Mineral Oil Hydrocarbons in Dairy Products

Table of Contents

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Introduction

For some time now, mineral oil hydrocarbons in foods have been the subject of intense discussion. Also regularly confronted with measurable residues of mineral oil hydrocarbons, the dairy sector is being called upon to determine potential input sources and to use targeted measures to prevent their transfer to foods.

The term 'mineral oil hydrocarbons' (MOH) describes a complex mixture of various substances containing between 10 and 50 carbon atoms. According to their nature, MOH are divided into two groups: 'MOSH', which represent the fraction of mineral oil saturated hydrocarbons, consisting of paraffins and naphthenes, and 'MOAH', which represent the mineral oil aromatic hydrocarbons substance group.

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Use and Input Sources

Mineral oils are derived from the fractional distillation of petroleum and are used in a variety of spheres, *inter alia* as (food-grade) lubricants, processing aids, dust collectors, adhesives, and as separating, coating and glazing agents. In addition, paraffin oil is used as a carrier, adhesive or active substance in plant-protection products. Mineral oil products may also inadvertently or unintentionally come into contact with foods. Recycled-paper-based packaging and transport materials for both raw materials and products may contain mineral-oil-based printing inks from the admixture of printed material (e.g. newspaper). These food-contact materials may also have higher MOH levels from their deliberate treatment or coating with mineral oil products. The improper use of the relevant oils and lubricants may also lead to elevated levels.

Essentially, MOSH and MOAH entry routes into foods can be divided into three groups:

- **Migration:** Mineral oil hydrocarbons from food packaging and contact materials enter the food through direct contact or via the gas phase (i.e. evaporation, transport and recondensation).
- **Contamination:** In principle, entry can occur along the entire process chain. Important factors here are environmental factors (exhaust fumes, emissions, particulate matter, etc.), as well as oiled machine parts used in harvest and production processes. Thus, entry can occur even at the food-raw-materials stage.
- **Additives/Auxiliary substances:** These can affect various food-processing stages, and involve permitted (i.e. food-grade) products used for technical reasons.

In the dairy sector, consumer goods may be contaminated by direct contact with labels, waxes, care products and packaging films. MOH input via cattle feed, whether due to environmental pollution or contamination on farms, is in principle conceivable, but needs to be examined more closely.

Limits and Benchmarks

To date, there has been no binding regulation of mineral oil hydrocarbons in foodstuffs with legal limits. Ordinances currently in force in Switzerland only concern migration into the food from packaging materials, and corresponding maximum migration values are defined. The Ordinance of the Swiss Federal Department of Home Affairs FDHA concerning materials and objects intended to come into contact with foodstuffs (Foodstuffs and Consumer Goods Ordinance), for example, requires that consumer goods made from plastic material contain only those manufacturing materials that are included in the List of Permitted Substances (Annexe 2). For substances for which no specific maximum migration values have been stipulated, the total migration value of 10 mg/dm^2 for the surface coming into contact with the food, or 60 mg/kg of food for consumer goods from plastic that are intended to come into contact with foods meant for infants and small children, applies.

Nevertheless, in the past, a number of retailers adopted 2 mg/kg MOSH – originally intended for foods stored in cardboard cartons, such as rice – as a general maximum value in food, and accordingly producers were required to demonstrate that they did not exceed this value. Measurements have shown, however, that such a low limit is neither representative nor feasible for many dairy products.

For the toxicologically more alarming MOAH, the European Commission has published recommendations for limits, urging the removal from the market of products reaching or exceeding these limits. Since this recommendation is not legally binding, however, it is up to the EU Member States to implement it. The limits of quantitation are stipulated as follows:

- 0.5 mg MOAH/kg – dry foodstuffs with a low fat/oil content (≤ 4% fat/oil)
- 1 mg MOAH/kg – foodstuffs with a higher fat/oil content (> 4% fat/oil, ≤ 50% fat/oil)
- 2 mg MOAH/kg – fats/oils or foodstuffs with > 50% fat/oil.

Mineral oil components like MOSH and MOAH are fat-soluble mixtures, so they accumulate in foods with a higher fat content. In such products, including some dairy products, a higher basic level of contaminants is to be expected due in part to environmental, and hence unavoidable, causes.

Instead of a general tolerance value, the German Regional Consumer Protection Association "Länderarbeitsgemeinschaft Verbraucherschutz" (LAV) and the Food Federation Germany recommend the use of food-specific benchmarks for MOH. Such benchmarks have been determined for various food categories on the basis of over 12,500 individual datasets from the economic and monitoring spheres. The values established here are to be understood as guidelines and recommendations for practice, and indicate what MOH levels are to be expected in food. The measured MOH values consist of contributions along the value chain as well as environmental contaminants. Here, a benchmark for MOSH and MOSH analogues in milk and dairy products was set at 22 mg/kg milkfat. For MOAH, the maximum limits of quantitation apply irrespective of the food category, i.e. content should not be determinable using standard methods.

Based on our experience and measurements to date, we consider the benchmarks defined for milk and dairy products to be realistic assessments and useful aids for practice. Thus, the exceeding of the benchmark for MOSH could be an indication of an avoidable input source, and grounds for further clarification. However, as already mentioned by the publishers, in no circumstances should this value be misinterpreted and applied as a limit.

The following calculation is used to determine the benchmark for milk or dairy products with a known fat content:

$$Product - relevant\ benchmark = 22\frac{mg}{kg} \cdot \frac{fat\ content\ [\%]}{100}$$

Table 1 lists the expected MOSH content for some dairy products and for milk.

Table 1: MOSH benchmarks for milk and dairy products

Product	**Fat Content g/100g**	**MOSH Benchmark mg/kg**
Milk		
Full-fat milk	4	0.9
Milk drink	2.8	0.6
Non-fat milk	0.1	0.0
Yoghurt		
Natural yoghurt	3.6	0.8
Greek-style (higher-fat) yoghurt	10	2.2
Cream		
Double cream	35	7.7
Single cream	25	5.5
Coffee cream	15	3.3
Butter		
Premium, cooking and whey butter	82	18.0
Clarified butter	98	21.6
Cheese		
Emmentaler	31	6.9
Gruyère	32	7.1

Produkt	Fat Content g/100g	MOSH Benchmark mg/kg
Cheese		
Sbrinz	33	7.3
Bernese Alpine Cheese*	38	8.4
Berner Hobelkäse*	41	9.1
Appenzeller	32	7.0
Appenzeller, 1/4-fat	11	2.4
Tilsiter	29	6.4
Raclette	28	6.2
Brie	24	5.3
Camembert	24	5.3
Vacherin fribourgeois	30	6.6
Vacherin Mont d'Or	23	5.1

*Median from R. Sieber (2012), Zusammensetzung von Milch und Milchprodukten Schweizerischer Herkunft ['Composition of Milk and Dairy Products of Swiss Origin'], ALP science No. 538.

It should be borne in mind, however, that the benchmarks were determined on the basis of the 90th centile, and so 90% of the market-typical MOSH values in dairy products taken into account in the study lie below this value. The exceeding of the benchmark may be an indication of an avoidable contamination, and should lead to an investigation of the cause within the manufacturing and packaging processes. Important points for further assessment are:

- **Packaging:** Composition and type of packaging as well as length of storage of the food (length of contact with packaging material), best-before date
- **Raw-materials situation:** Manufacturing processes and food contact materials at all stages
- **Product:** Purpose and usual quantities consumed.

Owing to unavoidable input sources, but also to the use of permitted auxiliary substances, it must be assumed that the input of mineral oil hydrocarbons cannot be avoided in all cases, even with an optimised manufacturing and packaging process. Published in 2017, the Toolbox of the German Federation of Food Law and Food Science "Lebensmittelverband Deutschland e.V." is a useful guideline that can be consulted for risk analysis, presenting specific contamination sources and listing stage-related measures in a clear compilation.

Toxicity and Analytics

The potential health risks arising from MOH are wide-ranging. MOAH may contain polycyclic aromatic compounds with genotoxic and carcinogenic properties. A European Food Safety Authority (EFSA) revision of the risk analysis for mineral oils was published in September 2023. In it, the conclusion was reached that current dietary exposure to MOSH does not pose a health risk for any age group. Regarding MOAH, an increased presence of 3- or polycyclic aromatic substances is thought to constitute an increased risk, especially for younger age groups.

Analysing MOH in foods is a demanding task. Previous methods have not yet allowed us to separate complex mixtures like MOH into their individual constituent parts. Thus, the chromatograms show largely unresolved and overlapping signals which converge into a hump. MOSH and MOAH are separated by means of liquid chromatography (LC), which is combined with gas chromatography with flame ionisation detection (GC-FID) for further separation and quantitation.
The analysis is complicated by hydrocarbons occurring naturally in food, since these overlap with the signals of the mineral-oil components in the chromatogram. Because these hydrocarbons have a chemical structure similar to that of the mineral oil hydrocarbons, they cannot be separated from the latter by conventional methods. Examples of such

substances are natural n-alkanes, terpenes and olefins occurring in plant-derived raw materials. Dairy products also produce signals that overlap with the measurement range for mineral oils and were assigned to natural components of the feed (‘grass peaks’). The concentration of the measured substance is derived from the area integration of the respective peak. For the correct quantitation of mineral oil in foods, these naturally occurring substances must be identified and excluded from the MOSH quantitation (Figure 1). Moreover, the analytic methods used do not allow for a separation of MOSH and POH (polyolefin oligomeric hydrocarbons) from certain plastic packaging whose toxicity is unclear.

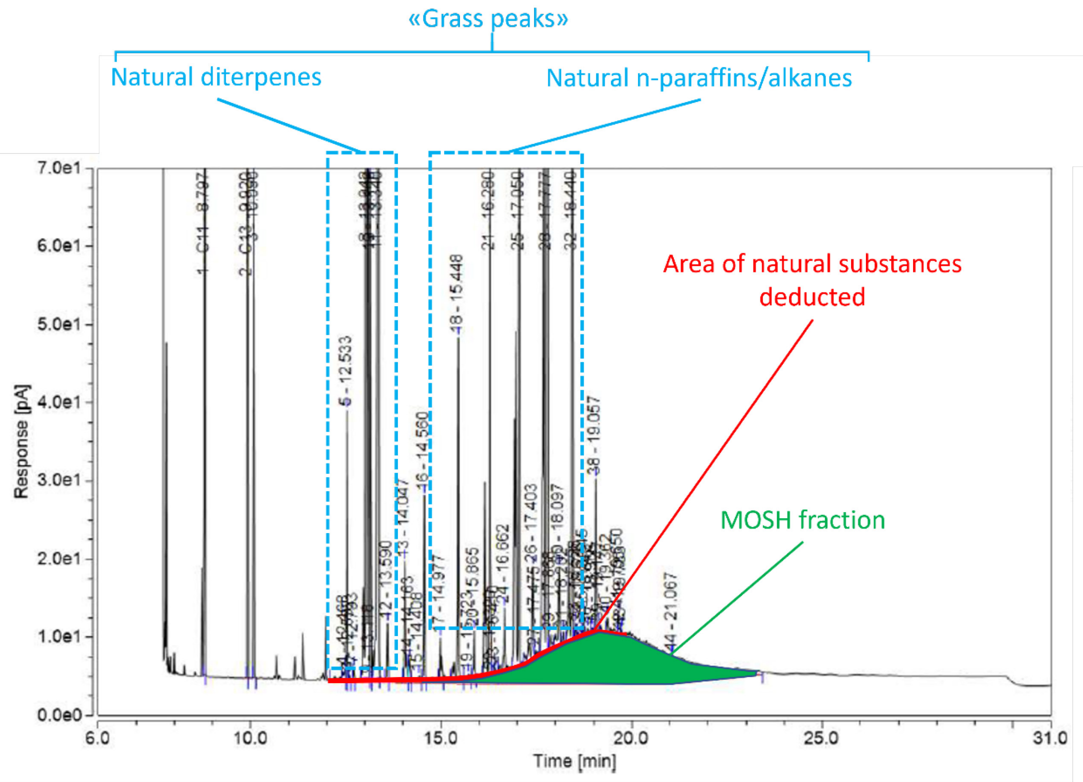

Figure 1: Analysis of a MOSH chromatogram using the example of a butter sample

The previously mentioned additives or auxiliary substances are by-products of mineral-oil refinement, i.e. purified mineral-oil components (e.g. paraffin waxes). These permitted food additives are likewise analytically indistinguishable from undesirable MOSH. Together with the POH and polyalphaolefins (components of synthetic lubricants and hot-setting adhesives), this group belongs to the so-called MOSH analogues.

To determine the source of mineral oil hydrocarbons in food, close examination of the GC chromatogram is essential. Here, signal intensity is plotted against retention time. The longer the retention time, the higher the boiling point of the detected substance, and the longer-chained its carbon backbone (gas < liquids/solvents < oils < waxes). Contaminants with higher boiling points migrate onto the surface of the food via direct contact (food packaging and other contact materials during the manufacturing process) or are introduced at an earlier stage in the value chain. In addition, low-boiling-point substances can migrate via the gas phase and can even reach the food from the outer packaging if the packaging material has inadequate barrier properties.

To check whether transfer from the packaging-material components to the food has occurred, measurements from the packaging are compared with the food. Where migration has occurred, characteristic, often periodic signals (e.g. even and odd alkane peaks in mineral-oil waxes or only even signals in POH from polyethylene packaging; see Figure 2a/b) are found in the chromatogram of the food. In addition, mixtures of various hydrocarbons from different sources are frequently detected in packaging (Figure 2a/b). Regarding Figure 2a, it should be added that in addition to the characteristic MOSH signals that can be assigned to the packaging, the butter already exhibited a significant burden of MOH of unknown origin (markedly increased signal area below the packaging peak).

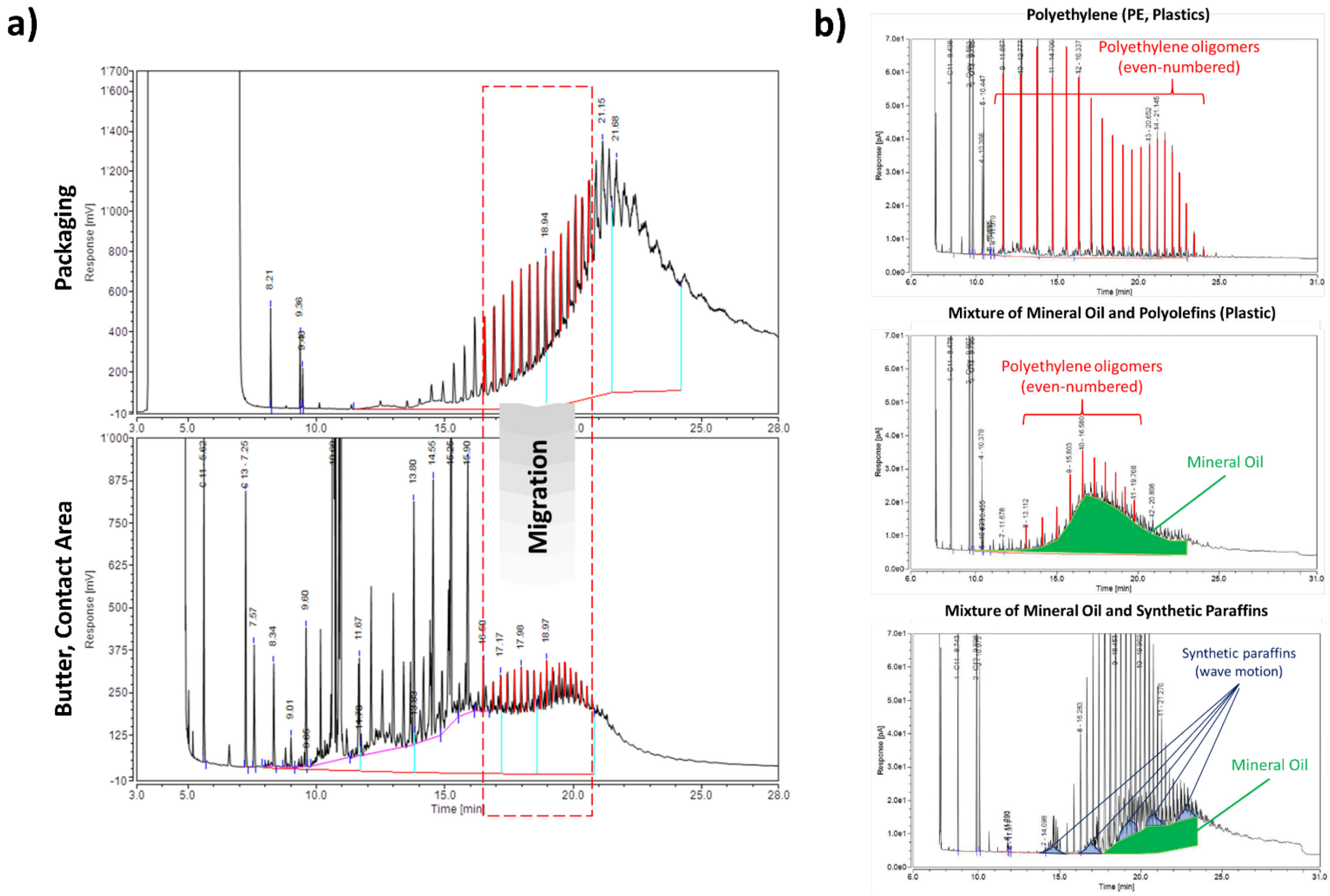

Figure 2:
(a) Migration of mineral-oil wax from packaging to food;
(b) Different compositions of butter packaging and their characteristic signals

Data Situation

Although many products have been examined in terms of the mineral oil hydrocarbon issue, internationally there is a gap in the data with respect to milk and cheese. Working together with the Zurich Cantonal Laboratory, Agroscope examined Swiss cheese for mineral oil hydrocarbons. Several cheese varieties with different fat levels were randomly selected and analysed. MOAH were not detected in any of the examined samples. Levels of MOSH detected fluctuated dramatically, supporting the hypothesis that contamination with MOSH increases with increasing fat content. By contrast, the assumption that environmental contamination of cheeses was higher in densely populated, industrialised areas could not be unequivocally confirmed. While this probably tends to be true, it is judged to be a negligible factor.

Currently, we lack the data resources to assess the spread of background levels and outliers – data which should be compiled internationally before measures are taken. This data corpus would also need to cover regional and variety-specific aspects, which makes its compilation accordingly complicated.

In a further series of tests, cheese wheels were rubbed with paraffin oil, thus assigned to the MOSH, then ripened and stored as commonly done in practice. The cheese was tested twice in total: one day after contamination and at the end of the storage period. The sampling involved removing a cylinder from the cheese and dividing it into three zones – rind, edge and core – then measuring these separately and comparing them with one another. Migration of the oil into the edible portion of the cheese was not detected in any of the examined cheeses.

Conclusions

The presence of mineral oil hydrocarbons in milk and dairy products is an important issue that has been hotly debated for some time now. Although currently there is no binding regulation with legal limits, it is important to identify avoidable input sources and prevent input with targeted measures.
Mineral oil hydrocarbons are fat-soluble, and therefore accumulate in foods of higher fat content. Thus, the potential input of mineral oil hydrocarbons varies according to product category, manufacturing process, environmental influences, etc. A general limit for foods is therefore neither representative nor practicable. To assess the input of mineral oil hydrocarbons in milk or dairy products there are benchmarks that have been determined for various food categories. The exceeding of these values in a product could be indicative of avoidable input sources. This should lead to an investigation of the cause across all manufacturing and packing processes, and to measures being taken if possible.

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