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Honey authenticity: data trust, harmonisation of analytical methods, reference database and markers for honey authenticity

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Overview

Honey is a natural, complex mixture of different sugars produced entirely by bees. According to the UN,[1] there are more than 90 million managed beehives around the world producing about 1.9 million tonnes of honey worth more than £5 billion a year. Given the size of the market and the immense environmental benefits of beekeeping – three out of four crops depend on pollination by bees – it is an industry on which both livelihoods and lives depend.

Target for adulteration

As a labour-intensive, high-value expensive product with an often complex supply chain, honey is subject to internationally and nationally agreed definitions – and is a target for adulteration. Testing honey is therefore critical, but there is no single universal analytical method available which is capable of detecting all types of adulteration with adequate sensitivity. A variety of methods are used to detect honey adulteration and each test has strengths and weaknesses.

NMR's 'chemical fingerprint'

Testing for honey adulterated with added sugars may be based on analytical techniques using 'fingerprinting' tools, such as those using nuclear magnetic resonance spectroscopy (NMR). This is especially helpful in detecting certain types of adulteration, such as the addition of cane or beet sugars. Bees generally forage on plants that use the same photosynthetic pathway as beet sugars. This makes it difficult for traditional tests based on isotopic differences to provide effective results. The 'chemical fingerprint' provided by NMR is specific to the sample that has been tested and can be compared with the fingerprint from other sample results enabling the user to assess consistency.

Hidden databases

Interpretation of results depends on comparison against a reference database of authenticated samples. The reference database needs to be representative of the variation that can occur, which includes differing beekeeping practices, origins, seasonality and variations in climate. Information is also needed on the collection of reference samples, curation of databases, interpretation and reporting of data. The nature of the reference databases is key to understanding how the results have been interpreted.

However, these reference databases are owned by and commercially sensitive for the testing laboratories that have developed them. How can such data be shared in a trustworthy way between key stakeholders along the honey and analytical supply chain so that all parties can have confidence in honey authenticity test results?

Our research is looking into the implications of these hidden databases, especially in terms of the trust related to the validation certificates and the value that they have in the honey supply chain.

Introduction: exploring the authenticity challenge

The challenge

Honey is a complex, naturally occurring product that has become a target for adulteration, like other high-value food products such as olive oil, whisky and wine.

Technology is increasingly playing a role in tackling many of the pressures facing food production and the supply chain, such as availability, quality, safety, nutrition and authenticity.

However, unlike other food products at risk of adulteration, which are made from harvested produce such as olives or grapes, honey is sourced from free roaming bees and their hives, which are not always pinned to a fixed location. As such, the tech-enabled provenance trails that have been suggested for other high-value food products are not straightforward.

Contested tests

In addition, testing protocols are contested due to the very nature of honey. There is a range of technical tests that can be applied to test the various components of the official honey definition. However, across the community of stakeholders in the honey sector, there is no consensus on exactly how these technical tests should be applied.

While the various tests that are used by labs to produce Certificates of Authenticity (CoA) are inherently sound, there is a human element when it comes to application and interpretation. This is reflected in the language used in the analysis.

Consensus and compliance challenges

All of this matters as there are significant areas of disagreement and/or ambiguity. These include over the application of the test processes, the interpretation of the test results (with regard to the official definitions of honey), and the sharing of the data that underpins some of the tests. The legal ramifications are also complex.

While technologies such as blockchain exist for food chain security, these do not address the challenges faced by regulators and food business operators when it comes to sharing data from certain testing methods such as nuclear magnetic resonance (NMR) technology and stable isotopic analysis. In particular, information is required on the collection of reference samples, curation of databases, interpretation and reporting of data.

In recent years there has been discussion and investigation into how tests can be combined and interpretations aligned, but there remain challenges in obtaining consensus for regulatory compliance. The recent reports[2] from the Government Chemist set out these challenges clearly.

Data trust frameworks: a way forward

We believe that innovative data sharing mechanisms such as data trusts could enable a new mechanism to achieve trustworthy sharing of data between key stakeholders along the honey analysis and supply chain. Previous work on how a data trust framework might enable the permissioned sharing of data among collaborating stakeholders offers one such approach to the challenge of regulatory compliant testing for honey authenticity.

This report has been produced to present the findings and recommendations of a short investigation carried out on behalf of the FSA. The work offers a way forward to this challenge and builds on the recommendations from a previously funded FSA project on data trusts, which included a honey case study.[3]

Approach

We see honey authenticity as a socio-technical challenge, recognising the interaction between people and technical systems.[4]

The Data Trust Framework as described in the previous FSA reports[5] and a paper in the journal Nature[6] offers a solution that adopts these principles and builds on similar approaches implemented elsewhere, for example iSHARE in the Netherlands.[7]

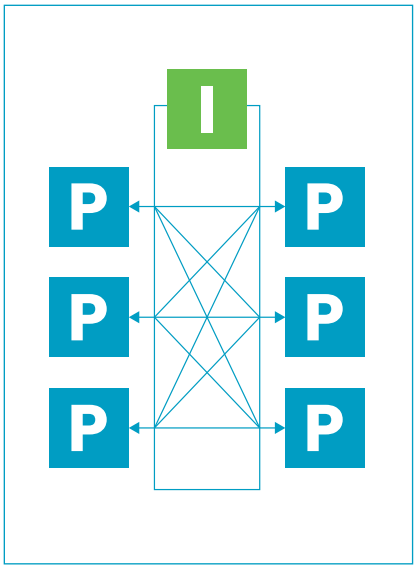
What is a data trust framework?

A trust framework can be defined as a legally enforceable set of specifications, rules and agreements that govern a multi-party system established for a common purpose, designed for conducting specific types of transactions among a community of participants, and bound by a common set of requirements.[8]

Who does a trust framework serve?

A trust framework can therefore be implemented as a kind of club established to meet the needs of members who have similar needs that they cannot easily satisfy on their own and are not met elsewhere. A key component of the implementation is the identity ecosystem framework that ensures that not only trust is maintained, but that the underlying legal guarantees can be appropriately implemented. Multilateral agreements can then be used among participants to enable secure collaboration and thus provide business models that extend the value that can be created from existing resources and processes.

Mission-driven platforms



The secure sharing of data offers new business models, one of which can be categorised as the mission-driven approach. Peer-to-peer intermediation is enabled by an initiative that captures the needs of the community without actively matchmaking participants.

Business model configuration for mission-driven data sharing initiatives [9]

The context

What is honey?

Honey is tightly defined under a 2001 European Directive, implemented in each of the then member states, which defines honey as

> 'the natural sweet substance produced by Apis mellifera bees from the nectar of plants or from secretions of living parts of plants or excretions of plant-sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in honeycombs to ripen and mature'.[10]

Internationally, the Codex Alimentarius Honey Standard[11] has a wider coverage than the EU directive. Rather than exclusively covering honey from Apis Mellifera (European honeybee), it applies to all honeys produced by honeybees and covers all styles of honey presentation offered for direct consumption. It establishes naming, chemical properties, level of contaminants, labelling of honey and other characteristics.

How is honey regulated in England?

The Honey (England) Regulations 2015 provide the basis for the marketing of honey to consumers. The key aims are to:

- protect the use of the reserved description 'honey' by setting a minimum expected compositional standard for our market
- instil consumer confidence in UK that the honey is what it says it is
- create a level playing field for industry and fair trading
- prevent misleading or fraudulent practices on our market

The 2015 Honey England Regulations cover honey from the Apis mellifera (European honey bee) and lay down reserved descriptions that must be used which relate to:

- the source from which the honey is obtained (eg blossom, honeydew)
- the processes by which it is extracted (eg drained, extracted)
- the way it is presented (eg comb, chunk honey, filtered honey, baker's honey)

Honey must comply with set specifications. There are a range of general quality criteria for honey focused around its colour, consistency, flavour and aroma. No additions are permitted, except for other honey, and no pollen or constituent particular to honey may be removed except where this is unavoidable in the removal of foreign inorganic or organic matter. The honey must be free from organic or inorganic matters foreign to its composition. It must not have any foreign tastes or odours, have begun to ferment, have an artificially changed acidity, or have been heated in such a way that the natural enzymes have been either destroyed or significantly inactivated.

As well as the quality criteria above, for honey to be labelled as honey it must comply with a set of specific compositional requirements, including set prescribed levels for:

- Sugar content: fructose and glucose content
- Moisture content
- Water-insoluble content
- Electrical conductivity
- Free acid (a measure of honey condition deterioration)
- Diastase (used as an indicator of honey freshness. It is also a parameter used to determine whether the honey has been extensively heated during processing)
- HMF (HydroxyMethylFurfuraldehyde – used as an indicator of heat and storage changes in honey)

How are honey regulations enforced in England?

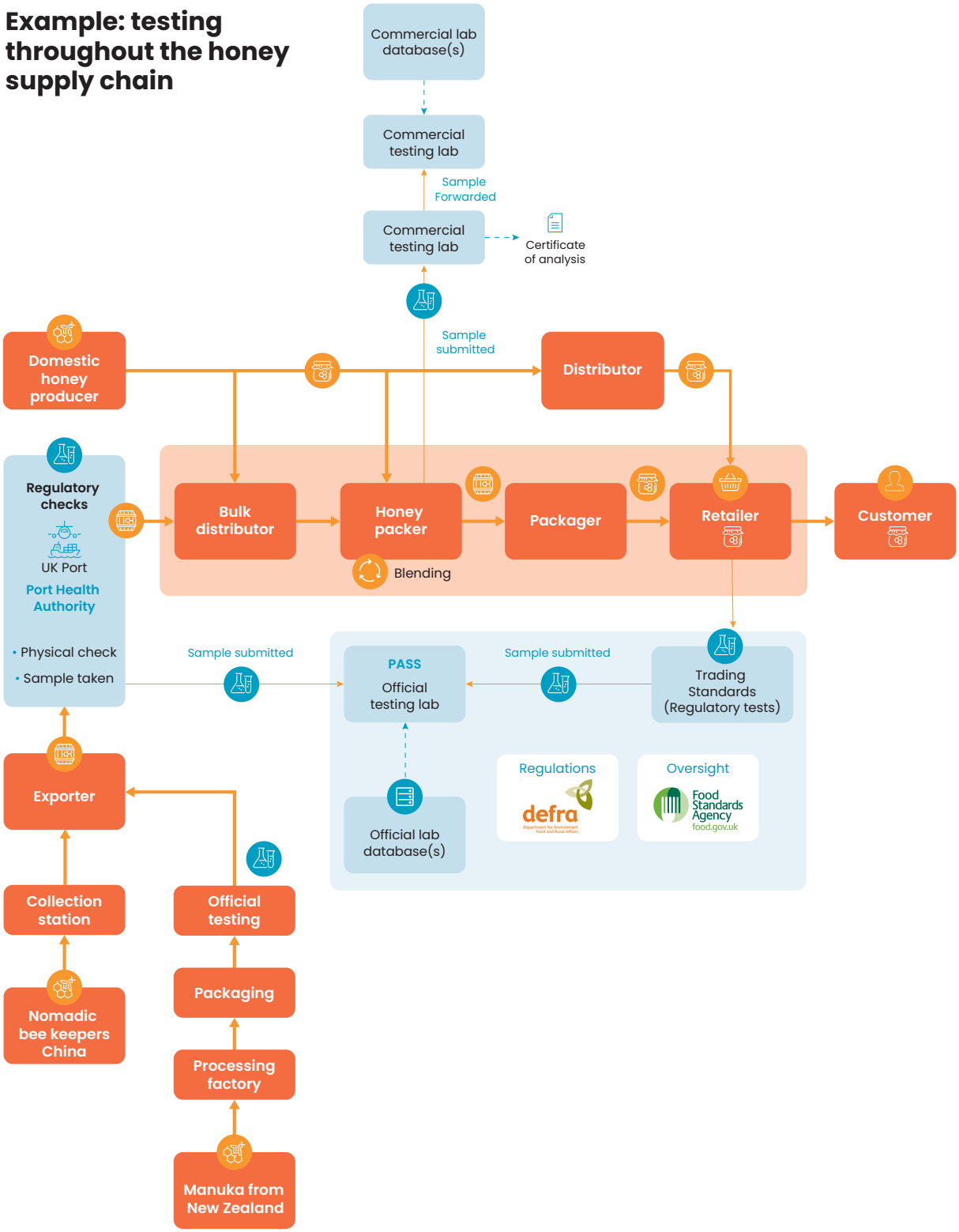
Regulation of the honey market is necessary to protect the use of the reserved description 'honey' by setting a minimum expected compositional standard and instil consumer confidence in the UK that the honey is what it says it is. It is also necessary to create a level playing field for industry and fair trading, and prevent misleading or fraudulent practices.

The Food Standards Agency (FSA) has oversight for food enforcement policy. Rules are enforced on the ground by local authorities such as trading standards officers, environmental health officers and public health officers who adopt a risk-based approach on enforcement. The tendency is to take an improvement notice approach with backstop criminal sanctions for failure to comply.

Product of Animal Origin (POAO) imports, which includes honey, are subject to mandatory checks (100% documentary; 15% minimum additional checks) by Port Health Authorities.

While key quality indicators (such as HMF, diastase etc) are set in honey rules, other non permitted additions such as added sugars are not specifically provided for but are implicit in the rules that "No pollen or constituent particular to honey may be removed except where this is unavoidable in the removal of foreign inorganic or organic matter".

Example: testing throughout the honey supply chain



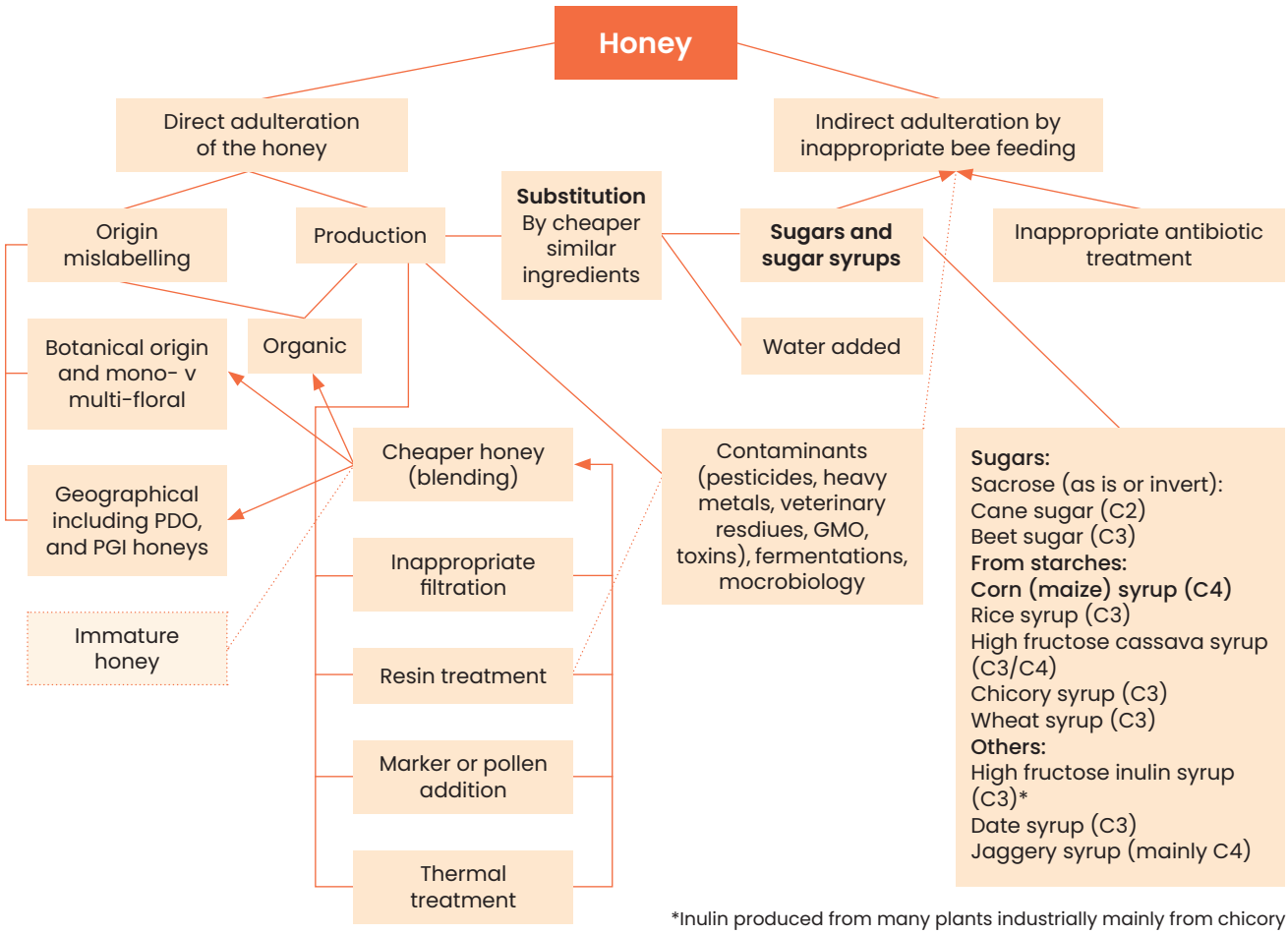
Where test results are queried, the FSA recommends applying a weight of evidence approach. This approach includes gathering information on product traceability – from beehive to jar – and results from any other testing that has been undertaken. This can also involve carrying out follow-up discussions with the relevant business.

Where the honey originates from the UK, there is no requirement for a business to test their honey but it is considered good due diligence and business practice to do so, to ensure the product meets the required standards.

How is honey adulterated?

Honey adulteration can be direct – sugar/syrup added to the honey at some point in the supply chain – or indirect, in the form of deliberate inappropriate bee feeding with sugars when nectar is naturally available. Direct adulteration is thought to be the most common. Other varieties of adulteration are shown in the diagram below.[12]

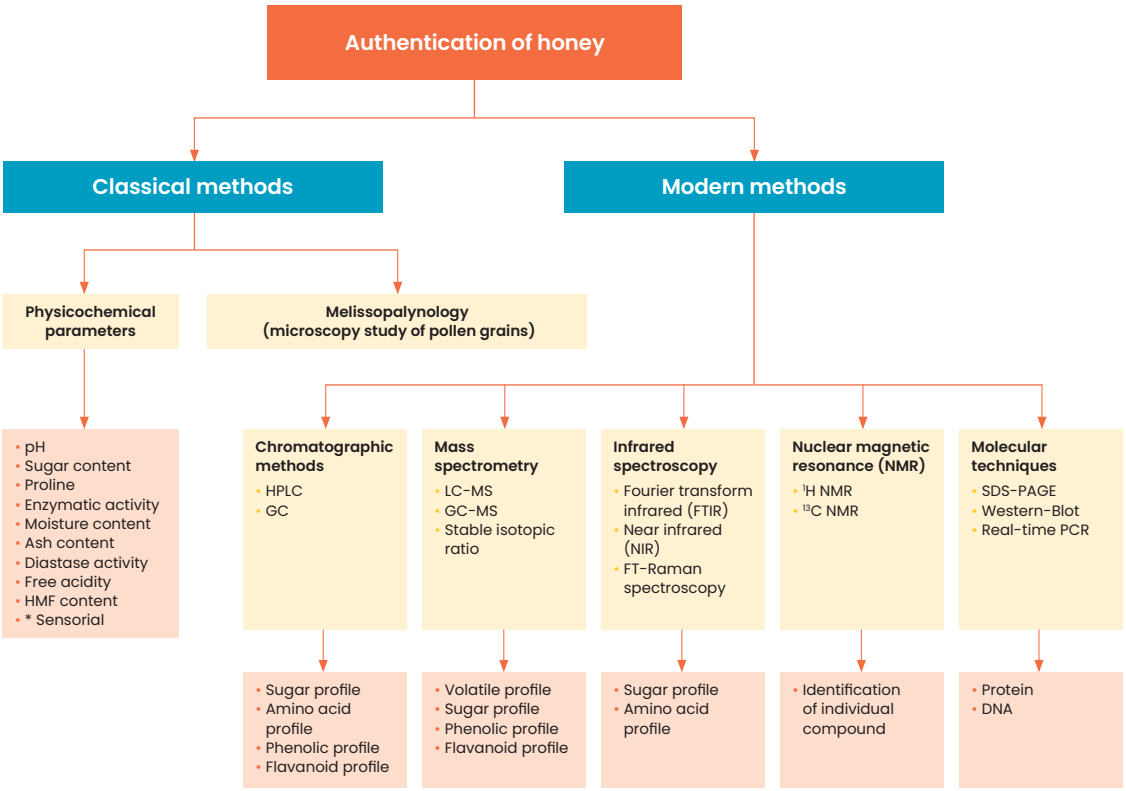
'Immature' honey, where the honey is removed early from the hive and then the moisture reduced, is a matter of much discussion. It falls foul of the Codex definition as the honey is not matured by bees in the hive, yet in the context of nomadic Chinese beekeeping in more humid Asian environments, it may be necessary to remove honey early to avoid fermentation.



*Inulin produced from many plants industrially mainly from chicory

Honey authenticity – methods available for testing

Analytical techniques to authenticate honey include the following:[13]



There are significantly different perspectives on the ways in which testing methods are applied to honey. These relate to different perspectives on how honey should be defined, and also how rules and regulations should be applied as practices.

The NMR issue

We have seen that the problem of honey authenticity:

- is multi-faceted, involving the nature of honey itself, testing regimes, testing processes, supply chains, practices in different cultures and consumer demands (for a product they know as 'honey' at an affordable cost)
- contains a wide divergence of perspectives and interpretations on the application of regulations, testing practices and analysis of results
- involves issues unique to NMR testing where it is being used to test honey for adulterants while not being universally accepted as an appropriate test, and comparison data is a challenge in terms of it being fit for purpose and furthermore not accessible as part of an audit or full comparison process

We are primarily interested in NMR testing, which is at the centre of the current debate.

The reference database challenge

The 'chemical fingerprinting' of NMR testing can find the added sugars that other tests cannot. However, interpretation of results from NMR tests depends on comparison against a reference database of authenticated samples, such as ones of known, verifiable origin and type.

To ensure it is robust, the reference database needs to be representative of the variation that can occur in a product such as honey. This includes differing beekeeping practices, different origins, seasonality and variations in climate. This should ideally be publicly available or available for scrutiny by all.[14]

A particular concern is that most NMR tests of UK honey are conducted by European labs. While European countries tend to consume primarily European honey, UK blended honey tends to be composed of honey from further afield, such as China, Mexico and Argentina.

Due to the different beekeeping practices and higher humidity in some of those regions, it is more likely to include immature honey. There is concern that these honey blends are not reflected in the samples used in the reference database, which may then affect the results. However, it is impossible to know if this is the case if the databases are not accessible.

Uncertainty, frustration – and urgency

NMR testing is being widely used but is producing contested results, and is not currently accepted as a yes/no test within the UK regulatory system, nor is it in the European Union. However, it is widely used.

This is causing uncertainty, a lack of clarity, and frustration throughout the honey supply ecosystem. It is also creating inefficiencies, especially for local authorities who act as a primary authority and deal with referrals from other local authorities and port authorities, who may be using a range of testing labs and processes.

There is a palpable sense of urgency to address this in a robust and practical way that works for all perspectives and so that all may have confidence in the honey testing regime.

> “The current situation is causing uncertainty and frustration throughout the honey supply ecosystem.”

What needs to be done

As a result of our research and fieldwork, we have identified two possible routes to resolving the issues outlined above.

1. An open, international reference database

The ideal: an open, international reference database of the 'chemical fingerprint' of a very large number of honey samples. It would be produced by sending every NMR lab coded and measured samples from a wide selection of honey samples from different regions and sources.

This process would reveal the variability between samples, the variability of different testing labs and the variability of different types of measurements against other measurements. The goal would be to create one central and regularly updated reference database against which to test all honey samples.

While the potential benefits would be immense, the challenges associated with creating such a database should not be underestimated. It would require buy-in and cooperation from the honey industry, the testing industry and regulators. It would need to be an international effort. All stakeholders would need to feel confident that all the samples collected and submitted are of unadulterated honey to avoid corrupting the database. There would be commercial ramifications for the labs that currently test against their own proprietorial reference database.

2. Better access to the current reference databases

At the very least, greater confidence in honey testing processes requires a way to identify which reference database is being used when a sample is NMR tested, along with a means to verify the results while maintaining a laboratory's commercial confidentiality.

We explore this scenario further below with our data services and dashboard solution.

The solution

Our work to date has focused on clarifying the scope and depth of the problem. We will continue to consider these problems and incorporate mechanisms to address them into our 'data and dashboard services' solution.

Ongoing activities addressing this include further investigation of NMR processes, further analysis of positions in the community, legal aspects and implications for these positions, and the mapping and modelling of what data needs to be captured and made securely accessible.

Data services

We are building a picture of a coherent, if divided in terms of outlook, community across the honey supply chain, and we believe that data services can play a role in bringing the community together. We see that we can work with the supply chain practitioners individually to develop data-centric services that can be of benefit to them.

Facilitated discussions can then be arranged that extract and interlink services between stakeholders. These services can address existing practices, overcome existing challenges and ultimately offer new business models that save money and create tangible benefits. We see this as a virtuous circle iterating between the social and the technical.

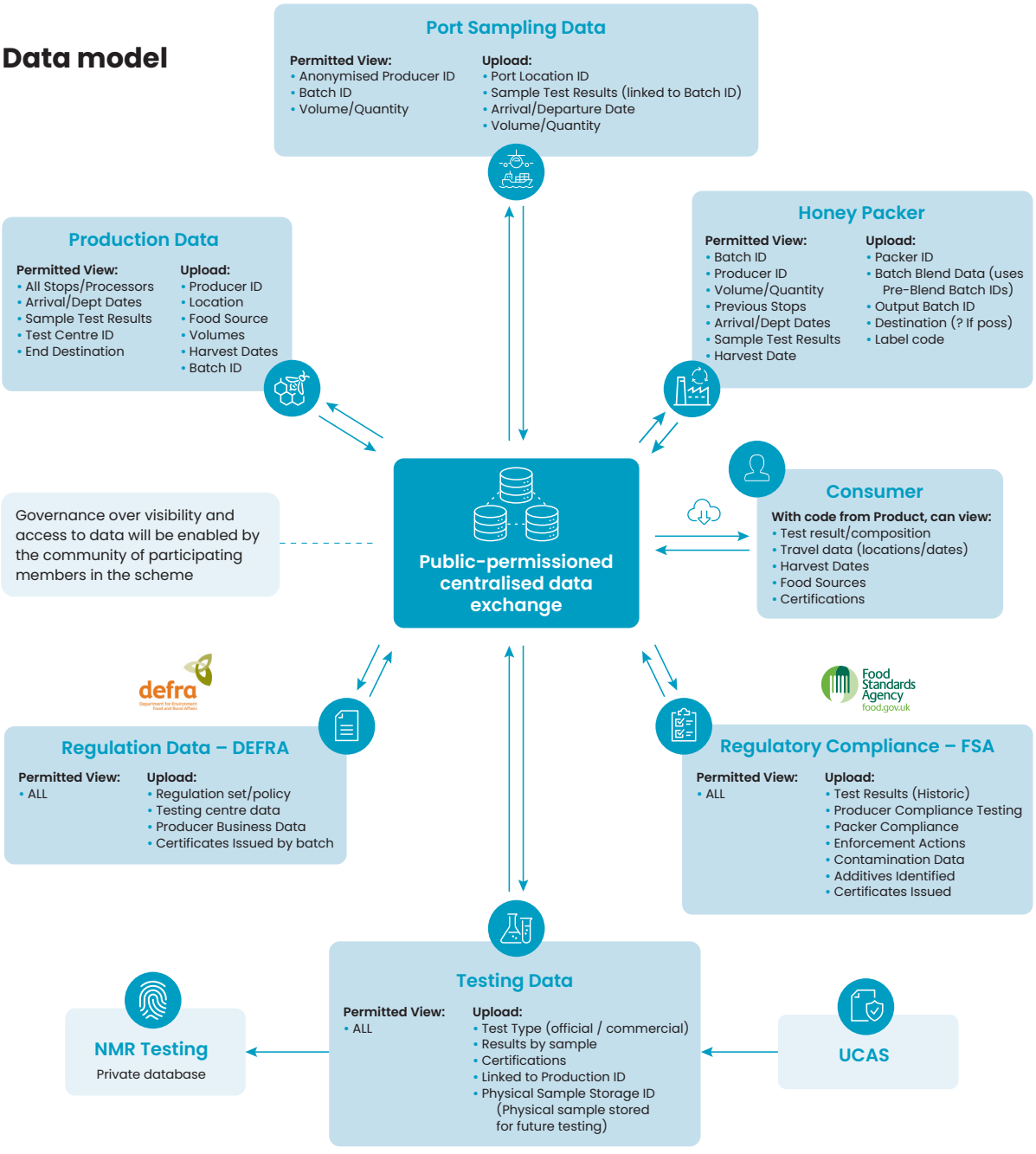
A roadmap for a collaborative approach

The data services framework we propose provides a roadmap for a collaborative approach that establishes a coalition of willing, community of interest and practice around:

- agreement about purpose
- interoperability of systems
- mapping operations between organisations
- governance and oversight among organisations (to include regulations and legislative compliance

The following diagram captures the types of data that can flow between stakeholders in the honey supply chain, with their permission. This information has been distilled from our research and stakeholder interviews.

Data model



Proof of concept

Dashboard services

Contained's BlueRing supply chain coordination system provides a switchboard and a dashboard for users to enable interoperability and visualisation of their data sharing activities. As proof of concept we have focused on developing a solution for the use case of a someone wishing to a submit a sample of honey for testing.

The BlueRing system allows registered users to coordinate supply chains from their perspective by creating order manifests and adding and managing data associated with a batch of goods. We have expanded this to incorporate the case of a sample from this order being sent for testing.

A system for the honey sector

This has involved creating new 'actor types' to prepare the system for the honey sector. Beyond the proof of concept, the next stage is to tailor these to specific roles from the sector and iteratively co-create new interoperability services. These can subsequently be adopted for testing regimes in other sectors.

Work is ongoing on developing these services. The proof of concept enables a request to be made to a test centre, a sample to be submitted and then the resultant Certificate of Analysis can be viewed online together with details of the component tests.

The secure configuration of the system allows the data owners to give access to regulatory bodies and others, if permissioned, and access certain parameters of the test results.

Enabling secure analysis

This allows an independent body to be given access to the test results but also, importantly, the approach in conducting the test and interpretation of the results. In cases where there is a dispute or a confirmation check needed, the test process can be securely analysed and ratified.

The aim is that this platform will enable and support the discourse among the community. This will be facilitated through a trust framework implementation we will assemble from the participants in this research activity who have indicated an interest in taking this further forward. Once the initiative is established, others will be welcome to join.

The BlueRing development team has created processes to enable use cases:

- Key stakeholder roles can be represented: test lab, producer, lab test requester
- Lab test can be requested
- Certificate can be uploaded
- Certificate can be accessed by requester
- Further analysis of use case to add granularity to steps is ongoing, including second step to NMR lab, and interrelationship with FSA as regulator with oversight of NMR databases

Implementing the data sharing governance ecosystem

We are conducting further work on how we will design and implement a sustainable solution that could persist beyond the project. This involves working with a small study group drawn from a coalition of the willing who are interested in exploring how permissioned access to certain test data can help develop a consensus within the community around honey authenticity assurance. Other bodies involved with test data analysis and food product certification may wish to participate in this activity.

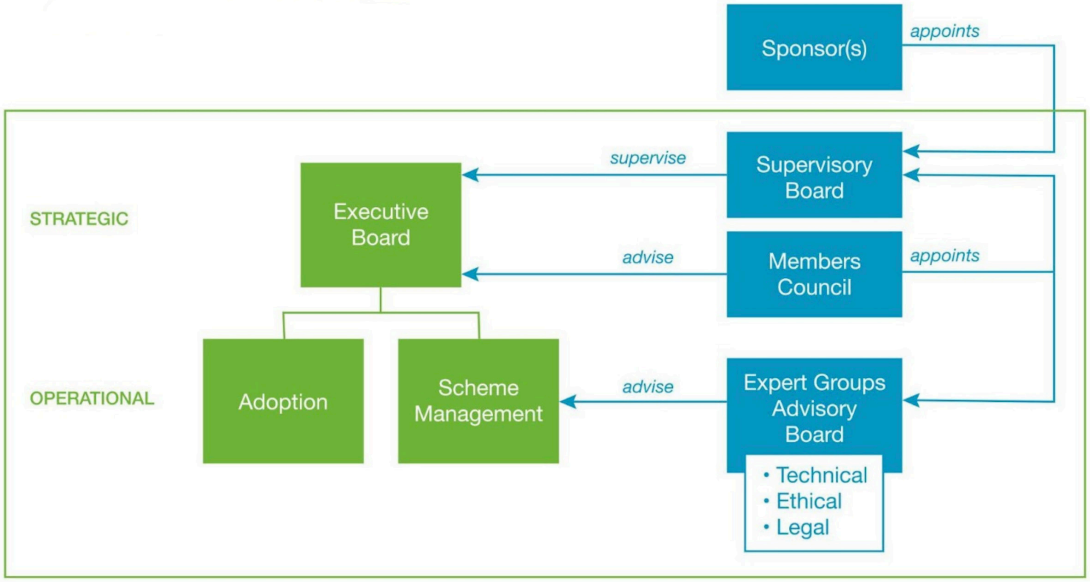
The need is to implement a data trust framework that supports the secure and specific data sharing services needed by this community to address the concerns regarding testing and authenticity in the honey sector. The framework will enable the community to agree on the data sharing services they need. These formal agreements would be available to enable them to share and access data securely in the honey production supply chain.

Any such solution will require a governance system to enable the community to build trust among the data sharing users as well as agree definitions of rules and roles. This approach will enable us to integrate the technical data sharing mechanisms we have developed as a proof of concept with existing services from regulators, trade bodies and other stakeholders.

We envisage a minimalist start to this process with a basic data sharing agreement to further test this approach. However, the goal is to move towards a more ambitious governance model similar to the approaches we have previously explored.

Two-tier governance structure for data exchange collaborations

The two-tier structure[15] is designed to optimise the balance between federated input from the participating stakeholders and an efficient delivery executive that satisfies the agreed needs of the community.



Follow-on activities

This project has taken the form of a research investigation and also the development of a technical proof of concept for the data trust framework approach. Focusing on the delivery of a relatively straightforward transaction – the request and satisfaction of a commercial honey authenticity test – has enabled us to unpick the wider complexities of such a service.

In addition to further development of the data and dashboard services solution, we are producing three academic papers:

- Data sharing club: between the marketplace and the aggregator (submitted)
- Barriers to sharing closed data: a case study (in development)
- Policy implications/opportunities for application of the data trust framework as an entity (data-sharing club) (conference identified for autumn)

The papers will each contribute to the theory and practice and be interdependent eg Business model innovation literature (marketplace); Collaboration and co-creation (communities of practice); Sharing of closed data (aggregation).

Methodology

Research / stakeholder engagement

We have spoken to the individuals listed below at least once in video calls of typically an hour long each. All interviewees have been interested and engaged. We appreciate the input of all our interviewees but emphasise that this work is the authors' alone. Interview involvement does not signify endorsement of the contents by the interviewee or their organisations.

Name	Organisation	Role
Franz Ulberth	European Commission	Head of Unit - Joint Research Centre
Adrian Charlton	Fera Science Ltd.	Principal Scientist
Nigel Payne	Eurofins Scientific	Public Analyst at Public Analyst Scientific Services (PASS)
Michelle McQuillan	Defra	Team Leader of the Food Compositional Standards team
Jay Madden	Minerva Scientific Ltd	Director
Baljit Bamrah	FSA	Head of Data Innovation
Sophie Rollinson	Defra	Senior Scientific Officer
Stephanie Meli	Open Identity Exchange (OIX)	Member Manager
Nick Mothershaw	Open Identity Exchange (OIX)	CEO
Emma Shaw	Open Identity Exchange (OIX)	Operations and Membership Manager
Christian Eib	Intertek	General Manager

Name	Organisation	Role
Diedrich Harms	Intertek	Head of Analytical Operation & Expert Services
Giles Chapman	FSA NFCU	Head of Analytics and Futures
David Pickering	Surrey County Council	Team Manager
Emily James	Oxfordshire County Council	Team Leader, Lead Officer Food Standards
Dale Gibson	Bermondsey Street Bees	Co-founder
Jay Maddon		
Cathal Henigan	Rowse	Purchasing Director
Paul Dobson	Premier Foods	Quality, Safety and Environmental Director
Alison Lord	Tesco	Surveillance and Authenticity Manager
John Roe	Morrisons	Trading Standards and Compliance
Julie Fallows	Duerrs	Technical Director

Literature review and academic research

We have identified around 20 papers related to the challenges and opportunities of sharing and accessing data. While this covers the spectrum of open and closed data, it is all useful for our purposes. In a separate strand we are examining papers related to NMR testing practices. Distilling the literature is enabling us to design an analytic framework that will be used to guide further, formal interviews and analysis of wider findings. Complementing this is our development of the implementation of the trust framework.

References

Note: References still to be expanded and formalised

1 See, Food and Agriculture Organisation of the United Nations (FAOSTAT). https://www.fao.org/faostat/en/#home

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4 Mumford E (2006) The story of socio-technical design: reflections on its successes, failures and potential. Information Systems Journal 16: 4 https://doi.org/10.1111/j.1365-2575.2006.00221.x

5 www.food.gov.uk/research/cutting-edge-regulator/food-data-trust-a-framework-for-information-sharing

6 www.nature.com/articles/s43016-021-00346-1

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8 Temoshok, D., Temoshok, D. and Abruzzi, C., (2018). Developing trust frameworks to support identity federations. US Department of Commerce, National Institute of Standards and Technology. https://csrc.nist.gov/publications/detail/nistir/8149/final

9 Acquier, 2019

10 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:32001L0110

11 CODEX STANDARD FOR HONEY - CODEX STAN 12-1981. Adopted in 1981; revised 1987 and 2001 under the auspices of the Codex Committee on Sugars (CCS). The Codex Alimentarius Commission (CAC) is a Food and Agriculture Organisation (FAO) / World Health Organisation (WHO) sponsored body charged with the development of food standards to protect the health of consumers and ensure fair practice in international trade of food and agricultural products.

12 (Walker et al, 2022)

13 Walker et al (2022). npj Science of Food (2022) 6:11 ; https://doi.org/10.1038/s41538-022-00126-6

14 https://food.blog.gov.uk/2021/03/18/from-beehive-to-jar-honey-authenticity-explained/

15 www.food.gov.uk/research/cutting-edge-regulator/food-data-trust-a-framework-for-information-sharing

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Steve Brewer and project team
Infoculture Ltd
6th May 2022

Project team:
Steve Brewer, project lead (Infoculture and University of Lincoln)
Alex Szymborski (Contained Technologies UK Ltd)
Dr Phil Godsiff (Infoculture and University of Exeter)
Michelle Pauli (Infoculture)
Professor Simon Pearson (University of Lincoln)
Professor Jeremy Frey (University of Southampton)
Dr Kyle Alves (Infoculture and University of Exeter)
Lisa Bamford (Stoats & Weasels)

DRAFT

Contact details

Steve Brewer
Steve Brewer
steve@infoculture-lab.com
Infoculture Ltd

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