohydrogenation takes place in which polyunsaturated oils are partially hydrogenated. Such a process often results in some *trans* formation although this is predominantly vaccenic acid rather than elaidic acid commonly produced by chemically-catalysed hydrogenation of vegetable oils. If ruminant animals are fed diets enriched in polyunsaturates as a means of enhancing these oils in the meat or the milk it is necessary to protect them from biohydrogenation in the rumen.

Richardson (1992) describes a patented process to produce unsaturated milk fat and meat from cattle. The shorter chain saturates (C4:0 to C10:0) in milk are synthesised in the mammary gland directly from acetate and butyrate in the blood and are not affected by diet. Longer chain fatty acids, however, are transferred in the mammary gland from blood triglycerides into the milk and these therefore can be affected by the diet of the cow. Unsaturated acids such as oleic and linoleic acids come from the cow's diet but simply feeding more of these does not mean an increase in the milk. To achieve an increase in unsaturates in the milk it is necessary to feed a highly unsaturated oil such as corn oil in a form in which it is encapsulated. Such encapsulation protects the oil from breakdown in the first two stomachs of the animal and, by doing so, allows the unsaturated fatty acids to be better incorporated into the milk.

Cows were fed a control diet for 12 days to allow the fatty acids to acclimatise to this diet and then this was changed to one containing 3% w/w of corn oil for the next 12 days with a changeover day on day 13. The fatty acid content of the milk after 11 days (i.e. towards the end of the control period) and 25 days (i.e. at the end of the period when corn oil was fed) is shown in Table 7. On day 13 when the change took place there was an almost immediate reduction in C18:0 and C18:1 to levels below those shown for 25 days. The C18:2 levels however, showed a gradual rise over the 12-day period of feeding encapsulated corn oil. There is no indication in the patent on the effects of this diet on other saturated fatty acids, nor is there any information on feeding corn oil beyond the 12 day experimental period.

This process is based on work originally carried out in the 1970s (Scott et al, 1971) in which oils were encapsulated in a formaldehyde-treated protein.

The effect on the milk of feeding various encapsulated oils is shown in Table 8.

Table 7 Effect on milk fatty acids of feeding encapsulation corn oil to cows (interpolated from Richardson (1992))

Fatty Acid	11 days	25 days
Stearic (C18:0)	15.8	11.9
Oleic (C18:1)	32	26
Linoleic (C18:2)	3.4	6.2

Table 8 Effect on cow's milk of feeding oils encapsulated in formaldehyde-treated protein (from Scott et al, 1971)

Fatty acid	Control	Sunflower oil	Corn oil	Groundnut oil
C14:0	11.9	8.4	7.9	9.7
C16:0	31.1	19.5	20.5	22.1
C18:0	13.5	10.6	9.8	11.0
C18:1	29.5	27.4	28.8	25.3
C18:2	4.2	25.1	20.1	20.5
C18:3	2.7	1.6	1.8	2.9
Other	7.1	7.4	11.1	8.5
Total C14-C18 saturates	56.5	38.5	38.2	42.8

Feeding either sunflower oil or corn oil encapsulated this way resulted in over 30% reduction in saturates compared with the control.

In a further study Mattos and Palmquist (1974) compared the effects of adding 3.6kg/day unprotected or 3.6kg/day formaldehyde-protected full fat soya flour to the cows' diet. They found that addition of full fat soya flour to the diet increased both milk yield (from 18.3 kg/day to about 19.5 kg/day) and fat content (from about 5.3% to about 5.6%) irrespective of whether the soya flour was protected or not. Adding unprotected soya flour to the diet resulted in a reduction in saturated fat in the milk from 65.9% to 51.9% (21% reduction). Protecting the soya flour gave a further reduction in saturates in the milk down to 48.0% (27% reduction). The biggest effect, therefore, is obtained by simply adding 3.6kg/day of full fat soyaflour to the cows' diet. Protecting that soyaflour by encapsulating in a formaldehyde-treated protein shell reduced the saturates further but by a much lesser amount.

Perhaps a more 'acceptable, means of encapsulating and protecting fatty acids from biohydrogenation in the rumen is to use whey protein concentrates and isolates rather than formaldehyde. Feed enriched in polyunsaturated fatty acids was protected in this way to increase the PUFA content of cow's milk (Juchem et al, 2006)

Not all researchers, however, found these positive effects when using protected feeds. Martin and Thomas (1987) compared barley, protected barley, oats and protected oats and found no difference in saturated fat content of the milk between the two pairs (unprotected compared with protected). They did, however, see a significant difference between barley and oats with milk produced from cows fed barley containing about 75%

saturates and milk produced from cows fed oats containing about 62% saturates.

Assuming, though, that it is possible to change the fatty acid profile of milk by feeding rumen protected lipid supplements (as most researchers show is the case) does this then have any effect on the blood cholesterol profile of humans consuming these modified milk fats? Noakes et al (1996) would suggest that it does. In a nutritional trial they fed volunteers two diets, one containing dairy products from normal milk fat (containing 70% saturates) and the other containing dairy products from a modified milk fat (containing 51% saturates). These feeding periods followed a two-week baseline feeding during which volunteers were given a low-fat diet which resulted in a baseline total cholesterol level of 5.89 ± 0.89 mmol/L. In the trials in which milk fat from the two sources were used the diets consisted of a low-fat background diet providing 15% of energy from fat. To this a further 20% of energy came from either normal or modified milk fat. Total cholesterol levels in the group fed the normal milk fat were 6.50 ± 0.98 mmol/L. In the group fed the modified milk fat total cholesterol levels were 6.22 ± 0.82 mmol/L. These results were significant at $P < 0.001$ and prompted the authors to express the view that, if this were applied to the population, it would result in a 9% reduction in the risk of developing coronary heart disease.

Noakes et al (1996) do also make the comment that the lipid base in the encapsulated feed should be rich in monounsaturates in order to improve the oxidative and flavour stability of the milk. The addition of vitamin E also helps maintain oxidative stability.

Research work is currently in progress at Reading University on the manipulation of the fatty acid composition of both milk and meat by including wholegrains containing polyunsaturates in cattle diets. To a certain extent having the polyunsaturates contained within the wholegrains imparts some protection from biohydrogenation in the rumen, although some of this must take place because the natural *trans* levels in the milk and meat are also slightly elevated.

It is important to recognise that feeds encapsulated, be that using a formaldehyde-based process or one using whey protein, are going to be more expensive than conventional feeds. This will therefore not only have an effect on the cost of milk produced in this way but this cost effect will also carry through to products made from the milk (butter, cheese, cream etc)

Genetic changes

Gibson (1991) evaluates the potential for genetic change in milk fat composition and identifies the following issue. There is a greater economic value to the producer in investing in increasing milk yield from each cow than there is in altering the milk fat composition. This would then suggest that any genetic process used to improve milk fat composition would inevitably result in a higher-priced milk. In addition there would be issues of consumer acceptance of the use of genetic changes to produce a lower-saturated fat milk.

Filled milks

It is possible to produce 'filled' milks. These are milks in which the milk fat has been replaced by a vegetable oil. They are often used as coffee creamers in individual portioned tubs. Whilst the fat content is no lower than that of whole milk (and, indeed, in some cases where it is intended to simulate cream for coffee it may be higher) the fatty acid profile can be considerably improved in terms of the degree of saturation. The United States FDA does not permit the use of filled milk saying that it 'is an adulterated article of food, injurious to the public health, and its sale constitutes a fraud upon the public'².

Industry views

The main changes that have been made to milk (apart from total fat reduction in skimmed and semi-skimmed milks) have been to make feeding changes to cattle to give an enhancement in the omega-3 content of the milk. Although this has resulted in a reduction in saturates such a reduction has been quite small (of the order of about 5%). Even so such changes have been quite limited and the resulting milk does demand a premium in terms of price and its positioning as a premium healthy product on the retailer's shelves.

3.2 Cream

Dairy cream has a variety of uses in the food industry from being used in sauces and soups to a range of dessert toppings. When being used in its native liquid form many of the comments and potential changes discussed in the previous chapter (3.1) on milk would also apply to cream in terms of ways of changing the fat phase composition. One attribute which high-fat (>35%) creams have which milk does not is the ability to aerate when whipped. This makes it also suitable therefore for whipped dessert toppings.

It is, however, the solid fat crystals and globules in cream which stabilise a whipped foam. During the last stages of whipping a network of partially coalesced fat globules develops which stabilises the air cells producing a stiff, stable foam (Needs and Huitson, 1991). Changing the fatty acid content of the milk as described in chapter 3.1 will affect the ability of the solid fat globules to stabilise such a whipped foam because, as the saturates content of the milk decreases, there will be less solid fat available to act in this way.

Dairy cream analogues (i.e. whipped non-dairy creams) generally use fats such as palm kernel oil as their base - these are even more saturated than the dairy fats they are replacing. Increasing the solid fat content in such products increases the foam stability and the degree of overrun³ that can be achieved (Talbot, 2006b). For example, a palm kernel stearine based non-

² www.fda.gov/opacom/laws/milkact.htm

³ Overrun is the degree of aeration of a whipped system (cream, ice cream, toppings etc) and can be defined as (volume of aerated product – volume of non-aerated mix)/(volume of non-aerated mix) x 100%. So, if on aeration the volume of a mix doubles, then the overrun is 100%

dairy cream with 95% solid fat at 20°C will give a foam with a greater emulsion stability and overrun than one based on HPKO33 with a solid fat content of only 68% at 20°C. The degree of saturates will, however, be very high.

Allen et al (2006) at the University of Leeds have, however, described a way in which a liquid, polyunsaturated oil such as groundnut oil could be used as the basis of a whipped non-dairy cream. They achieve this by using an acid-induced protein aggregation to stabilise the foam. Groundnut oil-in-water emulsions are stabilised with sodium caseinate which has been acidified with glucono- δ -lactone. Typically, 20g sodium caseinate was used per litre of oil-in-water emulsion which would mean that there will be a small contribution of sodium to the whole emulsion. Very high overruns (up to 600%) are achievable with this method but long whipping times are needed making the application unsuitable for home or small-scale foodservice use. It does, however, provide possibilities for applications where industrial quantities of whipped dairy or non-dairy creams are used as dessert toppings. Apart from the obvious benefits of being able to produce this type of system from an oil which is low in saturates and high in unsaturates there are other benefits such as a lower degree of foam drainage and serum separation on storage. Because the foam is stabilised by acidification it does, however, have an acid pH compared with a dairy cream which is neutral. This may have implications in some applications in terms of interaction with other components of the product.

Just as there are vegetable oil-based analogues to other dairy products there are analogues to dairy cream. These are usually based on blends of buttermilk, vegetable and hydrogenated vegetable oils and while the total fat content of these creams is approximately 50% of that of the analogous dairy product the saturated fat content expressed as a percentage of the fat phase can be as high if not higher than in dairy cream. Because of the lower total fat content the absolute level of saturates (per 100ml of product) is lower than in dairy cream.

3.3 Cheese

Cheese can be divided into a number of groups each distinguishable by their total fat and saturated fat content. Traditional hard cheeses such as Cheddar, Stilton and Wensleydale typically contain 30-35% total fat and 19-23% saturates. Brie, being a softer cheese, has a lower total fat content of 24% and a lower saturates content of 16%. This is also typical of the levels found in full fat processed and spreadable cheeses. However, some processed cheeses contain lower levels of either saturates or total fat. An 'economy' brand of processed cheese slices, whilst still containing 22.5% total fat contain only 10.5% saturates; the same retailer's 'healthy' versions contain 10% total fat and 6.6% saturates. Extra Light spreadable cheeses can have as little as 5% total fat and 3.3% saturates. In most cases the percentage of saturates in the total fat phase is about 60-70% which is the level of saturates in milk. This indicates that no changes have been made to the fat phase itself either by the use of softer butter fractions or by blending in vegetable oil.

It is possible to make reduced-fat cheeses by removal some of the milk fat prior to cheese manufacture. This method can affect the maturation of the

full cheese flavour. An alternative approach (Nelson and Barbano, 2004) has been to remove the fat after cheese-making by a combination of temperature and gravitational forces. Essentially the process involves shredding the cheese, holding at between 20°C and 33°C, and then centrifuging. There is a linear relationship between the temperature and the amount of fat removed with approximately 60% fat removal at 32°C. The authors claim that 50% of the saturated fat in cheese can be removed in this way.

Both reduced fat and reduced saturated fat cheese are described by Silver et al (2000) using soft fractions of butterfat (see chapter 4.1 for more detail).

Wester (2004) describes the production of a spreadable cheese analogue from a blend of 33.3% wood stanol esters, 59.7% rapeseed oil and 7% of an interesterified blend of palm stearine and coconut oil. The resulting product contained 2.6% saturates.

Industry views

Only cheeses which start from milk can be called 'cheese'. Other products need to be labelled as 'cheese analogues'. Thus the ratio of saturates:unsaturates in the cheese is dictated by that in the milk. While it is possible to make reduced fat cheeses the texture of the product is not as good. Having said that, any changes that are being made to cheese are in the direction of fat reduction rather than specifically saturated fat reduction. Reduced fat cheeses are made by starting with a low-fat milk and then fermenting this. Reducing the fat does make a more rubbery end product which in itself makes it more difficult to produce.

Although most cheddar cheeses contain about 34% fat there is scope within the Food Labelling Regulations to reduce this slightly and still stay within the requirements for cheddar cheese. The Regulations state that the maximum water content in cheddar cheese can be 39%. This means that there can be a minimum of 61% 'dry matter'. The minimum fat content for cheese is 48% of the dry matter - in this case 29.3% fat. A cheddar cheese containing the maximum amount of water and, say, 30% fat would therefore fall within the scope of the Food Labelling Regulations and allow a fat reduction of over 11% compared with cheeses currently on the market. In terms of whether such a change would have an effect on the texture of the cheese, the industry view is that it is difficult to be precise because fat reductions of this level have not been widely examined (the industry has usually looked at greater fat reductions than this that would then allow a claim to be made). It is thought, however, that the cheese might be slightly less creamy, slightly more crumbly but not to anywhere near the same extent as with a 25% fat reduction. Clearly, there is scope here for the cheese industry to examine such a reduction in fat and determine whether or not there may be any sensory difficulties in making such a change.

Processed cheeses are cheese blended with milk protein to give a lower fat content (typically 20-25% fat compared with about 35% in traditional Cheddar cheese). It is possible to make spreadable processed cheeses with

very low fat contents by structuring the water phase of the oil-in-water emulsion with milk proteins and alginates, for example.

Soft spreadable processed cheeses are available in a variety of fat levels ranging from 5% up to 24%. The 'lighter' varieties generally outsell the full-fat varieties

In terms of cheese analogues products are available which contain the same total fat content as cheddar cheese (i.e. about 34%) but which are produced from blends of skimmed milk with a vegetable oil. One example, available commercially, uses wheatgerm oil and the resulting product contains only 5% saturates (with 10.5% monounsaturates and 18.5% polyunsaturates making up the 34% total fat). Because the total fat content has not been reduced the texture is that of a full-fat cheddar cheese.

3.4 Yoghurts

There are yoghurts with fat levels as low as 0.1% on the market but there are also other, more 'luxurious' yoghurts available with up to 8% fat and Greek yoghurt can have fat levels as high as 10% with saturates approaching 8%. Clearly there is a matter of consumer choice here because very low-fat, very low-saturates are available if consumers want to purchase them.

Although yoghurts are generally considered to be low-fat even lower fat levels could be achieved with the launch⁴ of a new range of yoghurt cultures which increase the texture of yogurts while allowing the fat levels to be reduced.

3.5 Ice cream

Fats in ice cream products are of two distinct types - those found in the bulk ice cream itself and those found in the coating. Although historically many ice cream manufacturers have used the same fat in both applications (usually palm kernel or coconut oil) more recently there has been a segregation in terms of using either dairy fat in the ice cream or real chocolate as the coating. The two types of application will be considered separately.

3.5.1 Ice cream

Ice cream has fat contents ranging from as low as 4% up to levels as high as 18% (in highly indulgent ice cream products). Within the fat phase of the ice cream the saturates level can vary from about 45% up to as high as 90%. This range is indicative of the type of fat used in producing the ice cream.

Ice cream goes through a number of stages in its production. These can be essentially summarised as mixing, pasteurisation and homogenisation, ageing, aerating and partially freezing the mix, extrusion and hardening (Arbuckle, 1986). In terms of the fat phase of the ice cream, perhaps the most important stage is the ageing stage in which the ice cream mix is held

⁴ www.foodnavigator.com/new3s/printNewsBis.asp?id=70667

for a few hours at about 4°C. It is in this part of the process that a large part of the fat crystallises.

Ice cream has traditionally been made with butterfat (for dairy ice cream) or with coconut oil, or occasionally, palm kernel oil (for non-dairy ice cream). All of these fats are high in saturates - butterfat can contain between 60% and 75% saturates, coconut oil more than 90% saturates and palm kernel oil 80-85% saturates. These high levels of saturates allow an ice cream to be produced which aerates well and retains its shape and structure after production while at the same time having a relatively short ageing stage. They also have the advantage to the consumer of melting well below mouth temperature, a critical factor in ensuring that the ice cream does not taste waxy even when the mouth has been cooled by the ice cream.

Various Japanese patents describe alternative fat phases. One from Fuji Oil (1980) describes the use of the middle-melting fraction of palm oil. As this also contains 60-65% saturates (mainly palmitic acid) it seems to give little benefit over butterfat. Another patent (Lotte, 1982) discloses a way of making ice cream with oils such as sunflower oil which are very low in saturates. It is necessary in producing such ice creams to use a sucrose fatty acid ester as an emulsifier.

Dilley et al (2006) have patented a range of compositions which produce good quality ice cream from blends of vegetable oils containing between 35% and 55% saturates. The fat phase of the system containing 35% saturates is a blend of palm fractions plus 23% sunflower oil which gives a good balance in total between saturates (mainly palmitic acid), monounsaturates (oleic acid) and polyunsaturates (linoleic acid). The inventors claim that this, along with nine other compositions which they disclose gives ice cream which can be aerated to 100% overrun and has a good shape retention and texture without a waxy mouthfeel. All of these blends allow a considerable reduction in saturates compared with butterfat and coconut oil to be achieved.

Other ice cream systems are described by Heritage et al (2006) in which the fat phase is a blend of palm oil and rapeseed oil having a total saturates content of 36%. Fat levels ranging from 2.9% to 7.0% fat are used which generate overall energy levels from saturates of 8.0% to 10.1%.

Dreyers in the USA have patented a 'slow churn' process to making ice cream⁵ in which lower temperatures, higher pressure and longer times are used. This is said to give finer ice crystals and to break up the fat globules so that the ice cream tastes as though there is more fat present than there actually is. Using this technology Dreyers are reducing fat levels in ice cream from 14% to 5.5%.

3.5.2 Ice Cream coatings

Although in more recent years many ice cream coatings have conformed to the standards of identity of 'real' chocolate⁶ other ice cream coatings are

⁵ www.bizjournals.com/eastbay/stories/2004/02/02/story6.html

⁶ Chocolate itself is considered in chapter 7.1

based on the lauric fats, coconut oil or palm kernel oil. Both of these contain high levels of saturated fatty acid, lauric acid being the main one. Palm kernel oil typically contains about 82% saturated (about 48% being lauric acid) and coconut oil about 94% saturated (about 49% being lauric acid). There is, therefore, considerable scope for reduction in saturates in such coatings. Clearly moving to real chocolate with a saturates level of about 60-65% would be a step in the right direction but would be an expensive move to make. Cain et al (1999) developed an ice cream coating which would have a similar level of saturates as real chocolate but would be more economical because it is based on palm oil fractions. They define the fat on the basis of the main triglyceride groups (SSS <10%; SUS 25-80%; SSU 2-20%; SUU+USU 8-60%; UUU <10%). Taking the extremes of these ranges would mean that the saturates level of the coating could vary from 40% to 70%, all of which provides a significant improvement over coconut oil or palm kernel oil and, at the lower end, over chocolate itself.

3.6 Desserts and mousses

Chocolate mousses typically contain between 8% and 15% total fat but the saturated fat content of the fat phase can in some instances be quite high ranging from about 55% up to almost 90%. Some of the structure of the mousse results from the saturated fat which is present but, equally, there are other ways of producing a stable aerated structure which do not involve fat. It is possible that some of the technology described by Allen et al (2006) could be used in this application.

Cheesecakes and other desserts can range widely in total fat (typically from 4% up to 21%) and saturated fat (typically from 2% up to 11%) with saturated fat contributing between 45% and 80% of the total fat phase. The higher levels are much higher than would be found in either cheese or butter (which could be used as a binder for the biscuit base) and so, again, there should be some scope for reduction in saturates in these higher level products.

4 Fat-based spreads

Fat-based spreads can be divided into two broad categories - butter and butter analogues based on vegetable oils. The latter group contain margarines (which have the same total fat content as butter) and reduced-fat or low-fat spreads.

4.1 Butter

The saturated fat content of butterfat can vary, typically, between about 60% and 75% depending on seasonality, feed etc. Clearly all the methods described in chapter 3.1 relating to ways of altering the fatty acid composition of milk will carry through as ways of altering the fatty acid composition of butter(fat). However, even with 'standard' butterfat there is a further option open to food processors as a means of reducing saturated fat and that is to fractionate the butterfat. Although, potentially, a better split could be obtained between hard and soft fractions of butterfat if the fat were fractionated from a solvent solution, for a number of reasons (simplicity of processing, retained flavour, 'naturalness') a 'dry'

fractionation process is to be preferred. In this the butterfat is held at a specific temperature at which it is partly solid and the solid and liquid parts of the butterfat are separated by filtration (either pressure or vacuum filtration).

This process yields a hard fraction in which the saturates are enriched and a soft fraction in which they are depleted. Clearly, in the food chain as a whole some use needs to be made of the saturate-enriched fraction in order to make the whole process economical but the saturate-depleted 'oleine' fraction is of use in a range of applications. Silver et al (2000) describe such a process together with the use of the oleine fraction in a range of both fat-reduced and saturated-reduced cheeses. By fractionating at different temperatures they reduced the total saturates in butterfat from 62.8% to 59.9% (when fractionated at 13°C) and to 56.4% (when fractionated at 10°C). Somewhat surprisingly, fractionating at 7°C gave a soft fraction with 58.0% saturates.

Apart from applications in cheese these softer butterfat fractions can be used to produce butters which are spreadable directly from the fridge because of their lower saturated fat content. A further benefit is that a significant proportion of the butter flavour partitions into the soft oleine fraction allowing this to be used to give butter flavour to a wide range of dairy and bakery products but at a lower level of use.

It is also possible to produce spreads which are based on a combination of butterfat and vegetable oils. This allows the buttery flavour to still be apparent to consumers whilst at the same time reducing saturates and increasing monounsaturates and polyunsaturates.

Epidemiological evidence in Poland would suggest that replacement of butter by margarines high in polyunsaturates and low in *trans* would reduce the risk of coronary heart disease (Willett, 2000). For economic reasons (elimination of price support for butter), there was a large-scale switch from butter to polyunsaturated margarines during the 1990s which resulted in the P/S ratio increasing from about 0.3 to 0.5. At the same time there was a 20-25% reduction in coronary heart disease.

Industry views

In terms of saturates reduction the market is moving towards 'spreadables' rather than butter. These are blends of butter with a vegetable oil such as rapeseed oil. Doing this gives a big reduction in saturates compared with butter itself - typically a 35-40% reduction of the 55% or so saturates in butter. Also on the market are lighter spreadables which typically contain about 30% saturates in the spread. The main driver for these products is total fat reduction whilst retaining 'butteriness'. This does, however, also result in lower saturated fat contents as well.

No extra hardstock is needed when, for example, rapeseed oil is blended with butterfat so it does result in a straight reduction in saturates without any boosting back of saturates for textural and structural reasons.

Although the use of butter oleine to achieve a saturates reduction and a spreadable texture is feasible it is not seen as economic because of the cost of the process and the cost of the stearine by-product. It is possible to label the product 'spreadable butter' (unlike those produced by blending butter with vegetable oils).

Unlike vegetable fat-based spreads which are produced in scraped-surface heat exchangers, butter is churned. The difference in processing is such that it may be difficult for a butter manufacturer to produce a less saturated spreadable blend because the only equipment they have is for churning. This need not be a barrier because there are products available which allow a churned spreadable blend to be made with a fat content of 60% (i.e. a 25% reduction compared with butter and a lower saturated fat content as well).

4.2 Vegetable oil based spreads and margarines

Over the past 20 years, full-fat (80%) margarines have all but disappeared from the market having been replaced by reduced fat spreads of a range of fat contents (from 19% up to about 75%). The average fat level in spreads is now probably about 60% with those positioned in a 'heart health' sector having significantly lower fat levels (usually less than 40%). With this overall reduction in fat content there has been an accompanying reduction in saturated fat levels and, in most cases, a complete removal of hydrogenated vegetable oils. Saturated fat levels are typically between 20% and 25% of the fat phase of the spread (i.e. in a 40% fat spread there would be between 8% and 10% saturates, expressed on the product). There is the potential to reduce saturates by a further amount to say 15-16% of the fat phase but this would then result in a softer product. Perhaps a typical amount of spread to be used on two slices of bread to make a sandwich would be about 15g indicating that the amount of saturated fat coming from the spread in such a sandwich would be only about 1.5g. It is also now possible to have reduced fat spreads (about 35% total fat) which contain added omega-3 oils including EPA and DHA from fish oil.

As with butter such products are water-in-oil emulsions. The highly saturated nature of butter can be replaced to a certain extent by the use of unsaturated oils such as rapeseed oil, sunflower oil (in polyunsaturated spreads and margarines) and olive oil (in monounsaturated spreads and margarines). However, to give texture and structure to these products it has been necessary to use a hardstock. Such hardstocks have traditionally been based on partially or fully hydrogenated vegetable oils. An example of such a hardstock is mentioned by Cain et al (1996) where a spread is made from 87% sunflower oil and 13% of the stearine fraction of a chemical Interesterified blend of fully hardened palm oil and a fully hardened palm kernel oleine fraction. With the move to replace these types of oils with non-hydrogenated fats the use of solid fractions of vegetable oils has come more to the fore. These fats, however, are high in saturates and, indeed, a high level of solid fat is necessary to give structure to the spread or margarine.

To have structure at room temperature, spreadability at fridge temperature and palatability at mouth temperature, the fat phase of a fat-continuous

spread should ideally have the following melting profile (Gabriel et al, 1990):

Table 9 Ideal melting profile of fat phase of fat-continuous spreads

Temperature (°C)	% Solid fat
10	25-40
15	22-30
20	14-21
25	8-12
30	<6
35	<2

Such a melting profile does allow for some considerable variation in the fat phase composition and hence in the saturated fat level.

Another fairly recent change to these products has been the introduction of plant sterol or stanol fatty acid esters (in products such as Flora Pro-activ from Unilever and Benecol from Raisio). These components have the effect of reducing blood cholesterol (see Miettinen, 1996). However, Wester (2000) of the Raisio company in Finland has also discovered that these components will in themselves structure margarines and spreads and are capable of either partially or totally replacing the saturated triglyceride based hardstocks. Although Wester says that more than 60% of the stanol fatty acid ester is unabsorbed this is mainly the stanol portion of the molecule rather than the fatty acid portion so there would be a further benefit in using unsaturated stanol fatty acid esters rather than saturated ones for this application.

In an extension of this patent Wester (2004) shows that wood stanol esters have a similar solid fat content between 20°C and 40°C to those of conventional margarine and spreads hardstocks such as partially hydrogenated soyabean oil, palm stearine and Interesterified blends of palm stearine and coconut oil. The 'structuring' characteristics of this wood stanol ester is such that it can be used at levels of 30-35% with rapeseed oil alone to give an acceptable spread (i.e. no highly saturated hardstock is present). Plant sterol esters, on the other hand, have a much lower solid fat content than do stanol esters making them much less useful in themselves as spreads hardstocks (although they do still possess the cholesterol-lowering properties).

Using a combination of rapeseed oil and stanol fatty acid esters (with fatty acids from rapeseed oil) Wester produced a 60% fat spread of which only 48% was absorbable. This had a saturated fatty acid content of 3.1g/100g product. A 40% fat spread was also produced with a saturated fatty acid content of 3.6g/100g product.

Cain et al (1989) describe the formulation of an 'edible plastic dispersion' which in its description is effectively a zero-fat spread based on gelled aqueous phases.

Industry views

The legislation on fat based spreads is changing which will make it very difficult to be able to make reduced-saturates or low-saturates claims. At present if a spread has a saturates content of 25% or less of the fat phase of the product then a low-saturates claim can be made. In future it will be necessary for there to be less than 1.5g/100g of product for a low-saturates claim to be made. This is almost impossible. For example, Gold Lightest has the lowest fat content of any fat-based spread currently on the market at 19%. This contains about 4.8% saturates - just at the level of 25% of the total fat phase. Going much lower than this would be very difficult and would compromise product quality. Lower fat content spreads have been on the market in the past but the fact that they are no longer produced gives an indication of the difficulty of marrying the technology with any consumer acceptability of the product. Indeed, to go much lower would require the use of some ingenious thickeners and gelling agents which may then go against the retailers' and consumers' desires for 'clean' ingredient labels.

Stanol and sterol esters have been referred to in chapter 4.2 as both having functionality as cholesterol-lowering agents and functionality as hardstocks. Only the esterified fat component (about 40% of the stanol or sterol ester) is declared as fat in terms of nutritional labelling and this is often based on rapeseed or sunflower oil fatty acids rather than more saturated fatty acids. Normally about 20-25% of the fat in a spread is the hardstock - and this is usually rich in saturated fatty acids. When sterol or stanol esters are used the level of hardstock can be reduced by about 5% to 15-20%. Typical level of use of plant sterol esters is about 12.5%. The use of these ingredients therefore gives a combination of fat reduction, saturates reduction and cardiovascular functionality.

It was felt that there is sometimes an inconsistency in labelling of fat in spreads between various manufacturers with some declaring the levels of each of the four main categories of fatty acid (saturates, monounsaturates, polyunsaturates and trans) whilst others either do not declare all categories or decline to mention on the label the *trans* content (if hydrogenated fat is present) leaving the consumer to try and work out what the actual levels are. The comment was also made that there is even less nutritional information on a pack of butter with often only total fat and saturates being declared and no mention of the fact that it also contains *trans* fatty acids.

4.3 Nut and chocolate spreads

These are generally quite high in fat (typically 35-45%) of which saturates comprise some 13-22%. In many ways these are similar in structure to confectionery fillings and need such a fat content in order to form a continuous phase within which the solid components are distributed. Taking the fat content much below about 35% would result in a thicker, possibly more crumbly product which was difficult to spread. Increasing the unsaturates would theoretically improve spreadability but would result in greater oil exudation and 'puddling' on the surface of the spread. Usually a small amount of a highly saturated fat is included in the formulation to 'structure' the spread and prevent this oil exudation.

5 Meat products

In this category 'meat' is subdivided into 'mammalian meat products' which covers carcass meat from cattle, sheep and pigs; 'processed meat products' including sausages, burgers, pies etc; 'poultry meat products'. Although not meat as such further sub-categories in this section briefly discuss eggs and fish.

5.1 Mammalian meat products

The main mammalian animal fats which are consumed as part of meat are those from beef, pork and lamb/mutton sources. They have fatty acid compositions as shown in Table 10. Although the saturated fatty acid content ranges from 37% to 65% the level of monounsaturated oleic acid is quite high and meat provides one of the major sources of this type of fat in the British diet. The main saturated fatty acids are palmitic and stearic acids rather than the more cholesterolemic lauric and myristic acids. Sheep fat contains a higher level of total saturates than does beef or pork fat but almost all of that difference is from stearic acid, the palmitic acid content being almost the same in fat from all three animals. So, although there is a higher saturated fat content in sheep fat it is more of the kind that is considered by many nutritionists to be neutral in terms of effect on cholesterol levels.

There are three main types of fat in meat - Intermuscular, intramuscular (usually seen as marbling) and subcutaneous (probably the easiest of the three to remove by trimming of the meat). Visible fat is higher in saturates so trimming this fat from meat will have a proportionately greater effect on saturates reduction (Li et al, 2005).

Table 10 Fatty acid composition of mammalian animal fats (from Gunstone, Harwood, Padley, 1986)

Fatty acid	Lard	Beef	Mutton
C12:0	Tr	Tr	0.6
C14:0	2.0	2.5	5.6
C16:0	27.1	27.0	27.0
C18:0	11.0	7.4	31.7
Total SAFA	40.1	36.9	64.9
C14:1	Tr	3.0	
C16:1	4.0	10.8	1.6
C18:1	44.4	47.5	31.7
C18:2	11.4	1.7	1.6
C18:3	Tr	1.1	0.2
Fat content (%) of minced meat*	9.7	16.2	12.3

* from McCance and Widdowson, 1998

The breed of the animal can itself affect the relative levels of saturated fat. There is a general relationship between the ratio of polyunsaturated:saturated (P/S) fatty acids in beef muscle and the total fat level in the muscle (Scollan et al, 2006). The less fat there is in the muscle

the greater is the P/S ratio. Sourcing meat from breeds with a lower fat content will therefore have a double effect on reducing saturates.

Cattle feed also has an effect on the P/S ratio - cows fed grass had a P/S ratio of 0.09 whilst those fed a concentrate rich in linoleic and linolenic acid had a P/S ratio of 0.24 (Scollan et al, 2006)

The method described in chapter 3.1 of feeding ruminants polyunsaturated oils protected in a formaldehyde-treated protein shell to increase polyunsaturates in milk (Scott et al, 1971) also has an effect on the body fat of the animal. Sheep fed safflower oil encapsulated and protected in this way had their perirenal saturated fat reduced from 49.4% to 40.8% (17% reduction) whilst their subcutaneous saturated fat was reduced from 40.2% to 23.4% (42% reduction).

Scollan et al (2006) found that feeding cattle on diets enriched in linseed or fish oils had no effect on polyunsaturated:saturated (P/S) fatty acid ratios unless the oils were protected from hydrogenation in the rumen. Then the P/S ratio could be increased from 0.07 to 0.22. Feeding protected fish oil, however, did not increase P/S ratios.

This method of reducing saturates was further studied by Garrett et al (1976) who found that feeding a protected supplement based on a mixture of 70% sunflower seeds and 30% soyabeans reduced palmitic acid content in both muscular and fatty tissue in lamb and beef by levels ranging from 18% to 44%. Stearic acid levels remained more or less the same, oleic acid showed some reduction and linoleic acid increased significantly (5-6 fold in some cases).

In non-ruminant animals such as rabbit the inclusion of up to 3% sunflower oil or 3% linseed oil in the diet in place of animal fat decreased the total saturates in leg meat by 17% and 13% respectively (Tres et al, 2006).

Small (1990, 1992) describes a method of reducing the saturated fat content of fragmented (i.e. minced or ground) meat. This involves mixing minced meat with an unsaturated vegetable oil at a temperature in excess of 100°C for about 5-10 minutes. During this time the hot unsaturated oil solubilises a significant part of the saturated fat in the meat and there is an interchange of fatty acids between the meat and the oil. The oil phase is then removed by boiling water or steam.

In the example given fragmented beef is treated with Puritan oil (this is a sunflower-oil based product from Proctor and Gamble, USA). The fatty acid distribution in the raw and processed beef is given in Table 11.

Another patent claiming to reduce both cholesterol and fat levels in meat (Chapman, 1988) involves exposing a thin layer of meat to ultraviolet light to convert the cholesterol into a range of intermediate products before finally forming vitamin D3. The ultraviolet light also produces free radicals in the meat which are claimed to improve the binding characteristics of the meat. After UV treatment the meat is comminuted at a low temperature and various salts and acids added which allow the bulk of the fat and the vitamin D3 to separate out and be removed. One example shows the fat content of an English sausage being reduced from 32.1% to 1.0%.

Table 11 Effect of treating fragmented beef with Puritan oil

Fatty acid	Raw mole %	Processed mole %
C14:0	3.4	1.1
C14:1	1.1	0.0
C16:0	29.2	17.5
C16:1	5.1	2.1
C18:0	13.5	6.9
C18:1	38.9	42.1
C18:2	1.5	24.2
C18:3	0.2	2.4
Others	7.4	3.8
Total SAFA	46.1	25.5

Gamay (1993) in a separate patent comments that the formation of free radicals in this way could result in the creation of health hazards. He also criticises the patents of Small (1990, 1992) because the process produces only a pre-cooked meat which, because of the vegetable oil content, could not even be described as meat. Gamay's method of reducing the fat content in meat involves comminution down to a small size followed by pH manipulation and fractionation.

Industry views

The fat contents of beef, pork and lamb have all decreased steadily over the past 10-20 years by breeding and feed changes, improved butchery methods and closer trimming to remove excess fat (see Table 12). Other methods relating to farming techniques such as reducing the use of castration in animals can also result in lower fat contents.

Table 12 Changes in fat contents of carcass meats

Decade	Procedures	Beef	Pork	Lamb
1950s-1970s		25%	30%	31%
	Breeding, Feed changes Traditional butchery			
1990s		20%	20%	26%
	Modern butchery Remove back fat			
		15%	8%	18%
	Further trimming (seam butchery)			
Today		5%	4%	8%

As well as this, actual fat levels in pigs, for example, as determined by fat depth have also been reduced to an average of about 11mm, by a combination of animal breeding and feeding regimes. If further decreases

were to be made then the fat would become softer and less saturated. While this may seem to be a benefit nutritionally it does cause problems in meat products in that the fat separates (particularly a problem in bacon where stringing and honeycombing of the fat can occur) and the increased unsaturation also results in a higher degree of rancidity. In general, the changes which are now taking place are to increase carcass weight while keeping the ratio of fat:lean constant.

In beef and lamb the breeding objectives are different to those for pork. The market objective is more in favour of lean growth rather than fat reduction.

As consumers become more aware of the availability of leaner cuts of meat and leaner varieties of mince and are educated about the effects of saturated fat on health it is highly likely that sales of the 'healthier' segments will grow at the expense of the standard varieties.

However, a paper from the British Nutrition Foundation (Williamson et al, 2005) contains information showing that the fat levels in these three meats are significantly lower in Denmark than in the UK (2.5% for beef, 5.5% for lamb and 2.1% for pork). Whilst the paper does point out that these differences may be due to a number of reasons (sampling techniques, feeding regimes, different breeds and cuts of meat) the data does suggest that there could be even further reductions in fat content in these meats. Clearly the cut is important - although the fat content of pork is now being quoted as 4%, lean pork leg can contain less than 2% fat. Because fat is intrinsic in meat, trimming becomes uneconomical after a certain point - for example, trimming of fat from the outside of meat cuts is possible (and is carried out) but trimming of marbled fat within an area of lean meat becomes almost impossible.

In terms of changing the fatty acid compositions of the meats there is an upper limit on linoleic acid that can be achieved in pork but increasing oleic acid further could be possible by increasing the rapeseed element of the diet. Ruminant animals are different (as already discussed in terms of protecting unsaturation from biohydrogenation in the rumen). Cattle fed on grass have a higher n-3:n-6 ratio but not necessarily a higher polyunsaturated:saturated ratio.

As well, of course, as meat products prepared in the home, a significant quantity are used in foodservice applications. Here high-trim cuts are usually specified with grilling as opposed to frying being recommended (although dry frying can be used to reduce overall fat because the product effectively fries in its own fat). Example recipes which are available for foodservice use are free from additional fat, salt and sugar and also contain vegetables to help towards the 'five-a-day'. It was considered to be important to reduce fat by butchery methods and not to rely on chefs in foodservice to trim off excess fat.

It was commented that, in terms of mince a maximum of 75% visible lean meat is needed to have a good texture in the end product. For example, it is possible to produce mince with a visible lean content as high as 95% but if, for example, this is made into burgers it would produce a very dry burger. On the other hand, however, foodservice recommendations are to

specify the use of mince with 90-95% visible lean and to dry fry this rather than use additional oil. At present, there is a great tendency for the retailers to dictate what the specifications of, for example, mince will be in terms of the visible lean content. Undoubtedly this whole area is also consumer-led - the retailers will specify what the consumer wants to buy and those varieties with either too high or too low fat may, for one reason or another, not sell as well and therefore not be specified. For example, as has already been noted, mince with very low (<5%) fat content, is very dry and 'cardboardy' in texture.

5.2 Processed meat products

Processed meat products fall into a numbers of sub-categories - bacon, ham, sausages, burgers and pies as well as components of ready meals. In almost all cases the level of saturated fat expressed as a percentage of the total fat is quite high, typically 35-50%. However, some products in this category have higher levels of total fat than others and it is these groups of products where some attention ought to be focused.

Bacon, for example, contains from about 6% total fat in 'healthy range' products to over 25% in some streaky bacons. The saturated fat ranges from about 35% up to about 48% of the total fat. This means that, depending on the choice of product, a consumer could purchase bacon with as little as 2% saturates or as much as 13% saturates. Because of the nature of the product, back bacon contains less total fat than does streaky bacon.

Sliced ham generally contains even lower levels of fat (typically 1-3%, although some of the more 'premium' cuts can contain up to 6% fat). This means that even in the premium cuts the saturated fat content is usually less than 3%.

Sausages are potentially a more problematic area than bacon or ham because the fat is often intrinsic in the meat whereas in bacon and ham it can often be trimmed before sale (or even before consumption). Indeed, both the fat content and saturated fat content of sausages vary enormously. Total fat content varies from 1.8% to 27.2%, whilst saturated fat varies from 0.7% to 10.9%. The more 'premium' sausages have the highest total fat contents (Food Standards Agency, 2003b) with fat contributing to the texture and 'succulence' of the sausage. This does, however, beg the question as to whether it is necessary, even if the total fat content is high, for there to always be the same level of saturated fat present. Most sausages contain between 35% and 45% saturates when expressed as percentages of the fat phase, i.e. approximately the levels of saturated fat found in lard and beef tallow. However, one sample contained only 20.8% saturates (as a percentage of the fat phase - 5% saturates/24% total fat) suggesting that it is feasible to reduce the saturates level whilst having enough total fat in the product for succulence.

Beefburgers tend to use meat with a lower fat content than that which is found in pork sausages and so, although typical saturates levels in the fat phase are often higher at 40-55%, the saturates content of the burgers are lower (typically 3-10%).

In meat pies and slices, pork pies and sausage rolls the fat from the pastry plays as much of a role in fat and saturates as does the fat from the meat. Total fat contents range from 12-20% of which 30-45% are saturates meaning that these products typically contain 4-8% saturates in total. Reducing the saturated fat content of both the pastry and the meat will reduce these levels further.

Reducing saturated fat in processed meat products can, in theory, be achieved by various strategies, not least of which is to reduce the total fat level in these products. There are limits, however, to this. It is difficult to go below about 10% fat in products such as frankfurters based on ground meat emulsions, or below 20-30% in dry fermented sausages (Colmenero, 1996). Fat reduction is generally achieved by either using leaner cuts of meat or by adding non-fat and, in some cases, non-caloric ingredients such as water. Leanness in the meat usually depends on either different methods of breeding or feeding the animal or fat reduction in the meat by physical or chemical methods.

Adding water to processed meat products such as hamburgers and sausages means ensuring that the extra water is bound within the whole matrix. Proteins are often used for this, soya proteins, dairy proteins and egg proteins all have applications in this way. Alternatively gums and hydrocolloids can be used to enhance the ability to retain water. Konjac flour, for example can also give sensory properties which are close to those given by fat (Keeton, 1992).

It is reported (Bloukas and Paneras, 1993) that pre-emulsification of part of the fat with a non-meat protein helps to partially replace the animal fat with a vegetable oil to reduce saturates levels. They replaced added pork and beef fat in frankfurters with olive oil whilst controlling overall protein levels at 10%, 12% and 14%. They found that it was possible to produce low (10%) fat frankfurters with olive oil replacing animal fat. In this system a recipe containing 12% protein had sensory characteristics closest to those of the standard product.

Processed meat products such as frankfurters and salami involve the production of a meat emulsion which is then extruded and cooked. Ambrosiadis et al (1996) looked at replacing the lard normally added to such emulsions by more unsaturated oils (soyabean oil, sunflower oil, cottonseed oil, maize oil and 'palmine'). While all of these replacements reduced the saturated fat content none of the end products were considered by a consumer panel to be as good in terms of appearance, texture, flavour and colour as the control containing lard. The closest any of the replacements came was the system containing 'palmine' instead of lard. There is no description in the paper as to the exact nature of 'palmine' but its name suggests that it could be palm oleine (the low melting fraction of palm oil). The apparent differences between this work and that of Bloukas and Paneras (1993) shows that there is disagreement over whether softer oils (such as olive oil) or harder fats (such as lard and palm oil) give a more stable emulsion and a better product.

As already indicated, in meat pies the fat can come from both the meat and the pastry. Indeed, as meat becomes more and more closely trimmed there is a greater likelihood of the pastry playing a greater role. Clearly the size

of the pie also plays a role with portion sizes ranging from 130g up to 250g in a range of steak and kidney pies (Consumers' Association, 2004b). Within this range saturated fat contents varied from 4.8% up to 9%.

Industry views

In terms of whether or not it is possible to either supplement processed meats with more unsaturated fats or to replace saturated fats with unsaturated fats, the comment was made that it is not really possible to use, for example, a low-fat, highly-trimmed meat in sausages and then to add an unsaturated oil to bring the total fat content up to what is normally used for sensory properties (succulence etc). This is because, unlike the natural fat in the meat, added oil would not be within the meat's cellular structure and it would split out of the sausages. Pork backfat is often added to sausages. This is then in addition to the fat which is intrinsically in the meat. Direct replacement of pork backfat with, for example, rapeseed or olive oil is not considered to be feasible. There may, however, be ways of achieving this by the use of emulsifiers, for example. Some research is needed in this area.

British sausages are mainly of the 'coarse ground' variety rather than the emulsion-based frankfurter type. They are also subject to a minimum meat content of 42% (in pork sausages) (Food Standards Agency, 2003). This meat content is taken as consisting of both lean meat and fat. Replacing the fat content then has meant that the lean meat part has had to be increased resulting in a more expensive sausage and also a drier, more crumbly sausage (Das et al, 1995). Replacing fat with water which has been a strategy used in other parts of the world, notably North America, is not generally an option because, even if the lean meat content were maintained at the same level, the overall lean meat plus fat level could fall below the minimum permitted for the product to be called a sausage. Fat reduction may be possible in sausages to a certain extent and this will mean that some of the saturates will also go down *pro rata*. However, even fat-reduced sausages will, in general, still have a red traffic light - so how will the consumer distinguish between a high-fat sausage and a lower-fat one (unless the reduction is such that a reduced fat claim can be made)?

The problem is less acute with burgers because it is believed that the total meat content of both burgers and economy burgers is generally higher than the minimum compositional standards (minimum 80% total meat in 'burgers' only 15% of which can be fat, and minimum 60% total meat in 'economy burgers'). Replacement of the fat component with other ingredients may well then be possible, although in some instances the compositional standards may still present a problem.

Although the traditional British sausage is of the 'coarse ground' variety there is still significant consumption of frankfurter or hot dog sausages. These are produced in a completely different way starting with an emulsion which is extruded into a synthetic cellulose casing before going into an oven to heat-set the sausage. After this the casing is stripped off. In this type of product there is a maximum fat content of 19-20% above which it is not possible to go because the fat would then start to break out during cooking. It is also possible to make quite low-fat, low-saturate types with fat levels of less than 10% and saturates of about 3%. Going lower is considered to be

possible but significant reductions to, say, less than 5% would then start to adversely affect the texture of the sausage. One driver to reducing the total and saturated fat has been to enable introduction of hot dog sausages into schools. While this has been achieved in terms of the product's characteristics and nutritional breakdown it, nevertheless, still carries the tag of a processed product.

Pâtés and, to a lesser extent, terrines have a high fat content which could be reduced without major detriment to the product. However, a significant proportion of these are imported from continental Europe.

Meat pies and pasties contribute about 0.5% of dietary energy daily from saturates but it is considered that a significant proportion of that (possibly even the major proportion) is from the pastry rather than the meat content. This makes reducing saturates in pastry (see chapter 6.1) of as much importance in meat products as in bakery products. Pork pies contain quite a high fat level (typically ranging from 17% to 28% compared to 17% to 21% in steak pies) but the frequency of consumption of pork pies then also needs to be taken into account. Products based on minced beef and sausages are consumed more frequently than are pork pies.

There has been a general upgrading of 'quality' of meats used in ready meals (on the basis of fat content) with more and more products in retailers' premium brand products. Indeed, the retailers can play a big part in fat reduction in meat and meat products since most processed meats are sold under the retailers' own ranges. Because lean meat is more expensive than meat with some fat there is a price effect to take account of. A three-way discussion between the retailers, the processors and the Food Standards Agency may be helpful in moving this area forward more quickly.

5.3 Poultry meat products

Chicken and turkey form the main components of poultry meat consumed in the UK. The fat contents of these meats are shown in Table 13.

Not only are the total saturates levels of these poultry fats below those of mammalian animal fats, more importantly, the total fat content of chicken and turkey meat is some five to eight times lower than beef, pork or mutton/lamb.

Table 13 Fatty acid composition of chicken and turkey meat (from McCance and Widdowson 1998)

Fatty acid	Chicken dark meat raw	Chicken light meat raw	Turkey dark meat roasted	Turkey light meat roasted
Total fat	2.8	1.1	7.0	1.9
Saturates	26.43	28.18	30.00	32.63
Monounsaturates	45.71	43.64	35.43	35.26
n-6 Polyunsaturates	16.43	20.00	21.43	19.47
n-3 Polyunsaturates	3.21	3.64	3.86	3.16
trans	0.71	0.91	1.57	0.53

Where fat contents are higher in poultry products are in breaded and coated chicken products. Chicken nuggets, for example, can contain 13-16% total fat of which about 20% is saturated giving saturated fat contents in the end products of about 2-5.3.0%. While the total fat content is the same the saturated fat content is much lower (<10%) in some 'economy' branded ranges resulting in saturates of less than 2% in the end product.

Chicken Kiev's have higher total and saturated fat contents (20% and 6-8% respectively). The level of saturated fat expressed as a percentage of the total fat is also higher at 25-40%. This could be a combination of different frying oils being used and the fat resulting from the garlic filling. Even though this may be solid before cooking it will melt on cooking and be runny when consumed so, from a textural point of view there is no real reason why a much softer, more unsaturated fat base could not be used for this, possibly based on an unsaturated margarine type of product as opposed to the more traditional garlic butter.

Work carried out on Japanese Quail suggested that there is some limited scope for reducing saturates by dietary supplementation of coriander seeds (Ertas et al, 2005). When 4% of coriander seeds were introduced into the quail's diet total saturates in the bird's breast muscle reduced from 40.73% to 36.45% (10% reduction). While there is no indication that this would work in other types of poultry it is a route that should be considered for mainstream poultry such as chicken and turkey.

5.4 Eggs

Chicken eggs contain about 11.2% fat (McCance and Widdowson, 1998) broken down into 28.1% saturates, 38.5% monounsaturates, 14.4% n-6 polyunsaturates, 0.7% n-3 polyunsaturates and 1.1% trans. This gives a saturates/unsaturates ratio of 0.51.

A report by the Egg Nutrition Advisory Group of Australia (2005) concludes that there is insufficient evidence to excessively restrict egg intake as part of a healthy diet and that reducing saturated fat levels should be the primary focus in reducing blood cholesterol levels.

A patent from Meier and Wilson (1998) discloses the use of L-DOPA (L-Dihydroxyphenylalanine) orally administered to poultry to reduce both cholesterol levels in eggs as well as the saturates/unsaturates ratio. The control eggs (from White Leghorn hens) have a S/U ratio of 0.84. Administering 40mg/kg body weight of L-DOPA per day reduced this ratio to 0.68; administering 100mg/kg body weight per day of L-DOPA reduced the ratio further to 0.63. L-DOPA is also used pharmaceutically in the treatment of Parkinson's disease.

5.5 Fish

In terms of its fatty acid composition, fish is rich in polyunsaturates, particularly the long-chain polyunsaturates, EPA (eicosapentaenoic acid)

and DHA (docosahexaenoic acid). These fall into the omega-3 category of fats and their consumption is to be encouraged.

Processed fish products fall mainly into the sub-groups of canned fish and breaded/battered fish.

Canned fish is either canned in brine or in oil, the latter, of course, contributing to total fat, although because it is generally an unsaturated oil such as sunflower oil it does not contribute significantly to saturates. Nevertheless, it is not unusual to find canned tuna and salmon with total fat contents of 9-10% and saturates of 1.0-2.5%.

Coated fish products range in total fat from 7% up to about 15%. Most of these are based on cod and, surprisingly, they seem to fall into two distinct groups with regard to saturated fat content. One group contains saturates of 10-15% of the total fat phase, while the other group contains 45-50% saturates expressed as a percentage of the total fat phase. This means that some of these products will contain total saturates of about 1% and others 4-5%. There is, then, clearly scope for considerable reduction in saturates in the higher level group, probably by making a change in the frying oil used.

6 Bakery products

Background

The presence of some solid fat is necessary for many bakery products. In the absence of *trans* fatty acids this solid fat will, of necessity, contain some saturated fatty acids. Fats crystallise in a number of different polymorphic forms and those which crystallise in the β' form are particularly useful in bakery products both because of their small crystal structure but also because of their ability to stabilise gas bubbles and hence maintain a lightness of texture in the product.

Depending on the type of product being made the fat has different functions. In cake batters it allows an even distribution of air cells to be produced. As these expand during baking the solid fat crystals which have held the aerated structure in place up to that point melt and are then able to expand with the air bubbles thus still maintaining the texture. In most bakery products the fat coats the flour to reduce gluten hydration and the formation of gluten networks. All of these require a solid fat. Traditionally, in the home, solid fats such as butter or lard would be used and industrial bakers still need to have the same structuring properties although these are now usually obtained from vegetable fats (and these are usually used at a lower level than the home baker would use)

Potential literature solutions

Scavone (1994) of The Proctor and Gamble Company in the United States patented a β' stable, low-saturate, low-trans all purpose shortening based on a combination of a low-saturated liquid oil blended with a hardstock based on PSP and PSS triglycerides (essentially obtained by complete hydrogenation of palm mid-fraction) together with antioxidants and emulsifiers. No details are given in the patent about experiments carried out using this shortening in a bakery application.

Using a completely different technology Masui and Takahashi (2005) disclose a product rich in diglycerides for use in bakery products. These were developed not for any cardiovascular benefits but to inhibit body fat accumulation and are comprised of a mixture of 60-80% diglycerides in which at least 90% of the fatty acids are unsaturated, and 20-40% of a blend of trisaturated triglycerides (45-75%) and triunsaturated triglycerides (10-50%). This type of product (also known as DAG-Oil) is more fully described in chapter 11.2.

Industry views

The paucity of potential literature solutions indicates that this is not an easy area in which to reduce saturated fat. In many bakery products the harder saturated fat has two functions - one is to coat air or carbon dioxide cells in the mix and provide a type of crystalline membrane to hold these air bubbles, while the second is to interact with the flour particles. Both functions are necessary to obtain a good textured, cake, biscuit, pastry or bread. Reducing either total or 'hard' fat will compromise the texture of the final product.

It is possible to go some way towards fat reduction by the use of emulsifiers in the dough or batter but the use of such products then goes against the consumer's desire for 'clean' labels. This has prevented many manufacturers moving into this area.

There are often launches of and increased interest in reduced-fat bakery products in January and February (post-Christmas 'guilt') but then sales often drop off to about 50% of what they were in the first couple of months.

We have to ask the question 'why are there so few reduced fat bakery products?'. This is before even starting to ask what can be done to reduce saturates in particular.

It was felt that reductions in saturates level in bakery products ought to be possible but that there would be consequences to this in relation to cost, handling of doughs, new product developments, labelling and changes to the product.

6.1 Pastry

Traditionally in both home and industrial production of pastry, lard containing 40-45% saturates has been the fat of choice. It is difficult to pick out from industrially produced pastry products (pies, tarts etc) exactly what the fat contribution from the pastry is. The nearest it is possible to get is from the ingredient declaration of industrially-produced, pre-prepared shortcrust and puff pastry intended for home use. A typical shortcrust pastry contains about 30% fat of which approximately one-third is saturated, whereas a typical puff pastry contains slightly less total fat (about 29%) of which over 60% is saturated. The saturates content of the industrially-produced shortcrust pastry is less than that of lard whereas the saturates content of the industrially-produced puff pastry is much greater than that of lard. Both products contain a blend of vegetable oil and hydrogenated vegetable oil so there will also be some level of *trans* fatty acid present.

It is, however, now possible to obtain white cooking fats intended for use as alternatives to lard in home preparation of products such as pastry. These can have saturates levels as low as 21-22% and are based on non-hydrogenated vegetable oils.

Potential literature solutions

Zellen and Miller (2005) describe a method of making low-SAFA pastry in which the fat phase is a highly unsaturated oil which is normally liquid at room temperature. By freezing or partially freezing this oil to below 0°C the oil has the physical structure and texture of a normal pastry fat such as lard or a hydrogenated shortening. They claim that this allows a good pastry to be produced. The colder and harder the fat phase the more suitable it is for puff (flaky) pastry.

If, for example, a pastry fat such as lard were replaced in this way by, say, rapeseed oil then a reduction in saturates from about 40% to less than 10%. This is a patented process which could limit its widespread use unless the inventors were prepared to licence the technology. It is, however, restricted to pastry and it is interesting to speculate on whether it would also be applicable in other bakery products such as biscuits and cakes

Industry views

The solid (i.e. saturated) fat which is used in pastry shortenings and also in biscuit doughs coats the flour particles preventing the formation of a tough gluten network. Harder fats are needed for this to ensure good coating; softer fats do not separate the flour grains sufficiently to prevent the gluten network from forming. Harder fats also contribute to the eating characteristics of pastry. If the pastry fat is too hard, however then it can be difficult to block out the pastry without risk of it cracking. On the other hand, if it is too soft then the compressed air used to attach the pastry can blow the crimp of a covered pie off. Fat contents in pastry have been reducing slightly from 50% to 40% (both levels based on flour).

As in other parts of the food industry moves have been made away from hydrogenated and *trans*-containing fats to *trans*-free systems. In some instances this has even allowed a reduction in saturates as well, i.e. the saturates level in the new fat system is less than the saturates in the old fat system even when *trans* has also been removed. Having said that, the industry now feels that they are at the limit of saturates reduction in pastry.

The solid fat content is important and, since there can be a wide variation in the ambient temperature in bakeries, a flat melting profile (giving more or less the same solid fat content over a wide temperature range) is preferred.

The idea of reducing oil and mixing temperatures to 0°C to allow more unsaturated oils to be used had not been considered before but the comment was made that this would result in increased energy use.

Having said that, it was felt that shortcrust pastry was the least sensitive system. The main requirement of the shortening was to prevent gluten

development. However, the influence of solid fat content on this had not been specifically defined.

Laminated products such as puff pastry (and also laminated puff biscuits and crackers) need to have a fat whose rheology is similar to that of the dough. If it is too high (as indicated by higher solid fat content) then the dough will tear; if it is too low (as indicated by lower solid fat content) then the oil will soak into the dough rather than provide separation between the laminations.

6.2 Biscuits

Background

The solid (i.e. saturated) fat which is used in pastry shortenings and also in biscuit doughs coats the flour particles preventing the formation of a tough gluten network. Harder fats are needed for this to ensure good coating; softer fats do not separate the flour grains sufficiently to prevent the gluten network from forming.

Biscuits have been a product segment in which there may have been a small increase in the level of saturated fat as a result of the removal of partially hydrogenated fats. Although butter was, and is still, used as the dough fat in premium quality biscuits many biscuits used a blend of palm oil with some partially hydrogenated vegetable oil as the dough fat. These oils were typically partially hydrogenated palm oil, rapeseed oil or soyabean oil used at between 10% and 25% of the blend (the remainder being unhydrogenated palm oil). In many cases these blends have been replaced as dough fats by palm oil itself. This would give a saturated fat content to the fat phase of the biscuit of about 50% compared with about 65% if, for example, butter were used as the dough fat.

Food Standards Agency (2002) for example, quotes digestive biscuits as containing 24.1% fat (broken down into 12.2% saturates, 8.9% monounsaturates, 1.6% polyunsaturates and 1.6% trans). Such a biscuit is now more likely to be produced from palm oil and, with the same fat content would contain 12.3% saturates, 9.2% monounsaturates and 2.7% polyunsaturates. Shortbread biscuits contain 27.5% fat broken down into 18.2% saturates (66.4% on fat phase), 6.7% monounsaturates (24.4% on fat phase) and 1.3% polyunsaturates (4.7% on fat phase) (Food Standards Agency, 2002) - a fatty acid distribution similar to that of butterfat.

Both total fat and saturated fat in digestive biscuits have reduced slightly since 2002 down to 21.5% and 10% respectively in a branded product example and 18.1% and 8.5% respectively in a retailer's own brand product. The latter example shows a reduction in total fat of 25% and in saturates of 30% compared with the 2002 information.

Reduced fat biscuits can be produced but only by including emulsifiers such as DATEM esters, sodium stearoyl lactylate and mono- and diglycerides of fatty acids. For example, full-fat custard creams can contain over 23% fat and almost 15% saturates. Reduced-fat custard creams, however, can contain less than 18% total fat and less than 9% saturates. In such an

example, reducing the total fat content by 25% also allowed a reduction in saturates of over 40% (although the calorie content in both full-fat and reduced-fat biscuits are almost identical)

Generally speaking, some fat which is solid at room temperature is necessary in a biscuit in order to give the biscuit its correct texture and snap. Replacing a solid dough fat with a completely liquid oil will give a much softer biscuit and one which will have an oily feel - indeed oil exudation from the biscuit would be a serious issue with biscuits produced in this way.

Work is being carried out at the Satake Centre for Grain Process Engineering, Manchester University by Dr Grant Campbell on the formation and stabilisation of bubbles in food which clearly has relevance to structural characteristics in bakery products and which may therefore also have some relevance to saturated fat reduction. Unfortunately, time did not permit a discussion of this area with Dr Campbell at UMIST. However, a presentation which he gave at the 52nd BCCCA Technology Conference (2005) discussed work carried out on biscuit aeration and texture. Much of this was achieved by positive aeration of doughs at different pressures. The research also studied the effect of biscuit sheeting on subsequent degassing of the doughs. Sheeting in which the final thickness was achieved by a small number of large reductions resulted in less removal of gas than did a more gentle sheeting regime. Clearly processing in such instances has as much effect on the final product texture as does the type of fat being used.

It is often considered that savoury cracker type biscuits contain significantly less fat than do sweet biscuits. In some instances this is correct with some of these products containing less than 10% fat. Cream crackers, however, can contain 12-15% total fat and, in some instances, this is about 50% saturated fat. This is not too different from the fat content of rich tea biscuits. Other savoury biscuits, especially those which have a 'puffed' laminated texture can contain up to 30% total fat of which, in some instances, 70-80% of the fat can be saturated. In extreme examples the saturated fat content of the savoury biscuit can be 22-25%. This is much higher than in most chocolate coated sweet biscuits and is clearly an area that the biscuit industry needs to address. The main problem is again one of functionality - that high saturated fat content is needed to give the 'lift' to the laminated biscuits and to separate the dough layers (similar in many ways to puff pastry). This means that alternative technology either in processing or in the form of other ingredients to give the same effect is needed.

Potential literature solutions

In a completely different type of technology cookies have been made using DAG oil (a mixture of diglycerides rather than triglycerides). This is more fully described in chapter 11.2.

Work has been reported by Talbot (2006c) in which specific palm fractions were used to replace whole palm oil as a biscuit dough fat. In the example given the total fat content in the biscuit reduced from 17.3% to 12.1% and the saturates reduced from 8.8% to 5.5%.

Industry views

As most manufacturers have now replaced partially hydrogenated dough fats with non-hydrogenated alternatives, palm oil is now the main fat used as a biscuit dough fat. Although it is theoretically possible to use a dough fat with a lower level of solids and a greater degree of unsaturation there are a number of issues with this.

The whole process of mixing the biscuit dough revolves around having the fat in a plasticized form. If the solid fat content of the dough fat is decreased it will become increasingly difficult to get the fat in such a form and so biscuit manufacturers would then need to look at different ways of actually incorporating the fat into the dough. This may mean the use of different dough fats for different biscuit types meaning significant investment in both fat storage and mixing.

In terms of processing, mixing and forming of the biscuits becomes more difficult when softer dough fats are used. In batch operations where quantities of up to 1 tonne of dough can be mixed and stored in a hopper prior to rolling and forming it is likely that simply the weight of the dough would be enough to cause some oiling out. This could be further exacerbated during rolling and forming of the dough sheets

If more unsaturated dough fats are used rancidity becomes an increasingly important factor and shelf-lives will need to be reduced.

In chocolate coated biscuits the degree of migration of dough fat into the chocolate will increase if a softer, less saturated dough fat is used. This then, in turn, causes softening of the chocolate with accompanying consumer handling issues and a greater risk of fat bloom formation. The same comment applies to changes being made in the fat phase of biscuit creams - the softer they are the greater the rate of fat migration between the cream filling and the chocolate coating.

As with dough fats, the fats used in biscuit creams have changed over the past few years from partially hydrogenated to non-hydrogenated systems. In some instances this change has had considerable implications in terms of crystallisation characteristics with the non-hydrogenated alternatives not always crystallising in the same way or at the same rate as the original partially hydrogenated cream fat. In some instances, palm kernel oil is still being used as a cream fat, again mainly for its positive crystallisation characteristics compared with lower saturated but slower crystallising creams. This is clearly a target for the oils and fats industry to produce biscuit cream fats with the crystallisation characteristics of palm kernel oil but with significantly lower levels of saturated fat.

There are also potential regulatory issues with some biscuits, particularly shortbread where butter at a minimum level needs to be used. The fat level needs to be a minimum of 24% and at least 70% of that needs to be butterfat. This level is probably needed in order to obtain a recognisable shortbread texture but perhaps the definition of butter could be explored - for example, would butter oleine (the soft, more unsaturated fraction of butter - see also chapter 4.1) still be classed as butter in this context?

The idea of using specific palm fractions to allow reductions in both total fat and saturated fat (see Talbot, 2006c above) has been used in the United States but resulted in some handling problems in that the doughs were softer than the normal doughs. The biscuits produced in this way were, however, acceptable. This then may present a partial solution to saturates levels in biscuits in the sense that it could be used for 'robust' doughs.

The use of lower-saturate dough fats results in denser biscuit doughs. If too liquid a dough fat is used then the dough texture becomes too homogeneous - it is necessary to have pockets of fat throughout the biscuit dough which, on baking, melt to leave a hole.

The sales of 'healthy', i.e. low-fat biscuits are static at about 5 million packets per month.

6.3 Cake

Reduced fat cake products are available on the market but their scarcity is something of an indication of the difficulty of producing them. Alternatively it could be an indication of a lack of acceptance of the product by the consumer. They tend to be mainly in the 'plain' or iced cake slice sector in which a fairly plain sponge cake forms the bulk of the product with a fat-free icing as the main decoration.

As an example one of the major retailers produces lemon slices with (a) over 16% fat and (b) less than 2% fat achieved solely through recipe formulation as opposed to portion size. Indeed, if anything the low-fat version has slices that are slightly heavier than the full-fat portion. The trade-off, however, for such a significant degree of fat reduction is the use of a much longer list of additives, predominantly emulsifiers such as DATEM esters and stabilisers such as pectin, guar gum and carageenan. The low-fat slices are also cheaper than the full-fat product.

Similarly, full-fat (18.5%) and reduced-fat (12.9%) Cherry Bakewells are available where, despite a lengthy ingredient list the main difference seems to be in the composition of the cake portion of the product. Again, emulsifiers are needed to achieve the fat reduction - in this case, mono- and diglycerides of fatty acids and polyglycerol esters of fatty acids. As well as having a much lower total fat content the reduced fat product also contains less saturated fat when expressed as a proportion of the total fat indicating that these beneficial changes can be made providing it is accepted that extra emulsifier will be needed. There is no difference in price between the full-fat and reduced-fat products

Industry views

Reducing the total fat content of batter-based products such as cakes will result in adverse structural changes in the end product and, because reduction in fat is usually accompanied by an increase in the water content, there will also be an increase in water activity. This then will have further implications for the product in terms of a reduced shelf-life and an increased possibility of mould growth. If the fat is present only for shelf-life reasons, i.e. to ensure a low water activity, rather than for any

structural properties it may impart then it might be possible to replace a more conventional bakery shortening by an oil such as rapeseed oil or sunflower oil.

The fat in a cake batter has a functionality in terms of providing a 'membrane' around the air cells and allowing them to expand during baking whilst still protecting them from collapse. A further function of the fat in a cake batter is to coat the flour allowing water retention and gluten hydration to take place.

The harder the fat is the more effective it is at performing both of these functions. Hard fats can only be produced by including either saturated or *trans* fatty acids. As the industry has gone to great lengths to remove hydrogenated fats and *trans* fatty acids from such products this leaves only saturates to perform this function. If these harder fats are replaced by softer (more unsaturated) ones then the quality of the cake batter is compromised resulting in a heavier, tougher texture in the cake.

Cake shortenings need a balance between liquid and solid fats. The liquid fats are needed to provide an interface on the surface of bubbles in the cake batter but solid fats are then needed to stabilise these bubbles as they grow.

Different cake batter types may well require different fat phases for optimal performance. The optimisation of the fat phase for specific cakes would need to be carried out. Carrying a wider range of bakery fats in a factory could be problematic when manufacturers are trying to consolidate their ingredients as much as possible.

Creams and toppings are generally more significant in terms of fat content than is the underlying cake.

Butter creams are subject to a minimum level of 22.5% butter (and no other fat) being present. The question of butter definition can again be raised - would a butter oleine also be classed as butter? On the other hand, whilst this would help to reduce saturates there would be significant cost implications to the bakery industry not only because fractionation adds to the cost but also because it is possible that butter oleine would not have the 'intervention' status of butter.

Shelf-life stability is again an issue because extra tolerance is needed in such creams due to the ambient storage of cakes.

6.4 Other bakery products

Although the fat content of bread is quite low compared with many other bakery products it does have a very specific function and one which, in many ways, is related to its saturated fat content. This function relates to a solid fat's ability to stabilise gas bubbles as mentioned earlier and is best described by Brooker (1996) when he says that the fat crystals which attach themselves to gas cells in the dough act almost like a cell membrane around the gas bubbles allowing the bubbles to grow as the dough ferments. Crystals are necessary for this to occur and liquid oil does not function

anywhere near as well. Omitting the fat phase altogether is even worse. This was demonstrated by Smith and Johansson (2004) who compared bread weights and volumes when emulsions of differing solid fat contents were used in bread. As the percentage of solid fat in the emulsion increased so the density of the bread as defined by weight/volume decreased. With an emulsion containing 20% solid fat the bread density was 0.259 g.ml^{-1} . Increasing the solid fat content to 60% reduced the density to 0.241 g.ml^{-1} . With no fat present in the bread density increased to about 0.29 g.ml^{-1} . As well as giving a lighter loaf, the presence of solid fat contributed to a slower rate of staling.

Sabanis and Tzia (2006) compared a number of unsaturated liquid oils with a commercial vegetable shortening and a bakery margarine in bread based on durum wheat flour at levels ranging from 3% to 11%. They found that olive oil improved the dough the most in terms of its rheological, sensory and staling properties, although levels of addition above 7% were to be avoided.

Industry views

The amount of saturated fat used in bread is very low at about 1% but it is highly functional, mainly for the reasons given by Brooker (1996) and it would prove impossible to take it out.

7 Chocolate and chocolate confectionery

The main areas where fats and saturated fats are found in confectionery are in chocolate and chocolate-flavoured coatings, chocolate fillings, toffees and caramels. There is very little (usually less than 1%) fat found in sugar confectionery products such as gums, jellies, mints etc.

7.1 Chocolate

The very nature of chocolate is defined by its hardness, bite, snap, gloss (as a result of contraction in moulds) and overall texture. These sensory characteristics are, in turn, a function of the fat phase of the chocolate and, more specifically, a function of the solid fat content of the chocolate. This level of solid fat is only achievable by having a certain proportion of saturated fat in the chocolate. Reducing the saturated fat level significantly will reduce the solid fat content which, in turn, will adversely affect all the sensory properties which are prized in the product.

Chocolate is also subject to quite restrictive legislation (European Union, 2000). With regard to the fat content, chocolate must contain a minimum of 25% total fat and only cocoa butter and milk fat contribute to this figure. Plain chocolate can be made solely from cocoa butter; milk chocolate falls into two types, one containing a minimum of 3.5% milk fat, the other containing a minimum of 5% milk fat. Cocoa butter contains 60-65% total saturates, milk fat contains 60-75% total saturates. Typically, then the fat phase of chocolate will contain about 65% total saturates. Even at a minimum fat level of 25% this is about 16% saturates in the chocolate itself. At a more normal fat content of about 30% then there will be about 20% saturates in the total chocolate. The chocolate legislation allows very little

to be done about reducing this, at least while still maintaining the total fat content at about 30%.

The only scope there is - and it is a very minimal scope - is within the permitted vegetable fat. The EU now permits the use of 5% vegetable fat to be added to chocolate but this vegetable fat must be sourced from one of six basic oils. Palm oil and shea butter are two of these oils. These oils are normally fractionated to produce a fraction rich in the higher melting triglycerides of the type also found in cocoa butter (the so-called symmetrical SOS-type of triglyceride). This fractionation leaves a much softer, more unsaturated oleine fraction. As fractionation is a permitted process within the chocolate regulations, these fractions could be used in chocolate.

There are, however, two issues with this approach. The first is that adding 5% of palm oleine or shea oleine will result in a softer chocolate. This can be countered by reducing the milk fat content but such an action may well take the chocolate outside the scope of one or other of the milk chocolate definitions. The second issue is that even taking this approach does not make a huge difference to the total saturates. A chocolate containing 30% total fat of which 25% is cocoa butter and milk fat and 5% is palm oleine will contain about 18% saturates (16% from the cocoa butter/milk fat plus 2% from the palm oleine). This is a reduction of only 2% from a chocolate containing either no or a normal vegetable fat and could also be achieved by reducing the total fat content in the chocolate to about 27.5%.

It is possible to produce chocolate with the minimum fat content of 25% (see industry comments below). The EU legislation, however, is worded such that, as far as the regulations are concerned, only cocoa butter and milk fat count towards the fat content - not vegetable fat. This is clearly at odds with the level of fat that is declared on the label of chocolate products where all types of fat present in the chocolate need to be declared. This means that if the true fat content of chocolate is reduced to below 30% then the amount of vegetable fat that can be used in the chocolate needs to be reduced to below the permitted 5%. This will then have implications to the overall cost of the chocolate and, in some cases, its functionality in terms of bloom and heat resistance.

Chocolate containing only 25% fat cannot therefore contain any vegetable fat. Such a chocolate would contain about 16-17% saturates.

The possibilities that there are then are:

- a) chocolate as currently produced in the UK containing about 30% total fat including 5% 'conventional' cocoa butter equivalent (vegetable fat) which would have a saturates content of about 20%.
- b) Chocolate as currently produced in the UK containing about 30% total fat including 5% of a softer, more unsaturated vegetable fat and a lower milk fat content to compensate for the softening of the vegetable fat, which would have a saturates content of about 18%.
- c) Chocolate containing only the minimum fat content of 25% and no vegetable fat which would have a saturates content of about 16-17%.

While the last option is possible the lower fat content would (a) make it more difficult to produce and (b) give it a different texture in the mouth. Option (b) would allow a 10% reduction in saturates.

The effect of stearic acid on cardiovascular health is, however, something that needs to be considered in relation to saturates in chocolate. A significant proportion (up to two-thirds) of the saturated fat in chocolate is stearic acid. Other parts of this report discuss the cholesterolic effects of stearic acid in comparison with other saturated fatty acids. It is important also to bear in mind the cardiovascular benefits of other components, particularly in dark chocolate, such as polyphenols.

There is also a trend to 'premium' chocolates with higher cocoa solids content. These do not usually contain any vegetable fat or any milk fat but it is often suggested that their high cocoa and, particularly, high polyphenol contents confer health benefits. Cocoa liquor which is used as the main source of cocoa solids in these chocolates typically contains about 55% fat (cocoa butter). This means that a 70% cocoa solids chocolate can contain about 40% total fat and about 26% saturates.

Industry views

It is technically possible to make chocolate with less than 25% fat - levels of 18-24% are possible and have been patented. If, for health reasons, fat intake is to be reduced then 25% minimum fat in chocolate is an unnecessary limit. It is, though, enshrined in EU law and would require legislative changes to be made to allow such reductions to be made.

Softer, more unsaturated cocoa butters could be used in chocolate. For example, cocoa butter from Brazil is usually richer in the more unsaturated SOO triglycerides than cocoa butter from West Africa and Malaysia. Brazil is, however, now a net importer of cocoa butter and so this softer cocoa butter may not be readily available. Alternatively it may be possible to include cocoa butter oleine (the soft fraction from cocoa butter fractionation) as a component of chocolate. Thirdly, it may be possible to modify the level of saturated fatty acids in cocoa butter by plant breeding. All of these routes, however, will produce a softer chocolate unless, for example, the milk fat content is also reduced to counteract this.

Because of the textural and legislative difficulties associated with reducing saturated fat in chocolate a number of the leading chocolate manufacturers have collaborated in a 'Be Treatwise' message which stresses the importance of moderate consumption. Smaller portion sizes, often aimed at an 'under 99 calories' claim, have also been introduced.

7.2 Confectionery fillings and products

Both the total fat content and the saturated fat content of confectionery fillings can be reduced by replacing the fat to a greater or lesser extent by a fat mimetic or even by an aqueous system. Campbell (2002) describes a filling system based on water, a fat mimetic, a sucrose substitute, flavouring and a humectant. In systems such as this it is important to also ensure that the water in the filling is unable to interact with the coating composition. In particular, it is important to prevent any sugar in the

coating being dissolved in the aqueous phase of the filling as this will weaken the coating and eventually cause it to collapse.

Industry views

Products such as cereal bars have a certain health image - but they often have a chocolate component. Using less chocolate on such products would help to reduce both fat and saturated fat. There is, however, a public perception that healthy products don't taste good.

The trend towards the use of 'natural' ingredients, especially the view that if it cannot be found in the kitchen cupboard it should not be used, means that some technological solutions to fat and saturates reduction are not possible because of the additives which would be necessary.

Lauric fats which are used as biscuit or wafer creams in some confectionery countlines could be replaced by palm fractions. This would give a significant reduction in saturates (by some 30%) but in terms of breadth of application could be quite limited.

As with some other products the question of benefit to the manufacturer of reducing saturates is important. In general the texture and taste, followed by the cost of fillings and filled confectionery products is more important than the level of saturates - unless a reduction in this allows the product to go through a threshold. If a claim could be made or if a different traffic light colour could be achieved then a reduction in saturates level would become an important factor. But for so many confectionery applications a fairly high level of either fat *per se* or saturated fat in particular is needed for functionality that generally these products are not near a threshold. The industry cannot invest if they see no business benefit.

Over the past five years or so the industry focus has been on removing *trans* fatty acids from products. Although this has resulted in some increase in saturates the industry has had as a target that removal of *trans* should not result in a saturates level higher than the original saturates + *trans* level.

7.3 Toffees and caramels

Industry views

With the replacement of hydrogenated vegetable oils in these products, often by fractions of palm oil, there has been an increase in total saturates (even though this has also, in many cases, been accompanied by an increase in *cis*-unsaturates). Since the industry has expended a great deal of effort on making these changes (indeed, not all changes are yet complete) there does not appear to be any further development work in progress on reducing the saturated fat levels in toffees and caramels.

Once again, the question of functionality is the main stumbling block to further saturates reduction. Higher unsaturates results in toffees with less ability to retain the shape and a greater propensity to flow. This then adversely affects downstream processes such as enrobing and wrapping which are geared to the products always having the same shape, size and structure. The comment was also made that there is a limitation on what

the fat suppliers can produce that is both lower in saturates and functions the same as a higher saturated fat would.

Another factor to take into account is that toffee fats are often used for other functions in the factory, e.g. cream fats or biscuit dough fats. In such cases the fat is selected for the most critical operation even though, perhaps, a lower saturated fat could be used for the other applications. Tankage and storage would not allow separate fats to be used for each particular application.

8 Savoury snacks

Many savoury snacks are produced by industrial frying. Solid fat content is much less important in such processes because the frying is carried out at temperatures well above the melting point of any fat medium likely to be used. What is important is to have a frying oil which is as oxidatively stable as possible in order to (a) prolong the 'fry-life' of the frying oil and (b) give as long a shelf-life as possible to the fried snack without it becoming rancid.

For these reasons, partially hydrogenated vegetable oils have often been used as industrial frying oils. With the move away from such oils in food they have been replaced by a variety of oils. In many cases these have been either low-melting fractions of palm oil or sunflower oil modified (by plant breeding techniques) to have increased levels of oleic acid. Even so, there is a balance between oxidative stability and unsaturated fatty acid content in that, generally speaking, the greater the degree of unsaturation the lower the oxidative stability. This means that the new breed of 'mid-oleic' sunflower oil (Nu-Sun) has a higher stability than traditional polyunsaturated-rich sunflower oil and that high-oleic sunflower oil is oxidatively more stable still. Furthermore a naturally stable canola (rapeseed) oil has been bred in North America with a low level of saturates.

The stability of these oils and their level of saturates are shown in Table 14

Table 14 Oxidative stability and saturated fatty acid content of frying oils (from Dzisiak (2004))

Oil	Saturates (%)	Oxidative Stability Index (hrs at 110 °C)
High-oleic sunflower	6.9	14.5
Naturally stable canola	7.7	17.0
Normal canola	9.3	7.9
Mid-oleic sunflower	10.5	4.8

High-oleic sunflower oil has a very low level of saturates and because the unsaturated fatty acid content is primarily oleic acid (monounsaturated) it also has a reasonably good oxidative stability index. These numbers need to be contrasted with, for example, palm oleine which has an estimated oxidative stability index⁷ at 110 °C of 24 hours and a saturated fatty acid content of about 39%. Greater oxidative stability can be obtained with palm oleine but at the expense of an increase in saturates.

⁷ Estimated by doubling the Rancimat Induction Period measured at 120 °C

Various patents exist for the production of reduced saturated fat rapeseed and other oils (Wong et al, 1996; Shah et al, 2005; Weselake et al, 2005; Thompson et al, 2006) but these are all using genetic modification as a means of obtaining this kind of fatty acid composition.

Significant changes have been made to the types of industrial frying oils being used in the production of savoury snacks. The saturates content (as a percentage of the total fat) is either in the range of 40-50% (possibly indicating a preference for the use of palm oil or palm oleine as the frying medium) or much lower at around 12% (where a much more unsaturated frying oil was being used). Total fat contents typically ranged from about 25% up to 35%. This meant that the saturates level in the end product was either quite low at 2-4% or quite high at 13-15% depending on the frying oil being used.

Some of the changes made to the frying media were originally to replace partially hydrogenated *trans*-containing vegetable oils. The challenge to the industry was what to replace these with. In many instances the answer has been to replace them with sunflower oil - in some instances this has been the high-oleic acid variety of sunflower oil which has the added benefit of better oxidative stability than traditional sunflower oil. This approach is now being adopted by the leading manufacturers of these types of product. However, this approach has not yet been adopted across the industry and it is possible to still find savoury snack products with the much higher level of saturates, even in some products made by manufacturers who have changed to a lower saturate oil in other products.

Clearly, adoption of an oil such as high-oleic sunflower oil across the whole savoury snacks category would lead to a significant reduction in saturates. However, sourcing of the oil would then become an issue because it is still at such a stage in its life-cycle that it is in fairly restricted supply and manufacturers have to contract well ahead for it rather than purchase on the spot market as they can with some other more commodity oils.

9 Soups, sauces, ready-meals

9.1 Soups

Soups are generally low-fat products (Food Standards Agency, 2004a). The highest level surveyed was 5.8% and almost 70% of products contained less than 3% fat. Soups containing croutons add significantly to the total fat content (in some instances bringing the total fat up to about 18%). They also can contain quite high levels of saturates (about 60%) suggesting that if a different frying medium were used the saturates level could be reduced even if the total fat content stayed the same.

9.2 Sauces

Cooking sauces come in two main varieties - those which are liquid and sold in jars to pour on or stir in to home cooked pasta and meat dishes, and those sold dried in packets to which water is then added to reconstitute the sauce. The liquid stir-in sauces range in fat content from less than 1% to over 30% and in saturates from zero to about 9%. The low-fat sauces are

generally tomato-based sauces for use on pasta, although the sauces high in saturates are also pasta sauces containing mascarpone as well as tomato - in this case 75% of the fat phase is composed of saturated fat. Although there are examples of high-fat and high-saturate sauces to be found these types of product generally contain less than 10% fat and less than 3-4% saturates. A group of ready-to-use sauces which perhaps give greater cause for concern are those which are short shelf-life, chilled sauces containing cheeses such as mascarpone and mozzarella in which the total fat content is typically about 10% and the saturated fat content about 5%.

The dried packet varieties of sauce mix are, in general, low in fat and saturates although it is possible to find one or two varieties containing up to about 9% fat of which over half is saturated fat.

Table sauces such as tomato ketchup and brown sauce contain very little fat and so contribute little in terms of saturates to the diet. Stock cubes can contain up to about 5% fat typically half of which is saturated (irrespective of whether it is a beef stock cube or a vegetable stock cube). The manufacturers of these products could well look at the formulation to see if the saturated fat component used could be replaced with a less saturated alternative.

Although, in general, sauces and dressings do not contribute in themselves a high level of fat into the diet they can in some instances contain a significant level of fat (for example mayonnaise and other salad dressings). Nevertheless the major manufacturers do already produce lower fat varieties of products such as mayonnaise and salad dressings.

9.3 Ready Meals

The term 'ready meals' can cover such a wide spectrum of dishes that it is difficult to give specific recommendations. The main categories, however, are segregated below together with comments relating to each of them.

In 2004 the Consumers' Association carried out a survey of a range of ready meals looking at, amongst other things, fat and saturated fat levels (Consumers' Association, 2004b). One of the issues that can be highlighted from this report is that of portion size. Not only were there big differences in saturated fat expressed per 100g but there were also big differences in portion size which in some instances exacerbated the effect of saturates (i.e. high saturates per 100g and big portion size) but in other instances reduced the effect.

The large differences that can be seen in both total fat and saturated fat contents in ready meals begs the question as to why, if it is possible to have good products with low levels of fat/saturates, don't more products use these formulations. Often large differences are seen within the range of products produced for the same retailer. There should be scope for a re-evaluation of recipes to reduce the levels of saturated fat in many of these products.

Pasta

Both fresh pasta and canned pasta products such as spaghetti rings generally contain little fat or saturates. The areas which are of greater concern are

stuffed pasta products (ravioli and tortellini) and lasagne. The stuffed pasta products contain typically from 5-9% total fat (compared with about 2-3% in unfilled fresh pasta) of which half is typically saturated fat. This clearly comes from the filling which is often cheese or meat based. Perhaps this is an area where a reduced-fat cheese could well be used without encountering any adverse textural effects.

With regard to lasagne portion sizes can range widely from, for example, 300g to 600g (Consumers' Association, 2004b). Saturated fat contents ranged from 1.4% to 4.9% but portion size differences meant that actual consumption of saturates per portion could range from 4.2g (300g portion) to almost 20g (550g portion).

Asian dishes

Many soups and sauces are 'structured' in terms of their thickness and creaminess by saturated fats. Indeed many Asian dishes use, for example, coconut milk to give texture to dishes such as curry and dips. Inglett et al (2002) investigated the possibilities of replacing coconut milk in a Thai green chicken curry with Soytrim. Soytrim is based on a 1:1 mixture of soy flour and oat bran and is made by dispersing these ingredients in boiling water and homogenising. They replaced coconut milk with Soytrim at levels of 50%, 75% and 100% replacement. At 75% replacement the saturated fat content of the fat phase of the curry reduced from 74.4% down to 18.8% (about 75% reduction). In terms of sensory properties, a panel could distinguish this from the control and generally scored it lower. When only 50% coconut milk was replaced by Soytrim, however, there was no statistical difference between the scores for the two types of curry. In that case, the saturated fat reduction, though significant, would be less.

As with many other ready meals portion size can vary from 375g to 500g in Chicken Tikka Masala (Consumers' Association, 2004b) resulting in saturated fat contents ranging from 0.7% to 3.8%. Although these ranges may not seem as broad as in some other ready meals when the smallest portion size coincides with the lowest saturated fat content and the largest portion size with the highest saturated fat content, the amount of saturated fat per portion can range from 2.7g up to 17.6g. This can also be the case when a high-fat content Indian dish also contains a high proportion of saturated fat within the total fat. This is particularly found in dishes rich in coconut cream which can typically contain about 16% total fat of which 90% is saturated.

In terms of supermarket ready meals, Chinese dishes tend to be lower in both total fat and saturated fat than do Indian dishes.

Fried foods

Mainly of relevance to fried foods and foodservice outlets the invention described by Buckley (1990) would, nevertheless, also have some use in-home for quick production of reduced fat French fries, burgers etc. Essentially this process first pre-cooks the food (be it French fries or a meat-based product) by microwave. The food then passes along a conveyor where it passes through a well-controlled mist of heated oil or oil/water. It can then, if preferred, also be sprayed with a flavour appropriate to that of the fried food. The oil can be chosen to have a very low saturates content and because it is not being used at 180°C in an industrial fryer, the

oxidative stability of the oil may be less of an issue. The amount of oil on the product is also much better controlled than in an industrial fryer where oil is absorbed through and into the product. In this case the oil is only on the surface meaning that not only can the saturates level be controlled but the total fat content will be less than with the conventional product.

Many of the comments made about the use of different frying oils in the production of savoury snacks (chapter 8) apply also to the use of these oils in fried foods. A balance between saturates level and oxidative stability needs to be made. Highly unsaturated oils such as sunflower oil are nutritionally more acceptable than more saturated oils such as palm oleine but they are also oxidatively less stable. This has two effects. Firstly the lower oxidative stability can shorten the life of the frying oil in industrial frying. Secondly because a proportion of the oil carries through to the final products it can also have implications on the shelf-life of the product. Oxidation is, however, temperature-dependent with a general rule of thumb that it proceeds at half the rate for every 10°C drop in storage temperature. Since most fried foods in the ready meals sector are either short shelf life chilled products or longer life frozen products the reductions in storage temperature in both groups should allow replacement of more saturated oils obtained from palm oil by more unsaturated oils such as sunflower oil or high-oleic sunflower oil.

Pizzas

The total average fat content of pizzas can range from just over 2% up to almost 15% with the lowest amount being found in 'healthy eating' and children's ranges and the highest in those pizzas with 'extra cheese' toppings. The levels of saturated fat within these ranges also varies considerably with the 'economy' ranges of cheese and tomato pizzas having the lowest proportion of saturates (34% of the fat phase) even though their total fat content is mid-range (9.4%) (Food Standards Agency, 2004b).

The type of topping plays a overwhelming role in both total fat content and saturates content because, in most cases, the fat content of the base is very low. In cheese and tomato pizzas total fat content ranges from 9.0-11.8% (excluding the healthy and children's ranges) whilst saturates range from 41-48% of total fat (excluding the economy range). Meat topped pizzas have a comparable total fat content (8.8-11.7%) but a slightly lower saturated fat content (41-45%) possibly reflecting the differences in saturated fat in cheese and meat. Not surprisingly, vegetable topped pizzas have lower total fat contents (7.3-9.6%) but a wide range of saturated fat contents (39-51% of total fat phase).

When comparing take-away pizzas with retail pizzas, the take-away pizzas usually had a lower total fat content than retail pizzas but a greater proportion of the fat phase was saturated in take-away pizzas. This trend was apparent in all three types of topping.

The nature of the topping is clearly of great importance in terms of a potential reduction in saturated fat. The use of reduced-fat cheese or reduced-fat meat will give an overall reduction in saturates. Indeed, this might be one of the most ideal uses of reduced-fat cheese because in a molten form some of the textural drawbacks may not be as apparent.

As with many other ready meals, portion size plays a big part in determining fat and saturated fat intake. The portion size on cheese and tomato pizzas, for example, can vary from 56g up to 365g! The portion size of some pizzas is the whole pizza while in other cases the portion size is half a pizza (and, very occasionally, one-third of the pizza. Whilst to some extent there is a relationship between the size of the pizza and the size of the portion (i.e. the larger the pizza the more likely a portion is to be a half or even a third of the pizza), there is not total consistency in this, even within the same retailer. It is also likely that the consumer ignores this anyway and generally treats the whole pizza as a serving! Saturated fat in cheese and tomato pizzas can vary from 1.5% up to 6% (Consumers' Association, 2004b) with saturated fat per serving ranging from 2.3g (in a 135g serving) to 18g (in a 365g serving).

Quiches

With a combination of egg and either milk or cream making up the bulk of the filling and pastry the outside of the product there is clearly great potential for such a product to contain a high proportion of saturated fat, and, indeed, this is often the case. Total fat contents range from about 15% to 21% and saturated fat typically makes up 40-50% of this thus contributing 6-10% of the product. There may be some scope for reduction both by making whatever changes are possible to the pastry shortening and also reducing the fat content of the dairy components in the filling.

Foodservice

Not all of the major High Street fast food outlets declare the saturated fat content of their products (although they do declare total fat contents). Because some companies only quote nutritional contents per serving while others quote them both per serving and per 100g it is not easy to compare across the board (because portion sizes are different from each manufacturer). Consequently the best comparison that can be made is of saturated fat as a percentage of total fat.

In French fries this can vary from less than 10% to up to 30%, the variation being indicative of different frying oils being used. As a comparison with fries and chips purchased in supermarkets (usually either microwave or oven cook), the fast food outlets have much higher total fat levels (about 15% compared with up to 7% in microwave or oven chips) but the proportion of saturated fat within their fat phase is often lower with some oven chips containing up to 50% saturates in the fat phase. The higher total fat content in French fries from fast food outlets is influenced by the thinness of the product compared with the thicker chips often bought for home cooking. If the fast food companies were to produce thicker French fries then they could well contain less fat overall and by ensuring that the frying oil used is low in saturates the total saturates in the product would be reduced considerably.

Straight hamburgers (i.e. burger, bun plus relish) contain 35-45% saturates within the fat phase, the greatest proportion of which comes from the hamburger patty itself (which can have a fat phase containing about 50% saturates). This compares with beefburgers from a supermarket which contain typically 40-55% saturated fat as a proportion of the total fat phase. The total fat content of the hamburger patty is about 18% again comparing

well with levels found in supermarket bought beefburgers which range from 7% (in a 'healthy' version) to 24%.

10 Other food sectors

Breakfast cereals

In general these contain much less than 1g of saturated fat per serving so in terms of further reductions in saturated fat in the diet they can be excluded as a target sector. There are, however, one or two exceptions to this which have been highlighted by the Consumers' Association (2004a, 2006a, 2006b).

The main problem areas with regard to fat and saturated fat are the 'crunch' type of cereals where both levels can be high. In percentage terms some of the worst offenders contain as much saturated fat per 100g as do thick pork sausages (Consumers' Association 2006a). Some hot oat breakfast cereals also contain a higher proportion of total fat (8-9%) which contributes a total of 1-2% of saturated fat to the product. Some muesli products also have a higher total fat content (typically about 5%) but as a significant proportion of this fat will come from nuts and seeds within the muesli it is not only seen as 'healthier' but the saturated fat content will also be quite low.

Other problematic areas in breakfast cereals are those which contain fat-based inclusions. These are generally either fruit flavour or chocolate-flavoured (or indeed, in some instances, may be chocolate itself). Potential solutions are to either replace these inclusions by either fruit/dried fruit pieces or gelled fruit analogues or, if a fat-based inclusion is still wanted then to replace this with a softer, more unsaturated fat. Although it is necessary to maintain the integrity of the inclusions they are not going to be handled in a way that chocolate would be and, in some cases, they are being consumed in a hot cereal in which the fat melts anyway.

Baked beans

Baked beans in tomato sauce are, in themselves, very low in fat. The only variety which shows any significant amount of total or saturated fat is that in which sausages are canned together with the beans giving, typically, 3-4% total fat and 1-2% saturates.

Hot noodle-based snacks

Although these can often contain significant levels of both fat and saturates (typically 16-19% fat and 7-11% saturates) they do not form a significant proportion of a diet typical of the UK population and so they have not been considered further in terms of how reductions can be made. However, some of these products may be based on fried noodles and there changes in the nature of the frying oil (as discussed in more detail elsewhere in this report) may improve the fatty acid profile.

Drinks

Carbonated and fruit-based drinks are very low in fat and so have not been considered any further.

Hot chocolate drinks, however are another area altogether. These can contain up to 13% total fat of which over 90% is saturated and can therefore

contribute significantly to the diet, especially if then made up with whole milk. There are, however, indications that either fat contents in these products are coming down or that there are lower-fat alternatives available, for example, less than 6% total fat in some hot chocolate drinks and less than 2% total fat in malted drinks.

Smoothies are becoming increasingly popular as a quick and easy way of obtaining some of the recommended five portions of fruit per day. However, they do often also have a yoghurt base to them which can contribute some fat. Some of these are richer in fruit than yoghurt (and often use a low fat yoghurt) and so contribute relatively little in terms of total or saturated fat. Others, however, are richer in yoghurt and use whole milk yoghurt, sometimes at levels of up to 75% of the smoothie. These then can contribute some 2.5% total fat in the drink with the saturates content of whole milk (i.e. about 65%) - in other words, about 1.7% saturates in the smoothie. Clearly, there is some scope here not only for using low-fat yoghurts in these drinks but also, in the longer term, the use of milk fats with a lower saturates content resulting from changes to cattle feed.

Vegetable products

The main area where fat is included to any great extent is in potato products - chips, roast potatoes, potato croquettes etc.

Chips purchased for home heating, either in an oven or microwave, typically contain between 2% and 5% total fat and seem to fall into two groups as far as their saturates level is concerned. One group contains saturated fatty acids which are about 12-16% of the total fat, while the other group contains saturated fatty acids which are about 45-50% of the total fat. This must be a clear reflection of the frying oil which has been used. Since most of these products are sold and stored frozen there ought to be much less of an oxidative stability issue in moving from a frying oil with 45-50% saturates to one with only 12-16% saturates and therefore a recommendation would be that all of these products be pre-fried in a low-saturates oil.

In many ways the same comment can be made about other pre-prepared potato products (roast potatoes, croquettes, waffles etc). Total fat contents range from about 2% up to about 12% with the highest levels generally being found in potato waffle products. Again, however, the saturated fat when expressed as a percentage of the total fat is either between 10% and 20% or is around 50%. The same comments and recommendation could then apply to these as applied to chips.

Canned vegetables contain less than 1% total fat and so are not considered any further.

Salads

Whilst salad vegetables themselves contain very little fat (other than in perhaps components such as avocado and nuts) the dressing used in salad pots (coleslaw etc) can contribute up to 15% total fat. The fat used is, however, generally low in saturates (usually less than 15% saturates in the fat phase).

Rice

Savoury and other rice products are low in fat (less than 4%) and low in saturates (less than 2%)

Sandwiches

Both the total fat and saturates content of prepared sandwiches depend on (a) the spread, (b) the dressing, and (c) the filling. In some products mayonnaise is used in place of a butter or vegetable fat based spread. Where this mayonnaise is reduced-fat then a lower total fat content overall can be achieved. The filling also plays a great part in total and saturated fat with cheese filled sandwiches being the worst of all in this respect containing typical total fat contents of 21-24% and saturated fat contents of 6-8% in the overall product. Egg, poultry and tuna based sandwiches contain the lowest levels of total fat (ranging from 2% up to 15%) and saturated fat (ranging from 1% up to 4%). Ham and bacon containing sandwiches come somewhere in the middle with 2-16% total fat and 1-7% saturates. These also contain the highest level of saturates when expressed as a percentage of the fat phase itself.

Because of the complexity of sandwiches there ought to be scope to make some reductions in both total and saturated fat and perhaps the first point of focus ought to be cheese sandwiches.

11 Fats and Oils

In discussing what can be done in various specific food product categories we should also include what can be done by the oils and fats industry itself to provide fats which would be more suitable for different applications.

In one sense, the technology available to the oils and fats industry is such that, to a large extent, whatever fatty acid composition is needed it can be supplied. Indeed, it is often possible to go further than this and define specific triglyceride structures - in other words, define exactly where on the triglyceride molecule specific fatty acids should reside. The ability to do all of this, of course, does not necessarily help the food industry in general address functionality issues. For example, the oils and fats industry could supply sunflower oil for use in a confectionery coating application but such supply does not help the end user to be able to produce a hard crystalline coating from that oil!

In many applications, the oils and fats manufacturer is key and in reducing saturated fat levels in food it may be necessary for the oils and fats manufacturer to embark on lengthy, expensive developments to provide fats which provide the same degree of functionality but at a lower level of use as existing products. This is by no means an easy thing to achieve and manufacturers will need to be assured that there is a large enough end market to warrant spending significant time and resources on such developments.

11.1 Optimisation of saturated fatty acid composition

Chapter 2 gave an introduction to this by asking whether some saturates were nutritionally better than others. This section takes this a stage

further and looks at what practical alternatives there are, assuming that some solid fat, i.e. saturated fat, is needed for product functionality.

So in looking at what the oils and fats industry could do in terms of reducing saturates we need to take a step back and ask ‘why do we want to reduce saturates?’ As the purpose of this study is to look at saturated fat reduction and not total fat reduction it cannot be for any reasons of reducing obesity levels because the calorific content of a saturated fat is the same as that of an unsaturated fat. Indeed, it can be argued that certain types of saturated fatty acid even have a lower calorific content (see below). The reason for reducing saturated fat, then, must be related to the effects which these fatty acids have on the risk of cardiovascular disease and on blood cholesterol levels in particular.

In chapter 2 it was mentioned that not all saturates are equal in terms of the effects they have on cardiovascular disease risk. Unfortunately, different studies give different conclusions, often being dependent on the amount of carbohydrate being replaced by the different fatty acids. The number of clinical studies that have been carried out in this area is very large and so the information and comments made in this section are not based on the conclusions of a full and systematic literature search but are based on selected papers.

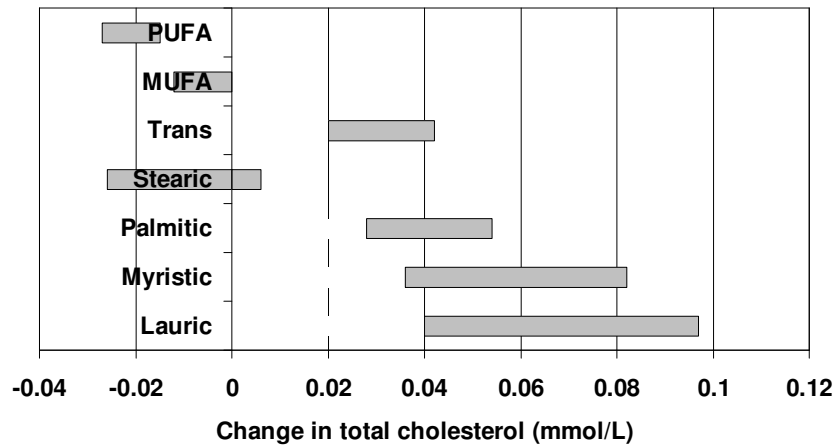
Mensink (2005) compared the estimated effects of isocalorically replacing 1% of energy from carbohydrates by a particular fatty acid on LDL cholesterol levels, HDL cholesterol levels and the all-important ratio of total:HDL cholesterol. These effects are shown graphically in Figures 1-4.

From the data shown in Figure 1 it can be seen that lauric, myristic and palmitic acids all raise total cholesterol levels with the shorter chain acids raising total cholesterol levels even more than was found with *trans* fatty acids. In contrast, stearic acid is either neutral in this respect or even slightly cholesterol-lowering with results overlapping those found with monounsaturated fatty acids. These results are for total cholesterol, i.e. ‘good’ HDL cholesterol and ‘bad’ LDL cholesterol. The more pertinent question, then, is what effect these fatty acids have on each type of cholesterol. If the saturated fatty acids are raising HDL cholesterol then such increases could be considered beneficial. If, on the other hand, they are raising LDL cholesterol levels then this would be considered detrimental.

From Figure 2, increasing the chain length of the saturated fatty acid reduced any change in the ‘good’ HDL cholesterol levels suggesting that the shorter chain lauric and myristic acids would be beneficial in this respect, that palmitic acid would be similar to monounsaturated fatty acids and that stearic acid was statistically indistinguishable from *trans* fatty acids in this respect.

Figure 1

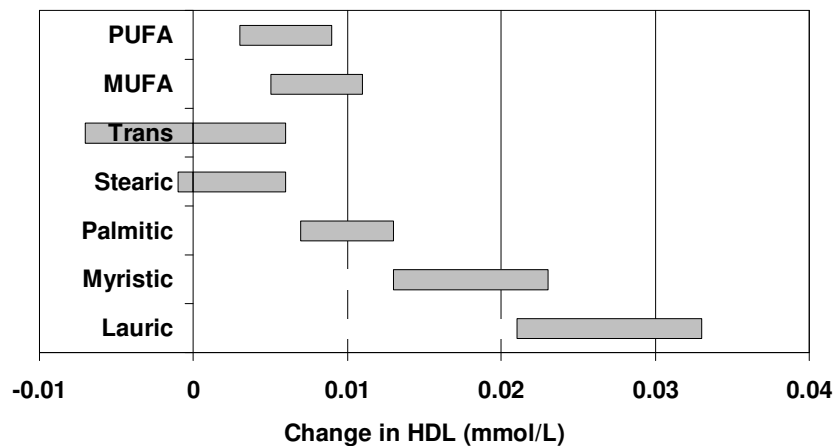
Effect of different fatty acids in changing total cholesterol levels (1% replacement of carbohydrate)



Source: Mensink (2005)

Figure 2

Effect of different fatty acids in changing HDL cholesterol levels (1% replacement of carbohydrate)

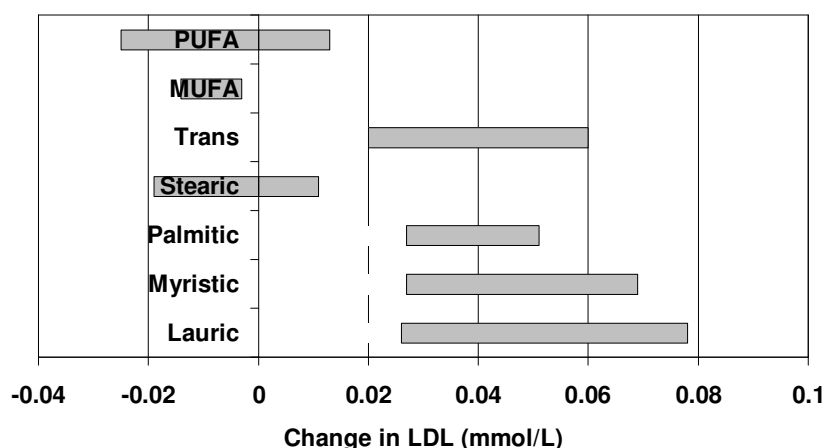


Source: Mensink (2005)

In terms of effect on LDL cholesterol, the results in Figure 3 would suggest that palmitic, myristic and lauric acids are all equally bad (although, in terms of the length of the error bars, they could be considered to be progressively worse) in raising the 'bad' LDL cholesterol levels and, in this respect are no better than *trans* fatty acids. Stearic acid, on the other hand, shows a neutral to slight lowering effect similar to that found with mono- and polyunsaturates.

Figure 3

Effect of different fatty acids in changing LDL cholesterol levels (1% replacement of carbohydrate)



Source: Mensink (2005)

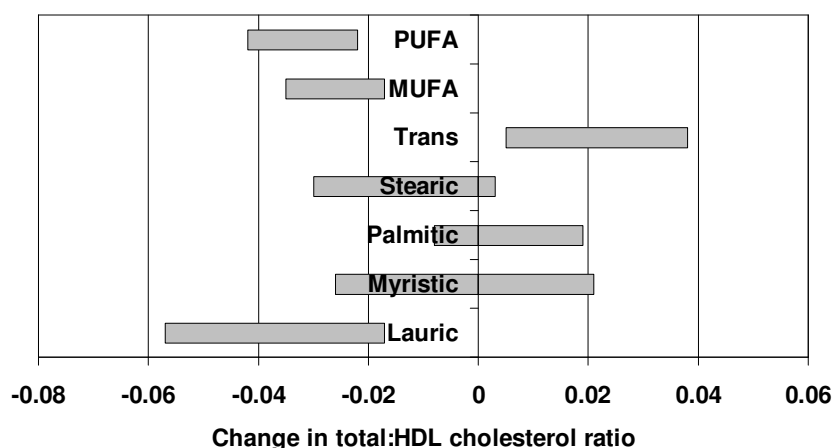
Combining the data in Figures 2 and 3 we can see that lauric, myristic and palmitic acids raise both HDL and LDL cholesterol levels (hence the effect of also raising total cholesterol levels). Stearic acid has very little effect on either type of cholesterol and can therefore be considered to be similar to the carbohydrate which it was replacing in this respect. *Trans* fatty acids raise LDL cholesterol and either lower or have little effect on HDL cholesterol (so worse than any of the saturates on a 1:1 basis). The unsaturated fatty acids raise HDL cholesterol and lower LDL cholesterol making them doubly beneficial.

When we look in Figure 4 at the effect on the ratio of total to HDL cholesterol (a factor which Mensink considers to be the most important risk factor for cardiovascular disease) we see that *trans* fatty acids are clearly worse than the other fatty acids (although there is some overlap with palmitic and myristic acids, but not with stearic or lauric acids). Comparing the saturated fatty acids themselves, there is overlap between stearic, palmitic and myristic acids and, to a slight extent, with lauric acid which behaves more similarly to the two types of unsaturated fatty acids. This is mainly due to the highly elevating effect of lauric acid on HDL cholesterol.

The work described above (Mensink, 2005) was based on replacing 1% of carbohydrate isocalorically by different fatty acids. Judd et al (2002) went much further and replaced 8% of carbohydrate isocalorically by different fatty acids. At this higher level of replacement the distinction between the effects of stearic acid on the ratio of total:HDL cholesterol and those of a blend of lauric, myristic and palmitic acids is much more marked (Figure 5).

Figure 4

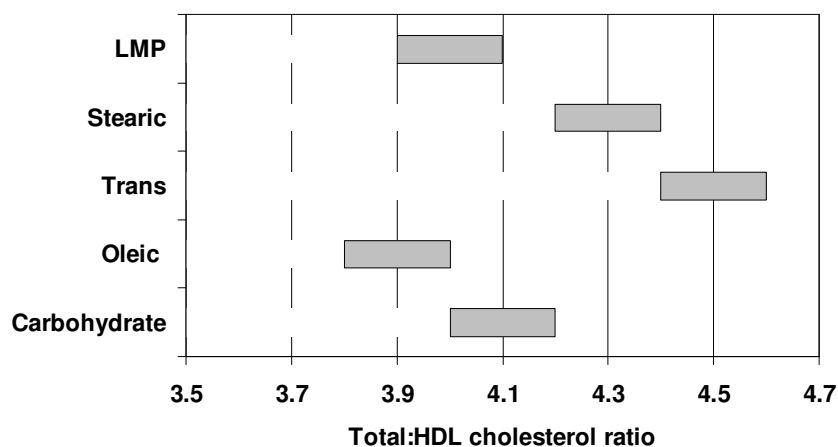
Effect of different fatty acids in changing total:HDL cholesterol ratio (1% replacement of carbohydrate)



Source: Mensink (2005)

Figure 5

Effect of different fatty acids in changing total:HDL cholesterol ratio (8% replacement of carbohydrate)



Source: Judd et al (2002)

LMP = 30% C12 + 15% C14 + 55% C16

Trans fatty acids raise the ratio significantly but there is now also a clear distinction between stearic acid and the shorter chain saturates. These two sets of results taken together would suggest that the effects of the different saturated fatty acids on the ratio of total:HDL cholesterol are somewhat dependent on the levels being consumed.

Sundram et al (1998) recommend a fat system which accounts for 30% of total dietary energy in which 20-40% of this is saturated (especially palmitic

acid) and 15-40% is polyunsaturated (mainly linoleic acid). This would mean 6-12% dietary energy from saturates and 4.5-12% dietary energy from polyunsaturates. They say that this could be achieved by blending of oils (and give an example of 67% palm oil and 33% corn oil as fulfilling these requirements) or that by suitable engineering a triglyceride system containing the appropriate mix of fatty acids could be produced. They go further by saying that they have a preference that the saturated fatty acids in this system should include palmitic acid, lauric acid and myristic acid and that there should be less than 5% by weight of stearic acid in the fat blend. To a certain extent this recommendation is contrary to some of the medical and nutritional references which they quote in the patent which essentially conclude that lauric and myristic acids are both cholesterolemic, palmitic acid may or may not be depending on the individual, and stearic acid is neutral in its effects on total cholesterol.

The conclusion regarding the effects which palmitic acid has on total cholesterol levels is from work by Heyden (1994) and Hayes (1991) which says that in people with a high total cholesterol level, palmitic acid can raise cholesterol levels further, whereas in people with less than 200mg total cholesterol per dl serum palmitic acid is neutral in its effect. They also quote a study in monkeys (Khosla, 1992) which showed that monkeys had a better HDL/LDL cholesterol ratio when fed a diet rich in palm oil (i.e. palmitic acid-rich) compared with a diet rich in high-oleic safflower oil (i.e. monounsaturated-rich) or one high in high-linoleic safflower oil (i.e. polyunsaturated-rich). They concluded from this that saturated fatty acids were necessary for increasing both HDL and, therefore, the HDL/LDL cholesterol ratio in blood serum.

It has also been shown that the level of dietary intake of the polyunsaturated linoleic acid (C18:2) is critical in whether or not palmitic acid raises cholesterol levels. Hayes and Khosla (1992) showed that there was a threshold effect - if linoleic acid (n-6 PUFA) formed greater than 6% of dietary energy intake then palmitic acid had no effect on LDL cholesterol levels. At low levels of PUFA intake, however, there was a large effect of palmitic acid on LDL cholesterol with higher palmitic acid intakes contributing to higher LDL cholesterol levels. This effect of linoleic acid on the effects that palmitic acid has on cholesterol levels could be one of the reasons for the discrepancies we find in the literature with some studies showing that palmitic acid raises cholesterol levels while others show it has no effect. Wilke and Clandinin (2005) also studied this effect and found similar results.

While some research (for example, Baer et al, 2004) would suggest that palmitic acid is to be preferred over stearic acid other research would suggest the opposite is true. Some researchers suggest that this may be due to stearic acid being less well absorbed by the body than the shorter chain saturated fatty acids (Kritchevsky, 1994).

Givens et al (1991) describe two further important factors in relation to the saturated fatty acid content of fats. The first of these is that as the chain length increases the digestibility of the fatty acid decreases. This is particularly noticeable from C18 (stearic acid) and longer. The second factor that they mention is that the absorbability of fat is influenced by the positional distribution of fatty acids, especially saturated fatty acids, on the

triglyceride molecule. Saturated fatty acids such as stearic acid are better absorbed when they are present on the 2-position of the triglyceride molecule and less well absorbed when present on the 1- or 3- position of the triglyceride molecule.

There are, however, conflicting reports in the literature about positional effects of fatty acids. Mattson et al (1979) showed that, in rats, stearic acid was absorbed well by the body if esterified at the sn-2 position on the triglyceride but only about 55% of it is absorbed if it is esterified on either the sn-1 or sn-3 position. The general rule of fatty acid distribution in vegetable oils is that the sn-2 position is filled with unsaturated fatty acids and then the sn-1 and sn-3 positions are filled with the remaining saturated and unsaturated acids. This means that even in fats with quite a high saturated fatty acid content such as cocoa butter, very little of that is present in the sn-2 position. The situation is, of course, completely different in an interesterified oil in which the positions of all the fatty acids are randomised and a significant proportion of the saturates could then be in the sn-2 position.

However, more recent studies have shown that stearic acid is actually much better absorbed than would be indicated in those earlier rat studies with stearic acid being 94% absorbed, palmitic acid 97% absorbed and the remaining common fatty acids >99% absorbed. (Baer et al, 2003). Sanders et al (2003) found a reduction in postprandial plasma triglyceride after volunteers were fed randomised (Intesterified) cocoa butter in comparison to normal cocoa butter. Intesterification increased the proportion of stearic acid in the sn-2 position from 9.2 mole% to 25.4 mole%. These, and similar results found with Salatrim (see chapter 11.3) indicate that the position of stearic (and other) acids on the triglyceride molecule could affect its absorption.

All of this would suggest that of the usual saturated fatty acids found in oils and fats, the longer chain ones (palmitic and stearic) would be less cholesterolemic than the shorter chain ones (lauric and myristic), and that there may be a positional effect suggesting that having these fatty acids on the 1- or the 3-position could result in a lower degree of absorption.

All of this means that more research is needed before we can draw any final conclusions as to whether some saturates are better than others, although of the major saturated fatty acids found in food fats there appears to be more positive evidence concerning palmitic and stearic acid than there does about lauric and myristic acid.

In many food products a certain level of solid fat is needed, or a particular melting profile/melting point is required. Individual triglycerides have different melting points which are predominantly dependent on the fatty acids which they contain. The longer the chain length of these fatty acids the higher is the melting point. The more unsaturated the fatty acids are the lower is the melting point. To a certain extent these two properties could be used to advantage in maintaining the physical characteristics of a fat whilst obtaining a reduction in the degree of saturation. How big that reduction will be is dependent upon how far the industry (and consumers) are willing to go in terms of moving outside the realm of 'normal' fats.

For example, POP melts at around 36 °C (Hagemann) and POO at around 18 °C. Ignoring any eutectic effects (which, of course, in practice would not be the case) a 50:50 blend of the two fats would melt at 27 °C and contain 50% saturates (all palmitic acid). If we now look at the analogous case with stearic acid in place of palmitic acid we find that StOSt melts at around 43 °C and StOO at around 23 °C. If a particular application, let's say a bakery product, needs a fat with a melting point of 27 °C then the 50:50 POP:POO blend would, in theory, provide this. However, by replacing POP and POO with StOSt and StOO a melting point of 27 °C could, again in theory, be produced by blending 20% StOSt and 80% StOO. Now there is only 40% saturates in the blend. Interactions of triglycerides will mean that the solution is not quite as simple as this but, nevertheless, the principle will hold in general that by increasing the chain length of the saturates in a particular blend it should be possible to, at the same time, reduce the degree of saturation and still maintain the required physical characteristics.

The triglycerides mentioned above are commonly found in vegetable oils, notably in palm oil and shea butter or can be produced using oil modification techniques traditionally used in the oil processing industry (although this may include full hydrogenation). It is possible to go beyond this by extending chain lengths even further but this then takes us a bit further away from fatty acids found in large quantities in the food chain. For example AOO (A=arachidic acid with 20 carbon atoms) has a melting point of about 29 °C and so would more than fulfil the physical criteria in the above example with only 33% saturates.

There may be other ways of achieving these targets using less conventional triglycerides - but these may result in other issues of consumer acceptability because, for example, they involve production of specific fatty acids by complete hydrogenation.

It may, therefore, be possible to look at some aspects of saturated fatty acids in a more positive light by (a) using saturated fatty acids which are less cholesterolemic, (b) using saturated fatty acids which are less digestible, or (c) positioning saturated fatty acids on a triglyceride molecule such that they are less well absorbed.

In theory, then, this means that fats with specific compositions tailored to meet particular functional and health needs could be produced. There would, undoubtedly, be cost implications to the development and manufacture of such triglycerides which, at this stage, would be unquantifiable because they would be so dependent on the types of triglyceride necessary and how close to or far away this is from naturally occurring triglycerides and fatty acids.

11.2 Diglyceride-rich oils (DAG oil)

Most oils and fats contain diglycerides to some extent, usually at levels of between 1% and 10%. Diglycerides, or diacylglycerols (DAG) exist in two basic forms - 1,3-diglycerides (in which the two fatty acids are esterified on the 1- and 3-positions of the glycerol molecule) and 1,2-diglycerides (in which the two fatty acids are esterified on the 1- and 2-positions of the glycerol molecule). Despite their chemical similarity the two types of

diglycerides are metabolised differently in that the fatty acids present in 1,3-diglycerides are more likely to be burned as energy rather than stored as fat (Sikorski, 2005). As such they can help in body weight management and body fat management. It has also been observed that postprandial blood triglycerides are reduced when 1,3-diglycerides are metabolised. So, although these products have been developed (mainly by Kao in Japan and ADM in the USA) predominantly to address the issues of body weight and body fat management their use may also be relevant in reducing the risk factors associated with cardiovascular disease and Type II diabetes.

The ADM patent (Sikorski, 2005) covers the use of DAG oil with 40-100% 1,3-diglyceride and 50-100% unsaturated fatty acid. Examples are given of the use of DAG oil in a range of bakery products (cake mixes, muffins, brownies). Extensive descriptions are given of its use in cookies as either a partial or complete replacement of a partially hydrogenated shortening. This showed that DAG oil can replace up to 50% shortening without significant changes being observed or without any need to change the manufacturing process. Although cookies can be made from 100% DAG oil it is then necessary to make changes to processing and to use a crumb softening agent to obtain shelf-lives more like those of conventionally produced cookies.

The FDA has given GRAS (Generally Recognised As Safe) clearance to DAG oil for use in vegetable oil spreads and home cooking oil⁸. These are mainly based on unsaturated fatty acids obtained from soyabean oil, rapeseed oil, corn oil or olive oil (FDA, 2000).

Although the GRAS approval was based on diglycerides which are predominantly unsaturated it is possible to introduce a degree of saturation and theoretically, at least obtain a system which would have physical properties normally associated with a much more saturated triglyceride system. However, the FDA GRAS approval limitation (vegetable oil spreads and home cooking oil) includes an estimate that its proposed use would add between 6 grams and 16 grams per person per day to the current intake of monoglycerides and diglycerides from other sources. This would suggest that further studies might be needed if DAG oil were to be used more broadly than this to ensure that there were no adverse effects from higher consumption levels.

11.3 Fat replacers

Fat replacers fall into a number of different categories. In terms of ease of substitution of conventional fat components those replacers which still possess a triglyceride-type composition are the easiest to use. The general principle behind these is to have a mix of both short- and long-chain fatty acids on the same triglyceride molecule. Commercial examples of such products are Salatrim (developed by Nabisco and described in a range of patents by Wheeler - Wheeler (1994) is just one example). As their name suggests they are composed of Short And Long-chain Acid TRiglyceride Material. Usually this means a mix of acetic, butyric and propionic acids (as the short-chain acids) coupled with stearic, (arachidic) and behenic acids

⁸ www.enovaoil.com/about/newsartical.asp?id=13

(as the long-chain acids). This type of product is commercially available from Danisco under the trade name Benefat™.

In a clinical trial (Finlay, 1994) subjects were given Salatrim on low (1800 kCal/day) and high (2500 kCal/day) energy diets. The proportion of energy from Salatrim was 7.6% on the low energy diet and 6.8% on the high energy diet (assuming Salatrim to have a calorific content of 5 kCal/g). There was increased stearic acid excretion when Salatrim was consumed with only 72.4% being absorbed on the low energy diet and 63.5% absorbed on the high energy diet. There is a suggestion that these low levels of absorption could be due to the randomised position of stearic acid on the Salatrim molecules (Kris-Etherton, 2005). Sanders and Berry (2005) studied the level of blood lipids found immediately after consuming diets enriched in Salatrim compared with other fats and found lower levels of plasma triglycerides compared to diets enriched in oleic acid (high-oleic sunflower oil) and stearic acid (cocoa butter). They also found that Factor VIIc (an indicator of blood coagulant activity) was lower with Salatrim than with the other two fats.

Such triglycerides are also described by Givens (1991) in which triglycerides such as 2-butyryl-1,3-dipalmitin are used in chocolate-type products and 2-propionyl-1,3-distearin is used in sugar cookies. Margarines can be made using a blend of both triglycerides.

The advantage of triglyceride-based fat replacers is that in many applications they can be directly substituted for the normal fat. Other fat replacers are available which are either protein-based or carbohydrate-based and, whilst, they undoubtedly have their place in many applications as fat replacers they do also have certain limitations. The protein-based ones, for example, are often limited to applications which are subjected to no or only a limited amount of heat. They are also usually only of use in aqueous media. Despite these restrictions they should always be a consideration in the armoury of a product developer looking to reduce fat levels in totality - and that could then have the knock-on effect of reducing saturates.

12 Other research

The LIPGENE project referred to in the introduction is looking at a number of aspects which are related to dietary fat and which to different extents impinge on the saturated fat content of the diet.

Firstly, it is looking at the effects that dietary fats have on the development of metabolic syndrome (the combination of high blood lipids, high blood pressure and insulin resistance). This will be achieved both by a complex analysis of data from 13,000 subjects and from a human feeding study involving 480 volunteers over a 3-month period.

Secondly, it will study ways of producing linseed oil enriched with the kinds of long-chain omega-3 polyunsaturates that are found in fish oil. These have a function in reducing metabolic syndrome. Coupled with this is a study into changing the fatty acid compositions of dairy milk fat to one with

more monounsaturates and less saturates and trans, and poultry meat to one enriched in long-chain omega-3 polyunsaturates.

The LIPGENE project also has sections related to raising consumer awareness of the health risks associated with metabolic syndrome and looking at the economics of changing agricultural and food technologies to improve the balance of fats in the diet.

The Biotechnology and Biological Sciences Research Council (BBSRC) sponsor a number of research projects in British Universities in the general area of fats in relation to diet and health. Examples are:

- Influence of amount and type of fat on vascular function in subjects with insulin resistance - Kings College London (Sanders TAB, Chowienczyk P)
- Palatability, satiety and the stimulation of appetite: a role for learning - University of Sussex (Yeomans MR)
- Perception of flavour in fat emulsions: interactions in mouth, gut and brain - University of Nottingham (Spiller RC et al)
- Gastrointestinal adaptation to fats: implications for feeding and obesity - University of Sheffield (French SJ, Read NW)

The BBSRC have also started a Bioprocessing Industry Club (BRIC) to support industrially-relevant research in bioprocessing and there is also information that they are also starting a Diet and Health Research for Industry Club (DRINC) but there is no mention of this on the BBSRC website.

13 Recommendations

In 1973, Frederick Stare summarised the proceedings of a symposium of the US Institute of Food Technologists with some recommendations for action to be taken by the food industry to improve the nutritional characteristics of food. Many of those recommendations are still valid over 30 years later:

- Design of foods with less fat and more water
- Replace part of the saturated fat with either mono- or polyunsaturated fat
- Produce red meat low in saturated fat and meat products in which saturated fat is replaced by polyunsaturated fat
- Develop strains of animals that convert a higher proportion of feed to protein rather than fat
- Slaughter cattle earlier to produce leaner meat
- Educate consumers about how to cook leaner meats without adding saturated fats
- Reduce saturated fat in dairy products
- Reduce saturated fat in baked goods

In defining recommendations from the information summarised in this report some aspects of the 'how' will be added to the 'what' of Stare's list.

13.1 What can the food industry do?

Many areas of the food industry have already started to address the whole issue of saturates reduction. Unfortunately in the past few years this has been somewhat clouded by the perceived need to remove *trans* fatty acids in the form of partially hydrogenated vegetable oils from the diet. This move has, in some product areas, resulted in an increase in saturates.

Significant reductions, for example, in the total fat content of many retailer-branded ready meals and similar products has been achieved over the past couple of years (both since the 2002 NDNS survey and also during the time of replacing hydrogenated fats by non-hydrogenated alternatives). Although difficult to quantify *per se* some of this total fat reduction will also have included saturated fat reduction.

In considering what industry could do it is useful to first look at some of the things that have and could be identified as barriers to reducing saturated fat in foods.

13.1.1 What are the likely barriers to saturated fat reduction?

Reduction of saturated fat is, to some extent, linked to reduction of total fat (although that is not explicitly the brief of this report). In many industries some reduction in total fat has been carried out successfully (for example, skimmed and semi-skimmed milk). In others, however, significant barriers have been encountered to the reduction of fat. In most cases, this has been because the fat has had a very specific functionality in the product and any reduction therefore has effects (often adverse effects) on the production, the quality in textural and sensory terms and the economics of the product. A good example of this is in the area of reduced fat bakery products where the fat has specific and well-defined functionality in terms of stabilising the aeration of batters and doughs, in interrupting the formation of gluten networks and in providing light, open textures to products. Although the fat in its totality plays a role in all these characteristics it is, in many cases, the saturated (or solid) fat which displays the greatest functionality. Barriers which have therefore been encountered to reduction of total fat in bakery products are also likely to be encountered in reducing saturated fats in particular.

The barriers to reducing fat in bakery products have been well summarised by Sharp (2000) following a survey of 34 people working in the bakery industry. These can be summarised under various headings.

- Labelling
 - In order to be able to make a claim a 25% reduction in total fat needs to be made in comparison to a standard product. This is often too difficult to achieve and it was thought that changing this to allow a claim to be made after 10% reduction in total fat would give the industry more of an incentive to make such a reduction. Because, in many bakery applications, much of the functionality comes from the saturates in particular, it is likely that there would also be more incentive to reduce saturates if a claim could be made at a level of reduction lower than 25%.

- Economic
 - Manufacturers need a justification to reduce fat. Lower cost ingredients would be one such justification but it is unlikely that the technical problems associated with fat (and saturated fat) reduction would allow manufacturers to replace existing bakery fats with cheaper alternatives.
 - Development of lower (saturated) fat systems costs money and if manufacturers are then prevented from making a claim because the degree of reduction they can achieve is not great enough then they are unlikely to devote resources to such development. The same is true for ingredient suppliers - they too will need to see a market for any lower-saturated, more functional alternatives they may be able to develop.
- Technical
 - Although there is a degree of understanding of the role of fat in the specific products that a manufacturer produces there is much less understanding about the role of fats in foods in general. There is less knowledge about the role of saturated fats in particular and even less about what the effects would be of replacing saturated fat with other ingredients be these unsaturated fats, carbohydrates, emulsifiers, or, simply, water. Much more general research, the results of which would be generally available, is needed.
 - Reduced fat doughs are generally more difficult to handle which also makes manufacturers less likely to move into this kind of product area unless they have some form of incentive be that economic or labelling.
 - The texture of reduced fat bakery products is often different from that of their full-fat counterparts making consumer acceptability less. Much more research is needed in either universities and research associations or in the development laboratories of ingredient suppliers to develop ingredients which will retain the expected texture even when fat and, particularly saturated fat, is reduced. Because the solution may reside in a combination of ingredients it may be necessary to encourage ingredient supply companies to work together on this. On the other hand, intellectual property rights may well be such an issue with this approach that such developments would be best done by independent research laboratories.
 - A 'salami' approach could be adopted in which small reductions are made in saturates to the standard products such that any textural or handling differences are seen as insignificant, allowing both consumers and manufacturers to adjust to these changes before then removing the next 'slice'. There are, however, problems with this approach in that no claim of saturates reduction could ever be made because it would simply be the standard product that is changing slightly over time. It is also unlikely that with this approach the degree of saturated fat reduction which has been targeted by the government would be achieved in the desired timescale.

A further factor which needs to be taken into account in reducing fat which could in some products prove to be a barrier is that of microbiological stability and safety. This is very much dependent on what is used to replace the fat.

If a saturated fat is replaced by an unsaturated fat this is unlikely to have a major effect on, for example, the water activity of the product and therefore on its microbiological stability. It could, however, still have a significant effect on the overall shelf-life of the product because the increase in unsaturation will mean a reduction in oxidative stability. The end product could therefore become rancid more quickly thus reducing its shelf-life.

If, however, the fat is replaced by an aqueous-based fat replacer or by any other system which increases the water activity of the product then there would be a considerable risk of higher microbiological instability meaning that the product would need to have a reduced shelf-life or, at worst, become completely unviable as a consumer product. Gross reductions of fat in products such as low-fat spreads could also give rise to microbiological problems either because the emulsion inverts completely from oil-continuous to water-continuous or there is so much water even in a water-in-oil emulsion that the water droplets become big enough to allow microbiological growth.

In 2001, the Food Standards Agency commissioned a report on the 'Barriers to the Development and Uptake of Reduced Fat Foods' (Knox et al, 2001). Some of the barriers which were identified then are equally relevant to the issue of reducing saturated fat in foods. The more relevant ones are listed below together with updated comments.

- In some sectors, notably meat, there was little or no demand from customers for reduced fat products. In the light of the data presented in chapter 5 this could be because butchery and trimming of fat in uncooked meat has improved to such an extent that consumers see these as already being low in fat.
- Functionality of fat. This is still likely to be one of the main barriers to saturated fat reduction because in many cases the functionality is related more to the saturated part of a fat than to the fat as a whole.
- Lack of ingredients innovation. There is a limit to what a fat processor can achieve with normal vegetable oils, especially if hydrogenation (even complete hydrogenation) is considered to be a 'no-go' area. Specific structured triglycerides can be produced, particularly by means of enzyme-catalysed technologies and these could have very specific benefits and functionalities in allowing reductions in total saturates - but, more often than not, they are likely to be triglycerides that are not normally found naturally in oils and fats.
- Labelling is still an issue, possibly even more so than it was in 2001. The inability to make a 'reduced saturates' claim because a reduction of 25% needs to be made is a huge barrier for many manufacturers. If they are able to make a 10% reduction this could be a step towards achieving the government's target on saturated fat but, in the absence of being able to claim this on packs, there is

no incentive for the manufacturer and no way for the consumer to quickly and easily recognise such a reduction. Similarly, unless a product is just within either the amber or red band for signposting, making such reductions will not allow the product to move into what is perceived as a healthier category. Again neither the manufacturer nor the consumer benefits from making such reductions.

- **Costs.** Reducing saturates will, in many cases, mean added costs either because more expensive ingredients will be necessary in order to maintain functionality or because, for example, the meat and foodservice industries will have to pay for the fat trimmed from meat products to be removed. Both of these factors are then likely to have an impact on product pricing. This, in turn, will either mean reduced margins throughout the supply chain or increased prices to the consumer.

13.1.2 Suggestions for further food industry action

One of the simplest ways of reducing total energy intake, fat intake and saturated fat intake is to reduce portion size. This is applicable to products such as ready meals, confectionery and bakery products, snack packets etc - simply make them smaller so that consumer eats less. This approach is not particularly applicable to products like whole milk, butter, spreads etc where the consumer takes a 'portion' from the bottle or packet to the extent they consider appropriate. There is, of course, the risk in this approach that the consumer will simply self-compensate and eat 'just another one' because products are smaller or lower in calories.

Dairy industry

In terms of products the full range of options from whole milk to skimmed milk is already available. The only thing that the dairy industry can do to reduce saturates further is to change the balance of fatty acids in milk. This will mainly involve changes to cattle feed and may or may not require the use of rumen-protected feeds.

A lot of work has already been done in this area but it is one where there are sometimes conflicting results and so it would be necessary for the industry, probably working together with academia, to truly define the effect of changes in feed on the fatty acid composition of milk and then to implement these. There is also an economic element to take into account in that (a) such feed will probably be more expensive than current feed and (b) it may (or may not) adversely affect milk yield. These may result in milk prices being increased. The producers should not be expected to bear all of this increase.

If successful, it could reasonably be expected to result in a total decrease of about 25% in saturates in milk. If this is carried through to all those dairy products produced from the milk then an overall reduction in dietary energy from saturates of about 0.75% could be expected.

The development of whipped cream analogues based on liquid vegetable oils along the lines of those being studied at the University of Leeds by Allen et al (2006) would allow the replacement of some aerated dairy cream

products with lower-saturate alternatives. This is probably some way off in terms of commercial development and may also involve the use of ingredients not normally found in the kitchen cupboard (i.e. sodium caseinate, glucono- δ -lactone).

Although reduced-fat cheese has a more rubbery texture than full fat cheese and is therefore not so attractive to the consumer in its native form it would not be as obvious to the consumer when the cheese has melted. The use of a reduced fat cheese would be a way of reducing both fat content and saturates in products using melted cheese such as pizzas, filled pasta, quiches, nachos etc.

Smaller reductions in fat which still allow the cheese to be labelled as normal (within the Food Labelling Regulations), for example reducing the fat content in cheddar cheese from about 34% to about 30%, should be examined by the cheese industry. If such changes produce only minimal changes in sensory and textural characteristics this could be an easy way of making a 10% or so reduction in both total and saturated fat

The possibility of introducing more vegetable oils into cheese analogues as alternatives to some of the current processed cheeses on the market should be explored. While they could no longer be labelled 'cheese' consumers may be happy to accept this for the health benefits they confer.

There are at least two patents which have been granted in 2006 aimed at reducing saturated fat in ice cream. These allow a saturates level of about 35% of the fat phase (compared with about 65% in dairy ice cream and 80-90% in traditional non-dairy ice creams). Taking a typical fat content in ice cream of about 8% this would mean about 2.5% saturates in the product compared with 5-7% in more traditional alternatives. So, even a conservative estimate could give a reduction of 50% in saturates in ice cream.

Switching from chocolate-flavoured coatings on ice cream to real chocolate would also allow a reduction in saturates but would be a more expensive product.

Spreads

Any changes in the fatty acid composition of milk would also, of course, benefit the fatty acid composition of butter. Even the most optimistic of expectations, however, would still not give a butter with a lower saturates level than most of the reduced-fat and low-fat spreads on the market today. Fractionating the butter and using the oleine in spreads would help further but (a) this would be expensive and (b) the issue of what to do with the stearine would need to be addressed.

A greater use of plant sterol or stanol fatty acid esters as hardstocks in spreads might allow some further reduction in saturates as well as conferring cholesterol-lowering benefits to the spread. They are, however, expensive ingredients and, if used more widely, (a) would push the price of spreads up and (b) there may become a problem in terms of availability.

Meat products

As with dairy products, changes to animal feed will come through as changes to the fatty acid composition of the meat. Some papers quote reductions in saturates of between 18% and 44%. Even if we take the lower end of this range, say a 20% reduction in saturates as being possible by feeding changes, and we assume that half of the saturated fat intake from meat and meat products (2.8% of dietary energy) is from the meat itself then a reduction of about 0.3% of dietary energy from saturates would result.

In terms of butchery and trimming of cuts of meat the industry has made great strides over the past 10-20 years by reducing fat content from 25-30% down to 4-8%, and it is difficult to see how much more fat can be trimmed from these products.

There is, in theory, still scope for further reductions in the fat content of mince, sausages and burgers but this is likely to be at the expense of the texture and succulence of the products unless some way can be found of replacing the more saturated meat fats with unsaturated vegetable oils.

Bakery products

As has been explained in section 6 this is a very difficult area in which to make significant reductions in saturates in the short term. This is not to say that they cannot be achieved but much more background research needs to be carried out on the functionality of saturates in these products and how low they could be taken before such products could be commercialised. Suggestions for some of this research are made in chapter 13.4. The problem may be made easier if consumers are ready to accept the use of some emulsifiers and stabilisers in the product.

Confectionery

Without changes to the chocolate regulations it is almost impossible to make any improvements to the saturates level in chocolate. Since it has taken about 30 years to agree the current EU legislation it seems unlikely that any changes will be made to this in the short term. There is scope for small changes either by changing the nature of or reducing the level of the vegetable fat used in chocolate but these could result in textural changes in the chocolate which would need to be compensated for by other changes.

There may be some small scope for reductions in the non-chocolate part of confectionery but, as these are made, so the problems of fat migration and fat bloom formation become greater.

Savoury snacks

The main issue with savoury snacks is the nature of the frying oil which is being used. Essentially the oils used fall into a mid-saturate type (about 40-50% saturates) and a low-saturates type (10-20% saturates). Although there is a gradual move towards the low-saturates type of oil (typically high-oleic sunflower oil), the mid-saturates is probably still the predominant frying medium. The ideal situation would be for all products to be fried in the

low-saturates oil but there are two factors which may dictate against this. The first is that oxidative stability will be reduced (although some of this may be moderated by the use of antioxidants in the oil, improved packaging of the snack and reduced shelf-lives). The second is that there may not actually be enough high-oleic sunflower oil currently available to be able to make an across-the-board change.

In the 2002 NDNS 0.4% of dietary energy came from saturates from this source. Most of the frying oil changes have been made since then. Assuming that eventually a large-scale switch could be made then it ought to be possible to bring this down to 0.1% of dietary energy from saturates.

Ready meals

There is some scope for saturates reduction in ready meals but, to a large extent, this will be specific to a particular type of meal making general recommendations difficult to make. Some examples, however, are given below:

- Replace garlic butter in the filling of 'Kiev' products with a less saturated fat phase
- Replace highly saturated coconut cream in Asian dishes with a more unsaturated system (perhaps low-fat coconut milk for the flavour and vegetable oil for the texture)
- Use reduced-fat cheese in pizza toppings, filled pasta and quiches and possibly even in sandwiches
- Increase the thickness of French fries in foodservice outlets to reduce their total fat content.

One area where a more general recommendation can be made is in fried products. These generally fall into two types - those with saturates about 40-50% of the fat phase (most likely to be because palm oil or palm oleine has been used as the frying medium) and those with saturates about 10-20% of the fat phase (where, for example, a sunflower oil of some type has been used). As many of these products are either for chill storage over a few days or for frozen storage, oxidation of the frying oil resulting in rancidity ought not to be an issue even with the more unsaturated oils and so switching to a low-saturate oil will give an overall reduction in saturates.

A further area where reductions in saturates could result is in portion control of ready meals. Smaller portions (or at least more similar portion sizes across manufacturers and retailers) could reduce fat and calorie intake.

General comment

In a number of sectors there are already lower-fat or lower-saturates products on the market running alongside full-fat products from the same manufacturer. To a certain extent, reduced-fat products seem to suffer from some sort of stigma in the consumer's eyes where they think that the product is going to be inferior and not taste as good so they ignore it and go for the full-fat product. This then makes the lower-fat products niche products.

In many areas, however, the consumer's perception is a false one and, tasted on their own, the reduced fat products are perfectly acceptable. While there may be a difference when tasted against the full-fat product it is often difficult to perceive this simply by tasting the reduced-fat product alone. If, in such cases, manufacturers and retailers were to re-label the reduced-fat product in such a way that it was perceived as the 'standard' and re-label the original product as an indulgent luxury product then the benchmarks would move in a nutritionally positive direction, the reduced-fat product would no longer be seen as niche and the consumer would still be able to make the choice between the two types. Clearly, significant consumer and market research would be needed to confirm whether such changes ought to be made or not.

13.1.3 Suggestions for ingredients industry action

The need for more research into new ingredients which will allow a reduction in saturated fat to be achieved has already been highlighted. Some of this research will need to focus on the changes in texture and sensory characteristics that are found when saturates are reduced and at ways of minimising these. As already mentioned this may involve multiple ingredient suppliers working together on the problem rather than trying to tackle it in isolation by just changing their own ingredients. It may well also necessitate work being done in universities and research associations in order to overcome issues of Intellectual property rights resulting from a number of ingredient manufacturers working together.

The oils and fats industry, in particular, have a role to play in this whole issue but they can only do this in conjunction with their commercial partners in the food industry in general. If specific triglycerides can be defined as permitting an overall saturates reduction in particular applications then the oils and fats industry may well be in a position to produce those triglycerides. Since the development of these could well be very costly, they must have a reasonable guarantee that such development will result in commercially viable products.

The oils and fats industry can probably even now make some improvements to current systems (especially in combination with other components such as emulsifiers and antioxidants). To make major leaps forward, however, there are two main fundamental pieces of research needed. The first is accurate, agreed conclusions regarding (a) the comparative benefits or detriments of specific saturated fatty acids, (b) importance of the position of fatty acids on the triglyceride molecule, (c) effect of chain length on degree of absorption and metabolism. The second relates to the functionality of fats, especially saturated fats in the end food products. Only with the combination of these two pieces of research can the oils and fats industry make major strides in producing fats which will be nutritionally better than those currently used.

13.1.4 Suggestions for machinery manufacturer action

One comment that has emerged, particularly from the bakery industry, is that reduced fat products handle differently. This is particularly the case with reduced fat doughs in pastry and biscuits. Some of these handling

problems may be overcome by changes in production methods which, in turn, could be achieved by modifications to existing process equipment.

13.2 What could consumers do?

A significant part of the solution is already in the consumers' own hands. There are many examples of both 'full-fat' and 'reduced-fat' products on the market in many sectors of the food industry. If consumers were to take advantage of the low-fat versions of many of these, then the intake of saturated fatty acids would probably reduce to a level close to that of the Government's target.

For example, if all whole milk and all semi-skimmed milk consumers switched to skimmed milk, then there would be an overall reduction of 1.1% of dietary energy from saturates. Whilst this is unlikely to happen even 50% of whole-milk consumers switching to semi-skimmed and 50% of semi-skimmed milk consumers switching to skimmed milk would give a reduction in dietary energy from saturates of 0.40-0.45%. If half of the butter consumers changed to a low-fat spread there would be a further reduction in dietary energy from saturates of 0.35%. Add to this reductions that consumers could make by simply switching to other reduced-fat or reduced-saturate products and it is not unreasonable to suppose that a reduction in dietary energy from saturates of 1% could be achieved without any intervention from the food industry!

Although the target for saturated fats is 11% of dietary energy most consumers have no idea what this equates to in terms of the products they consume. Assuming a daily calorific intake of 2500 kCal for men, 11% of this equates to 275 kCal/day from saturated fats. With a calorie content of 9kCal/g, this is equivalent to 30g of saturated fat per day. Even then most consumers do not know how much of what they eat makes up that 30g of saturated fat.

It would be useful, therefore, to indicate to them what size portions of commonly consumed foods make up this 30g of saturated fat by, for example, describing how much of each food contains, say, 5g saturates. Eat six of these in one day and they have then reached the recommended maximum daily intake.

For example the following portions of food contain 5g each of saturated fat:

- 9g butter
- 25g chocolate
- 22g Cheddar cheese
- 1 (i.e. half a pack) supermarket cheese and onion sandwich
- 3 digestive biscuits
- 1 pork sausage

It is very easy to get to 30g saturates per day!

The whole area of snacking and lunchboxes is a good one to target as well because generally the 'preferred' snacks and components of lunch boxes are also high in saturated fat - confectionery, fried snacks, cakes, biscuits, pork pies, sausage rolls etc.

It is not difficult to replace a lunch box high in saturated fat with one which is much lower, for example. Simply by choosing the right kind of sandwich (thicker bread, low-fat spread, low-saturates filling) and different options with regard to snacks and drinks in the lunch box it is possible to reduce saturates from a level over that recommended for the whole day to one containing less than 20% of the recommended daily intake.

Moving to lower-fat or lower-saturated fat versions of existing foods will of course help overall saturates reduction. It has already been mentioned that if everyone who consumes whole or semi-skimmed milk converted to skimmed milk we would, as a nation, reduce our average saturated fat intake by 1.1%. This is 45% of the total targeted reduction by one simple action.

Booklets such as 'Getting the balance right' published by British Meat Nutrition Education Service give good guidelines to consumers about obtaining the correct energy balance from fats and other nutrients in food separated into five main sectors - fruit and vegetables, bread and other cereals and potatoes, meat fish and alternatives, milk and dairy foods, foods containing fat and foods and drinks containing sugar. This indicates daily amounts to be consumed from each group with guides as to portion sizes to obtain a balanced diet.

Information on how to cook meat and meat products to have as little fat as possible in the end product is important. For example, the media (television, magazines etc) should be giving consumers information on dry-frying (using the fat in the meat as the frying medium), grilling, and draining excess fat from meat after it has been cooked etc.

13.3 What could government do?

Education

Government has a great responsibility in educating the consumer about fats in general but about saturated fats in particular. The kinds of messages indicated in chapter 13.2 need to be given to consumers to enable them to understand just how easy it is both to exceed guideline daily amounts of saturated fat but also, on the other hand, how they could make changes which could bring them well within the FSA guidelines of 11% energy from food.

This means separating to some extent messages about saturated fat from messages about total fat insofar as messages about total fat are more related to energy intake and energy density of foods and, hence, linked to obesity, whereas messages about saturated fat are more related to cardiovascular disease risks.

Consumers are already confused by the messages they get about fat. They probably now understand that *trans* fatty acids are bad for them (without actually knowing what these are) and that these are obtained from hydrogenated fats. Most, however, do not realise that a fully hydrogenated fat does not contain *trans* fatty acids. In that sort of knowledge arena such fats would be rejected by both consumers and retailers because they would still have a 'hydrogenated fat' label. It is probable that few consumers

know that dairy products such as butter and cheese also contain *trans* fats, albeit naturally occurring ones.

They also hear and read about omega-3 oils from fish being good for them - so not all oils are bad. Bringing saturates into the discussion needs careful education of the consumer as to which oils are beneficial and which oils are not within the total arena of oils and fats.

Sometimes fat reductions in general and saturated fat reductions in particular can be achieved by an increased use of additives in the product. Generally the consumer is against such an approach but here again some education is needed to tell consumers which additives are also fairly normal components of the food chain (and which are not). For example, diglycerides and, to a lesser extent, monoglycerides are found naturally in oils and fats. Similarly, lecithin is a natural component of soyabeans, sunflower seeds, egg yolk. Both types of component are, however, also used as emulsifiers and need to be declared as such.

How Government can help the food industry

There were a number of areas where industry felt that the Government made it difficult for reductions in saturates to be made. These are summarised below. Some of these may need changes to be made to 'the way things are done', others may need legislative changes or exemptions to be made.

- One of the barriers perceived by the food industry as inhibiting significant developments in the area of saturated fat reduction is that of labelling. In order to be able to make a reduced saturated fat claim there has to be a reduction of at least 25% in saturated fat compared with the standard product. This is a very difficult thing to achieve in many food sectors. Smaller reductions of, say 5-10%, in saturated fat may be easier to achieve and will also confer health benefits to the consumer (especially if these can be achieved in a number of food sectors) but the manufacturers will not be able to make any claim on this. This means that it is unlikely that the consumer will actually know about such reductions unless they compare labels after the change had been made with those from some time ago - this is highly unlikely. Without the ability to make some form of claim there is no incentive to the food industry to make such changes. Equally, it may be possible to make small 'salami'-like reductions over a period of time. These may occasionally add up to a 25% reduction compared with the starting point but because they have been made in step-wise amounts again no claim can be made.

Recommendation: define a means of allowing manufacturers to inform consumers of saturates reductions less than the 25% which would at present allow a claim to be made.

- Linked to the above are comments about the traffic-light type of signposting. This does not distinguish sufficiently between products in the amber and red categories in terms of different fat contents. Unless a product is just inside the lower limit of amber or red the motivation for a manufacturer to make changes is reduced.

Recommendation: consider how the traffic light system could be modified to still give sensible information to consumers but also give

more motivation to manufacturers to make reduction in fat and saturates

- Proposed legislative changes on fat-based spreads may make it impossible to make the reduced-saturates and low-saturates claims that are at present possible. At present it is possible to have a low-saturates claim if less than 25% of the fat in the product is saturated. There is a proposal to change this to only allowing a 'low in saturates' claim if the saturates level is below (or equal to) 1.5g/100g product. If it becomes no longer possible to do this (and the new limits are almost impossible to achieve) how will the consumer be able to choose between various kinds of spread?
- It was felt that the National Diet and Nutrition Survey gives a false view of the energy coming from both fat and saturated fat from carcass meat because it also includes other ingredients under the general heading of meat. Whilst products such as meat pies and pasties are noted separately, beef, pork and lamb all have 'and dishes' included with them which allows fats/saturated fats from sauces and other ingredients to be included with them giving a false impression of how much is actually coming from the meat itself.
Recommendation: separate carcass meat consumed as such from dishes which include it as a component in future NDNS surveys.
- The Catering Waste Directive will mean that there will be an added cost associated with trimming fat from meat because butchers, foodservice companies etc will need to pay to have this removed. This will mean less incentive to trim meat as closely as it could be. Some meat processors use the excess trimmed meat as a fuel in the boilers (after having gone through a suitable rendering process) but even this can fall foul of EU regulations when in reality (a) it is taking the fat out of the food chain and (b) allowing the use of fuel from non-fossil sources.
Recommendation: exemption for trimmed fat from the Catering Waste Directive
- If fat is removed from a meat product by, for example, close trimming then it needs to be used elsewhere. Ideally, it should not go back into the food chain otherwise there is no overall reduction in fat consumption. Non-food uses for the fat need to be found. One possibility is to use the trimmed meat fats as a basis for biodiesel. Such use may need Government's help to link the meat and biodiesel industries together.

13.4 What can research do?

This section is headed 'research' rather than 'academia' because although much of this research is likely to be done in universities, some could well be carried out in other research establishments including those within food manufacturers. It is intended, however, to be an indication of the kind of research that may be carried out in the longer-term rather than any specific modifications that food manufacturers make to their current portfolio of products.

Norton et al (2006) reviewed the whole area of what might be possible in terms of using chemical engineering to reduce satiety, produce different forms of emulsion etc aimed at fat and/or calorie reduction. Examples are:

- Emulsions that are unstable in the stomach. Such emulsions result in a layer of fat forming on the top of the stomach which signal a feeling of satiety to the brain and therefore limit consumption
- Fats and emulsions that pass undigested into the ileum. These then send signals to the brain to slow digestion
- Liquid oils are digested more quickly than solid fats. The use of Pickering emulsions of liquid oils within solid fats could help to slow down digestion.
- Slow down stomach emptying and the digestive process as a whole by the use of hydrocolloids which gel in the acidic environment of the stomach.
- The use of low-fat emulsions to give the impression of full-fat products
- The use of duplex emulsions (fat around water around liquid oil)

Micro-encapsulation is an area which perhaps needs more exploration as a means of introducing monounsaturated and polyunsaturated oils into products such as confectionery coatings and fillings where a specific level of solid fat is needed in order to maintain texture. By including microencapsulated liquid oil in such systems the saturated:unsaturated ratio could be changed positively. The use of microencapsulation as a means of introducing sensitive materials into foods has been reviewed by Gouin (2004).

There is a limited amount of knowledge within the food industry on the real functionality of saturated fats in a wide variety of products. Fundamental research is needed about (a) exactly what the role of saturated fat is in those foods where it does impart specific functionality and, perhaps more importantly, (b) what are the effects of replacing saturates with unsaturates, carbohydrates, emulsifiers, water etc.

The dairy, meat and bakery industries have all been identified as sectors where there may be significant scope for saturates reductions to be made but with the industry's present level of knowledge of the functionality of saturated fats in these products much more research needs to be undertaken to define the way forward.

Dairy industry

- Effects of feeding different diets (whether rumen-protected or not) on the fatty acid composition of the milk and meat
- How can saturated fat be reduced in aerated dairy products (creams and desserts) while maintaining aerated structure and, ideally, without the use of an abundance of chemical additives?
- How can the fat in cheese be reduced without producing an unacceptably rubbery texture?

Processed meats

- How could pork backfat be replaced in sausages by a more unsaturated oil?

- Is it possible to reduce saturated fat in both the meat and pastry of pork pies?
- How can the saturated fat content of mince and burgers be reduced whilst not making the product too 'dry'?

Bakery industries

Organisations such as Campden and Chorleywood Food Research Association have considerable experience across the full range of bakery products and would be able to carry out much of the basic work necessary to determine the relationships between saturated fat levels in dough fats and shortenings and functionality in the product. The following are all questions which arose during discussions with the industry.

- What is the effect of solid fat content in pastry doughs on pastry quality and especially on gluten development?
- Define which cake systems only need fat for shelf-life and evaluate a more liquid oil in these applications
- Is it possible to functionally reduce the fat content of creams (including buttercreams)?
- How low in solid fat (and hence saturates) is it possible to go in a cake shortening and still retain the functionality of stabilising air bubbles in the cake batter to give a good texture in the end product?

13.5 What can the retailers do?

In many product sectors the retailers have a key role to play because, in many cases, they determine prices and the price they are willing to pay for either raw materials or processed foods can dictate how much the manufacturer can do in terms of fat reduction. This is a big issue in meat-based products where the greatest proportion of these are sold under the retailers own labels. But it is also an issue in, for example, bakery products where saturated fat reduction may mean either a more expensive product and/or the use of emulsifiers and other additives. Insistence that all ingredients in a product must be such that they could be found in a consumer's kitchen cupboard will restrict developments along these lines.

In many areas there is a need for tripartite consultations between the retailers, the food manufacturers and the Food Standards Agency to try to define (a) what is desirable but, perhaps more importantly, (b) what is possible.

14 Summary

What, then, is possible? If the changes suggested in this report are carried out is it really possible to reduce saturates from 13.2-13.4% of dietary energy down to 11%? This, of course, is a very difficult question to answer because it depends on so many factors - research defining the fundamentals needed to help the industry make the necessary changes, manufacturers ability to produce low-saturate products, consumers' willingness to change to these products and help from the Government in both educating the consumer and making such changes easier and less restrictive for the food industry.

On the basis of some of the recommendations made in chapter 13 the following reductions could be seen as targets for each of the various industry sectors:

Sector	Potential reduction in dietary energy from saturates
Dairy	0.75%
Ice cream	0.1%
Spreads	0.1%
Butter	0.2%
Meat products	0.3%
Processed meats	0.1%
Coated (breaded/battered) fried products	0.1%
Bakery	0.25%
Savoury snacks and potato products	0.3%
Total	2.2%

On this basis the reduction ought to be possible but it does depend, particularly, on (a) significant changes being achieved in the fatty acid composition of both milk and meat as a result of feeding changes and (b) the ability of the bakery industry to find ways of reducing saturates in their products.

15 Acknowledgments

Thanks are due to all those people and organisations who helped in providing background information, suggestions as to how some reduction in saturates may be achieved and what the barriers are to further reductions. Because they were assured that the information they provided would be used anonymously they cannot be named personally, but their help was invaluable.

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