

Fat — What is it ?

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The word "fat" is used extensively in food legislation, but lack of definition can result in confusion over what is meant. The nature of analytical methods for "fat" and the resulting extracts are explored. Definitions are proposed for "fatty acid", "fat", "a fat, or fats" and "fatty matter", and their suitability for legislation and implications for analytical methods are discussed.

Introduction

In everyday language, the meaning of fat is clear enough—lard, cooking oil, and the greasy globules which float in hot food are obvious examples. But for quantitative purposes, such as framing limits in legislation or codes of practice, a stricter definition of fat should be required. Yet here is the first problem. Whilst definitions of "*an oil or fat*", and its plural "*oils or fats*" are common, a definition of "fat" as such, is not. But to be rigorous, there is a great deal of difference between the two.

Chemicals which may loosely be called "fat", or which could appear in an analytical fat extract include:

Glycerides of fatty acids.

Fatty acids and their salts.

Phospholipids (e.g. lecithin).

Waxes (esters of fatty acids with monohydric alcohols) e.g. beeswax.

Hydrocarbons—natural and mineral oil fractions.

Sterols, fat soluble vitamins, fatty alcohols.

Various miscellaneous additives e.g. stearyl tartrate.

Such substances as waxes, fatty acids and hydrocarbons, occur naturally in small amounts in commercial oils and fats, and are considered an integral part of them. It is doubtful that such chemicals in their pure form should be called "fat" in a strict definition, or when added in small amounts to a product. If fat is defined in purely chemical terms, it is clear that "a fat", such as beef fat or palm oil, is not all "fat".

For initial considerations, it is useful to describe loosely three entities;

Fat—a mixture of glycerides of fatty acids.

A fat, fats—commercial oils and fats.

Fatty matter—the sort of fatty chemicals obtained in an analytical extract.

Potential for confusion

In normal usage, such definitions become blurred. In Pearson¹, under "Eggs", lecithin is distinguished from fat, whereas under lard, fat appears to be equated with total fatty matter. Such lack of definition and consistency can lead to problems.

Food additives, such as emulsifiers and stabilisers, can appear in fat extracts. In "cream" soups, a small amount of fatty additive such as lecithin could raise the total fatty matter from between $2\frac{1}{2}$ –3 per cent. to over 3 per cent. Does this added lecithin qualify as "fat" for the purposes of the code of practice, and thus lower the butterfat requirement from $2\frac{1}{2}$ –1 per cent.?

The Cocoa and Chocolate Products Regulations 1976, require milk chocolate flakes to have 12 per cent. of fat (undefined in the regulations). Fatty emulsifiers can be added up to 1.5 per cent. Again, are these "fat"?

A more trivial example is block suet, required by the *Food Standards (Suet) Order 1952*, to contain 99 per cent. of fat (undefined). Given likely proportions of non-fatty acid glyceride constituents, it seems improbable that any block suet will contain 99 per cent. of fat, defined chemically.

A particularly interesting additive is glyceryl-mono-stearate—an example of fat as defined so far. Should this be included in the fat requirements of ice cream containing non-milk fat? The regulations do not define fat, or milk fat for that matter.

The above are examples where the assumption "total fatty matter equals fat", would be to the benefit of the manufacturer. This is not the case for food claiming to be low in fat, and containing fatty matter other than fatty acid glycerides, such as emulsifiers or fatty acids. A normal analytical fat figure might be deemed unacceptable in a Court if the method could include fatty matter which was not strictly "fat". An example could be low-fat yoghurt, if lipase activity hydrolyses glycerides. Although the calorific value would be almost unchanged by hydrolysis, the released fatty acids would no longer be defined as "fat".

Stricter Definitions

The need for stricter definitions is therefore apparent. The initial loose definitions provide three bases for "fat" content—the weight of commercial oils and fats, the weight of a particular chemical species (fatty acid glycerides), or the weight of fatty chemicals such as in a "fat" extract, per unit weight of product.

The definition of fat as "glycerides of fatty acids", is insufficient by itself, since fatty acids have not yet been defined. An exhaustive list, either of specific acids or by detailed chemical class, would be cumbersome and liable to be rendered obsolete by a newly discovered acid. A more general description, with provision for inclusions or exclusions as necessary, although losing academic rigour, should be adequate for legal purposes. Additives such as glyceryl esters with acetic, lactic and citric acids amongst their organic acids would be excluded by the definition:

Fatty acid: a monobasic organic carboxylic acid containing carbon, hydrogen, and two atoms of oxygen only, and occurring as a glyceride in a naturally occurring oil or fat, but excluding aromatic compounds and compounds with less than four carbon atoms.

A specific fat (e.g. milk fat) or the more general "a fat or oil", could be defined as:

Anhydrous fatty matter extracted from a single natural source, consisting mainly of fatty acid triglycerides with relatively small proportions of co-

extracted fat-soluble substances, excluding any additives or further ingredients, but including such a fat after refining and/or hydrogenation.

Included in the definition are fats or oils *not* normally thought of as commercial oils, for example the fatty matter in wheat. A blend of oils and fats from single natural sources is described as “fats”, the plural of “a fat”.

Analytical Fat

Normal analytical methods for fat are really for fatty matter. Such entities are variously called free fat, combined fat, total fat, crude fat, lipoids and so on—the result of a particular method rather than the amount of a group of chemical species in the sample. Before attempting a definition of “fatty matter”, factors deciding the amount and type of chemicals appearing in fat extracts need to be examined. This opportunity is used to highlight some practical aspects of fat determinations.

(i) ACCESS OF EXTRACTANT TO THE FATTY MATTER

Blocking mechanisms include cellular microstructure (e.g. solvent extraction of cereals), and obstruction by a mass of immiscible phase (e.g. mincemeat). Fat globules can become coated with protein to form emulsions (e.g. milk). Methods for overcoming this problem include drying at 100°C, hydrolysis of starch and protein by acid or enzymes, and breaking emulsions (Rose Gottlieb).

(ii) WHICH CHEMICALS ARE EXTRACTED AND TO WHAT EXTENT ?

There are two main types of extraction. Werner Schmid and Rose Gottlieb methods have a partition between solvent and aqueous phase, where mainly hydrophilic species are not extracted. Conversely, continuous solvent extraction will eventually extract very slightly soluble substances, even if these would have remained in the aqueous phase during a partition. In both cases, the amount and type of chemicals extracted depend on the solvent used. It is not surprising that different “fat” methods give different results on the same sample.

Testing methods with known substances can give surprising results. The Rose-Gottlieb method might be expected to leave fatty acids in aqueous solution. Using 0.2 g of stearic acid converted to its ammonium salt, 30 per cent. appeared in the fat extract as stearic acid. With significant quantities of free fatty acids in a sample, exact reproduction of the method will be necessary for reproducible results, which with partial extraction of fatty acids, may not mean much anyway.

Half a gram of caffeine mixed with sodium sulphate were extracted for 4 h in a Soxhlet apparatus with light petroleum spirit. Thirty milligrams of caffeine were extracted. With chloroform or diethyl ether, extraction would probably have been complete.

(iii) CHEMICAL CHANGE, MAKING FORMERLY NON-EXTRACTABLE MATERIAL EXTRACTABLE, AND VICE-VERSA

Examples are: the action of acid on fatty acid salts, and the production of furans during acid hydrolysis of sugary material.

(iv) EXTRACTION OF CHEMICALS FOR WHICH THE DESCRIPTION "FATTY MATTER" IS UNSUITABLE

Non-fatty material is usually allowed for by dissolving out fatty matter with warm light petroleum spirit, and weighing the residue. Lactose, and caffeine, which crystallised out in the light petroleum spirit Soxhlet extract, are then excluded. It is important that the petroleum spirit is clear when poured off. Some meat products, when dried at 100°C then extracted with diethyl ether in a Tecator Soxhlet apparatus, gave a cloudy liquid when the fatty residue was warmed with petroleum spirit. On standing several hours, a small amount of a viscous liquid and clear petroleum spirit solution were obtained.

One way of defining fatty matter in a particular situation is as the extract from a prescribed analytical procedure. Each procedure tends to have limited application, so many definitions of fatty matter for different situations would be required. Such proliferation is avoided by requiring any extract to satisfy a single property before it can be called fatty matter. A criterion, often used practically, is solubility in a relatively small amount of warm light petroleum spirit, and relative non-volatility at 100°C. This shift of definition from a *method* to a *property* is quite significant since one definition, not many, is needed. Further, the selected property imposes a requirement on any method for fatty matter—caffeine and lactose, through an ill-considered method, could no longer be counted. When considering fatty matter in a *sample*, there should be the further requirement that there is no addition or subtraction of fatty matter due to chemical change during the extraction. Acid/base changes may be allowed to include, for instance, fatty acid salts (expressed as the acid).

Fatty matter might therefore be defined as:

"Substances which are soluble in a relatively small amount of light petroleum spirit and are relatively non-volatile at 100°C".

This defines a class of chemicals rather than amounts. Analytical fat methods are normally attempts to determine "total fatty matter".

Total fatty matter (in a sample): the total amount of substances contained in the sample which, with no chemical change other than acid/base effects, are soluble in a relatively small amount of warm light petroleum spirit and are relatively non-volatile at 100°C.

Extracts from a specified method are defined as: "fatty matter obtained by subjecting the sample to prescribed method X". This definition includes the effects of chemical change due to the extraction process.

The only methods for fat, or rather oil, enshrined in legislation in the U.K. are those for animal feeding stuffs. In the absence of milk powder, the method is a continuous extraction with light petroleum spirit. How does this "oil" compare with the species defined above? It is clearly not fatty acid glyceride "fat", nor one or all of the "fats" present, since other chemicals can be extracted, and some natural fat will be occluded. Total fatty matter is not determined, since some cereal fatty matter, and calcium and magnesium salts of fatty acids will not be extracted. It is not even "fatty matter", since there is no extraction of the residue with a small amount of petroleum spirit. For the purposes of the

Regulations, caffeine is oil. In short, the method produces a figure, the significance of which outside the prescribed method is doubtful.

Suitability as Legal Definitions

Any definition could be used in legislation, but some are more suitable than others. "Fats" would be useful to manufacturers since it relates to actual quantities of commercial oils and fats. From the enforcement point of view, fatty additives could not be sneaked in, to be included in a "total fats" requirement. Examples of "a fat", e.g. milk fat, cocoa butter, are used in existing legislation. "A fat" or "fats" requirements are suitable for enforcement at factory level.

Blends of individual fats also containing constituents not themselves qualifying as "a fat"—in effect, additives or further ingredients—would be described as "fats with (additive/ingredient)". An emulsion of fats, water and an emulsifier could be "80 per cent. fats with permitted emulsifier".

Total fatty matter is probably a good approximation to "dietary fat", and has a single meaning, irrespective of the method of determination. Where nutritional considerations are important, such as human "low fat" foods and animal feeding stuffs, it would be the best choice.

Specified methods giving fatty matter figures could be designed to give rapid results, and be useful as screening tests for quality control and enforcement at factory level. Foods of similar composition could have a reference method specified for enforcement. The method should relate to meaningful criteria, such as nutritional effects, commercial amounts or quality, rather than just producing a figure.

Chemical, fatty acid glyceride "fat" does not have much significance outside its academic definition, except that both fats and fatty matter would usually consist mainly of fatty acid glyceride. It could be used to control the quality of fats or fatty matter used, rather like the lean meat requirements in meat regulations—an important consideration when cheaper substitutes are forever being sought.

All the above entities have potential use in legislation. Several defined entities give flexibility and clarity, rather than perpetuating confusion over what "fat" is by defining it in many different ways for the purposes of various legislation. Even so, basic definitions can be modified for particular situations. For example, hydrocarbons, being of no nutritional value, but used as an additive or in processing, could be excluded from total fatty matter.

Analytical Implications

No doubt, difficulties in determining the defined species analytically have already occurred to most readers. But such problems are nothing new—as in determining the proportion of a particular fat in a product—a requirement of some existing legislation. Some specific fats can be estimated through a factor characteristic of that fat, e.g. butyric acid for butterfat, linolenic acid for horsefat—only roughly quantitative and often subject to interference. General fat

values (e.g. saponification value), fatty acid distribution and qualitative tests for presence or absence of types of fat can support an assumption that the total fatty matter is due to one particular fat. Methods in Pearson¹ abound for determining fat mixtures, but with blends of many, and perhaps hydrogenated fats, application of these today may be doubtful. Even qualitative tests may be invalidated by refining. Analytically, determination of the proportion of a specific fat or "fats" in total fatty matter is normally difficult or impossible, except for fats with special characteristics.

Total fatty matter determination presents two antagonistic problems—an extraction vigorous enough to release all the fatty matter, but mild enough to cause no chemical change which creates or destroys it—for most situations, an impossible task to achieve perfectly. A method could only hope to approach it, and different methods would be best for different situations. Assuming no chemical change, the most "correct" method is that which gives most fatty matter. The criterion of solubility in light petroleum confines total fatty matter to a definitive set of chemicals in the sample, which can be extracted by various methods to different degrees. Without this restriction, other chemicals, such as those in a continuous chloroform extraction residue (e.g. caffeine) would be included. Whilst chloroform extraction might be used to release fatty matter from the sample, only matter extractable by light petroleum from the chloroformic extract counts as fatty matter. This approach by-passes a need to specify a method in every situation—perhaps an impossible task even for the EEC—and puts the analyst very much back into the driving seat, both in deciding the most appropriate method in a given situation, and interpreting the result. The strict definition of total fatty matter provides sufficient discipline against inappropriate methods, and spurs the development of new procedures when the need arises.

Fatty acid glycerides could be estimated by heating then refrigerating total fatty matter with ethanol, to remove, for instance lecithin, which is soluble in cold ethanol and contains glycerol. The residue is hydrolysed, the free glycerol determined, and converted to "fat" using a factor depending on the type of fat expected. Some non-fat glycerides would interfere.

Specified methods are fine for producing reproducible figures—providing they work. Sample composition, even in a restricted area, can be very variable, and a single method may not deal with all eventualities. Quirks such as a large amount of emulsifier could render a partition method unusable—the phases may not separate. Microencapsulation or emulsions could render fat unavailable to continuous solvent extraction, producing nonsensical results. Specified methods often have a limited range outside which accurate measurement is not possible, for instance, low fat levels by the normal Gerber method with skimmed milk.

Conclusion

It is not surprising that different methods for "fat", as defined, or rather, as undefined at present, give different results. The proposed set of definitions present some analytical problems, but provide clearer objectives and criteria

than the present situation. The use of several definitions rather than only one for "fat" gives flexibility for meeting different requirements. Specified methods should give reproducible figures, but may not relate to anything meaningful outside the method, and may give practical problems if applied mandatorily. Where methods are not specified in legislation, interpretation of analytical results will, as now, require cautious application of judgement based on experience, to relate meaningfully to legal requirements.

References

1. Pearson, D., "The Chemical Analysis of Foods", Seventh Edition, Churchill Livingstone, Edinburgh, London and New York, 1976.

