

Review of Analytical Methods for Cell Cultivated Products

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Keywords: Safer Food and Feed, Surveillance, Emerging challenges and opportunities, Methods, Novel foods, Food crime

<https://doi.org/10.46756/001c.167297>

FSA Research and Evidence

Cell Cultivated Products (CCPs) represent an emerging class of novel foods produced through the culture and differentiation of animal or plant cells which includes cells from meat, seafood, fat and offal, offering potential benefits in sustainability, animal welfare, and food system resilience. As these products progress toward commercialisation, there is a growing need to understand how analytical methods can be applied to verify their authenticity, detect adulteration, and support effective regulatory oversight. This project focused on animal-derived CCPs, providing a comprehensive landscape review of current and emerging analytical methods with potential applicability to CCP detection and traceability, combined with an extensive programme of stakeholder engagement across industry, government, academia and the analytical community.

The review highlighted that no single analytical approach is currently sufficient to characterise or authenticate CCPs due to their inherent variability, evolving production methods, and similarity to conventional meat. Instead, a weight of evidence (WoE) framework drawing on genomics, proteomics, chromatography, spectroscopy, structural analysis and digital tools shows the greatest promise for analytical detection of CCPs. The work also identified major challenges including a lack of validated methods, limited reference materials, confidentiality barriers, and cost or accessibility constraints, which currently hinder the development of robust analytical testing strategies.

Stakeholder insights reaffirmed the need for harmonised standards, inter-laboratory studies, well-characterised datasets, and rapid, cost-effective screening tools to complement advanced laboratory methods. The project concluded that early establishment of metrological principles, traceability systems, regulatory clarity, and strong collaboration across sectors will be essential to maintain consumer confidence and ensure CCP integrity as the market expands. In order of priority, this report recommended further work be conducted on weight of evidence approaches, digital barcoding, epigenetics and microbial profiling, as approaches which may have the greatest potential for analytical CCP traceability. Overall, this work

provided an evidence-based foundation to guide future method development, support regulatory preparedness, and inform a coherent national approach to CCP authenticity testing.

1. Executive Summary

Cell Cultivated Products (CCPs) represent an emerging class of novel foods produced through the culture and differentiation of animal or plant cells which includes cells from meat, seafood, fat and offal, offering potential benefits in sustainability, animal welfare, and food system resilience. This project focussed on animal-derived CCPs — often referred to as ‘cultivated meat’ or ‘lab-grown meat’— which are manufactured by growing animal cells in controlled environments instead of rearing animals through traditional livestock farming. These products aim to provide sustainable, ethical, and resilient alternatives to traditional meat production. As the sector begins moving toward commercialisation, understanding how to verify the authenticity and safety of CCPs is becoming increasingly important.

This project, funded by the Food Standards Agency (FSA), reviewed existing and emerging laboratory methods that could help detect, identify, and authenticate CCPs within the food supply chain. It also gathered views from industry, government, academia, and analytical experts to ensure a broad, evidence-based perspective. The key project findings and recommendations are discussed below.

Key Findings

- **No single analytical test in isolation can accurately identify CCPs:** CCPs vary widely in how they are produced, the ingredients used, and the structure of the final product. Because of this, no single analytical method — whether deoxyribonucleic acid (DNA)-based, protein-based, or chemical profiling — in isolation, can reliably authenticate all CCPs. A combination of methods is required.
- **Strong potential for a ‘weight of evidence’ approach:** The most promising strategy is to combine multiple complementary techniques (e.g., genomics, proteomics, nutritional profiling, microscopy, and emerging digital tools) to build a reliable picture of a product’s identity. This mirrors approaches already used in upstream safety and quality evaluations during regulatory approval.

- **Challenges in detecting adulteration:** Because CCPs aim to mimic real meat, distinguishing them from conventional products can be difficult — especially in mixed and processed foods. Significantly, CCPs may be at risk of being diluted with cheaper conventional meat during early commercialisation. Current methods for species identification will not necessarily detect this type of fraud.
- **Lack of validated methods and reference materials:** Across all stakeholder groups, a consistent barrier identified was the absence of validated testing methods and well-characterised reference materials. This limits confidence in analytical results and makes routine enforcement difficult.
- **High future fraud risk:** Stakeholders widely agreed that adulteration, either CCPs mixed with conventional meat or the reverse, is highly likely without robust prevention and detection strategies. CCPs will initially be expensive, making economic fraud a concern.
- **Need for application of key metrology principles prior to scaling of products:** There is a requirement to embed traceability systems, validated testing approaches, and harmonised standards prior to CCP market expansion.

Key Recommendations

1. Promote the early adoption of metrological principles to ensure confidence in analytical traceability. Develop and validate analytical methods through the creation of harmonised CCP-specific testing standards. Conduct inter-laboratory studies to ensure reproducibility and build well-curated reference datasets and materials.
2. Adopt a weight of evidence approach to CCP authenticity testing as a single method is likely to be insufficient. Regulators and industry should combine genomic, proteomic, chemical, structural, and digital tools to create robust authentication systems.
3. Strengthen traceability systems and prevent fraud through the use of markers that differentiate between CCPs and conventional meat (e.g., environmental or microbial signatures, feasibility of inserting synthetic markers) and

exploring digital innovations such as blockchain and artificial intelligence (AI), alongside laboratory testing, to support transparency.

4. Improve accessibility and cost-effectiveness to support routine testing across UK laboratories utilising rapid and inexpensive screening tools (e.g., ELISA, spectroscopy-based methods) to complement more advanced confirmatory tests.
5. Enhance regulatory clarity and support by prioritising key areas such as method development and validation, the international harmonisation of standards and setting clear labelling and accreditation requirements.
6. In order of priority, it is suggested that the following approaches be further evaluated for their potential as tools for the analytical traceability of CCPs in the food supply chain: weight of evidence approaches; digital barcoding; epigenetics; and microbial profiling. Each potential approach has distinct advantages and limitations, which need to be carefully addressed and further investigated.

Conclusion

CCPs have significant potential to support a more sustainable and resilient food system. However, ensuring their authenticity, safety, and consumer confidence will require early action. A validated, harmonised, and weight of evidence analytical framework, underpinned by key metrology principles, which is further supported by strong collaboration across regulators, industry, and research organisations, will be essential to safeguard the integrity of CCPs as they enter the marketplace.

2. Introduction

2.1. Background

Cell Cultivated Products (CCPs), as part of a new wave of engineering biology products, offer the potential to provide alternative protein sources compared to traditional farming and agricultural practices, with purported benefits in protein quality, environmental impact, and improved animal welfare implications supporting global sustainability goals. As novel foods, there are potential safety risks. As it is anticipated that CCPs will initially command a higher price than conventionally produced products, risks to authenticity are also expected, by mislabelling and other fraudulent activities such as substitution.

[Table 1](#) outlines some of the potential risks associated with CCP-based materials.

Table 1. Potential risks associated with CCPs

Risk Domain	Description
Economic adulteration	Dilution, substitution, or mislabelling for economic gain.
Authentication limitations	Difficulty distinguishing cultured vs. conventional meat using existing methods; potential for misrepresentation.
Microbial contamination	Safety risks from inadequate sterilisation or process controls, possibly masking product quality issues.
Trace residues	Risk of trace residues from key sources such as the culture medium (e.g., foetal bovine serum), antimicrobials and scaffold materials.
Inadequate certification and labelling	Risk of misleading or false labelling without standardised verification (e.g., 'lab-grown', 'clean meat').
Traceability and technological gaps	Emerging tools (e.g., DNA barcoding, blockchain) promising but not yet fully effective across all product forms and supply chains.

In common with conventional food products, the potential for risks relating to mislabelling and authenticity of CCPs further highlights the need for traceability. There is an emerging need to understand the current state of laboratory methods that could be applied to the detection of CCPs. In order to address the key analytical challenges associated with the identification and detection of CCPs, the Food Standards Agency (FSA) funded a desk-based project to undertake a review of laboratory testing methods. This work aimed to inform the knowledge and evidence base that will support our readiness for potential future challenges. The core project aims are presented below:

1. Consider previously published research and complement the work and learnings of the FSA on CCPs
2. Identify and evaluate potential analytical methods for the detection, identification, and quantification of CCPs.
 - Consider the traceability of current and emerging CCPs, and differentiation from other proteins using analytical methods e.g. genomic or proteomic approaches
 - Consider emerging analytical methods and technologies
 - Consider the requirements for associated tools e.g. databases, reference materials

3. Identify knowledge gaps and discuss limitations and challenges relating to the analytical methods identified, including practicality and cost.
4. Offer recommendations on analytical methods, to inform the evidence base.

3. Strategy and methodologies

3.1. Deep-dive review of previously published research

The deep-dive review focused on assessing previously published research from UK Government and international agencies which included information resources such as governmental reports, e.g., Department for Food, Environment and Rural Affairs (Defra), Food Standards Agency (FSA) and Food Standards Scotland (FSS), and CCP submissions to regulatory authorities, e.g., US Food and Drug Administration (FDA) Pre-market Consultations.

3.2. Updated literature review

This literature review was informed by the proceeding deep dive review of previously published research which included recently published governmental reports, conference reports and review articles that identified CCP-associated hazards and the requirements for testing.

The literature review strategy focused on reviewing existing and emerging analytical approaches for analysing CCP-derived materials through online bibliographic searches. Standard search engines such as PubMed®, Science Direct™ and Springer Nature Link® were employed to conduct broad literature searches using keywords such as 'cell cultivated products', 'lab-grown meat', 'authentication' and 'detection' which were built into targeted Boolean searches. CCP terminology has not yet been fully harmonised in the scientific community which meant that alternative search terms used in literature (Chriki & Hocquette, 2020; Chuah et al., 2025; Lanzoni et al., 2024) were also incorporated, e.g., 'Cell-cultivated products', 'Cultured meat', 'Cultivated meat', 'Lab-grown meat' and 'Cellular agriculture'. The search results were data mined to ensure relevancy and literature/web resources used as the basis for the landscaping review.

Most literature returned as a result of the described search strategy focussed on alternative (non-CCP) proteins or authentication of conventional foods. As this is a review for current and emerging trends in CCP authentication, these were not selected for further review. This literature review was supplemented with similar searches in Google

Scholar™ and using Google™ as a general search engine for alternative sources of information – including scientific journalism and formal applications for CCP approval. Additionally, personal correspondence with organisations currently investigating authentication of CCPs further informed this review.

3.3. Stakeholder engagement strategy

The stakeholder engagement strategy focussed on contacting priority stakeholders representative of their sectors, inclusive of CCP developers, governmental agencies, academia/research institutes, CCP expert working groups and committees and the broader analytical community. Outreach activities aimed to raise the profile of the FSA CCP project and encourage participation in planned engagement activities such as the Focus Group meeting and online questionnaire (delivered via Microsoft® Forms) and through one-to-one discussions to solicit views and guidance.

The 'Analytical Methods for Cell Cultivated Products (CCP)' online questionnaire (Appendix A) was developed to target individuals involved in the food supply and associated diagnostics sectors, including primary production, supply and manufacturing. The anonymised questionnaire was publicised through stakeholder networks (e.g., Food Authenticity Network and personal professional network) and delivered through Microsoft® Forms between 10th February 2026 to 6th March 2026. The collated questionnaire responses were analysed to help provide broader insights into CCP testing within the UK and internationally.

In parallel, an FSA and LGC Focus Group meeting on the analytical detection of CCPs was held on the 5th February 2026 targeting a broad range of stakeholders (agenda presented in Appendix B). Central to the meeting were a series of questions which were devised to promote discussion within the group and generate targeted feedback:

- **Question 1:** Which analytical approaches do you feel could be used for the detection of CCPs in the food supply chain, inclusive of technologies (e.g., genomics, proteomics) and methods (e.g., NGS)?
- **Question 2:** How do you see analytical methods for detecting CCPs being employed (e.g. CCP approval process, supply chain verification, fraud detection) and how should these methods be employed effectively?
- **Question 3:** Due to cheaper animal products or short-term issues with supply chains, there is motivation for food fraud. What analytical methods could be used to check for adulteration of CCPs with conventional meats?

- **Question 4:** Are there any specific analytical challenges, limitations or barriers which stakeholders anticipate when it comes to methods for detection of CCPs? What are the main concerns?

4. Results

4.1. Deep-dive review of previously published research

As a 'novel food', CCPs are regulated following the principles laid down in assimilated regulation (EU) 2015/2283. This legislation addresses the assessment needs of introducing novel foods to the general public, and states that scientific evidence is required to ensure safety, but does not specify assessment methodologies.

International guidance (BIOTEC, 2024; Singapore Food Agency, 2025), identified potential hazards in novel foods and suggested the use of specific accredited food testing methods. These analytical methods typically detect potentially harmful residues, allergens and contaminants. In addition, Israel, a worldwide pioneer in CCP development, have recently published regulatory requirements on CCPs (Israel Food Control Services, 2025). The publication details that the detection of potentially harmful residues and contaminants is recommended, but does not specify recommended methodologies. While contamination, residue and allergen-based safety testing of CCP products is being considered extensively by regulatory bodies, testing for authentication purposes as part of regulatory framework does not appear to be prioritised.

Authentication testing in non-CCP 'alternative protein' foods such as insect protein powders is a current area of research (Defra project FA0197 (Fera Science Ltd., 2023)) that has been prompted by previous case studies involving adulteration of other protein powders (Fuso et al., 2024). There are currently no case studies for CCP adulteration. Authentication methods used in conventional meat and other alternative proteins may be relevant in this emerging field of research.

A limitation of the current reviewed publications concerns confidentiality and intellectual property. Publicly available applications submitted by companies intending to manufacture and commercialise CCPs were used to assess the current trends in identifying CCPs as part of their verification process. All of these documents included references to confidential material, with some confidential redactions obscuring information on identification and product characterisation methodology. Hence, this review is limited to what is available in the public domain.

4.2. Updated literature review

4.2.1. Introduction

The term 'Cell Cultivated Product' (CCP) refers to an emerging class of novel foods produced through the culture and differentiation of animal or plant cells which includes cells from meat, seafood, fat and offal, offering potential benefits in sustainability, animal welfare, and food system resilience. The project focussed on foods and feed derived from animal cell line culture. Other commonly used terms include 'cultivated meat', 'cell-based meat', or 'lab-grown meat'.

The first CCP became commercially available in Singapore in 2020, and applications for commercially available CCPs continue to be submitted and accepted in territories such as Australia, Israel, the USA and the UK (Chriki & Hocquette, 2020). At the time of writing this review, CCP manufacturing and applications for regulatory approval have a meat-based focus, with little mention of animal products such as egg and milk analogues.

Whilst each territory has a regulatory process in place to determine and confirm the safety of CCPs as a novel food (Bamezai & Chapman, 2025; BIOTEC, 2024; Lanzoni et al., 2024; Singapore Food Agency, 2025), there is so far little discussion on ensuring authenticity of CCP materials. Potential adulteration has recently been highlighted as a hazard in CCPs due to the limitations of current manufacturing technology. CCP production is typically expensive due to the developmental stage of the sector which increases the risk of adulteration to make products cheaper in order to compete with conventional meat products (Bamezai & Chapman, 2025). Despite this risk, authentication of CCPs has not yet been widely considered in the scientific literature. This is mainly due to the novelty and variability of CCPs and their manufacturing processes.

Despite the lack of consideration of CCP authentication, techniques used for the purpose of validation and safety can also be applicable for authenticity purposes. This current review explores the current trends in lab-based CCP detection, identification, and quantitation, and provides an overview of the practical viability of methods used.

4.2.2. Current and emerging methods

4.2.2.1. Genomics based approaches

Genomics-based methods are used for a wide range of diagnostic applications including speciation, genetic stability/identity, contamination assessment and epigenetics with applicability to CCP testing.

Speciation: Species identification is necessary for identifying potential hazards such as adulteration and contamination. Whilst commercially available speciation assays are available, assays targeting the animals used to produce CCP meat products, especially seafood species, are not commonly available. Suggested speciation techniques include Short Tandem Repeat (STR) or barcoding assays targeting taxonomic markers such as Cytochrome C Oxidase I (COI), several of which are commercially available for use for traditional meat testing.

Several applications submitted by companies (for CCP approval use a COI-based DNA barcoding method to confirm species identity (Food and Drug Administration (FDA), 2026; Vow Group Pty Ltd, 2023). A similar method of species identification using COI has been used in scientific literature to confirm the Halal status of a CCP (Mohd Kashim et al., 2022). Believer Meats, which submitted an application to the FDA to demonstrate the safety of cultivated chicken meat (Food and Drug Administration (FDA), 2026), targeted the mitochondrially-encoded cytochrome B gene (MT-CYB) to determine species identity in its master cell banks, which may also be applicable to test in its final product. UPSIDE, another developer, submitted an application for a chicken-based CCP (Food and Drug Administration (FDA), 2026), wherein TPM1 gene (fast-tropomyosin) expression was measured as a means of species identification, as it is specific to chicken meat.

In addition to single gene-based species ID, Believer Meats (Food and Drug Administration (FDA), 2026) utilised the Thermo Fisher Scientific™ RapidFinder™ Chicken ID Kit (a chicken-specific real-time polymerase chain reaction (PCR) kit) to validate its secondary master cell banks which represents another method with the potential to authenticate the final product. Variations of this kit are available for several other animal species used for CCPs and may therefore be a viable general method to detect adulteration in CCPs under specific scenarios.

Cell, cell line and genetic stability/identity: Both Believer Meats and Mission Barns (Food and Drug Administration (FDA), 2026) employed karyotyping (e.g., chromosomal analysis) as a method to assess cell stability, which is applicable to authentication in the finished product. Mission Barns specifically stated that GTG banding (G-banding using Trypsin and Giemsa), which is a cytogenetic technique used to identify structural and numerical abnormalities, was used to assess cell stability.

Believer Meats conducted ribonucleic acid sequencing (RNA-seq) and analysed the results in several different ways, identifying factors that are unique to the cell immortalisation process of this CCP, which could be relevant for future authentication purposes. Analyses comprised the characterisation of cell lines to identify whether the cell immortalisation process caused differentiation of the desired cell identity (Food and Drug

Administration (FDA), 2026; Pasitka et al., 2023), a genetic instability study comparing the expression of P53-regulated genes before and after cell immortalisation (Pasitka et al., 2023), and single nucleotide variant (SNV) analysis performed on *TP53* transcripts to further explore potential genetic instability due to cell immortalisation (Pasitka et al., 2023).

To analyse cell line stability, Believer Meats (Food and Drug Administration (FDA), 2026) used qRT-PCR to measure the expression of the TPM1 gene, which was stated to be highly conserved and functional in the culturing process, and therefore useful as a phenotypic identity marker. Similarly, Wildtype Inc (Food and Drug Administration (FDA), 2026) used qRT-PCR and RNA sequencing on specific myogenic genes (e.g. MyoD, Myf5, MyoG, Pax7) and adipogenic genes (e.g. C/EBP β), to assess cell line stability and confirm cell differentiation. GOOD Meat (Food and Drug Administration (FDA), 2026) carried out gene expression analysis of the FSP-1 gene (Fibroblast-Specific Protein-1) to confirm fibroblast cell identity. GOOD Meat also cited method 'AGL-CCP.2' to confirm cell line stability, which uses G-banded analysis and non-banded analysis to determine the karyotype, species and aberration data of the cell line.

Whole genome sequencing (WGS) was carried out for the Australian application for cultured quail meat (Vow Group Pty Ltd, 2023), the data of which was used to identify SNVs and their potential to cause toxicity, allergens and cancer. Results for the working cell bank cells and the final cultured quail cells were compared to conventional quail cells (*Coturnix japonica*). For a genetically modified (GM) CCP, UPSIDE (Food and Drug Administration (FDA), 2026), inserted TERT genes as part of production. In order to ensure this did not interrupt genes, PCR and Sanger sequencing were used to identify the insert location. Although intended for validation and safety testing, many of these methods could also be applicable in CCP authenticity testing.

Contamination: Various PCR techniques are often cited in CCP approval applications as the methods used to detect microbial contamination (Food and Drug Administration (FDA), 2026; Vow Group Pty Ltd, 2023). These methods have a potential application within authentication testing as indicators of outside contamination and adulteration. Published literature (Mariano et al., 2023) suggests testing for specific residues or contamination that would typically be in one of either CCPs or traditional meat, but not in the other. An example of this potential application for adulteration testing would be salmonella DNA detection as salmonella is detectable in virtually all conventional chicken but would not typically be present in lab-grown meat. A positive result for salmonella DNA in a chicken CCP would therefore flag the product for further investigation.

Genetically modified organism (GMO) detection: It has been suggested (Mariano et al., 2023) that a potential method to authenticate GM CCPs would be to detect the specific DNA sequence that has been modified or introduced in order to differentiate the intended products from any contamination or adulteration. This technique was employed by UPSIDE (Food and Drug Administration (FDA), 2026) in which Telomerase Reverse Transcriptase (TERT) copy number was detected using probes and endogenous actin beta (ACTB) as a reference gene. This differentiates the CCP from traditional meat because TERT is naturally occurring, and has an increased copy number only in the CCP. The intention of using this technique was to ensure the copy number was not above a certain level for safety purposes, however this technique could also be used for traceability purposes where applicable.

Epigenetics (Emerging): Epigenetic fingerprinting represents an emerging method to detect conventional meat-based adulteration of CCPs. This method facilitates the detection of DNA methylation patterns, which can change in a context-dependent manner, e.g., influenced by key environmental factors such as diet and stress. Epigenetic analysis applications include cell identification for authentication which has been explored in animal welfare monitoring (Whelan et al., 2023) and origin tracing of livestock (Venkatesh et al., 2023).

4.2.2.2. Proteomics based approaches

Residue detection: Several CCP applications (Food and Drug Administration (FDA), 2026; Vow Group Pty Ltd, 2023) cited the use of enzyme-linked immunosorbent assay (ELISA) and/or western blots to detect residual thermostable growth factors and hormones in their CCPs. While this was carried out for safety purposes, these techniques could also contribute towards a profile of what residues to expect in CCPs for authentication purposes. When the potential residues are known, ELISA is an ideal method for residue detecting due to its efficiency and sensitivity. ELISA should be preceded by extensive consideration of media components and additions.

Several discussions on the use of proteomics in CCP traceability commented on its limitations due to the heat inactivation of proteins (Food and Drug Administration (FDA), 2026; Mariano et al., 2023). Therefore protein-based testing may not be appropriate for processed CCP products, which typically require cooking similarly to traditional animal products. An exception to this would be heat-stable proteins.

Cell line stability: Alongside gene expression studies, Believer Meats (Food and Drug Administration (FDA), 2026) utilised Immunostaining for proteins such as vimentin, integrin B1, lamin A/C and lamin B1 to assess cell line identity and stability. UPSIDE Foods (Food and Drug Administration

(FDA, 2026) used a bicinchoninic acid assay (BCA) to analyse protein yield in order to measure cell line phenotypic stability. They also validated cell differentiation by using immunoblotting to detect tropomyosin expression in their product – a protein which is similarly expressed in traditional chicken meat.

Species and cell identification: UPSIDE Foods (Food and Drug Administration (FDA), 2026) conducted ELISA for meat species identification, however this technique was either not used or details were redacted from public release. This was not a widely used method in this context due to the expectation of CCP heat treatment inactivating detectable proteins. In the literature, ELISA has been used to detect residues of adipogenic differentiation in cultured fat to confirm cell type (Song et al., 2023). This method could be used for CCP identification and authentication purposes.

Other emerging methods: Immunoassays like ELISA can be used to detect veterinary drugs for CCP analyses (Mariano et al., 2023). Veterinary drugs would be unique residues found only in traditional meat. Furthermore, a collaborative group (Cultured Meat Safety Initiative) involving Vireo Advisors, Multus, Aberystwyth University, Extracellular, and the British Standards Institute (Vireo Advisors, 2026) are working towards developing and streamlining growth factor detection in CCPs for food safety, which may also have applications in authenticating CCPs.

4.2.2.3. Chromatography and Spectroscopy

Fatty acid and amino acid profiling: The amino acid profile for Meatly, a UK-based CCP pet feed, was analysed using high performance liquid chromatography (HPLC) following acid hydrolysis (Alta Bioscience Ltd, 2023). Wildtype Inc (Food and Drug Administration (FDA), 2026) used a standardised method (AOAC 996.06) involving gas chromatography with flame ionization detection (GC-FID) to measure omega-3/6/9 isomers and fatty acids. Similarly, Gourmey (2024) cited GC-FID as the method used to assess fatty acid composition in its product. Mission Barns (Food and Drug Administration (FDA), 2026) carried out standardised protocols; AOCS CE 1J-07 (gas-liquid chromatography) for fatty acid composition and USDA MSS2 (1993) method (ultra high performance liquid chromatography with ultraviolet detection (UHPLC-UV)) for amino acid profiling. GOOD Meat (Food and Drug Administration (FDA), 2026) also used the USDA MSS2 (1993) method for amino acid profiling. This method produces a 'fingerprint' of the product, which has been used in literature to detect adulteration in conventional foods (Bhandari et al., 2022). In the literature, chromatography and spectroscopy are used for fatty acid and amino acid profiling of CCPs (Kim et al., 2025; Song et al., 2022).

Flavour profiling: Flavour profiling using gas chromatography mass spectrometry (GC-MS) and specific chromatography-based instruments has been carried out in recent CCP literature (Lew et al., 2024; Mariano et al., 2025). A chromatography-based 'electronic nose' (HERACLES-II-E-NOSE) has been used to compare and quantify flavour profiles of cultured meat (based on the scaffolding used) compared to conventional meat (Lee et al., 2024). Alternatively, an 'electronic tongue' has been used (Mariano et al., 2025). This method could potentially be used to quantify certain residues in CCPs for traceability and authentication purposes.

Hazardous residue detection: Although residue detection has been carried out in the context of safety rather than authentication for CCPs, a deviated result for a heavy metal or mineral residue in a CCP can be a general indicator of adulteration. Virtually all CCP applications and other CCP safety literature (Food and Drug Administration (FDA), 2026; Gourmey, 2024; Hatano et al., 2026; Vow Group Pty Ltd, 2023) cited use of inductively coupled plasma mass spectrometry (ICP-MS) to test for heavy metals and mineral residues in their products. Mission Barns cited the specific standardised methods used as FDA EAM 4.7 and AOAC 2015.01. In addition to this, Wildtype and UPSIDE (Food and Drug Administration (FDA), 2026) tested for other residual minerals such as potassium, iron, sodium and zinc using inductively coupled plasma atomic emission spectroscopy (ICP-OES). UPSIDE Foods cited use of the standardised method FDA EAM 4.4 for this purpose. These methods have not yet been validated for CCPs but are considered as standard approaches in food testing.

Cell identification: HPLC has been used to detect residues of adipogenic differentiation in cultured fat to confirm cell type (Song et al., 2023).

4.2.2.4. Metabolomics

Metabolomic techniques are typically conducted during the CCP production process to assess cell line stability; however, this approach has been discussed as a potential emerging method for CCP authentication. The Good Food Institute (Good Food Institute, 2026b) through activities such as research grant funding supporting the development and optimisation of low-cost serum-free culture media for cultivated chicken meat, using metabolic modelling and spent media analysis (Good Food Institute, 2026c), have investigated future prospects for metabolomics testing in CCPs, as well as stating interest of testing services in analysing the metabolomics of CCPs. Specific methods suggested are metabolic flux analysis and general metabolic profiling. The current landscape review only identified limited scientific literature which does not generally appear to specifically support the application of metabolomics for authenticity testing.

4.2.2.5. Other methods

Cellular density and uniformity: Although not necessarily quantitative, qualitative methods such as staining under microscopy can be used to assess and characterise the cellular density and uniformity within a scaffold-based CCP. This has been demonstrated by Wildtype Inc (Food and Drug Administration (FDA), 2026) using 4',6-diamidino-2-phenylindole (DAPI) staining. This technique can be used as part of CCP profiling for authentication purposes, as cell uniformity is likely to differ between conventional meats and scaffolded CCPs.

Texture analysis: Texture analysis in literature is typically used for CCPs with scaffolds and microcarriers. It is often performed as part of characteristic profiling of a CCP, and to compare it to traditional meat (Chuah et al., 2025; Mariano et al., 2025). While this has sometimes been studied in a qualitative manner using techniques such as electron microscopy, quantitative measurements have been recorded using range of instruments including a TA.XTPlusC Texture Analyser (Stable Micro Systems, UK) (Murugan et al., 2024) and the TA1 Texture Analyzer (Lloyd Instruments, UK) (Yen et al., 2023).

Calorimetry: Differential scanning calorimetry (DSC) has been used to characterise CCPs in comparison to meat materials (Mariano et al., 2025). This technique identifies melting properties in the meat, and has been used to differentiate between a CCP and conventional beef (which has a typical temperature peak) (Yen et al., 2023).

4.2.2.6. Supportive tools

Artificial intelligence/machine learning: Using artificial intelligence (AI) to tackle conventional meat adulteration is a developing area of research (Jafari et al., 2025) with future applicability within CCPs. In recent literature, the use of AI has been discussed in the context of CCP safety testing. Research (Ng & Tan, 2025) notes that the lack of global streamlining of lab-based tests used to detect contamination and residues will cause issues with reproducibility in CCP food testing. It is suggested that machine learning can enhance the reliability and consistency of CCP safety testing results. Established supervised machine learning methods such as Partial Least Squares Regression (PLSR) or Support Vector Machines (SVM) can process large multifactorial datasets gathered from a range of methods.

Blockchain technology: Blockchain technology records and provides a transparent and immutable sequence of chronological events. This technology has been explored in the food sector as a means of authentication, certifying fair trade practises and ensuring food safety. More recently, attempts have been made to introduce blockchain technology for conventional meat authentication purposes, and this has also been reviewed as an option for CCP authentication. Internet of Things

(IoT) integration with blockchain has been highlighted as a specific method of real-time monitoring (Ahmadi Kaliji et al., 2025). Blockchain technology would be particularly useful in CCPs due to its transparency; consumers are notably wary of the safety of novel foods, and higher consumer confidence would be economically beneficial for the industry. While blockchain technology can be a useful tool in CCP authentication, it requires further research and validation to implement into current practises. The high cost of implementation would require stakeholder collaboration (Ahmadi Kaliji et al., 2025).

Reference materials: Whilst testing alongside a physical meat reference material would be preferable, providing individual meat reference materials would pose difficulties due to the wide variety of factors that influence conventional meat production. Believer meats (Food and Drug Administration (FDA), 2026) tackled this by using locally bought supermarket meat as reference materials, using the justification that the U.S. FDA indicated that established reference data may not capture 'real life' situations. Wildtype Inc (Food and Drug Administration (FDA), 2026), similarly, tests their CCP alongside a conventional salmon sample with no indication of it being a standard reference material.

Databases, repositories and bioinformatics: In an effort to streamline residue testing in CCPs, a collaboration of Vireo Advisors, Good Food Institute, and Singapore FRESH at National Technical University are building a Safety-Assessed Media Ingredient (SAMI) List (Vireo Advisors, 2026). This open-access resource will include ingredients used in CCP manufacture as well as lists of nutrients that relevant animals and fish produce and consume. This can be used as a reference database when detecting adulteration in CCPs.

Since 2025, there has been a collaboration between New Harvest, Vireo Advisors, the Alberta Machine Intelligence Institute, and Defined Bioscience to create a growth factor protein thermostability dataset (Vireo Advisors, 2026). Growth factors are present in CCP manufacturing processes, but it could be argued that they are heat-inactivated and therefore safe to be present in the finished product on the condition that it is cooked like conventional meat. An open-source curated dataset, embellished with further *in vitro* and *in silico* research on this topic, will provide guidance on thermostable growth factors in CCPs and whether they are likely to be detectable.

For quantitative comparisons to conventional chicken, UPSIDE Foods (Food and Drug Administration (FDA), 2026) developed a comparator database using data from the [USDA Agricultural Research Service \(ARS\) Food Data Central](#) comprising of reference proximate and mineral data. This database

can be used for comparison to CCP nutritional testing, as any deviations to the standard CCP results that resemble a conventional reference result may indicate adulteration using conventional meat.

4.2.2.7. Standardisation efforts

International standardisation is important to support the development and acceptance of CCPs within society. This will involve standardising the analytical approaches applied to CCP testing. ISO has established a new working group (TC34/WG30) to work on 'Tissue Culture and Cellular Food Technology Products' (ISO, 2026). As of writing this review, two proposals have been submitted - Guidelines for assessment of cell culture media components (Codex Committee on Food Additives) and Code of hygienic practice for manufacturing of cell-based foods (Codex Committee on Food Hygiene). These proposals aim to regulate the production process of CCPs, and should be followed up by guidelines on analysing the finished products from these processes.

4.2.2.8. Summary of current and emerging methods

The review highlighted the variety of current and emerging analytical methods that could support the detection, identification and authentication of CCPs. These methods span genomics, proteomics, chromatography, spectroscopy, metabolomics, and various supportive tools. Together, they illustrate both the potential and limitations of laboratory-based traceability approaches for this rapidly developing food sector.

Genomic approaches are the most widely explored, covering species identification, assessment of genetic stability, contamination detection and GMO verification. Techniques such as DNA barcoding, STRs, barcode assays, qPCR, WGS, RNA-seq and karyotyping are already used within CCP regulatory submissions and the methods may be suitable once adapted (repurposed) for authentication and traceability applications. However, many methods remain unverified specifically for CCPs, and while effective for species identity, they would need to be further validated for food authenticity testing purposes.

Proteomic approaches include ELISA, western blotting, immunostaining and protein profiling. These methods can detect residues such as growth factors or differentiation markers and help characterise cell line identity. However, heat-induced protein denaturation limits their usefulness for processed CCPs. Some proteomic methods may support adulteration detection, such as identifying veterinary drug residues indicative of conventional meat inputs.

Chromatography and spectroscopy (e.g., HPLC, GC-FID, GC-MS, ICP-MS) provide nutritional, fatty-acid, flavour and mineral profiles ('fingerprints') of CCPs. These profiles can highlight deviations from expected compositions and flag potential adulteration. However, as CCP manufacturing aims to closely mimic conventional meat, these differences may diminish over time.

Emerging methods include metabolomics, though current literature offers little support for its authentication utility; microscopy, texture analysis and calorimetry for assessing structural differences; and digital tools such as AI, blockchain, reference materials and databases. These supportive tools could enhance reproducibility, standardisation and data richness, although they require further development.

The approaches of weight of evidence, digital barcoding, epigenetics and microbial profiling appeared to provide the most promising potential as tools for analytical traceability of CCPs in the food supply chain. The scope and limitations of these are further discussed in Section 5.5 on "Recommendations on future work".

Overall, the review highlighted a broad suite of potentially useful analytical technologies for CCP detection, many of which could be repurposed from the tests already in place for verifying the quality, safety and nutritional status of the CCP as part of the authorisation process. However, none of these methods are yet fully validated for CCP traceability, and most face challenges in detecting adulteration or differentiating CCPs from conventional meat. [Table 2](#) summarises the current and emerging methods for CCP authentication, as well as the associated current limitations.

Table 2. Summary of current and emerging methods potentially suitable for CCP authentication

Method	Method type	Measurand	Data output for authentication	Main limitations in detecting adulteration
DNA barcoding	Genomics	DNA	Species identity confirmation	Cannot detect conventional meat adulteration
Gene expression	Genomics	RNA	Species and cell identity confirmation	Cannot detect conventional meat adulteration
Karyotyping	Genomics	DNA (chromosome)	Cell stability and species identity confirmation	Cannot detect conventional meat adulteration
Whole genome sequencing (WGS)	Genomics	DNA	Genetic stability and SNVs specific to CCPs	Unverified method

Method	Method type	Measurand	Data output for authentication	Main limitations in detecting adulteration
GMO-specific PCR and sequencing	Genomics	DNA	Genetic modification confirmation and copy number detection	Unverified method
Digital barcoding	Genomics	DNA	Unique DNA sequence to confirm CCP identity	Insertion of new DNA sequence and regulatory consequences
PCR-based microbial testing	Genomics	DNA	Confirmation of adulteration due to conventional meat -specific contamination	Unverified method
Epigenetics	Genomics	DNA methylation	Cell identification and authentication. Confirmation of adulteration due to conventional meat -specific contamination	Emerging and unverified method
Immunostaining (e.g. ELISA, western blots)	Proteomics	Hormones, growth factors	Profile of CCP-specific residues	Heat treatment of finished CCP will affect success of these assays due to protein denaturation. Unverified method
		Cell-specific proteins	Species and cell identity and stability	Heat treatment of finished CCP will affect success of these assays due to protein denaturation. Cannot detect conventional meat adulteration
		Veterinary drug residues	Confirmation of adulteration due to conventional meat -specific residue detection	Heat treatment of finished CCP will affect success of these assays due to protein denaturation. Unverified method
Amino acid profiling/fingerprinting	Chromatography and spectroscopy	Amino acids	Profile of CCP-specific components	With advancing CCP technology, may not detect conventional

Method	Method type	Measurand	Data output for authentication	Main limitations in detecting adulteration
				meat adulteration
Fatty acid profiling/ fingerprinting	Chromatography and spectroscopy	Fatty acids, omega-3/6/9 isomers	Profile of CCP-specific components	With advancing CCP technology, may not detect conventional meat adulteration
Flavour profiling	Chromatography and spectroscopy	Flavour residues	Profile of CCP-specific components	Unverified method
Inductively Coupled Plasma-Mass Spectrometry	Chromatography and spectroscopy	Heavy metal residues	Confirmation of general adulteration	Unverified method in CCPs
Cell staining and microscopy	Other	Scaffold-mediated cellular density and uniformity	Confirmation of adulteration due to diversion from characterised CCP	Qualitative measurement - would require AI development to process large datasets. Unverified method
Texture analysis	Other	Scaffold / microcarrier - mediated texture features	Confirmation of adulteration due to diversion from characterised CCP	Unverified method
Differential scanning calorimetry (DSC)	Other	Melting properties	Confirmation of adulteration due to diversion from characterised CCP	Unverified method
Artificial intelligence / machine learning	Supportive tool	Complex datasets	Profile of CCP-specific components	Requires further research and refinement
Blockchain technology	Supportive tool	Supply chain	Transparent and immutable sequence of chronological events for authentication purposes	Expensive implementation
Reference materials	Supportive tool	NA	Examination of multiple different measurands to form a baseline for comparison. Can aid in detecting adulteration	Difficulty in standardising conventional meat-based reference materials
Databases,	Supportive tool	NA	Comparative	Limited by

Method	Method type	Measurand	Data output for authentication	Main limitations in detecting adulteration
repositories and bioinformatics			data from multiple sources to reduce uncertainty in authentication	availability of open-access research

4.2.3. Stakeholder engagement exercises

4.2.3.1. FSA/LGC Focus Group Meeting – analytical detection of Cell Cultivated Products

A Focus Group meeting on analytical methods for CCPs was organised to collate expert stakeholder views on the potential of laboratory-based analytical methods for the traceability of CCPs in the food supply chain. The meeting was attended by 17 external participants, representing stakeholders from industry, government agencies, expert groups/networks, research centres, bio-tech companies, public bodies and accreditation services.

The Focus Group meeting provided an opportunity to review current and emerging analytical methods that could support the traceability, authenticity, detection, and potential quantification of CCP in the food supply chain. A series of structured questions were posed to the participants, to encourage engagement and discussion on key issues.

The first question centred around what types of analytical approaches could be used for the traceability of CCPs. Discussions included the description of what traceability at this level would mean, for example, qualitative detection, an estimated quantitative amount, or whether the focus was on differentiation between CCP vs conventional meat. Participants identified several analytical approaches which could help complement analytical traceability of CCPs, inclusive of genomics, proteomics, transcriptomics, metabolomics, the microbiome and metagenomics, and other approaches such as nutritional profiling and cell morphology metrics. It was noted that there was a general theme of analytical approaches from the upstream safety, quality and nutritional testing of CCPs as part of the authorisation process, could potentially be repurposed to contribute towards downstream analytical traceability of CCPs in the food supply chain.

The second question posed to the group was how the analytical methods should best be used. As part of the current approval process, analytical traceability was not a requirement (unless the CCP was genetically modified), and that enforcement would be based on the product specification and the General Food Law (assimilated regulation (EC) 178/

2002), as opposed to analytical traceability. It was suggested that analytical traceability may be useful for supply chain verification, for example by due-diligence testing, third-party auditing and regulatory inspection. Analytical tools could also be applied by manufacturers as part of their own quality and process controls. Additionally, analytical tools could be used for food fraud detection to help ensure CCP-labelled products were genuine and authentic.

The third question posed the issue of how detection of adulteration of CCPs with conventional meat could be achieved when in a mixed sample. Because CCPs initially may command higher prices, adulteration could flow from conventional meat to CCP, and not just the reverse. It was discussed that identifying markers present in conventional meats, but which were absent in CCPs could be an option. This included establishing environmental microbiome signatures and metabolites linked to animal physiology. Residues/contaminants which were typically present in conventionally reared animals could also be capitalised upon (e.g., presence of salmonella in farm-reared chickens, but absent in CCP chicken). Digital traceability (e.g., Blockchain) may also provide an additional tool, although it was discussed that this was costly to implement and was more likely to be used as a complementary approach. It was noted that that widespread CCP fraud may be unlikely in the immediate term due to small market size.

The fourth and final question involved what challenges, limitations and barriers participants saw in using analytical approaches for the traceability of CCPs. Key challenges included that it was hard to design one universal analytical test, and that the development of reference materials and databases were essential for validation and comparability. Many of the proposed methods may be unsuitable for deployment to UK Official Laboratories due to their specialised nature or without further training. It was also noted that quantification would be a lot harder than qualitative detection of a CCP. Cost-effectiveness and access to these analytical approaches was a concern, as was detection of CCPs when hybrid products (e.g., a mixture of CCP and conventional meat) was present in a product. The need for reference datasets, reference materials and harmonised methods was further reinforced.

Broader issues and concerns included the requirement for sampling guidance in this sector, as well as the requirement for method validation and uncertainty budgets. It was suggested that a UK National Reference Laboratory role for CCP authenticity could be used. Concerns were also raised that there may be a risk of an uneven burden on smaller companies if methods are too expensive. Participants also stressed the need to establish systems for traceability prior to market maturity and before issues arise. It was agreed that it was important to bed metrology in

at the start of the process, prior to any market expansion. Outside of the analytical state of play, it was discussed that public perception and communication were key towards potential adoption of CCPs, and that any enforcement tools should not delay the CCP approval process, which was already lengthy.

The Focus Group meeting concluded with discussions on the need to clarify future consumer labelling requirements in this growing sector, as well as the ongoing need for collaboration between regulators, industry, and research organisations. It was agreed that a weight of evidence (WoE) analytical approach may be the most realistic future pathway, and that future work must prioritise creating reference materials, validation frameworks, and accessible, cost-effective approaches to facilitate any routine testing.

4.2.3.2. Analytical Methods for Cell Cultivated Products (CCP) Online Questionnaire

The following summary is based on insights gathered from the questionnaire (31 respondents), focusing on key themes and trends across all questions, bringing together consensus views and recurring challenges, but also emphasising any notable divergences.

In terms of the definition of CCPs, there was good consistency in understanding that these refer to laboratory-grown or cultivated animal and plant cells which are used to produce food ingredients or whole products. It was understood that CCPs were often positioned as an alternative to conventional meat, reducing reliance on slaughtered animals. Depending upon the context, responses also highlighted that these equated to nutrient-engineered, nature-identical, or synthetic products. Overall, there was a strong conceptual alignment across academia, regulators, industry and laboratories about what CCPs are, even if the exact terminology differed.

For expected applications of analytical methods for CCPs, responses generally fell into one of three camps. This included applications for fraud detection and authenticity testing (verification of species origin and confirming the CCP content of a mixed product), supply chain verification (preventing economic fraud and protecting premium value products), and testing for regulatory safety and compliance (quality, safety and nutritional content). Authenticity and safety emerged as equally dominant priorities across all of these areas.



Figure 1. Microsoft® Forms generated word cloud based on answers to 'Question 8 - In your opinion, are there any existing techniques/platforms/tools which have the potential to be applied to the authenticity/traceability testing of CCPs?'

For techniques which were seen as the most promising, the strong overall consensus was that no single method was sufficient, and a weight of evidence approach was likely to hold the best potential. [Figure 1](#) shows a Microsoft® Forms generated word cloud based on answers to 'Question 8 - In your opinion, are there any existing techniques/platforms/tools which have the potential to be applied to the authenticity/traceability testing of CCPs?' which highlights the variety of potentially suitable methods for authenticity and traceability testing purposes. The most frequently cited technologies included genomics and DNA based method (PCR, qPCR, DNA barcoding, next generation sequencing (NGS)), proteomics and metabolomics (e.g., LC-MS/MS), chemical and residue profiling (LC-MS/MS for growth factors, scaffolds, media components etc., and stable isotope ratio for media traceability), microscopy and histology (e.g., looking at structural differences with scaffolds or cell density patterns), and spectroscopy (e.g., rapid screening using near-infrared spectroscopy (NIR), infrared spectroscopy (IR), Raman or surface-enhanced Raman spectroscopy (SERS)). Notably, emerging areas inclusive of AI and machine learning, digital traceability and Blockchain, and synthetic molecular barcoding, were also thought to play contributing factors for traceability of CCPs.

Whilst it was thought that DNA-based approaches may encounter challenges when trying to distinguish CCPs vs conventional meat, it was also recognised that DNA had the greatest potential for accurate and sensitive species identification. Overall, DNA approaches, proteomics, and chemical profiling were viewed as the three core analytical technologies, supported by more specialised and emerging techniques.

In terms of key analytical challenges, five main areas were consistently identified. A lack of validated methods meant that there were no agreed-upon international methods for proving a product is a CCP. Because the goal of CCPs is to mimic real meat, a further challenge was analytical methods may struggle to differentiate CCP from conventional meat, particularly in a mixed sample. A lack of appropriate CCP reference materials also precluded having confidence in results, creating difficulties

in authenticating CCP products. Expensive specialist instrumentation, technical complexity and advanced methods precluded easy and universal adoption of methods, particularly for public enforcement laboratories. Finally, data confidentiality and intellectual property (IP) meant that CCP producers may treat cell line characteristics as trade secrets.

For future analytical needs, it was anticipated that there may be an increased demand for CCP testing as products begin to scale. There was also a need for fast and cost-effective screening tests (e.g., ELISA, NIR) to complement specialised laboratory methods. To underpin the confidence in a result, there was a need for the development of reference standards, inter-laboratory studies, harmonised international terminology, databases for proteomics, metabolomics and genomics markers, and validated methods which could be applied on a routine basis.

For the perceived risk of adulteration, there was a common and very strong response that adulteration was very likely. Examples to justify this included recognition that CCPs may initially be expensive, making adulteration from conventional meats more likely during the early stages of market adoption. Conversely, should CCPs become cheaper in the long run, then the risk reverses where conventional meats may be adulterated with CCPs. An overarching theme was that hybrid products, containing both conventional meats and CCPs, would be particularly susceptible. Of equal note was that a number of responses emphasised the requirement that analytical testing approaches be in place prior to CCPs become widespread, due to the high fraud risk.

Potential preventative strategies to combat the risk of adulteration included strong traceability systems, certificate of authenticity regimes, biomarker or barcoding incorporation, and routine verification through accredited labs.

The aspect of support being required from the Government and regulators was one of the last common themes for potential supportive solutions. There was a high consensus that regulatory bodies should help provide funding for method development and inter-laboratory trials, as well as support the development of reference materials and validated methods. Support for harmonised international standards (AOAC, EU, UK, global collaboration) was also seen as central, as was clear labelling rules and transparency requirements. Finally, accreditation frameworks for CCP testing laboratories were seen as a universal requirement.

An underpinning theme throughout all the responses was that the risk from adulteration was universally recognised, and fraud was seen as inevitable without robust controls. It was also noted that some respondents emphasised the need for training programmes for

enforcement labs, as well as recommending public communication, engagement and education to reduce consumer confusion or misconceptions over CCPs.

4.2.3.3. General stakeholder engagement

Attendance at a series of workshops, meetings, webinars and hosting 1:1 meetings with stakeholders was engaged with, as part of making further informed judgements on some of the key issues (challenges and recommendations) associated with the use of analytical methods for the detection of CCPs in the food supply chain.

A live webinar on cultivated meats, produced by Affidia (Affidia s.r.l. SB, 2026), was attended in the January 2026 period. Whilst the webinar was primarily focussed on addressing key bottlenecks and identifying scaling solutions for cultivated meats, a question was posed by a member of the project team to the expert speakers on their views on the measurement needs and challenges for analytical traceability of CCPs. The expert panel agreed that traceability was important to help enable consumer choice and that it was the responsibility of the CCP manufacturer to demonstrate the purity of their own product. Aside from traceability to ensure market confidence, the panel said methods were required for a food safety perspective (e.g., contamination from pathogenic organisms) and that these methods would not be significantly different from those that are already routinely used. The panel finished on their reflections, suggesting that it was important that the relevant regulator set the appropriate guidance for (analytical) traceability.

A meeting was held with EpiTrace Technologies (EpiTrace, 2026), who represent a German firm involved in the production of epigenetic tools for livestock animals and their products. It was discussed whether epigenetics could be used as an additional tool for the analytical detection of CCPs in the food supply chain, since epigenetic markers can be used in the generation of animal passports as they provide a traceable link to the environment in which the animal has been exposed to (e.g., via DNA methylation). An epigenetic fingerprint, consisting of multiple epigenetic methylation patterns, can be used to trace an animal with a history in specific environments. Following the discussions, it was agreed that epigenetic approaches may hold some potential for CCP detection, for example with an epigenetic fingerprint being generated based on the specific cells and media in the bioreactor. However, challenges still remained as to how to account for different media conditions and the stability/heritability of epigenetic effects. Method validation including assessment of the performance of the epigenetic targets would be key to establishing this potential further.

A meeting with a representative from Innovate UK Business Connect (part of UKRI), was also held to discuss further concerns and opportunities associated with analytical detection of CCPs. An underlying requirement was the need for validated methods to provide evidence of the fitness for purpose of that method for detection of a CCP, but these also had to be rapid and cost-effective. It was discussed that a cost-effective screen could be utilised as part of a triage system to identify any potential red flags prior to employing a more comprehensive and costly confirmatory test for the presence of CCPs.

Both genomic and proteomic approaches may have some potential here, and again a weight of evidence approach using results from both analytical areas would be the most informative. Approaches inclusive of assessing the microbiome of CCPs may have some potential, as would testing for salmonella in conventionally reared chicken compared to CCP chicken, methods examining cellular density, and stable isotope signatures. All approaches may find it challenging when applied to a mixed sample consisting of both conventional and CCP meat, which would be further impacted upon when applied to cooked and processed food materials.

The benefits of labelling CCPs were discussed, as an aid to enable consumer choice and boost market confidence. Global legislation on CCPs was recognised as providing a barrier to labelling and CCP adoption, as different global regions were subject to different regulatory regimes. It was suggested that traceability should be embedded at the start of the production process, alongside key metrology principles, to enable market confidence, transparency and consumer trust.

Further stakeholder engagement was sought with the Risk Assessment and Communication Department at the National Centre for Food Science (Singapore), based on their track record, inclusion on a number of international CCP related initiatives, and being a representative of the international community. For potential analytical approaches to be used for the traceability of CCPs in the food supply chain, they advised a combination of approaches (weight of evidence) should be used, as no single method can uniquely identify CCPs across all matrices. In terms of how analytical methods for CCP detection should be used, they advised that analytical methods could be used to ensure food safety, verify product claims and maintain supply chain integrity, specifically citing some of the analytical methods already being used as part of pre-market approval. They also recommended that methods could include DNA-based species identification, high-resolution mass spectrometry (HRMS)-based non-targeted analysis (NTA), proteomics, lipidomics and metabolomic fingerprinting, stable isotope profiling and the detection of veterinary residues. Discussions also highlighted some of the scientific and technical challenges (similarity to conventional meats and lack of universal

biomarkers), methodological barriers (lack of reference materials, databases and consensus markers), and regulatory and practical concerns (lack of internationally standardised and validated methods).

Presentations and discussions at the FSA and FSS Innovation Showcase (13th March 2026) showed how approval time for novel products had been significantly reduced following pro-active FSA and FSS interventions and programmes such as the CCP Sandbox. Discussions also highlighted the need for further regulatory refinement as novel foods do not fit particularly well within the pre-existing regulatory framework, providing a challenge for authorisation and commercialisation of novel food products. Collaboration across all sectors was needed to ensure a proportional regulatory system, in line with the UK Government's Modern Industrial Strategy (Department for Business and Trade, 2025).

4.2.4. National and international standardisation approaches for CCPs

Harmonisation and standardisation of analytical approaches for the detection of CCPs is critical to the long-term success of the CCP sector. The landscape review has identified early standardisation efforts being driven by organisations such as the International Organization for Standardization (ISO) which has established a new working group (TC34/WG30) to work on tissue culture and cellular food technology products, and the Codex Alimentarius Commission which is proposing to develop guidelines for the assessment of cell culture media components (Codex Committee on Food Additives) and codes of hygienic practice for manufacturing of cell-based foods (Codex Committee on Food Hygiene).

In 2026, BSI is sponsoring a fast-track standard, entitled PAS 3500 – Requirements for DNA bar coding of engineered biological assets. This standard proposes the introduction of DNA markers into an engineered product as an aid towards IP protection, provenance tracking, safety and biosecurity. Whilst still in its infancy, this proposed standard, if approved, may have additional implications in facilitating additional analytical traceability of engineering biology assets in the agricultural sector (British Standards Institution, 2026).

4.2.4.1. Metrology and associated tools: dependency on reference materials and databases

The landscape review has identified emerging databases to support CCP authentication. These resources include the Safety-Assessed Media Ingredient (SAMI) List for media-ingredients and nutrient references, a thermostability dataset for growth factors, and comparator nutritional databases such as USDA Food Data Central. These resources help detect adulteration, including substitution with conventional meat.

5. Discussion: Challenges and recommendations for analytical detection of CCPs

The literature review revealed the availability of analytical methods being used to test for quality and safety requirements (residues, contaminants and allergens) as part of CCP approvals for market placement. However, the review also highlighted the lack of CCP specific methodologies whilst capturing the availability of existing techniques which range from genomics to proteomics technologies with variable applicability to CCP detection and authenticity testing. A weight of evidence-based approach is likely required to ensure the full traceability of CCPs within the food chain due to their inherent complexity and variability. Potential challenges associated with using analytical methods for the detection of CCPs in the food supply chain include limited transparency across the sector (e.g., IP and confidentiality issues) and the need for research focussed specifically on CCP authentication applications. Analytical methods for CCPs are being used extensively in safety, quality and nutritional assessment to support the approval process, but little is available for CCP detection purposes. Surprisingly, the review has identified only limited consideration of food fraud issues by developers and organisations which is critical to the future success of CCP materials within this sector.

Based on the landscape review (literature reviews) and stakeholder engagement exercises (Focus Group meeting, questionnaire and face-to-face meetings), a number of key themes were identified, both in terms of challenges and recommendations, to support the infrastructure for analytical traceability of CCPs in the food supply chain. These have been itemised below for ease of reference:

- **Challenge: Potential risk of adulteration and fraud associated with CCPs**
 - Evidence supported that there may be a significant risk of adulteration of/with CCPs in both directions (CCPs being adulterated with conventional meats, and vice versa) depending upon the market adoption of CCPs in the early and late maturation phases.
 - **Recommendation:** Traceability systems should be further strengthened, and incorporate biomarkers and barcoding where appropriate, use of digital traceability, to ensure robust verification tools. Systems for traceability need to be established before CCPs reach market maturity to ensure they are

effective once the sector expands. Embedding key metrology principles early in the process will help support long term consistency and comparability. Consideration should be given to establishing a centralised body such as a UK National Reference Laboratory to support CCP authenticity testing and provide authoritative oversight. Any analytical methods adopted must, however, remain accessible and cost effective to enable routine use across laboratories of varying capability.

- **Challenge: Analytical methods may struggle to distinguish CCPs from conventional meat, especially in hybrid or mixed samples**

- **Recommendation:** Markers and weight of evidence approaches should be developed as these had the greatest likelihood of providing the required level of discrimination and sensitivity. Several of the upstream analytical tools already used for safety, quality and nutritional assessment as part of the CCP authorisation process, could be repurposed to support downstream traceability activities, creating a more integrated and efficient system. Existing methods can be repurposed to tackle conventional meat-adulteration of CCPs. These methods include DNA and proteomics testing for pathogens and residues specific to conventional meat, and fluorescence microscopy to inspect the cellular density and uniformity of cells on a CCP-specific scaffold. The latter method may be enhanced by AI processing to identify divergences. Equally well, a promising avenue may involve identifying markers that are present in conventional meats but absent in cell cultivated products. These markers could include environmental microbiome signatures, metabolites linked to animal physiology, or residues typically found in conventionally reared livestock—such as salmonella presence in conventional chicken but absence in CCP chicken.

- **Challenge: Lack of validated methods and reference materials**

- This was identified as one of the major barriers to afford confidence in analytical traceability of CCPs.

- **Recommendation:** Develop appropriate reference materials, validated methods, harmonised standards, and inter-laboratory studies. The CCP testing infrastructure must be ready prior to CCPs scaling in the market.
- **Challenge: The advanced nature of many of the proposed analytical methods makes them expensive, technically demanding, and often unsuitable for routine or Official Laboratory use.**
 - **Recommendation:** Development of more accessible, rapid and cost-effective screening tests as complements to advanced methods based on techniques such as immunoassays (e.g., ELISA tests for veterinary drugs), spectroscopic and chromatographic (e.g., fatty acid and amino acid profiling) and non-targeted analysis (e.g., HRMS to characterise unknown organic chemicals in complex samples). Enforcement tools should not add unnecessary burden or delay to an already lengthy CCP approval process.
- **Challenge: Current regulatory structures do not yet support analytical traceability or routine enforcement for CCPs**
 - **Recommendation:** Further development of stronger regulatory, governmental and international support. Government and regulators should support method development, inter-laboratory trials, international collaboration, and clear labelling and accreditation frameworks. Clarifying future consumer labelling requirements will also be essential as the sector grows, ensuring that analytical approaches, regulatory expectations and consumer communication all align. Public perception is a critical factor for successful adoption of CCPs. Continued engagement, open communication and transparency will be vital to building trust and ensuring the sector develops in a responsible and accepted way.

The next sub-sections describe in further detail some of the key issues associated with analytical detection of CCPs.

5.1. Use of standardised food testing methods

The authentication of CCP species, cell types, and nutritional/mineral profiles has been demonstrated using standardised food testing methodology (e.g., validated / accredited laboratory methods to assess nutritional value, allergenicity, chemical residues and microbiological safety) in CCP approval applications. It is recommended that where appropriate these methods could be repurposed and, pending fit for purpose method validation and verification, be used for detection, authentication and identification of CCPs. The ease of method transferability is dependent upon factors such as the availability of reference materials and databases, cost-effectiveness & resource availability (e.g., the ability to implement necessary equipment, reagents, and trained staff). Currently, these methods, do not provide a comprehensive and evidence-based assessment. Due to novelty, there are no case studies of CCP adulteration, and so a comprehensive authentication protocol will require prediction and forethought.

5.2. Detection of conventional meat as an adulterant of CCPs

It has been predicted that the presence of conventional meat could be a common adulterant in CCPs. This poses an issue for CCP authentication because typical methods of authentication such as species identity and cell typing will not generally flag the adulteration. Additionally, while the chromatographic methods identified during the landscape review can form a 'fingerprint' – a powerful method of identification – this may also not be able to flag adulteration in future 'ideal' CCPs, designed to closely resemble conventional meat. The intention of manufacturers for CCPs is to attain a nutritional profile as similar to conventional meat as possible (Mariano et al., 2023). Wildtype Inc (Food and Drug Administration (FDA), 2026) has stated: 'Wildtype expects the product specifications below to more closely approximate conventional salmon by the time Wildtype salmon is available for commercial sale in the United States.'. Therefore, nutritional profiling may also not be able to identify this type of adulteration.

Existing methods can be repurposed to tackle conventional meat adulteration of CCPs. These methods include DNA and proteomics testing for pathogens and residues specific to conventional meat, and fluorescence microscopy to inspect the cellular density and uniformity of cells on a CCP-specific scaffold. The latter method may be enhanced by AI processing to identify divergences.

When testing for aspects specific to CCPs for authentication purposes, it should be noted that CCPs are variable, and so a valid testing method for one may not be widely applicable. Testing for scaffold-specific structures or residues will not be applicable in CCPs with no scaffolds. Similarly, while GMO CCPs can be authenticated using simple genomic methods, this will not be applicable for CCPs without genetic modifications.

5.3. A weight of evidence (WoE) approach to CCP testing

A weight of evidence approach (e.g., multimodal), using cumulative evidence from multiple methods and approaches with associated product traceability details, represents a viable solution to the CCP authenticity testing. A profile or 'fingerprint' can be built using analytical data of the CCP prior to commercial availability. This profile is likely to include genomic, proteomic, chromatographic and spectrographic-obtained data, alongside other data that may be immediately quantifiable through AI such as cell morphology data. AI may also be explored as a tool to process large datasets in weight of evidence authentication. CCPs should be tested alongside conventional reference meats in practice, the data of which should be enhanced by open-source databases of reference materials. Developing food sector specific AI-based infrastructure is likely to be complex and potentially costly, although partnering with academia/institutes to develop non-proprietary AI tools and platforms could be a viable option to minimise associated costs. Fit for purpose reference data resources are critical to the success of this approach and will require development and ongoing maintenance to ensure appropriate database quality, coverage and stakeholder accessibility. Access to verified CCP developer and manufacturer reference datasets is central to the success of any database driven authenticity resource. Blockchain technology can enhance authentication practises, but lab-based analysis is imperative to verify the integrity of the blockchain at various points.

5.4. Implementation and future prospects

A large-scale multi-faceted testing regimen of CCPs may not be realistic in practice due to the extensive research and implementation costs. Solutions to this have been discussed by the Good Food Institute (Good Food Institute, 2026b) who are working towards the characterisation of CCPs by introducing scaled-down sample sizes for analysis testing, and streamlining or bundling of laboratory-based assays (Good Food Institute, 2026a). This approach would focus on cost effective and standardised analytical tools (e.g., Western blots, qPCR, immunohistochemical staining and microscopy) to assess the quality of CCP materials inclusive of nutritional content, safety and cell quality attributes. Integrated solutions could facilitate the

analysis of all relevant markers within a single culture plate or kit through the application of current generation high throughput microscopy, image analysis and genomic platforms with minimal handling requirements.

Potential solutions should consider the variability of CCPs attempting market approval, as it is likely all CCPs will require a somewhat individualistic approach to authentication. In order to prepare comprehensive testing and authentication practises for CCPs, transparency of analytical and compositional data is vital.

Internationally, regulatory bodies have issued guidelines on safety testing of CCPs, however they do not contain guidance concerning testing methods specifically for fraud and authentication. Standardised, regulated and compulsory CCP authentication is imperative to future manufacture and commercialisation of CCPs in the UK. UK regulatory bodies should work alongside the scientific community to validate authentication methods and build evidence-based and standardised guidelines on CCP testing for authenticity. A holistic national framework supporting the development of guidance (e.g., methods and regulatory) and building strong stakeholder networks that combine regulatory, accreditation, research, developers and manufacturers is critical to the long-term success of the CCP sector and would help minimise challenges faced during the commercialisation process.

5.5. Recommendations on future work

5.5.1. Weight of evidence (WoE) approach

Developing a weight of evidence approach is the strongest overall recommendation in the report. It aligns with the repeated conclusion that no current single method is sufficient for analytical traceability of CCPs, especially for mixed, processed, or evolving CCP formats. This approach is the most promising as it best matches CCP variability; it is more robust than any single assay in isolation; it can combine orthogonal evidence from DNA, protein, chemistry, structure, and traceability data; and it may offer one of the most realistic routes for regulatory and enforcement use.

Upstream analytical methods used for the generation of nutritional, safety and toxicity profiles as part of the authorisation process, could be repurposed to serve as methods for analytical traceability. Among individual analytical domains, genomics appears the most mature and versatile in the report (PCR, qPCR, dPCR, NGS and WGS). DNA methods are already used in CCP approval contexts and are likely to be adaptable for traceability. Proteomic methods such as ELISA, western blotting and immunostaining, currently used to detect growth factors, hormones and cell-type markers, could contribute to CCP-specific residue or identity profiles. Chromatographic and spectroscopic methods already used for

amino acid, fatty acid, mineral and residue analysis, including HPLC, GC-FID, GC-MS and ICP-MS, could provide compositional “fingerprints” to support authenticity assessment. More broadly, these upstream methods could be combined within a weight of evidence framework, alongside reference datasets and conventional comparators, to support downstream verification of CCP identity and detect potential adulteration or substitution.

The approach could be developed by defining a core analytical panel for CCPs (e.g., DNA species identity markers; targeted residue protein markers; amino acid and fatty acid or mineral profiling; structural or microscopy-based features; supporting provenance and reference data, etc.) followed by establishing product-specific reference profiles. A decision framework could then be developed, followed by generation of SOPs for sampling, data interpretation, and escalation from screening to confirmatory testing.

The main limitation of a WoE approach is that scientifically it may be strong in principle, but it would be more challenging to apply operationally. This is because it depends on validated component methods, shared reference data, harmonised interpretation rules, sufficient access to CCP-specific information, and access to a range of analytical laboratory instrumentation which may not be common throughout all testing laboratories.

5.5.2. Digital barcoding

The review highlighted that currently, no single analytical approach is sufficient to characterise or authenticate CCPs due to their inherent variability, evolving production methods, and similarity to conventional meats. A unique digital DNA barcode inserted into a CCP genome could, in principle, be one of the clearest analytical traceability tools for CCPs, because it would create a specific, detectable, product-linked genetic signature that is absent from conventional meat. The central concept would be to engineer a short, unique, non-coding DNA sequence into the production cell line and then detect it in the final product using targeted PCR, qPCR, digital PCR, or sequencing. If the barcode were stable and present at a defined locus and copy number, it could support identity confirmation, provenance tracking, anti-fraud testing, and supply-chain verification, particularly in cases where species testing alone cannot distinguish CCP from conventional meat.

This is consistent with the report’s discussion of GMO-specific detection and the emerging interest in synthetic barcoding for CCP traceability, as well as the draft PAS 3500 on DNA barcoding of engineered biological assets. The approach also has advantages in that it recognised the review outcome that no current single analytical approach can guarantee CCP

traceability, but it also capitalised upon the use of analytical molecular biology equipment which are already established or accessible in a number of Official Laboratories (PCR, qPCR, dPCR and NGS).

One of the main limitations of this approach would be the UK market authorisation implications. If the CCP genome is deliberately modified to insert a synthetic DNA barcode, this is very likely to have regulatory consequences in the UK. The Food Standards Agency makes clear that cell cultivated products require market authorisation and that, where genetic modification is involved, businesses may need to proceed under the relevant GMO authorisation regime rather than relying only on the standard novel foods route. The FSA's earlier CCP guidance also states that for cell cultivated products produced using genetic modification, applicants should discuss the appropriate regulatory route with them.

A suggested robust development pathway for digital barcoding would be to design a short, unique, biologically neutral sequence that is absent from the source species genome and common contaminants; does not encode a functional protein; is unlikely to affect cell growth, differentiation, stability, or composition; and can be amplified reliably in short fragments, so it remains detectable after processing. Analytical assay development would involve developing a testing package, including: endpoint PCR for presence/absence screening; qPCR or digital PCR for sensitive quantification; confirmatory sequencing of the barcode and insertion junction; and possibility of using multiplex assays combining the barcode with species markers and internal controls.

Scientifically, this is a highly promising traceability approach because it creates a direct, specific, and testable marker that overcomes one of the main problems identified in the report: CCPs may become too similar to conventional meat for indirect methods alone to remain reliable. However, regulatory-wise it could create a more complex authorisation pathway, because the barcode itself is a deliberate genomic modification.

5.5.3. Epigenetics

Based on this report, epigenetics-based testing is presented as an emerging and currently unverified approach, but one with genuine potential for CCP traceability, particularly for distinguishing CCPs from conventional meat through DNA methylation patterns.

The report suggests that epigenetic testing could be used to generate an epigenetic fingerprint for CCPs. This would rely mainly on detecting DNA methylation signatures that reflect the biological and environmental history of the cells. In conventional livestock, methylation patterns are influenced by factors such as diet, stress, and environmental exposure,

and this report notes that these kinds of context-dependent signatures have already been explored for animal welfare monitoring and origin tracing of livestock.

Applied to CCPs, the principle is that cells grown in a controlled bioreactor environment may acquire a methylation pattern that differs from that of conventional animal tissues. In theory, this could support cell identification and authentication, differentiation of CCPs from conventional meat, and detection of conventional meat adulteration in CCPs, if conventional tissue carries distinct methylation signatures.

The stakeholder discussions in this report also suggest that an epigenetic fingerprint could potentially be linked to the specific cells and media conditions used during CCP production. This makes epigenetics attractive because it may capture information beyond simple species identity and could reflect the history and production context of the material.

The report is also clear that this is an emerging and unverified method. Major uncertainties remain, including how different culture media conditions affect methylation patterns. Whether epigenetic signatures are sufficiently stable and heritable would be a further question, as would whether signatures remain detectable in processed or mixed products. Finally, how much variation exists between CCP manufacturers, batches, and conventional comparators would need to be assessed.

Epigenetics-based testing is one of the more innovative longer-term options in the report. Its main value is that it may detect biological history and production-environment effects that are not accessible through standard species testing. However, because it remains emerging and unverified, it would require significant further development, testing, optimisation and validation, and potentially used as a broader weight of evidence approach rather than as a primary standalone test.

5.5.4. PCR based microbial testing

Based on this report, PCR-based microbial testing could contribute to CCP traceability, but mainly as a supporting and screening method rather than a standalone authentication tool.

The report suggests that PCR-based microbial testing has potential because it can detect microbial DNA signatures associated with conventional meat production, which are not normally expected in CCPs. In that sense, it could act as an indicator of possible adulteration, contamination, or loss of process integrity.

A key example given in the report is the detection of Salmonella DNA in chicken products. Since salmonella may be associated with conventional poultry production but would not typically be expected in a properly

controlled CCP system, a positive PCR result in a chicken CCP could serve as a red flag for further investigation. More broadly, PCR-based microbial testing could be used to look for: pathogens or spoilage organisms linked to conventional livestock systems; environmental microbiome signatures associated with farmed animals; and contamination events that are inconsistent with a controlled cell-culture process.

In this way, PCR-based microbial testing could support analytical traceability by helping to distinguish expected CCP microbiological status from signals suggestive of conventional meat input or external contamination.

Microbial profiling as an aid to analytical traceability could be developed by first defining relevant microbial targets, and then establishing CCP microbiological baselines. A panel of targeted PCR markers could then be developed, and responses and results could be linked through to agreed decision rules.

This report also makes clear that this is an unverified method for CCP authenticity testing. A positive microbial PCR result would not, by itself, prove adulteration with conventional meat, because contamination could also arise during processing, handling, or from ingredients. Therefore, this approach may be best used as part of a weight of evidence framework, alongside genomic, compositional, and other supporting methods.

Table 3. Table listing the potential, limitations and testing/development requirements associated with the top four approaches recommended for further development as an aid to analytical traceability of CCPs

Approach	Potential	Limitations	Development and testing requirements
Weight of evidence	Most promising overall approach. Combines complementary analytical evidence to support more robust CCP authentication and adulteration detection.	More complex to establish, standardise and interpret than a single-method approach. Requires strong reference data and agreed decision criteria.	Define a core analytical panel and interpretation framework; generate authenticated reference datasets; test against blinded authentic, adulterated, hybrid and processed materials; undertake inter-laboratory validation.
Digital barcoding	Strongest single method, but requires deliberate engineering with potential regulatory consequences. Could provide a highly specific analytical marker for CCP identity and provenance where a unique synthetic barcode is deliberately introduced into the production cell line.	Applicable only to deliberately engineered CCPs. Would have important regulatory implications and would require demonstration of barcode stability and analytical detectability.	Design a unique non-functional barcode; confirm stable genomic insertion; develop targeted PCR/qPCR/dPCR or sequencing assays; test performance in raw, processed, mixed and blinded samples; assess inter-laboratory reproducibility.

Approach	Potential	Limitations	Development and testing requirements
Epigenetics	Innovative and potentially powerful, but still early-stage. Supports authentication through DNA methylation signatures reflecting the biological and production history of CCP cells. May help distinguish CCPs from conventional meat.	Emerging and unverified. Signatures may vary with cell type, culture conditions and processing, and their stability remains uncertain.	Identify discriminatory methylation markers; build reference datasets for CCPs and conventional comparators; develop targeted assays; test robustness across batches, conditions, matrices and laboratories.
PCR-based microbial profiling	A useful supporting screening tool for detecting microbial signatures associated with conventional meat production but not normally expected in CCPs. However, likely to not be definitive on its own.	Indirect and not definitive as a standalone method. Positive findings may also reflect incidental contamination rather than adulteration.	Define suitable microbial targets; establish the normal microbiological baseline for CCPs; develop multiplex PCR panels; test against authentic, adulterated, contaminated and processed samples; validate sensitivity, specificity and reproducibility.

6. Conclusion

The rapid emergence of CCPs represents both an opportunity and a challenge for the UK food system. While CCPs offer the potential for more sustainable, ethical and resilient protein production, their novelty and technological diversity create substantial uncertainty around how best to ensure authenticity, traceability and consumer confidence. Through a comprehensive landscape review and stakeholder engagement activities, this project has identified key challenges and recommendations associated with analytical traceability for CCPs. This project has shown that although many analytical techniques currently exist, particularly those used in CCP safety and quality assessments, few have yet been fully validated or standardised for authenticity or fraud detection purposes. The literature and stakeholder evidence collectively demonstrate that CCPs are highly variable in composition, manufacturing processes and product formats, meaning no single analytical method can reliably verify identity across all products or detect adulteration in complex, mixed or processed foods.

A consistent theme across the review and engagement activities was the significant risk of future adulteration, driven by anticipated early-market costs and the possibility of products being mixed with conventional meat. Stakeholders repeatedly emphasised the lack of validated methods, insufficient reference materials and the absence of harmonised standards as major barriers to robust enforcement and routine testing. Embedding key metrology principles early in the process prior to CCP market expansion is essential in helping support long term consistency and

comparability of results. Addressing these gaps before CCPs become widely commercialised will be essential to support market integrity and consumer trust.

This review prioritised four approaches for further development, based on their potential as tools to aid analytical traceability of CCPs in the food supply chain. A weight of evidence approach appeared the strongest overall because it combined several complementary tests and is likely to be more reliable than any current single method, although it will be more complex to standardise and implement. Digital barcoding could provide the clearest single marker of CCP identity, but only where products are deliberately engineered, which may introduce regulatory challenges. Epigenetics is an innovative longer-term option that may help distinguish CCPs from conventional meat by reflecting biological and production history, but it remains at an early stage and is not yet fully validated. PCR-based microbial profiling is best viewed as a supporting screening tool that may help flag possible adulteration or contamination, but it is not definitive on its own.

Developing rapid, cost effective screening tools alongside advanced confirmatory methods will be critical to ensuring accessibility for both industry and Official Laboratories. Stronger collaboration between regulators, industry, and the scientific community will also be vital to drive method development, inter-laboratory validation and international harmonisation, while clear labelling expectations and traceability requirements will further support transparency.



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Acknowledgements

The project leads at the UK National Measurement Laboratory (LGC) gratefully acknowledge funding and support provided by the FSA as part of FSA Project FS900616 - Review of analytical methods for Cell Cultivated Products.

The project team acknowledge the kind support of Selvarani Elahi (LGC), who chaired the Focus Group meeting, and representatives from the following organisations who participated in stakeholder engagement activities: Bezos Centre for Sustainable Protein; Bright Biotech; Defra; FSA;

Hoxton Farms; Ivy Farm Technologies; Minton, Treharne & Davies; National Alternative Protein Innovation Centre (NAPIC); UKRI Microbial Food Hub; Reading Scientific Services Ltd (RSSL); The Quadram Institute; The UK Cellular Agriculture Manufacturing hub (CARMA) and the United Kingdom Accreditation Service (UKAS).

The authors also thank EpiTrace Technologies, the National Centre for Food Science (Singapore) and Innovate UK Business Connect (part of UKRI), for their valuable time during face-to-face meetings.

Published: September 01, 2026 BST.



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Supplementary Materials

FS900616 - Appendices

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