The Mineral Oil Signal Is Not a Molecule

MOAH, Measurement Uncertainty and Europe's Approaching 2027 Compliance Threshold

INTABIOTECH KNOWLEDGE CENTER | ORIGINAL RESEARCH & COMPARATIVE REGULATORY ANALYSIS

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ABSTRACT

Europe is approaching a decisive change in its treatment of mineral oil aromatic hydrocarbons (MOAH) in food. On 13 May 2026, Member States supported draft maximum levels and revised analytical-control provisions, with most proposed application dates beginning in January 2027; as of 29 October, the Commission's public status page still describes formal adoption as targeted rather than completed. The transition exposes a scientific difficulty: MOAH is an operationally defined, chemically heterogeneous chromatographic fraction, not a single toxicant or a uniquely identifiable contamination source. This article examines the toxicological rationale, analytical uncertainty, and supply-chain pathways that connect cocoa, edible oils, dry ingredients, lubricants and packaging. It distinguishes binding law from committee statements and prospective rules, compares EU, Spanish, British and US approaches, and evaluates the implications for procurement, laboratories and incident decisions. A proposed source-resolved evidence framework integrates validated measurement, process-stage sampling and causal attribution. The framework is a research agenda, not an established compliance method or a substitute for statutory obligations.

KEYWORDS: *mineral oil hydrocarbons; MOAH; MOSH; cocoa; food contaminants; analytical uncertainty; source attribution; regulatory compliance*

01 | The regulatory event: a decision made before a regulation is published

The regulatory turning point occurred on 13 May 2026, when the Standing Committee on Plants, Animals, Food and Feed (SCoPAFF) supported a draft Commission regulation establishing maximum levels for mineral oil aromatic hydrocarbons in specified foods, together with draft sampling-and-analysis rules. The Commission's public contaminants page still described formal adoption as targeted for October 2026 when checked on 29 October. Consequently, the adopted committee position, the proposed dates and limits, and an enforceable published amendment must not be presented as legally interchangeable. [1–5]

A companion joint statement, agreed by Member State representatives on 13 May, is immediately relevant to practice. It recommends using the maximum levels in the voted draft as the basis for Article 14 food-safety enforcement during the interval before their application. That statement is an administrative coordination position, not itself an amendment to Regulation (EU) 2023/915. Article 14 of Regulation (EC) No 178/2002 nevertheless remains operative, and unsafe food cannot lawfully be marketed simply because a future numerical limit has not yet begun to apply. [2,16,17]

The Commission indicates that most proposed maximum levels are scheduled to apply from 1 January 2027, with some later dates in 2028 or 2030. Precise obligations depend on the final published annex, product category, transitional provisions and effective dates. A business preparing 2027 purchase contracts should therefore maintain two fields in its compliance matrix: 'verified law in force' and 'approved draft / expected future obligation'. Neither field can substitute for the other. [1–5]

02 | Why this matters to ingredient manufacturers rather than only to regulators

MOAH contamination is relevant to commodities that travel long distances, undergo mechanical handling, contact packaging and pass through multiple processing stages. The draft's reported scope includes cocoa products, edible oils, cereals, herbs, spices, food supplements and compound foods. Those are precisely the product classes in which procurement specifications, packaging construction, supplier qualification and factory maintenance can alter exposure pathways. [1,3,4,28]

For ingredient suppliers, a single adverse result may affect an entire shipment, not merely the tested jar. It may also trigger disagreement over whether the signal is a true MOAH fraction, an analytical interference, contamination acquired before dispatch, or migration occurring after delivery. The cost of that uncertainty includes retesting, storage, blocked inventory, customer claims, and potentially a withdrawal or recall. A defensible response must address the science and the legal status simultaneously.

03 | MOSH and MOAH are analytical families, not individual substances

Mineral oil hydrocarbons comprise complex mixtures of compounds usually described in two operational fractions: saturated hydrocarbons (MOSH) and aromatic hydrocarbons (MOAH). The mixtures vary by carbon-number distribution, source, refining history and molecular architecture. EFSA's 2023 assessment considered mineral-oil-related hydrocarbons broadly in the C10–C50 range, while noting that natural hydrocarbons and polyolefin oligomers may complicate separation. [7]

A numerical result such as 'MOAH 1.1 mg/kg' does not identify a unique molecule, demonstrate the presence of a particular three-ring carcinogen, or reveal which machine, bag or coating caused the result. It reports a quantified fraction under a defined method and integration convention. Conversely, the fact that a fraction contains many compounds does not make the toxicological concern imaginary. Some aromatic constituents, particularly those with three or more rings, are associated with genotoxicity and carcinogenicity; the fraction's composition matters. [7,9]

The distinction is central to both honest communication and good science. 'MOAH detected' is a measurement statement. 'A hazardous three-ring constituent was confirmed' is a stronger chemical-identification statement. 'The packaging caused the contamination' is a causal statement. They require different evidence.

04 | Toxicology: what EFSA established, and what remains uncertain

EFSA's updated 2023 risk assessment concluded that estimated current dietary exposure to MOSH did not raise a public-health concern across age classes under the assessment's assumptions, while warning that the margin could narrow if mitigation ceased. For MOAH, EFSA identified concern arising from the possible presence of three-or-more-ring aromatic constituents and gaps in toxicological information for one- and two-ring fractions. These are not equivalent hazard conclusions for the two groups. [7]

The scientific opinion used scenarios for the assumed proportion of higher-ring MOAH in dietary exposure because detailed composition data were scarce. This is a consequential limitation: the same total MOAH mass can represent mixtures with different toxicological relevance. Regulators may therefore use conservative sum limits to manage uncertainty, but a sum concentration should not be misrepresented as a complete structure-specific risk characterisation. [7]

Neither a chromatographic non-detect nor a number below a proposed maximum level proves that all conceivable health risks are absent. It supports a more limited proposition: the analysed sample met a defined method's reporting criterion and, if the relevant limit is in force, may support compliance under that limit and its conditions.

05 | The measurement problem: the hump, the baseline and the interferent

Routine MOSH/MOAH analysis commonly uses online liquid chromatography coupled to gas chromatography with flame-ionisation detection (LC–GC–FID). The detector responds to hydrocarbon mass rather than uniquely

identifying each component. Complex unresolved chromatographic envelopes, or 'humps', must be separated from naturally occurring compounds, polyolefin oligomers, additives and other potential interferences. Sample preparation, fraction separation, baseline choice and integration rules influence the result. [7–10]

Comprehensive two-dimensional gas chromatography, often with mass spectrometry (GC×GC–MS), can provide additional compositional resolution, including indications of aromatic-ring number and possible source fingerprints. It does not automatically solve every attribution question. The European Union Reference Laboratory for Processing Contaminants issued guidance in 2025 specifically to harmonise interpretation and reporting and to help identify interferences and contamination sources. [9]

An analytical report suitable for a consequential decision should disclose the food matrix, sampled lot, sample preparation, analytical range, calibration and controls, limit of quantification, measurement uncertainty, recovery where relevant, treatment of interferences and whether an orthogonal confirmation was performed. A simple green/red dashboard is not an adequate substitute for these particulars.

06 | The low-LOQ paradox: a published standard does not validate every matrix

ISO 20122:2024 describes an online HPLC–GC–FID procedure for vegetable fats and oils, not for all foods. Its interlaboratory evidence supports suitability above 3 mg/kg for MOSH and above 2 mg/kg for MOAH. The standard also recognises the role of GC×GC–MS in examining suspected interference. This scope must not be silently extended to cocoa powder, botanicals or infant food, nor should the standard's published performance range be mistaken for proof of reliable quantification at every proposed lower regulatory threshold. [10]

This is not an argument that lower concentrations cannot be measured. Specialist laboratories can validate lower quantification limits for specified matrices, and the Commission's JRC guidance addresses fit-for-purpose performance. It is an argument that the laboratory must demonstrate the capability actually required by the intended food category and decision limit. A claimed LOQ is not self-validating, especially where extraction efficiency and interference differ markedly between oil, cocoa and powdered botanical products. [8–10]

The 2024 work by Bauwens and Purcaro examined improved saponification to reduce variability in edible-oil MOAH determination. A 2025 paper on discrepancies in GC×GC–MS confirmation likewise underscores the need for harmonised interpretation. Both are prior evidence that analytical disagreement is a real methodological issue, not a novel problem discovered in 2026. [13,15]

07 | Cocoa: the 2025 transport study changes the causal conversation

A peer-reviewed study published in Food Chemistry in late 2025 examined 28 cocoa-bean samples before and after transport in jute bags contaminated with mineral oil hydrocarbons. Mean MOSH increased from 0.9 to 9.6 mg/kg, and MOAH reached 2.3 mg/kg in the reported setting. The authors estimated that roughly 40% of transferred hydrocarbons reaching whole beans were present in shelled beans; subsequent processing distributed contamination into cocoa mass, butter and powder, with fat content influencing partitioning. [11]

This is unusually instructive evidence because it follows a plausible transfer mechanism across stages rather than merely reporting a finished-product positive. It also illustrates why source attribution cannot stop at the first positive laboratory result. Bag composition, storage duration, shell removal, equipment lubricants and phase partitioning can all influence the eventual profile. The sample set and conditions do not establish universal migration rates for every cocoa supply chain.

Earlier research on cocoa powders and associated packaging found both mineral-oil-related signals and polyolefin oligomer hydrocarbons, with contributions from primary plastic packaging and recycled cardboard. It follows that 'packaging' is not one homogeneous source and that different analytical families may overlap in a simplified report. [12]

08 | The cocoa mass balance is not the same as a compliance calculation

Consider a hypothetical, explicitly non-empirical batch of 5,000 kg of cocoa ingredient containing 0.8 mg/kg of measured MOAH. Its apparent total MOAH mass is 4 g. That elementary calculation does not tell us whether the

material entered through 5,000 kg of beans, a smaller contaminated sublot, a process lubricant or a packaging component. Nor does it establish how much would appear in cocoa butter after pressing. Partition coefficients, extraction yields and losses are needed. [11]

A stage-resolved mass balance can help identify implausible explanations: if measured total MOAH mass rises sharply after an identified operation, the process deserves investigation. Yet sampling uncertainty, variable recovery, water loss and changes in the operationally defined fraction can produce apparent changes even without a new contamination source. Mass balance should therefore be used with uncertainty bands and confirmatory measurements.

Crucially, averaging a high-MOAH lot with a low-MOAH lot is not a legitimate strategy for making non-compliant material acceptable. Article 2(2) of Regulation (EU) 2023/915 prohibits mixing food complying with an applicable maximum level with food exceeding it. Process modelling must not be repurposed as a dilution plan. [17]

09 | Oil refining: removal is process-specific, not a universal promise

Deodorisation and other refining steps can reduce certain volatile or semi-volatile MOAH fractions, but performance depends on molecular size, aromatic structure, temperature, residence time, vacuum, steam flow and the oil matrix. A 2024 experimental study of spiked coconut oil examined the effect of deodorisation conditions on different MOAH structures. It does not validate a universal 'MOAH-free after refining' claim for commercial oils. [14]

For a supplier of cocoa butter, seed oil, botanical lipid or algae-derived oil, the appropriate qualification question is whether a defined process, at commercial scale and under worst-case operating conditions, consistently achieves the target result without creating unacceptable oxidation, sensory damage or other contaminants. An operator should record both incoming contamination and post-refining residuals rather than infer performance from a generic processing label.

10 | Dry ingredients, spices and supplements: heterogeneity compounds uncertainty

Powders and dried botanicals can exhibit pronounced within-lot heterogeneity, contamination from transport sacks and contact surfaces, and extraction interferences from natural terpenes or lipophilic constituents. A single small grab sample may not represent a tonne of ingredient. A dry product with a low fat content is not necessarily analytically simple: complex natural co-extractives may complicate MOAH fraction assignment. [8,9]

The draft framework includes category-specific proposed values and certain special analytical provisions for difficult matrices. Exact thresholds, effective dates and transitional treatments must be taken from the final Official Journal text when published, not from a sales leaflet or a secondary summary. The practical priority today is a matrix-specific sampling and analytical validation programme. [1,3–6]

For nutraceutical blends, contamination may arise in a minor high-fat carrier or a coating rather than in the headline active ingredient. Ingredient certificates should identify the tested material and matrix, not simply display the brand of a laboratory. Where supplements are exported to multiple markets, the destination-country legal basis and the product's actual composition both matter.

11 | Packaging migration: a real pathway, but not the only one

Recycled paperboard, printing inks and some packaging components are established potential sources of mineral-oil-related migration. The 2017 EU monitoring recommendation explicitly encouraged investigation of packaging materials, functional barriers and processing equipment. The 2022 cocoa study provided product-level evidence for more than one packaging-related hydrocarbon family. [12,27]

But an attribution statement should follow an experiment. Paired tests of incoming ingredient, packaging construction and packaged product over realistic storage conditions are stronger than merely finding MOAH in a finished product and blaming cardboard. Migration depends on time, temperature, surface area, headspace, fat content and barrier design. A supplier's generic 'food-contact compliant' declaration does not quantify the MOAH barrier performance of a particular packaging configuration. Regulation (EC) No 1935/2004 supplies the general

EU safety framework for food-contact materials, but a migration claim still needs evidence appropriate to the article and its intended use. [19]

The idea of functional mineral-oil barriers is not new. Patent publications WO2013160199A1 and EP3554829B1 describe barrier approaches for paperboard or films. Any future research proposal must therefore focus on improved validation, source resolution or practical deployment and not assert invention of the barrier principle itself. [25,26]

12 | Process lubricants: 'food grade' does not mean zero transfer

Mechanical bearings, conveyor systems, hydraulic components, compressors, release agents and maintenance practices can create opportunities for unintended hydrocarbon transfer. A lubricant permitted for incidental food contact may still be inappropriate if used outside its conditions or allowed to enter food through a preventable leak. A certificate or classification for a lubricant is not a food-batch residue analysis. [7,22]

The United States expressly regulates certain incidental-contact lubricants under 21 CFR 178.3570, with substance-specific limitations. That is not an EU authorisation, nor does it establish that a finished food meets a future EU MOAH limit. A useful supplier audit should examine lubricant identity, locations, leak histories, maintenance records, changeover controls and the timing of affected production runs. [22]

13 | The EU legal hierarchy: what binds on 29 October 2026

First, Regulation (EC) No 178/2002 imposes general food-safety responsibilities, including the prohibition on placing unsafe food on the market, traceability and withdrawal/recall duties. Second, Regulation (EU) 2023/915 already sets binding maximum levels for listed contaminants, with a prohibition on mixing compliant and non-compliant foods where an applicable level exists. Third, the 2026 MOAH maximum-level amendment remained a voted draft in the Commission's published status information consulted for this article; its annex and timetable should not be described as an operative amendment until formally adopted and published. [1–5,16,17]

Fourth, the 13 May 2026 SCoPAFF statement establishes a harmonised enforcement approach using the voted draft's values as a reference under the existing general food-safety law during transition. It does not amend the underlying Regulation. Fifth, the draft sampling-and-analysis amendment and monitoring recommendation have distinct legal effects from the proposed maximum-level regulation. A recommendation and a binding maximum level are not synonyms. [2,5,6]

This hierarchy matters in customer correspondence. A technically precise statement might say: 'The tested lot is below our provisional purchasing specification, based on the SCoPAFF-voted 2026 draft; final EU legal thresholds and application dates will be checked against the published amendment.' That is more defensible than saying 'EU MOAH certified 2027' before the act exists.

14 | Spain: official control, evidence preservation and contractual risk

In Spain, EU food law applies directly, while official controls are carried out by the competent authorities within the national and autonomous-community system under the framework of Regulation (EU) 2017/625. A manufacturer facing an adverse MOAH finding should preserve the original sample identity, sampling protocol, laboratory report, chromatograms where available, chain of custody, packaging and lubricant records, and evidence of the affected batch genealogy. [18]

Where a result is disputed, the correct response is not simply to commission a second favourable analysis from a different grab sample. The firm should examine whether the samples were representative, whether the same matrix and method were used, whether the laboratories had suitable validated LOQs and whether a confirmatory technique resolved potential interferences. Procedural rights and the handling of official samples depend on the specific control circumstances and applicable national rules; a private counter-analysis does not automatically invalidate an official finding.

A supply agreement should allocate duties to disclose test method, notify excursions, preserve retained samples and cooperate in source investigation. It should avoid an unqualified promise that a shipment will satisfy any future law regardless of its final wording.

15 | Great Britain and Northern Ireland: divergence is not hypothetical

Great Britain has its own domestic food-law route and competent authorities; Northern Ireland requires separate consideration of applicable EU-linked rules. The British Food Standards Agency's alert updated on 16 January 2026 instructed businesses to stop selling, withdraw and recall specified imported confectionery products containing MOAH. This is concrete evidence that UK authorities can take action on MOAH safety concerns independently of the EU's pending numerical maximum-level package. [20]

The alert should not be used to claim that Britain has adopted every proposed EU category limit. It demonstrates a product-specific enforcement decision under British food-safety law. Importers need a territory-specific risk and compliance assessment; a certificate showing conformity with a US use authorisation is not sufficient proof of British acceptability.

16 | United States: permitted mineral oil uses are not blanket MOAH clearance

US federal law contains defined permissions for certain highly refined white mineral oil uses in foods under 21 CFR 172.878 and for specified food-contact applications under 21 CFR 178.3620 and 178.3570. These permissions have identity, purity, application and concentration conditions. They are not an unconditional licence for any petroleum-derived aromatic fraction, and they do not establish compliance with EU contaminant limits. [21–23]

The contrast is important for exporters. A product may be lawfully formulated for a specific US market use while presenting a separate compliance or safety question in Britain or the EU. Likewise, a low EU MOAH analytical result does not prove that every ingredient, processing aid or packaging component satisfies US food-additive law. The relevant comparison is of actual legal routes and intended uses, not slogans about which jurisdiction is 'stricter'.

17 | Feed and petfood: adjacent exposure pathways, different statutes

Feed and petfood suppliers should not automatically import human-food MOAH category limits into animal-feed specifications as though the same EU regulation directly covered both. Feed law, including applicable contaminant and feed-hygiene requirements, has its own scope. In the United States, 21 CFR 573.680 permits certain mineral oil uses in animal feed under defined conditions; it does not resolve European feed-market obligations. [24]

Nevertheless, the physical pathways -dust-control agents, lubricants, transport sacks, coatings and bulk handling- can overlap. A practical quality programme may investigate MOSH/MOAH in feed materials as a risk-management measure even when no identical human-food numerical limit applies. A company should distinguish voluntary customer specifications, feed-specific law and human-food requirements.

18 | A supplier qualification protocol that actually tests the hypothesis

A useful programme begins by ranking materials by fat content, supply-chain complexity, contact surfaces, historical incidents and customer-market exposure. It then records the incoming material's analytical baseline; samples representative stages of transport, storage and manufacture; and collects matched packaging and lubricant information. For each stage, sampling should be designed to detect meaningful changes rather than merely to produce a certificate.

When a signal is found, the first analytical task is confirmation: check chromatographic pattern, controls, potential interferences and LOQ. The second task is source comparison: examine matched upstream and downstream samples and plausible contamination materials. The third task is corrective action: replace or qualify the source, validate a barrier or process change, and repeat sampling over enough lots to estimate

reliability. None of these tasks should be replaced by an AI-generated confidence score without auditable underlying data. [8–10,11–13]

A negative result after corrective action is informative only to the extent that the method, sampling plan and variability justify it. Supplier approval should be conditional on change control: a new jute-bag supplier, printing ink, lubricant or packaging liner may invalidate the original evidence.

19 | Commercial implications for cocoa, oils and functional ingredients

For cocoa powder and cocoa butter, the 2025 transport study makes upstream packaging and logistics a high-priority intervention point, not a peripheral concern. For oils, refining and storage conditions deserve independent validation; 'refined' is not an analytical outcome. For botanicals, flavours and supplement blends, interference assessment and matrix-specific LOQ may dominate the reliability of a purchasing specification. [11–14]

The opportunity for ingredient companies is to offer more than a one-line declaration: a controlled evidence dossier linking product identity, process history, sampling plan, analytical method, quantified result, uncertainty, packaging and corrective-action record. This is not a licence to advertise unproven contaminant-removal technologies. It is a means of reducing disputes and improving the quality of decisions across a supply chain.

For INTABIOTECH's relevant ingredient domains, the immediate practical question is whether procurement and product-development teams can obtain defensible MOSH/MOAH evidence for cocoa, botanical extracts, dry powders and lipid-containing preparations before promising market access. Product-specific risk analysis is appropriate; no product efficacy or regulatory status is inferred merely from a corporate technology name.

20 | Research & Innovation Opportunity

Unresolved problem

Industry has validated methods for quantifying hydrocarbon fractions and a substantial literature on individual contamination routes. Yet a reproducible, economically feasible method for assigning a finished-product MOAH signal to specific supply-chain events across different matrices remains difficult, particularly near low decision thresholds. Analytical interference, batch heterogeneity and shared contamination pathways can generate competing explanations. [7–15]

What is already known and what is not

Known elements include LC–GC–FID quantification, GC×GC–MS characterisation, packaging barrier concepts, transport-related cocoa contamination, process-stage sampling and quality-management traceability. These are established fields, with prior publications and patents. Unknowns include how reliably a harmonised, source-resolved protocol can distinguish packaging from lubricant and raw-material contributions in routine commercial samples, and whether its added cost improves the correctness and speed of decisions. [9,11,12,25,26]

Proposed hypothesis and development pathway

Research hypothesis not established fact: a staged evidence protocol combining (i) validated fraction quantification, (ii) selective GC×GC–MS fingerprints, (iii) time-stamped batch and process-stage samples, (iv) material-flow reconciliation and (v) explicitly uncertainty-aware causal ranking will reduce false source attribution and unnecessary lot rejection compared with a finished-product-only test. A 'Source-Resolved MOAH Evidence Passport' is proposed as a documentary and experimental workflow, not a novel chromatographic instrument, a statutory certificate or a patentability claim.

Validation and falsification

A multicentre pilot should include at least three contrasting matrices: cocoa powder/butter, a vegetable oil and a botanical or spice blend. Blind contamination challenges should represent jute/transport, packaging and lubricant pathways, with matched negative controls and deliberately confounded mixtures. Pre-register performance endpoints: correct source attribution, false-attribution rate, reproducibility between laboratories, uncertainty calibration, time to decision, cost per lot and impact on unnecessary product holds. Include a

condition in which the method cannot distinguish sources; an honest 'indeterminate' output is preferable to confident error.

Regulatory constraints and industrial relevance

Any resulting protocol would need validation for its specific matrices and intended decisions, compatibility with applicable official-control methods, transparent audit trails and safeguards for supplier trade secrets. It would not change legal maximum levels or transfer responsibility from food business operators to software. Its potential industrial value is narrower and more credible: earlier identification of avoidable contamination pathways, better targeted corrective action and stronger evidence for international customer qualification.

21 | Conclusions: the future limit is numerical, but compliance is evidential

The 2026 MOAH initiative is an important regulatory signal because it connects a longstanding toxicological concern to forthcoming category-specific controls. Yet the numerical threshold is only one part of the problem. The reported signal is an operationally defined mixture, analytical methods have matrix-dependent limits, and the contamination may arise at several stages before the finished product is tested. [1–10]

The most defensible industrial response is to distinguish law in force from voted drafts, separate fraction measurement from chemical identification and causal attribution, and validate corrective measures on the actual product and process. Cocoa transport studies demonstrate why upstream interventions can matter. Analytical standards and reference-laboratory guidance demonstrate why a laboratory result needs context. The proposed research agenda is not a claim of invention; it is an invitation to test whether joining existing evidence streams produces better decisions.

For manufacturers, distributors and importers, the immediate priority is practical: review category exposure, verify the final Official Journal status before applying a legal threshold, qualify laboratories for each matrix, and document where contamination can enter the product. A future limit will be enforceable through law; a trustworthy compliance conclusion will still have to be earned through evidence.

RELATED KNOWLEDGE AREAS Food Safety; Regulatory Affairs; Processing Technologies; Biotechnology; Functional Ingredients; Sustainability; Emerging Research.

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