Communicating Food Safety, Authenticity and Consumer Choice. Field Experiences

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Abstract: The paper reviews patented and non-patented technologies, methods and solutions in the area of food traceability. It pays special attention to the communication of food safety, authenticity and consumer choice. Twenty eight recent patents are reviewed in the areas of (secure) identification, product freshness indicators, meat traceability, (secure) transport of information along the supply chain, country/region/place of origin, automated authentication, supply chain management systems, consumer interaction systems. In addition, solutions and pilot projects are described in the areas of Halal traceability, traceability of bird's nests, cold chain management, general food traceability and other areas.

Keywords: Consumer information, food traceability, food information management, fraud protection, meat traceability

1. INTRODUCTION

Food traceability has over the last decade become a well-understood topic, both in research and in practice. In Europe food chain traceability was given a special emphasis in Priority 5 of the sixth framework programme (2002-2006) resulting in over 14 different research projects, and a total research budget of over 140 Million € over four years, and involving up to 400 different participants across 30 countries. These projects include Food Trace [1], which set the ground work for electronic traceability, TRACE IP [2], which worked on origin determination and traceability, CHILL-ON [3] which used traceability for communication in the cold chain and finally Bright Animal [4, 5] which identified new ways of optimisation in the feed-animal-food chain.

A good guide to global efforts on larger scale traceability is given in the book "Food traceability around the world" [6]. In many areas, food traceability has become a main stream activity. Large software providers such as IBM and SAP offer food traceability solutions as do specialised providers, such as FoodReg.

In the particular case of meat production and related fields, such as animal husbandry and precision livestock farming, a number of efforts have been undertaken (see [7-10] and references therein) to use traceability in

- Animal tracking
- Feed optimisation
- Managing slaughter
- Managing the butchering process
- Origin determination
- Consumer information

This paper provides a review of first key concepts in section 1.1. Attention will then be directed at key obstacles to the implementation of traceability in Section 1.2. before dealing with the question how knowledge rights are managed in this field. Section 2 covers the basis for communication concerning food traceability. In the subsequent sections 3,4 and 5 relevant patents and non-patented technologies related to food traceability are reviewed. Section 6 summarises the contribution and point to a few key developments for the near and mid-term future.

1.1. Key Ingredients to Food Traceability

Traceability is generally not a complicated thing. Traceability is about *history* and *claims*, about *practices* and *performance*. ISO8402 "Quality management and quality assurance" defines it as follows:

> Traceability is the ability to verify the history, location, or application of an item by means of documented recorded identification.

This differs somewhat from other, newer definitions of traceability – such as the Codex Alimentarius definition [11] in that it makes explicit reference to records. Traceability is about records and record keeping.

Record keeping for the purpose of food traceability (in the following abbreviated as "traceability") is usually separated into two areas: internal traceability and external traceability; see Fig. (**1**). External traceability has also been called "chain traceability" on many occasions. Both areas have seen great activity in patents, trademarks, standards and other inventions; see below. Most commercial providers of software provide internal traceability solutions, while only a few have ventured into providing external traceability and derived purposes.

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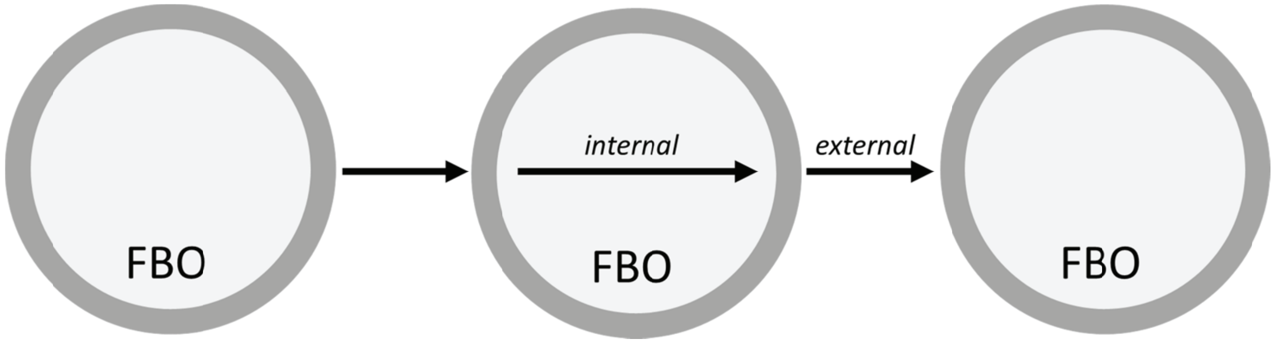

Fig. (1). Definition of *internal* and *external* traceability within and between food business operators (FBOs).

The additional challenge in the case of external traceability is that the exchange of data has to work across company borders. This leads to legal, commercial and psychological challenges which have yet to be overcome. However, it is this separation of the physical product flow from the information flow that provides the most interesting applications for the communication of safety, authenticity and consumer choice.

In order to work cross-boundary, food traceability needs to rely on unequivocal information that is available about a specific food item at least during its useful lifetime (i.e. shelf-life). Two principles need to be followed:

1. The principle of unique identification which requires FBOs to identify uniquely all items that at least are subject to different treatment within the own company
2. The principle of documenting of transformations which requires FBOs to document any transformation that either removes identifiers or creates new identifiers

Identifications systems are abundant; many are not globally unique and therefore violate the first principle. We note that the international standard ISO 15459 "Information technology -- Unique identifiers" operates a register of globally unique identifiers.

After identification, the next key ingredient in traceability is the possibility of exchanging information, preferably in an electronic format. Some closed systems have been developed and patented (see Section 4.2), but currently the most promising developments are

- ISO 12875:2011 "Traceability of finfish products -- Specification on the information to be recorded in captured finfish distribution chains" and ISO 12877:2011 "Traceability of finfish products -- Specification on the information to be recorded in farmed finfish distribution chains ". These standards are based on Trace Fish [12], a widely accepted and used standard in fish. ISO has until recently stayed out of standardising food traceability; its latest efforts in the area of fish may very well lead to other (semantic[1]) standards in the area of food traceability.
- OASIS based work in conjunction with UN/CEFACT, ISO and GS1 as exemplified in the standardisation effort FishBizz [13].
- EPCIS [14], the Electronic Product Code Information System. Created as an infrastructure for communicating RFID[2]-related information, EPCIS is used more and more for food traceability. The Norwegian National Project eSporing [15] uses EPCIS as a backbone to transport data enabling traceability for different food commodities.

ISO12875 and 12877 mostly work on the semantics or the "vocabulary", while FishBizz and EPCIS mostly work on the syntax, i.e. how to get the message across. None of the above approaches has yet turned into a de-facto standard.

The third key ingredient in food traceability is the legal administrative framework. In Europe, the General Food Law [16] governs the general case. Specific regulations for animal identification, food labelling, illegal, unreported and unregistered fishing exist. The United States signed the Food Safety Modernisation Act into law in early 2011. Other countries like Vietnam have sector specific regulations and laws. None of the regulatory systems have so far produced the emergence of standardised systems for external traceability.

1.2. Key Obstacles to Global Traceability

Although many efforts are being made particularly in South East Asia to accommodate European requirements on food traceability, the world of food is hardly traceable yet.

The milestones for the establishment of a national or global traceability system are quite easy to enumerate; see Table **1 [17]**. However, there remain three key challenges:

- Standardisation
- Corporate Privacy
- Smallholder integration

Standardisation

Food production is a truly global business. The 27 countries considered to constitute the European Union, exported food, beverages and tobacco for the value of 76bEUR and imported the same goods for the value of 80bEUR in 2010 [18]. With such volume of business, in order to enable the

[1] Semantic here refers to defining the vocabulary and its meaning. This is opposed to syntactic standards that define the way "words" from the vocabulary can be combined.

[2] Radio-frequency identifier

Table 1. Milestones for the Establishment of a Global Traceability System; Adapted from [17]

M1	Database of food production locations	Draws on existing schemes for farms and food premises Integrated with existing geospatial information
M2	Product type database	Based on UN Central Product Classification (CPC) Introduction in all relevant government processes
M3	Land use database	The link between premises and product types, supporting geo-traceability
M4	A world-wide unique numbering system	Apt for identifying: Product types, Batches, Trade units, Logistic units, Business partners, Business locations
M5	A traceability framework	Names uniquely all relevant parameters for a food stuff Decides on what data to store at what point Defines an exchange protocol
M6	Law on data ownership and confidentiality	Protect individuals and business Rules of access by governments
M7	Regulation to define 'obligatory data'	Data to be supplied to government *via* food information system
M8	Regulation on mandatory traceability	Transition timescale Small producers exempt if trading partners enter data
M9	Establish single, independent agency for food standards and safety	To govern the traceability scheme and ensure its use
M10	Integrate information for all official sanitary and phyto-sanitary inspections	To reduce unnecessary burden on FBOs and increase efficiency of the verification process
M11	Food information system deployed in modular architecture	Allow interconnectivity with variety of information systems
M12	Food information system connected to food businesses *via* non-government food information & traceability systems	Allow for privately run traceability systems that are capable of interacting with the system holding normative (and reduced) data
M13	Use of international standards for information interchange	Interconnect national and international systems
M14	Food information system with key capabilities	Store traceability data and referential databases Manage good practice compliance in addition to traceability
M15	Governments should directly fund only the core components of the traceability system roll-out	Governments can provide financial support to the adoption and use of systems used by food business operators, but the bulk of the cost should be borne by private industry
M16	Special support plan for micro-enterprises	Governments should recognise the special situation of microenterprises in the food chain and help them with the introduction of traceability

traceability of food items, standards are required for identification, product ontologies, exchange protocols and data capture/data query.

None of the aforementioned standards have found implementation in a satisfactory way. Table **2** summarises some relevant areas where standardisation is important and cites good candidates for world-wide standards.

As it stands, a food business operator wishing to establish a chain traceability system does not have a standard toolbox to choose from that would satisfy his providers', his clients' and the food safety authorities' requirements.

Corporate Privacy

In addition, the food industry is a very secretive industry. Open information access is not the rule, but rather the exception. Small margins, high volatility of demand and supply, vulnerability to government action all lead to the industry's reservations when it comes to revealing any data that is not required by a law or a regulation.

A few producers have discovered that information can be sold as an additional commodity. In a recent traceability implementation for a leading palm oil producer, the author was able to convince the company to reveal details of their sustainable production to final clients. The auditability of the information provided convinced sensitive clients to contract the producer as a bio-diesel supplier at an excellent price. However, such examples are yet scarce.

The fear of revealing data is not linked to large scale producers using "scary" ingredients like palm oil. When the author implemented a pomelo traceability system in Thailand, a small-scale fruit picker owning a single truck was very reluctant to join the pilot. As a reason she cited that she only declares half of her pickings to the tax authority. She was afraid that recording all her picking in a traceability sys-

Table 2. Standardisation in relevant areas of Traceability

Area of Standardisation	Standards	Main Challenges
Identification		
	GS1 set of identifiers	Heavily used in distribution and retail, but not very extended in primary production Membership organisation that requires individual operators to sign up National identification schemes usually not based on GS1 identifiers
Product ontologies		
	ISO 12875 and 12877	Only on fish; no similar ontologies available for other foods
Exchange protocols		
	EPCIS	Not apt for food traceability without modifications Adoption by large players mostly/only
Data capture		
	Code 128 encoded SSCC or GTIN+	Excellent adoption, but limited information transport
	RFID	Different frequencies in different countries; still very high costs that prohibit item identification

tem would enable the Ministry of Finance to tax her for the full amount.

This exemplifies that an acceptable traceability system needs to make arrangements both on the data collected as well as to rights to access such data.

Smallholders

The vast majority of FBOs are small to smallest scale operations. Many of those in agriculture are only semi-professional, i.e. farming only constitutes part of their income. In Palestine, olive oil production is almost entirely in the hand of smallholder producers [19]. In Vietnam, 90% of all shrimp and aquaculture fish production is in the hands of smallholders [20]. Even in Europe, according to EUROSTAT on average 95% of all broiler holdings in Denmark, Germany, Greece, Italy, Austria, Portugal and the United Kingdom hold less than 100 broilers.

Smallholders are characterised by lack of time and resources to implement complicated systems. In some areas, record keeping is not yet part of the general training and business culture. Automated identification and data capture often requires electricity which may not be readily available.

Smallholders have particular requirements that not usually covered by advanced electronic systems or standards. Membership requirements e.g. for identification schemes are a serious obstacle to their adoption by smallholders. Most of such association would probably not even be capable of managing the vast number of small-scale FBOs.

FoodReg, a specialist provider of food traceability solutions, has designed a mixed paper-electronic traceability system that relies on pre-printed labels and forms. Processors then convert the paper information into electronic information. The system has been piloted successfully in Indonesia in 2011 [21].

2. THE BASIS FOR COMMUNICATION

Products that are produced under certain conditions or following certain processes, but that are physically no different from other products (such as sustainably produced fruit vs. non-sustainably produced) acquire their product differentiation mainly in the information space, i.e. when information is made available in addition to the product. New products emerge such as products with attached sustainability information or products without any guarantees.

Traceability and especially chain traceability can achieve that goal in different ways, but it requires a consistent data interchange model from which to start.

- A protocol as the foundation of a data interchange model needs to describe
- A traceability unit description (i.e. what information is stored in what format)
- A format for lookup and querying

Typically the description of a traceability unit is divided into master or static data, which describes such data that supposedly is “inherent” in the element and “usage” data which describes actions performed on or with the element.

One of the hugely discussed items in the traceability world is how to setup a global traceability system. There are two basic models, the “hub” model and the “chain” model; see Figs. (**2** & **3**) [22].

In the hub model, data is copied to a “hub” and queries are then resolved solely on the hub. This model is similar to that of a centralised database.

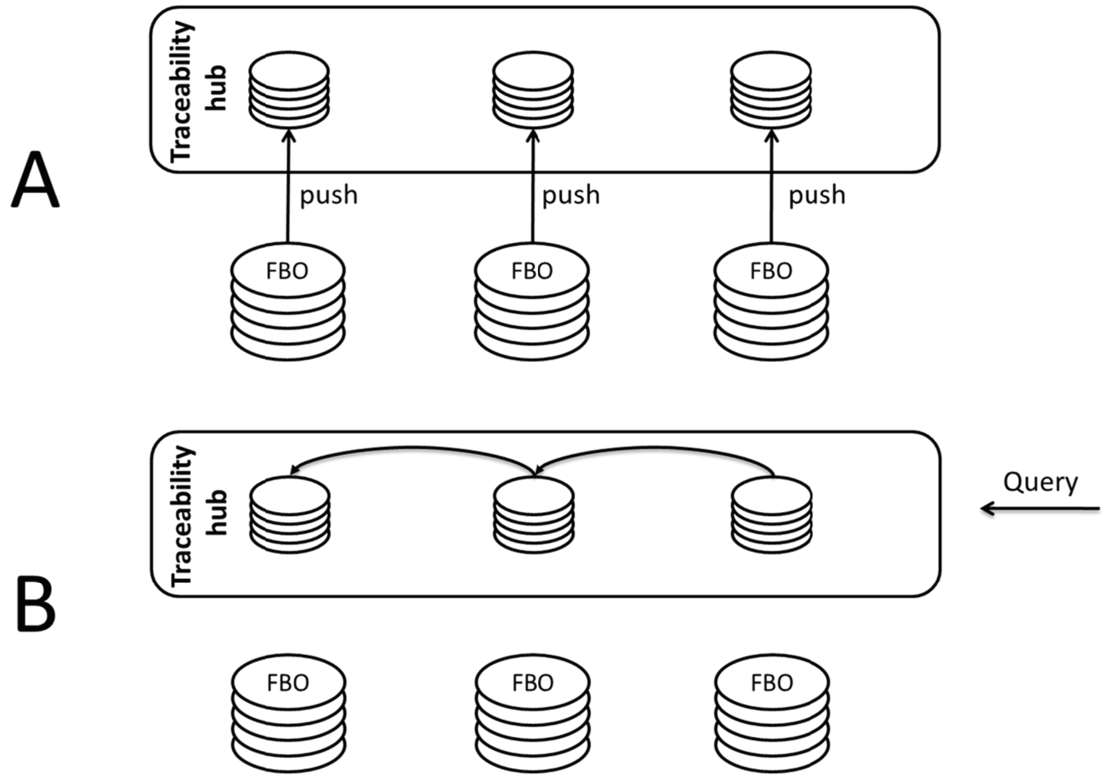

Fig. (2). The "hub" model of traceability [22].

In the "chain" model, data is left at its origin and queries are resolved by hopping from one node to another (a bit like DNS, the service that translates "web addresses", i.e. URLs, into IPs, i.e. numbers required for the data transport).

Mixed models are also under discussion, such as the "data specific" model, where some data is kept at the hub and some data is kept at its origin. This allows for a resilient resolution of some queries, while other queries will have to gather information directly from the data origins.

The last model effectively addresses the rather complicated question of privacy in food traceability by splitting information into two or three areas:

(a) company restricted information that is shared only based on private contracts between the FBO and its supply chain partners.

(b) regulatory information that is provided to food authorities in order to enable them to deal effectively with incidences, statistics requirements and other issues. The information required by the authority is legally required. It may be company specific, but can also be aggregated data only.

(c) compliance related information that operators of a standard compliance scheme might require to have access to. This is data that is required by standard scheme operators and governed by a private contract between the standard operator and the FBO.

Although this model clearly restricts the access to data and removes the fear of a privacy breach, the question still remains: who operates the traceability system? Internationally, five approaches have been observed:

1) The top down model, as seen in efforts in Malaysia, Indonesia, Vietnam, Thailand, China and other countries, where the government basically provides a system and expects FBOs to use it

2) The bottom up approach, followed by Norway where industry associations run a traceability system and ask their members to use them.

3) Partial models like the US, where data is requested and then stored on a per-case basis. This does not allow for general chain traceability, but chain-connects particular batches in case of incidences.

4) Standard operators like RSPO or ACC have mandated the use of a chain traceability system (UTZ Certified and TraceRegister, respectively).

5) Private companies, offering their services based on a legally enforceable contract with privacy guarantees.

None of the above approaches have really convinced the general food industry world-wide. In addition, the absence of an accepted data exchange format isolates the different systems making a world-wide approach additionally complicated.

The general loser is of course the consumer. Less information available means less (informed) choice, more insecurity (e.g. in the case of allergies) and more fraud. But it also means great inefficiencies (data retyping with consequent errors), errors in sourcing, more stock and less shelf life and a general loss of market access.

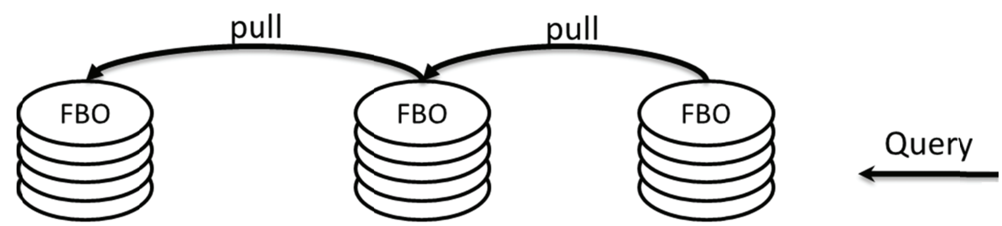

Fig. (3). The "chain" or "decentralised" model.

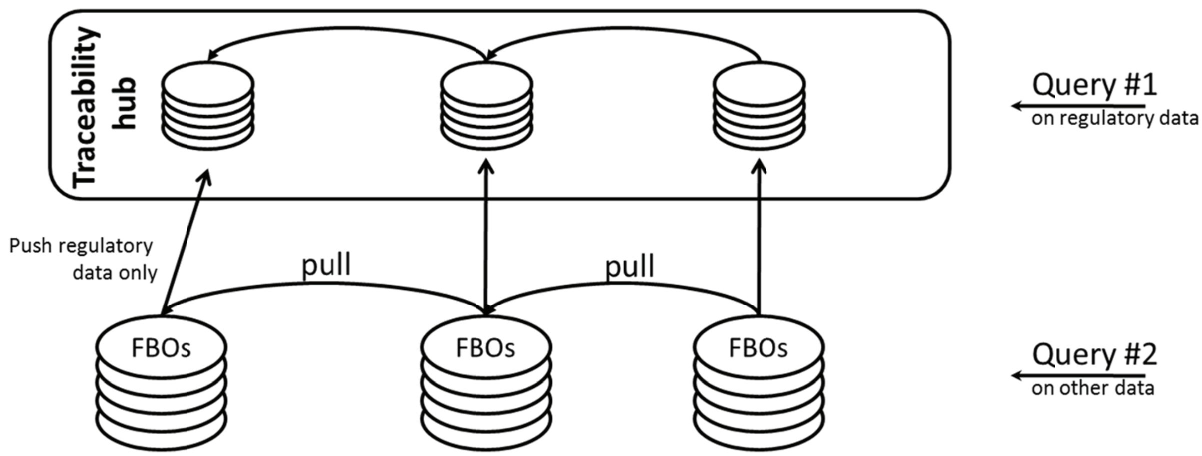

Fig. (4). The "data specific" model of food traceability [22].

3. COMMUNICATING SAFETY

While food traceability was around the implementation of the European General Food Law trumpeted mainly as a tool for food safety and risk management, the food industry took scarce notice. This can perhaps subsumed under what the English author Douglas Adams called "Somebody Else's Problem" [23] – a largely invisible thing.

But not only the food industry has not taken the subject quite seriously. This author has for example criticised the European cattle passport [24] for its lack of standardisation that would allow traceability across borders. Given that the cattle passport was one of the main tools to prevent the spread of bovine spongiform encephalopathy (BSE), a surprising fact.

Fortunately, a more positive approach was found starting with the advent of easy to use time temperature indicators.

3.1. Product Freshness and the Cold Chain

One of the very interesting applications of food traceability is the cold chain. Products requiring refrigeration are susceptible to temperatures above certain limits and their freshness and effective shelf life depend greatly on the temperatures they have been subjected during their lifetime. In order to model shelf-life, the EU project CHILL-ON [3] employed chain traceability to record the time-temperature curve of different food stuffs. While the detailed recording of such data is important for research, picking based on estimated remaining shelf-life and perhaps stocking, consumers require a simpler interface.

Patent WO/1999/039197 "SUBSTRATE FOR PACKAGING PERISHABLE GOODS OR FOR APPLICATION ONTO SAME AND METHOD FOR DETERMINING THE QUALITY OF SAID GOODS" [25] that gave rise to the product OnVu [26] commercialised now by Bayer provides the basis for an easy to use time temperature indicator (TTI). TTIs like OnVu record the time-temperature curve in a way that results in colouration or discolouration of the label. By comparing the colour of the label or parts of the label to a reference colour, usually printed on the same label, not only consumers but also supply chain partners can discard products that have been exposed to too high temperatures.

Patent WO/1999/039197 was special insofar as it included a photochemical activation process before which the label was inert and did not have to be stored in very cold environments. One of the main disadvantages of this and other TTIs is that they need to be calibrated against the food type.

Similar efforts have been reported using traffic light schemes [27] or integration into barcodes to automatically prevent sales when a product has expired (see e.g. [28] or [29]).

3.2. Specifics of Meat Traceability

Figure **5** shows a typical meat production chain with the three main steps of primary production (breeding, nursing and growing), processing (slaughtering and butchering) and finally distribution and retail.

Meat being the sensitive material that it is, especially in its raw form, meat traceability has received quite a bit of attention from inventors.

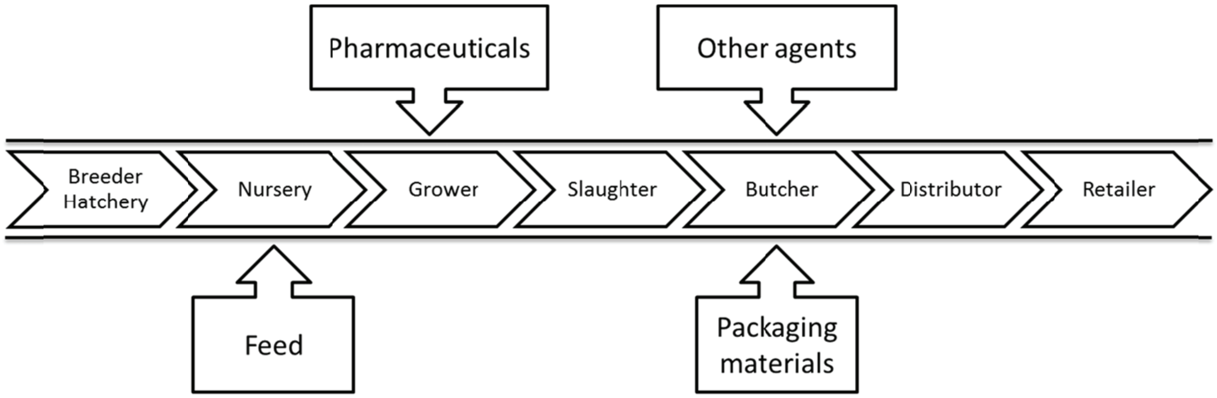

Fig. (5). A typcial meat chain with key ingredients.

In early stages, animal tracking is of great importance. US patent 7965188 "Radio Frequency Animal Tracking System" [30] describes a radio-frequency identification (RFID) system for animal tracking. This patent describes an improved RFID system, methods of using the system and of making the system. The patent addresses important issues, such as interference between tags. Such animal tracking systems, or electronic identification (EID) systems are key for a variety of purposes:

- Unique identification of individual animals for the purpose of animal health and food safety as part of legal requirements (especially larger animals, such as cattle, but increasingly also smaller animals like sheep and goats)
- Unique identification of individual animals for the purpose of demonstrating ownership (e.g. dogs or racing horses)
- Unique identification of carcases at the beginning of the slaughterhouse process
- Import/export or inter-state movements of animals
- Recording of health inspections

Such uses of data are also addressed partially in US patents 8037846 "Method and system for tracking and managing animals and/or food products"[31] and [32]. This patent uses the above mentioned "data specific" model (see Fig. (**4**)) and the figure of a data trustee to store and distribute data. The patent covers a full animal identification system with relevant data and their collection and management method, as a potential replacement for the National Animal Identification System (NAIS), the US equivalent of the European TRACES system or the Australian NLIS. Some countries like Malaysia require electronic ear tags for interstate movements.

US patent 8019662 "Livestock Inventory Tracking System and Methods "[33] addresses a similar area, but puts more emphasis on the inventory management and auditing. Counting animals is a very labour-intensive area and the patent publicises a system a method to automate this. The patent actually covers inventory management up to the final sale by using unique animal identification *via* RFID and tracking that through the supply chain. Similarly, US patent 8019633 "Livestock Management Systems and Methods " [34] covers livestock management from conception to consumption through the use of an Internet platform. This patent describes a system and method to collect all relevant data throughout the lifecycle of cattle (and potentially other livestock). It includes provisions for marketing related information such as certification (e.g. for beef marketing programs), but also for breeding, such as genetics improvement programs, environmental monitoring, risk management, e-commerce and a consumer value system.

A different area is addressed by patent EP1939811A1 "Method and system for associating source information for a source unit with a product unit converted therefrom " [35] which describes a computer system and imaging sensors that can be used to relate a carcass to meat cuts. Automation of this process is very important, since modern slaughterhouses have very high throughput. Whereas some slaughterhouses use RFIDs on carcass hooks and innards trays in conjunction with RFID-enabled "Christmas trees" for keeping the meat cuts together, this invention uses information inherent in the object (e.g. visual information). It relates this information to newly created parts of the same object by analysing image information and detecting equipment such as knifes. It then identifies all resulting objects (e.g. meat cuts) and relates them back to the original object (e.g. the carcass). The patent applicant is a Cryovac, but commercialisation has not been observed yet.

A similar question is addressed by patent WO2005052704 [36]. This patent describes a combined food processing and information handling system that traces the origin of a food items and links them to subitems in a way that the link to the original item is always preserved. Data collected on the originating items may include the original animal, farm or country of origin. Subitems are identified *via* tags and information about them (size, weight, shape, colour, water content etc) is linked to that identifier. This can be done either automatically or manually. The assignee of the patent is the large Icelandic firm Marel hf.

A slightly different area is addressed by very recent US patent 8079897 [37] assigned to Cargill. This patent describes a system and methods to track "interventions" made on carcasses with the purpose of microbial reduction. This can be e.g. washing of the carcass or steam pasteurisation prior to chilling. The system described in the patent records certain parameters of operating equipment and relates them to the carcass. If a particular carcass is later on rejected, a control system can detect whether a particular intervention was operating within a pre-determined range of processing parameters.

This is a clear example of merging food safety measurements with the product flow. By electronically recording such information in relation to particular product (sub)batches or individual units, not only the potential size of a recall/withdrawal (or a hold, if lucky) can be reduced substantially, but also the malfunctioning of equipment can be detected in an automated fashion and whenever that affects the product in any way.

4. COMMUNICATING AUTHENTICITY

One of the services built on top of traceability is to ensure – or at least provide evidence for – the authenticity of a food item. In many cases, consumers or even supply chain partners know little about the authenticity of a food they purchase. In some cases, holograms have been used to indicate authenticity – this obviates the fact that holograms are easily falsified.

In other cases sample-based verification methods have been used, such as chemical markers in alcoholic beverages [38]. Although such methods can be superior in the certainty of the results, they usually are too complicated to be applied other than on a sample basis.

Electronic traceability on the other hand has the potential to check the product flow on a continuous basis and detect anomalies that point to possible fraud.

In some cases, electronic traceability is the only way of determining whether authentic or fraudulent product is being circulated: for products such as sustainable palm oil there is no physical difference between the product produced according to sustainable standards such as the Round Table for Sustainable Palm Oil (RSPO [39]) and non-sustainably produced oil. The same is true for Illegal, Unreported and Unregistered (IUU) fishing. The product is not different between legally and illegally landed fish and only (electronic) traceability can provide assurance that a particular boat has the right to land the fish.

4.1. Identification

One of the critical elements in fraud prevention is of course secure identification. In order to access information about a food product and judge its authenticity, some form of identification is usually required.

One can differentiate the following types of identification

1) One that uses inherent product features for identification (such as surface structure, DNA or other features)
2) One that employs codes to be looked up elsewhere
3) One that codes information into an identifier to be used *ad-hoc* or used in a combination of look-up codes and locally stored information

A simple example for a mixed identification/information encoding system is US patent 8082191 "Egg code management method and egg search code management system" [40]. The system consists first of all of a two-part identification code, where the parts are called the egg collection data code and the egg search code. Both are printed directly on the egg to allow identification of small batches or individual eggs. The search code can be related to a particular set of history information. Absence of such information would allow for doubts in the authenticity of the eggs.

However, the management of such detailed coding systems is not always easy when items cannot be identified easily.

US patent 8090631 "Managing a material batch" [41] tries to address the problems related with batch identification. This is related to the complications that the food industry experiences with managing inventory based on batches. Failure to do so, however, opens the doors for the insertion of fraudulent material from other sources, since control is lost about the existing quantities in the supply chain. The patent tries to keep a balance between the cost of operation and the need for traceability by assigning "documentary" batch numbers, i.e. numbers which point to additional information without the warehouses having to be organised in batches.

Patent WO2011095562A2 "Package provided with a traceability and originality verification code, its production method and method for tracing it" describes a traceability and originality verification code printed on packaging material [42] which is "tamper-proof". This invention tries to deal with the fact that packaging material can be fraudulently reused. This and other similar methods require printing on the production line which makes it suitable only for high value consumer goods. Most foods would not qualify.

An interesting technology that has been used in this context is laser surface authentication as defined in WO2006016114 "AUTHENTICITY VERIFICATION OF ARTICLES USING A DATABASES" [43]. LSA™ analyses the microstructure of a surface and calculates an identifier from it. This method provides unique identifiers that are intrinsically linked to the analysed surface. If that surface e.g. belongs to packaging material, LSA™ provides individual package identification without the need for an identifier. The general idea of optically identifying materials was further developed in US patent 2011/0135160A1 "Method and device for reading a physical characteristic on an object "[44]. Such methods could potentially when applied directly to the food item eliminate the need for external ids that need to be attached to the product. This generally used method in the stricter sense only provides "packaging material traceability" because the identifier is not attached to the item, but rather to the material wrapped around it.

In animal or animal-based products DNA can be used as an inherent and unalterable "natural" identifier. Patent WO 03/087765 "SYSTEM FOR TRACING ANIMAL PRODUCTS"[45] describes a system to uniquely and cost-effectively identify animals based on their DNA. The use of an inherent identifier resolves the issues of relating carcasses to animals and meat cuts to carcasses. The patent is based on parentage and therefore does not require samples from all animals to be taken or kept, but rather only of the breeders. A similar system is used for tilapia production in Malaysia by the company Trapia with the Genopass™ system [46]. The system has been reviewed by the author [47]. Both systems are similar in that they use parentage as a basis for identification. In some circumstances this works fine (such as meat cuts or whole fish), but these methods still fail when mixing occurs, e.g. as in (fish) burgers. Another issue is that such systems require a central location for the storage of genetic samples, usually a laboratory. Genetic checking is neither quick nor cheap.

US patent US20110092379A1 "Genotyping method and means thereof for use in traceability schemes" tries to address the issue of having to store samples centrally [48]. It describes methods to obtain samples, genotype them, prepare them and compare them to single nucleotide polymorphism (SNP) profiles. The profiling removes the need to store samples and the need to extract DNA from all animals.

4.2. Acquisition and Transport of Information and Access to it

Oftentimes it is not only the food item itself that is of interest, but the conditions it has experienced, the processes it has been subjected to and the requirements to be addressed. This is the case for religious slaughter like Halal or Kosher [49], but also for the aforementioned sustainable production of palm oil.

For these items the transport of information is essential. Muslim consumers for example need to know for certain that a prepared meal does not violate their dietary laws. Certification is only a partial solution, since it usually is very easy to falsify. In the particular case of Halal, the existence of a large number of dubious certification schemes makes that particularly difficult. Traceability can again supply very valuable assurance in these matters; see e.g. [50] or [51].

Some of the issues related to the transport of information have been highlighted above. Here the author would like to concentrate on (a) the authenticity of codes and (b) the vulnerability of traceability systems with respect to "lost" steps.

US patent US8060758B2 "Item tracing with supply chain secrecy using RFID tags and an identity-based encryption scheme " [52] assigned to SAP AG describes a method to use an RFID with encrypted information where the encryption key is the batch number. (The patent describes additional methods.) The RFID chip can then contain more information than just an ID; it can for example contain recall information. Batch numbers can be stored at trusted third parties to enable the extraction of information when required. At each step of the supply chain, each supply chain partner can add information and re-encrypt the encrypted item. For full disclosure of the information therefore, all private encryption keys (batch numbers or other keys) will be needed. Recall information can be decrypted with just the knowledge of one key. Therefore a producer does not require the assistance of supply chain partners downstream.

Patent US20110204137A1 "Method and device for traceability marking and packaging line provided with traceability marking device" [53] describes a somewhat different approach to the same problem by using non-visible information on packaging material. The patent is assigned to Tetra Laval Holdings & Finance S.A. Here information is stored magnetically on the packaging material. Such information can only be an identifier, but can also contain supply chain information. The patent actually describes a device to visualise such information. Storing information in a non-visible form obviously increases the barrier for fraud. This is probably not enough for high value items, but surely enough for simpler products.

The international patent WO2011092727A1 "Traceability system for buffalo mozzarella, from source to consumption" [54] describes a sector-specific chain traceability system for buffalo mozzarella from source to consumption (as one embodiment). The system employs RFID and near field communication (NFC). Consumers can access the system to verify claims. Active RFID enabled data loggers record milk temperatures, milking times and milk tank movement (when removed from the farm). The milk is followed through transport to the cheese processor where again active RFID tags are used for data capture. The final product is then carried by a mozzarella "carrier" using active tags to the point of sale which can access an internet service to verify the cheese. The system is largely automated and uses MAC addresses to route information to the proper dairy web server. In this way the feedback loop between producer and point of sales is created.

Consumers can connect via different means and retrieve information items like quality reports etc.

The patent forms the basis of Value Go® [55] a trademark by the Italian IT firm Penelope SpA. However, this is another example for a closed system like many others. No attempt is made at generating or using internationally accepted standards for interoperability in food traceability.

Mobile devices are increasingly important in the supervision of the food chain. The Chinese patent CN201867837 "Mobile internet supervision device for source tracing of food" [56] assigned to the Shenzhen Academy of Inspection and Quarantine describes a chain traceability system together with a mobile access device based again on RFID.

However, a new system has recently emerged that may prove a more interesting answer to the question of secure transport of information. The author has long argued that the best way is to separate the information stream from the product stream. However, it has to be acknowledged that this approach has its own shortcomings:

(a) an attack on the database may compromise the information flow. Although for standard food items this may not be economically feasible, for high value items it certainly is

(b) the separation of the information flow from the product flow requires access to the original data recording whenever the product is subjected to a check. This requires that the information resource is available to anyone with a justified interest in the item. Providing such access is not an easy task.

The companies Crypto Codex [57] and 6DCP [58] address this problem [59]. Their patent-pending technology uses non-mathematical encryption which is claimed to be unbreakable. The encryption and compression technology can be used to transport about 50-200 non-encrypted charac-

Fig. (6). Safe, databaseless information: users scan e.g. a datamatrix code placed on a food item. The code has encrypted information which is then sent to an internet server to decrypt. If no internet is available, the information can be requested *via* MMS. Reproduced with permission from CryptoCodex [57] and 6DCP [58].

ters in a data carrier, such as a barcode symbol barcode (or any other data carrier, such as a matrix code symbol) that is readable by mobile phones. In areas where Internet connection is not available to phone users, a two-dimensional barcode reader application can be installed on the phone that then uses a secure SMS gateway to communicate with the server. This "Micro Database Less Encapsulation" allows for the secure transport of information along the supply chain. Traceability through the supply chain is made possible by tagging each individual, box and/or pallet with a unique encrypted identifier. With each change of ownership, supply chain partners accept the packages by scanning the uniquely encrypted barcodes with their existing 2D barcode scanners or a camera phone (with any free 2D barcode application). Each scanning event captures the exact time, date, and geolocation of the pallet/box/unit when it is scanned. Other critical information can be captured, depending on the needs of the client. Track and trace to the end user is achieved when consumers verify the authenticity of the item with their camera phone. The data captured from each scanning event is stored in a unique format referred to as a Cryptographic Key Log File; see Fig. (**6**). These log files are exportable to any format (i.e. XML) and compatible with database or reporting systems.

One of the other interesting applications of this technology that the author sees is securing logistics. A single 2D barcode can potentially contain the full content list of a pallet or of a container when the barcode is somewhat larger. Since the list of items is encrypted, the contents of the logistics unit can easily be checked against replacement even without access to the server of the originator of the shipment. Using cheap and ubiquitous mobile phones could enable border control personnel to check for anomalies.

In order to address the possibility of copying the identifier, the companies are developing a non-reproducable label as shown in Fig. (7). The upper layer is a standard QR code used for traceability purposes. The barcode can contain consumer incentives, such as coupons, to promote the scanning of the codes and thereby increasing the strength of the system. When the consumer peels off layer 1, a photosensitive layer 2 appears with a data matrix barcode. This barcode is used for authentication (and can again include consumer incentives). Layer 2 is in addition photosensitive, changing rapidly its colour to demonstrate authenticity. Layer 2 can also be used as a time temperature indicator.

The combination of a digital code with the analogue colouring yields a strong claim. The label is targeted to cost little more than a standard label, therefore it should be applicable to standard food items, especially those with high fraud rates.

4.3. Place of Origin

In some cases, full chain traceability is not required, because the only required data element is the country or region of origin. This is necessary e.g. for regionally restricted products (like Champagne, Parma ham etc), but is also required often in international trade ("Made in…").

For such purposes, a detailed chain traceability system may prove to be too expensive. The EU project TRACE IP [2] was dedicated to finding analytic methods – in addition to product flow traceability – that could pinpoint different

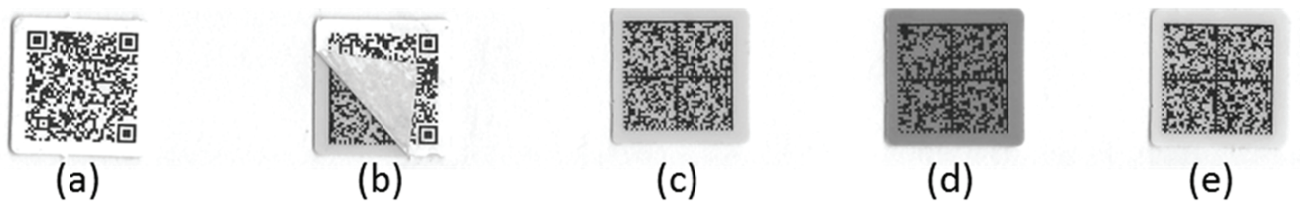

Fig. (7). Non-reproducable label: (**a**) layer 1 holding a QR Code for traceability, (**b**) layer 2 holding a data matrix code for authentication. (**c**)-(**d**) Layer 2 is photosensitive and changes colour rapidly (within 7 seconds). (**d**) In the end, layer 2 turns white and never changes colour again. Reproduced with permission by 6DCP and CryptoCodex.

food products on a map. A variety of techniques were used. As one result, the project came up with interactive food specification maps (see e.g. [60]) that would allow a laboratory to check whether certain analytical results are compatible with the region/country the food item is supposed to come from.

US Patent 2012/0066098 [61] and its equivalent EP2428907A1 describe a method for liquid foods of different origins which addresses the important problem of determining what batches are in a tank. The method described in the patent relates to calculating at each point in time the precise composition of batches in the liquid mix and secondly the relation to specific sites of origin where the liquid batches were produced. The inventors work for a milk producer and processor in Southern Sweden.

In the case where liquid sustainable palm oil products need to be separated from product from non-sustainable sources, the author has designed a traceability system together with the firm Yakin IT [62] that allows for a full mapping of the palm based biodiesel supply chain [63]; see Fig. (**8**). In a further development, a revised version of the system is capable of managing several sustainable palm biodiesel standards in parallel and can assign quantities to standards *post-hoc*, allowing the producer to have certain flexibility with the allowances that each standard provides. Currently two standards are relevant for palm-based biodiesel: RSPO [39] on sustainable palm oil production with an emphasis on primary production and ISCC [64] with an emphasis on biofuels and carbon savings with respect to fossil fuels. Other emerging standards include 2BSvs [65] and RSB [66]. The above described system provides purchasers of palm oil with detailed information regarding the origin and the processes that the biodiesel of a particular shipment has been subjected to. Where mixing occurs this is taken into account and reported consequently.

For agricultural produce, the Harvestmark system by Yottamark [67] has experienced a certain amount of adoption. Important for these systems are two US patents, US20110215148A1 "Attributing Harvest Information with Unique Identifiers" [68] and US20120059660A1 "Lot identification codes for packaging" [69]. Yottamark also holds US patents US7614546, US7766240, US7770783, US7823768 and US7909239. Patent US20120059660A1 describes a method whereby supply chain partners including consumers can access lot-specific information (as e.g. the origin of their produce) with a hand-held device such as a smartphone. The patent also describes the nature of a lotcode used for that purpose. US patent 20110215148A1 describes systems and methods to trace back units of produce to the fields they were grown.

4.4. Automated Authentication at the Point of Sale

The critical link in the authenticity chain clearly are consumers: if the consumer doesn't care whether a product is authentic or not, firms will find it difficult to eradicate either fake or grey market products. However, in certain situations a consumer would indeed like to purchase authentic products, but they have no means to make sure that they are doing so. Systems with registration numbers have been in place for many years in consumer electronics, but the adoption rate is unclear. In consumable goods, such as food, such systems have not been used in the past.

Patent US20120054049A1 "Tracking chain-of-commerce data through point-of-sale transactions" [70] describes methods and systems to include consumers in a "chain of commerce" mainly to open a communication channel for offers, but also for recalls.

The Spanish patent "Dispositivo antifraude y antipiratería para productos comerciales " (roughly translated as "Anti-fraud and anti-piracy device for commercial products") [71] goes somewhat further in trying to ensure the authenticity of an item. The system uses a combination of a authenticity traceability system called Verilabel [72] together with an apparatus that connected to point-of-sales (PoS) systems automatically checks the authenticity of an item; see Fig. (**9**). There is no need to replace or even modify current PoS systems as the apparatus is simply plugged between the barcode reader and the PoS system. This enables a mass checking of high-value consumer products, including food.

Systems using traceability up to the point of sales to authenticate products are relatively new. While the basic blocks are in place, innovations such as these take time in materialising on the ground. The rather conservative food industry with its limited budget for IT innovation will take time to adopt measure that in other industries are already well accepted.

5. COMMUNICATING CONSUMER CHOICE

Consumers have an increasing amount of choice with respect to the food they buy. They can choose to buy food online or in physical stores, where they usually find more than one brand per product category. For some categories they can decide to purchase organic, sustainable, without gluten, kosher, Halal or additive/preservative free. However, those that require or wish to adhere to certain standards of

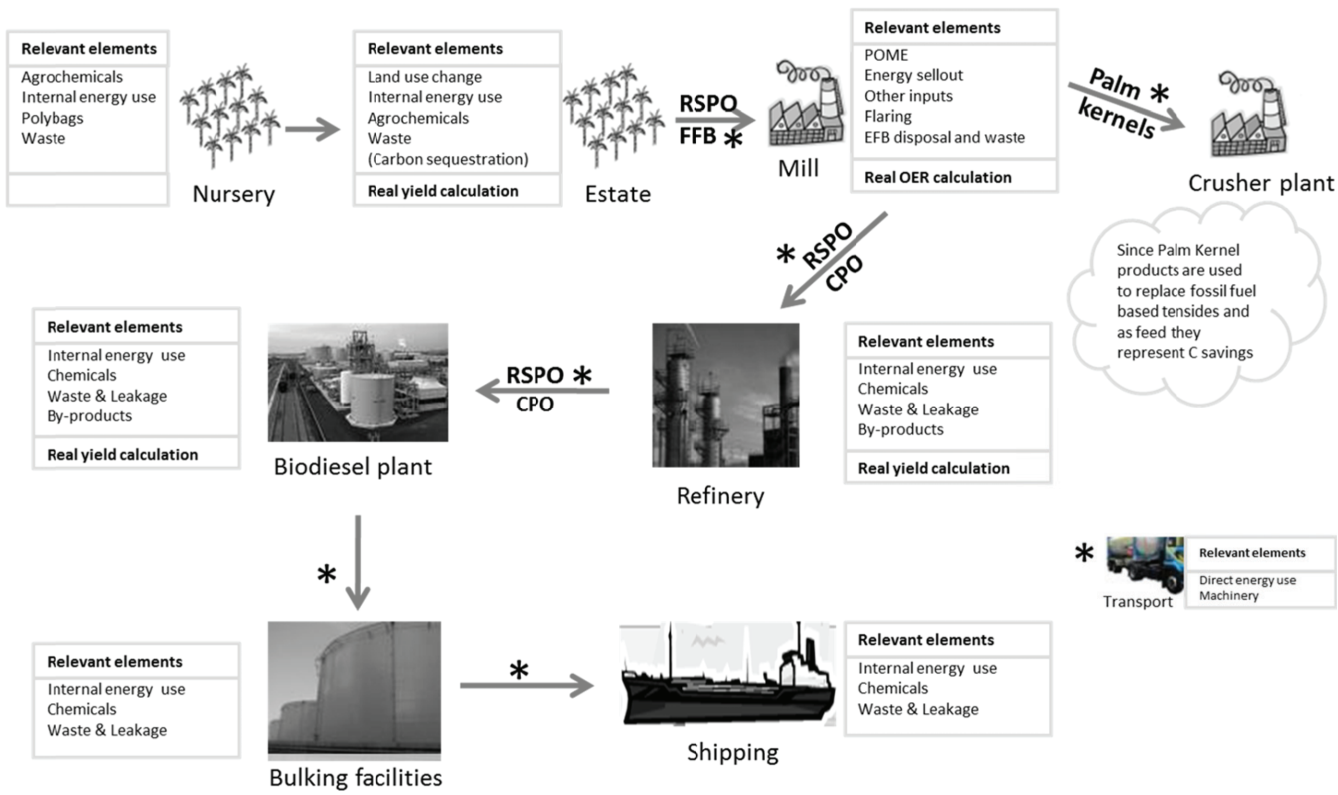

Fig. (8). The palm based biodiesel supply chain.

consumption know that it is very difficult to do so. Muslim consumers wishing to consume Halal products are lost in many supermarkets because of the large variety of unsubstantiable certification marks. Trying to go even deeper, consumers wishing to consumer hand-slaughtered meat (as opposed to mechanically slaughtered meat) cannot readily obtain such food. There is not much information available about our food.

On the other hand, the time consumers employ to make a decision about a repeat purchase (i.e. those of the same category) lies between 10 and 20 seconds (see e.g. [73]). In this time span a lot of information needs to be processed. Therefore most consumers will generally prefer easily processed over detailed information.

The author has long advocated [74] that consumers should be given a choice: those who wish make swift decisions should be given simple systems that use logos or the aforementioned traffic light system systems. However, those with a deeper interest (or those representing consumers whose business it is to invest time in such matters) should be given access to all kind of detailed information. The author firmly believes that transparency is an underused asset in food production.

First steps have been taken in this matter by several initiatives. Some food producers publish websites where consumers using traceability codes found on the packaging material can look up the origin and/or process parameters of the food; as one of the earlier examples see [75]. This can be used to link food items to the "story" of their production in an attempt to create a psychological link between the brand and the consumer [19].

On the other hand, the bulk of consumers will want to rely on trust. Given the very fast decision making process (see above) in a supermarket, most consumers will determine trustworthiness along two primary dimensions: integrity and competence; see [76] and [77]. Consumer develop trust for retailers and brands using these two dimensions and will make purchasing decisions then based on brands or the place they buy. This places the burden on brand owners and retailers to ensure that their products get safely to the consumer. For retailers backward traceability information becomes an essential part of their brand assurance and risk management, while for brand owners forward traceability is the main tool to ensure that consumers obtain their authentic product in good conditions. The key destination of a traceability system in this kind of "deferred responsibility" situations are not the consumer, but their safeguards. Please note that consumer oriented certification schemes such as the Marine Stewardship Council (MSC) would be understood in this context as brand owners: consumers base their purchasing decision on the logo printed on consumer packaging without checking the authenticity of the claim.

However, this author would like to argue that the public availability of data still makes an important difference. The availability of data makes a company (or a supply chain) auditable, so that in case there is a doubt, it can always be resolved. In addition there are consumer organisations, that by having access to data, could be a much more efficient guardian for consumer's rights. And finally, there are situations where consumers rely on information printed on the package without any means to verify it. Celiacs would be an example where for health reasons it is important to be able to ensure the veracity of information, Halal or kosher would be an example where this is important from a religious perspective and luxury goods is another example where consumers would like to make sure they are buying the real thing. In these situations we have a special motivation which goes beyond the simple act of buying food and this additional motivation can be the basis for an information service.

In the following we will look therefore at "active" consumers that **-** for certain products – take more time to make a decision and are thus potentially interested in receiving information electronically.

5.1. Active Consumers

US patent 20120005105 "Supply chain management using mobile devices" [76] describes a system where users can interact with traceability information via mobile phone. The described system can be used to transport recall data, historical data about the product, environmental score, it can use allergy filters, authenticate an item and so forth. It can also be used in the supply chain for its management.

Other systems with some similar characteristics have been mentioned above. However, this patent is assigned to IBM. IBM has invested in a partnership with the specialty traceability provider Trace Tracker [77] that supplies IBM with traceability technology in the form of the product GTNet. The aforementioned patent could well be the basis for a complete mobile solution rolled out to consumers. Earlier efforts e.g. by Transparent Goods, a defunct T-Systems subsidiary, were not successful. This may well be connected to the difficulty of scanning 2D barcodes with older phones. In the authors experience, modern smartphones have little trouble scanning 1cm x 1cm QR Codes reliably.

5.2. Religious Consumers

Some religions like Islam require their followers to follow certain dietary rules. *Halal* or *lawful* food should only be ingested, *musbooh* or doubtful and *haram* or forbidden foods must be avoided. Although most are familiar with the basic principles of avoiding alcohol and pork-based products, in reality Halal food production is a lot more complex; see e.g. [78].

Consumers of Halal products more often than not rely on personal trust relationships when purchasing e.g. meat products [79]. Of course this is a flawed basis for modern retail.

Retailers on the other hand, for fear of litigation, and in view of the many Halal certification schemes, often opt for not offering Halal products at all.

Provision of information on the Halal status could help. The Malaysian government organisation Labuan Corporation has e.g. implemented a Halal Track & Trace (HTT) system, as mentioned e.g. in [80, 81] that can be used to transport such information. The HTT system provides consumers with the option to check a particular food item for its Halal status. In addition, the system alerts the operator if any suspicious activity is observed and helps to recall if that should prove necessary. The system is under further development.

5.3. Health-conscious Consumers

Health-conscious consumers would also probably like to obtain more information about the food they consume. Products with medicinal characteristics that could affect consumers' health should probably be verifiable by consumers, at least for their authenticity.

A particular case in this area are bird's or swiftlet nests. These are saliva nests build especially by cave swifts. In Chinese culture bird's nests are a delicacy and command extraordinary high prices. The largest consumption market is China. Soup made from bird's nests are often consumed by pregnant women in order to increase health of the baby and the mother.

Fraud in bird's nests is common. Although China has banned imports from Indonesia and Vietnam because of avian flu, more than an estimated 60% of traded nests come from these countries. Nests are also dyed to increase the price.

Yakin IT [62] has created a consumer-to-producer traceability system that utilizes QR Codes and a smart phone application to assure consumers of the authenticity of the product they are purchasing. The system relies on statistical method to determine the authenticity: the more consumers check, the stronger a potential claim is. The particularity of this system is that it does not require assistance from the supply chain and is thus easier to implement than a full supply-chain solution.

6. CURRENT & FUTURE DEVELOPMENTS

This paper reviews a number of patents and non-patented developments in the area of food traceability and product authenticity. A number of angles have been treated in the text, but always with an eye on communicating safety, authenticity and consumer choice using traceability.

It is the author's opinion that most of the theoretical framework for traceability is well-understood. Mixing of liquids, or bulk materials may be an exception.

However, the sector has suffered greatly from three facts:

- That the food industry with its low margins does not have a large IT budget
- That there has been no single dominant player for standard setting
- That the food industry has yet to utilise information for its own benefit, rather than jealously hiding it

In Europe, the term traceability became main stream linked to food safety during the BSE scandal. An early, yet little efficient attempt to implement traceability by regulation has largely failed to improve the situation. The food industry was unimpressed and has done little to implement common

Fig. (9). Screenshots from the Verilabel solution for bird's nest authenticity. Reproduced with permission from Yakin IT.

standards for the exchange of food related data. Although such exchange would save money and reduce errors, the link to food scandals has not accelerated the adoption of food traceability solutions.

The patents that the author has reviewed in this paper reflect this situation. Most of them solve very specific issues without addressing the main issues:

1. Standardisation of food information exchange
2. Creation of credible models for data storage with no privacy issues
3. Integration of smallholders into the traceability effort

Many of the chain traceability systems here reviewed rather rely on a closed system approach trying to cover full supply chains without realising that the food industry is much too big to be covered by one system.

The author believes that EPCIS [14] may be a suitable standard for information exchange. EPCIS has the potential to be adopted by larger players. Some countries like Malaysia are building EPCIS infrastructures for small and medium enterprises. This is hopeful.

However, the next obstacle, unique identification for smallholders is not yet solved. The currently available models are not convincing. The author believes that unique identification is a matter of global concern and should perhaps be addressed at that level. Unless we will find a way to provide free-of-charge, non-subscription identifiers for smallholders they are not going to join the traceability world.

Regarding models for data storage, the author personally believes that private companies are the most trustworthy entities. He recognises, however, that this view is not shared by all in his own surroundings or in other cultures. The existence of an international standard like those that enable internet (e.g. HTTP and DNS) would allow everybody to choose a trusted party that meets his or her requirements. Segmentation of the information into two or probably three levels as exemplified in Fig. (**4**) is a necessary pre-cautionary step.

With regards to smallholders, clearly mobile devices are going to change the adoption of traceability. With an increased ease of data capture also by the illiterate using the ever more powerful phone, traceability will be made a lot easier. The additional effort should be compensated from processors or other larger players either by providing a premium as a share of greater efficiencies or by reducing other manual documentation efforts, e.g. to get paid.

Enabling consumers to choose products according to their own beliefs or preferences can give rise to a new sector of custom-made foods. Large staple food producers can differentiate themselves on the market by addressing particular consumer needs. And again, mobile devices will enable consumer feedback which can be used to improve products or markets.

Of the big players in the international markets only very few have profiled themselves in the area of food traceability. It will take a few thought leaders with a real will to get this underway.

CONFLICT OF INTEREST

The author declares to have no conflicts of interest.

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