Health promoting, safe seafood of high eating quality in a consumer driven fork-to-farm concept

EU Integrated Project no 506359

Traceability

- a literature review

Maria Randrup
and
Marco Frederiksen

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A report from RTD area 6

'Seafood traceability to ensure consumer confidence'

Project 6.1 METHODS

Traceability
- a literature review

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1. Traceability in general

1.1. Traceability defined

Four definitions of traceability are listed in Table 1.

Table 1. Definitions of traceability.

Organization	Definition
ISO 9000:2005 Quality management systems (International Organization for Standardization, 2005b)	The ability to trace the history, application or location of that which is under consideration. When considering product, traceability can relate to the origin of materials and parts, the processing history, and the distribution and location of the product after delivery.
Codex Alimentarius Commission (CAC) (Codex Alimentarius Commission, 2004)	Traceability/product tracing – the ability to follow the movement of a food through specified stage(s) of production, processing and distribution.
EU Regulation on the General Principles and Requirements of Food Law, EC/178/2002 (Anon., 2002)	The ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution.
ISO/DIS 22005 Traceability in the feed and food chain (draft) (International Organization for Standardization, 2005a)	The ability to follow the movement of a feed or food through specified stage(s) of production, processing and distribution. Movement can relate to the origin of the materials, processing history or distribution of the feed or food but should be confined to one step forward and one step backward in the chain.

The ISO 9000:2005 definition is very general whereas the CAC and EC/178/2002 definitions only apply to food or feed traceability. The ISO 9000:2005 definition comes from the standard for quality management, which is generally applicable and not confined to food only. However, as it appears in Table 1, it is expected that ISO 22005 will define traceability specifically with regard to food and feed by using a combination of the definitions of ISO 9000:2005 and CAC. In addition, aspects of EC/178/2002 are seen in the ISO 22005 definition ("one step forward and one step backward"). The definition in EC/178/2002 stems from the White Paper on Food Safety, resulting in food safety being the center of concern (Danish Ministry of Food, Agriculture and Fisheries, 2004).

1.2. Traceability – background and purpose

Food scandals such as mad cow disease (BSE) in the UK beef industry in 1996, dioxin contamination in Belgium in 1999, chloramphenical from contaminated seafood being used in animal feed, and the use of GMO and antibiotics have increased the demand for traceability (Ekman, 2002; Frederiksen & Gram, 2003; Derrick & Dillon, 2004). As a consequence of these events, companies have discovered that the inability to trace products through the food chain can ruin their business, as all the company's products will have to be removed from the market in case they cannot prove that certain batches of the product are not contaminated.

In this regard, it is worth noting that *withdrawal* refers to the removal of goods before they are delivered to consumers, while *recall* refers to the removal or return of goods when the goods already are available at the retail level (Anon., 2001).

Traceability facilitates product withdrawal and recall by making it possible to trace a product back to the source, to identify other products affected and to locate the products in question. This enhances consumer safety. Controls can be set up at the source of the problem to prevent the need for similar recalls, thereby reducing economic losses (Derrick & Dillon, 2004).

Another role of traceability in the food supply chain is to provide information to aid in managing and controlling processes, stocks, and quality (Food Standards Agency, 2004). Traceability may also assist in the prevention of fraud and in the authentication of labeling claims by making it possible to prove the product's origin, processing steps, etc. (Derrick & Dillon, 2004).

Traceability can also be used to add value to food products by providing information about the food which could differentiate one food product from the other (Ekman, 2002; Danish Ministry of Food, Agriculture and Fisheries, 2004). This information may include the origin of the food, catch method in the case of seafood, processing methods, environmental impact, animal welfare, etc. The target groups of this information are all the actors in the supply chain from the auction market, exporters, and producers to wholesalers, retailers, and consumers. If the information about the quality of the food product is passed on through the chain, the individual steps in the chain do not need to waste time by making quality inspections, since that has already been carried out earlier. However, this requires good mutual trust and cooperation between the steps in the chain (Frederiksen & Gram, 2003).

1.3. Tracing vs. tracking

Traceability encompasses both tracing and tracking (Figure 1). As explained in Table 2, tracing is done upstream *against* the flow of the product and towards the source, while tracking is done downstream *with* the flow of the product. Tracing is used during product recall situations in order to find the origin of the recalled product. Once the origin is found, tracking is performed to find the rest of the batch of products that have been recalled. Thus, when tracking a large batch of products, one may have to follow many paths in order to find out the destinations of all the products in that batch.

Table 2. Definitions of tracing and tracking.

Term	Definition
Tracing (back)	the capability to identify the origin of a particular unit and/or batch of product located within the supply chain by reference to records held upstream in the chain (Ekman, 2002)
Tracking (forward)	the capability to follow the path of a specified unit and/or batch of a trade item downstream through the supply chain as it moves between trading partners (EAN·UCC, 2002)

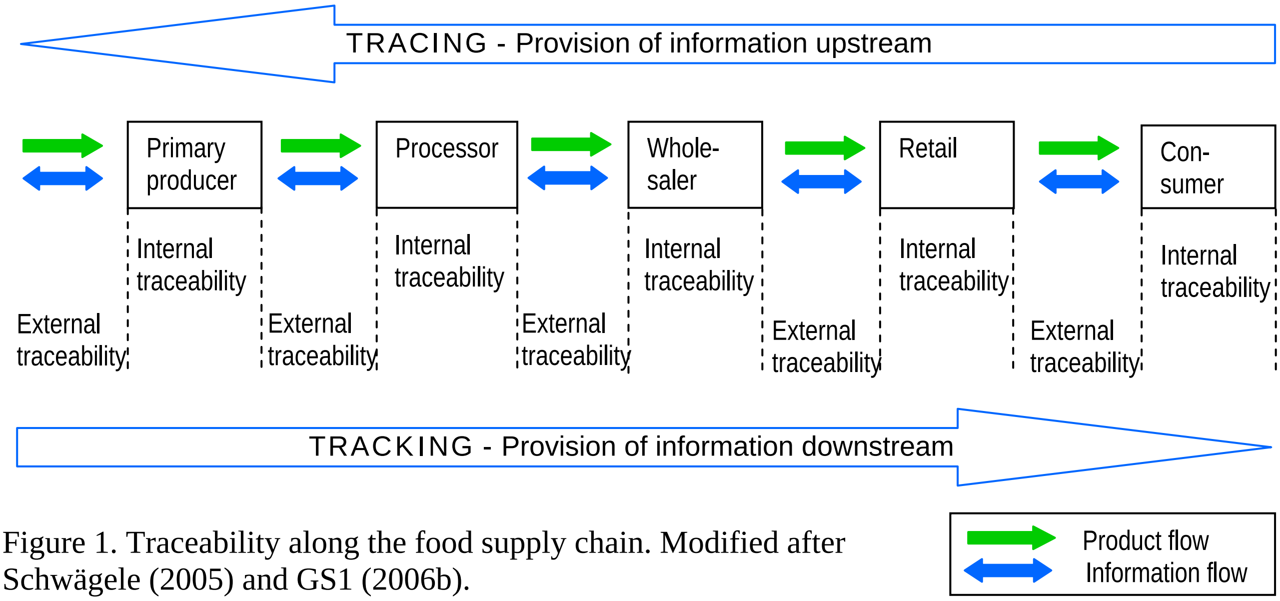

Figure 1. Traceability along the food supply chain. Modified after Schwägele (2005) and GS1 (2006b).

1.4. Types of traceability

The concept of traceability can be divided into internal and external traceability (Figure 1). Internal traceability is traceability within one link or company within the supply chain. With internal traceability, information about raw materials and processes within the company are linked to the final product separately in each stage of production, processing or distribution (Food Standards Agency - Food Chain Strategy Division, 2002).

External traceability, or chain traceability, is traceability between links in the supply chain. Product information is passed on from one link in the chain to the next to extend traceability for any product through all stages of production, processing and distribution (Food Standards Agency - Food Chain Strategy Division, 2002).

1.5. Traceability systems

A traceability system consists of record-keeping procedures that show the path of a particular product or ingredient from supplier(s), through all the intermediate steps which process the products, to consumers (Food Standards Agency - Food Chain Strategy Division, 2002). The products and the processes comprise the two core entities of a traceability system (Moe, 1998) (Figure 2). One must be able to trace both products and processes in a traceability system. In a basic system, only the essential descriptors are accessible (that is, information about the identity and amount of the products, what process they have undergone and when). Additional information can be supplied by means of the extra descriptors as required in the chain.

Traceability systems are commonly paper-based, based on bar codes or based on RFID tags (cf. section 2.1.).

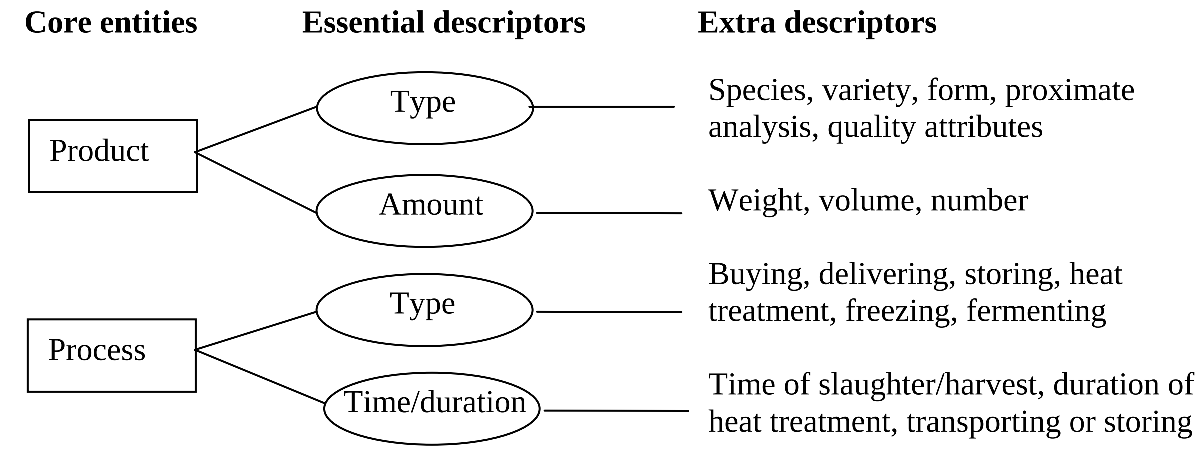

Figure 2. Structure of a traceability system. Modified after Moe (1998).

Several articles describe the development of traceability systems in food supply chains, components of a traceability system, analysis and verification of traceability, etc. (Dillon & Thompson, 2003; Morrison, 2003; Furness & Osman, 2003; Opara & Mazaud, 2001; Beulens et al., 2005; Dupuy et al., 2005; Bertolini et al., 2006; Van der Vorst, 2006).

1.6. Identification of batches and individual items according to GS1

A requirement of any traceability system is to have a means of uniquely identifying the products, either individually or in groups, or batches. GS1, formerly EAN·UCC, is an organization that designs standards, technologies and solutions to improve the efficiency of supply and demand chains by adding useful information to any exchange of goods or services (GS1, 2006b). GS1 has created a common language of electronic identification and communication. Terms in this language employed to describe the logistical hierarchy are shown in Table 3 and illustrated in Figure 3.

Table 3. Definitions of some terms in the GS1 logistical hierarchy (GS1, 2006b; EAN·UCC, 2002).

Term	Definition
Shipment	An item or group of items delivered to one party's location at one moment in time that have undergone the same despatch and receipt processes.
Logistic unit	An item of any composition established for transport and/or storage that needs to be managed through the supply chain.
Trade item	Any item (product or service) upon which there is a need to retrieve pre-defined information and that may be priced, or ordered, or invoiced at any point in any supply chain. This definition covers services and products, from raw materials through to end user products, all of which may have pre-defined characteristics.
Retail trade item	A trade item intended for sale to the final consumer through a retail point of sale. An item that can be considered as both a retail and a non-retail trade item is numbered and bar coded according to the rules applicable to retail items.
Non-retail trade item	Any trade item or standard grouping of trade items intended for sale through any distribution channel, other than a retail point of sale.

Trade items, both retail and non-retail, can be both individual items or individual items collected in a package (GS1, 2006a). For example, a single can of tomatoes and a package of three cans of tomatoes are both retail trade items.

a) Shipment
- May contain one or more logistic unit(s)
- Examples:
  - a truckload of crates of fish
  - a vessel full of canned tomatoes
  - 12 pallets of various items

b) Logistic unit
- May contain other logistic unit(s)
- May contain one or more trade item(s)
- May be a trade item
- Examples:
  - A pallet or container containing several boxes of canned tomatoes or several crates of fish
  - A box of canned tomatoes
  - A crate of fish

c) Non-retail trade item (trade item not crossing the point of sale)
- May be a trade item
- May be a batch/lot of trade items
- May be a serialized trade item
- Examples:
  - A box of individual cans of tomatoes
  - A box containing packages of three cans of tomatoes
  - A crate of fish

d) Retail trade item (trade item crossing the point of sale)
- May be a trade item
- May be a batch/lot of trade items
- May be a serialized trade item
- Examples:
  - A package of three cans of tomatoes
  - A single can of tomatoes
  - One fish

Figure 3. Examples of a shipment, a logistic unit, and trade items. Modified after GS1 (2006b).

Items are allocated certain numbers, called identifiers, according to their position in the logistical hierarchy and the desired precision of identification. This is shown schematically in Table 4, where the identifiers are colored according to which level of traceability they represent (the darker the color, the higher the level of traceability).

Table 4. Recommended GS1 identifiers according to desired precision of identification. Modified after GS1 (2006b). (SIN = Shipment Identification Number, SSCC = Serial Shipping Container Code, SGTIN = Serialized GTIN = GTIN and a serial number, GTIN = Global Trade Item Number)

Precision of the identification	**Level in the logistical hierarchy**			
	Shipment	**Logistic unit**	**Non-retail trade item**	**Retail trade item**
Generic	Not applicable	Not applicable	GTIN	GTIN
Specific (batch)	Not applicable	Not applicable	GTIN and a batch/lot number	GTIN and a batch/lot number
Unique (serialized)	SIN	SSCC	SGTIN	SGTIN

A batch, or a lot, unites products/items that have undergone the same transformation processes (GS1, 2006b). However, it is up to each company to define "batch" according to its needs (size of each product, value of each product, etc.). A batch can be the equivalent of a non-retail trade item, a logistic unit or it may be defined by the company's work shifts, for example. A batch ID is part of the specific identification of a trade item, but not part of the unique identification of a trade item.

1.7. Batch identification of reworked products

A batch identification may or may not change during processing. In two situations, the batch ID remains the same. These are during transfer and addition (Figure 4a and b). An example of transfer is filleting of whole fish. The fish undergoes a process, but the batch ID does not change. Addition of ingredients to the product, e.g. spices can be added to a fillet, does not change the batch ID of the main product, either. However, the batch IDs of the spices must be recorded in conjunction to the batch ID of the main product. In these two situations, the whole batch undergoes the exact same activity (Derrick & Dillon, 2004).

In the following two operations, the batch ID must change, as the process changes the composition of the main product in the batch. In joining (Figure 4c), several batches of the main product are combined and undergo the same process. Thus the batch ID of the end product is different from the batch ID of the three batches of raw material. For example, fish from three different suppliers can be combined into one batch. When splitting a batch (Figure 4d), the new batches will have to be given new batch IDs, as they will not undergo the exact same process. An example of this situation is the division of a batch of fillets due to insufficient space in a blast freezer (Derrick & Dillon, 2004).

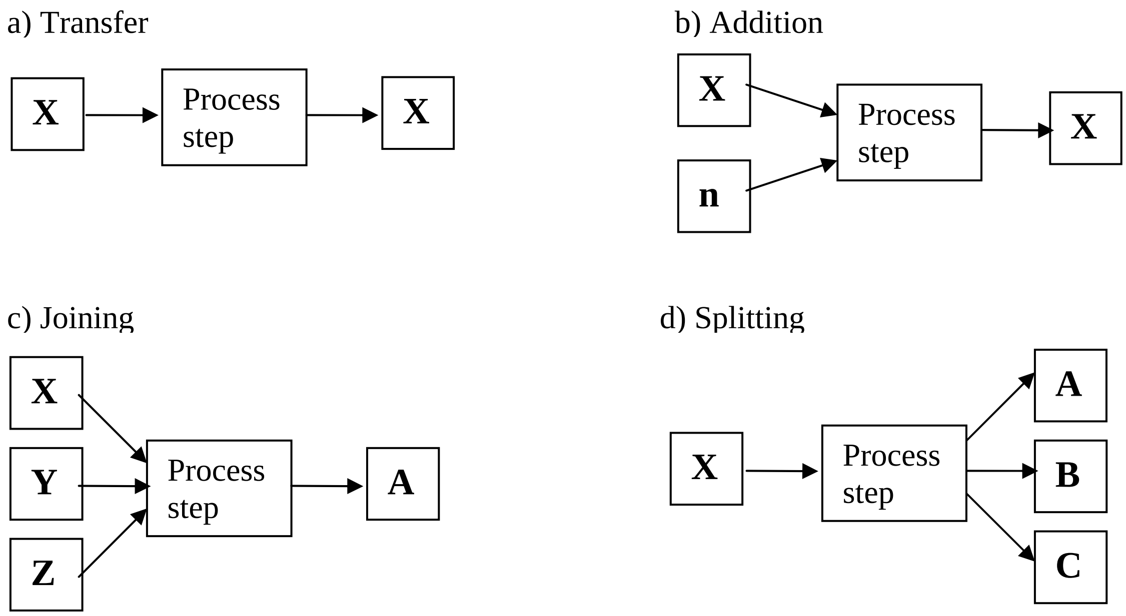

Figure 4. Four typical factory operations showing the a) transfer, b) addition, c) joining, and d) splitting of batches. Modified after Derrick & Dillon (2004).

2. Traceability in the fish industry

2.1. Data carriers

In the following text, the most common types of data carriers will be described. It is worth noting that as it is not yet possible to attach a tag or print a serial number on a fish, traceability of fish products is dependent on placing a marker, or data carrier, on the fish crate or packaging material. A result of this is a risk of substitution in open fish crates (Goulding, 2002).

2.1.1. Paper-based

As the name says, information in a paper-based traceability system is written on paper that follows the raw material through processing to retail. This is easy to use when dealing with large products of high value and in small quantity. However, when it comes to relatively small products which are produced in large quantities, it may be too expensive labor-wise to use a paper trail (Frederiksen & Gram, 2003). Moreover, it may take longer time to trace the product when using a paper-based system rather than a computerized system (Morrison, 2003).

2.1.2. Bar codes

Linear bar codes placed on the packaging material are the most used data carriers and have been in use since the beginning of the 1970's. Bar codes consist of bars and spaces, both of differing widths. The pattern of the bars and spaces encodes data. Bar codes are read using a beam of red light which detects changes in the amount of light reflected from the surface, on which the bar code is printed. These changes are converted to a digital signal, which in turn is decoded by a computer, thereby determining the information stored in the bar code. Bar codes can store a limited amount of data (Furness, 2006). Bar codes must be in the reader's line of sight and not more than a few centimeters away from the reader (Trienekens & Van der Vorst, 2006).

Many bar code symbologies have been developed. Among the most well known are EAN-8 and EAN-13 (for trade items), EAN-128 (for logistic units) and RSS (reduced space symbology for items with a small surface area) (Furness, 2006).

Bar codes are traditionally printed on packaging materials, but Nightingale and Christens-Barry (2005) are researching on the possibility of placing bar codes directly onto food products.

2.1.3. RFID tags

Due to the use of radio frequencies, RFID (radio frequency identification) tags placed on items can be read even if the reader and the tag are not in line-of-sight. This means that it is possible to use RFID tags in wet and harsh conditions, which are unsuitable for the reading of bar codes. An RFID tag can be either read-only or both readable and writeable. Furthermore, RFID tags are either passive, semi-active (battery-assisted) or active, depending on how they are powered. Passive tags are powered by the reader, active tags are powered by their own battery, while semi-active tags have a battery, but are also dependent on power from the reader (Furness, 2006; Lysis Ltd., 2004; Brody, 2006; RFID Centre, 2006; Cavoukian, 2004). Passive tags have the longest lifetime and are also the cheapest, but they have a shorter read range than active tags (Lyngsoe Systems A/S, 2006). RFID tags can store larger amounts of data than bar codes. However, RFID tags can also be used solely to store a unique identification number, which then is linked via the internet to a database, where practically indefinite amounts of data can be stored (Frederiksen, 2006).

The use of RFID tags for traceability and for economic benefits is dealt with in several articles (Jones et al., 2005; Wang et al., 2006; Hidaka, 2005; Stirling-Roberts, 2006). A traceability solution for a meat boning hall using a novel conveyor system and RFID equipment is also described (Mousavi et al., 2005), as well as the embedment of RFID tags in the walls of fish tubs (Anon., 2006). Further research is being conducted on how to improve RFID technology such that the influence of water and metal on the readability of RFID tags can be reduced (Harrop, 2006a).

2.1.4. Other data carriers

Other data carriers include:

- optical data carriers such as two-dimensional bar codes (in the form of multi-row bar codes or matrix bar codes) (Furness, 2006) and Optical Character Recognition (OCR) (Trienekens & Van der Vorst, 2006)
- magnetic data carriers such as a magnetic stripe (Trienekens & Van der Vorst, 2006)
- electronic data carriers such as touch memory (Furness, 2006) and smart cards (Trienekens & Van der Vorst, 2006)

Moreover, wireless temperature and location trace in near real time in the cold chain is possible with *Smart-Trace*™, which uses multi-hop network and radio frequencies (Richardson & Walker, 2006).

2.2. Standards for traceability in the fish industry

2.2.1. Tracefish

The Tracefish concept is a voluntary, electronic system of chain traceability which was developed in the EU Concerted Action project QLK1-2000-00164. The concept is comprised of three documents:

- CWA 14559:2003 Traceability of fishery products – Specification on the information to be recorded in farmed fish distribution chains (Danish Standards Association, 2003a)
- CWA 14660:2003 Traceability of fishery products – Specification on the information to be recorded in captured fish distribution chains (Danish Standards Association, 2003b)
- TraceCore – XML Standard Guidelines (Anon., 2005)

The two CWAs (CEN Workshop Agreement) specify what information should be generated and kept by each of the food businesses in the supply chains of captured fish and farmed fish, respectively. The third document is a technical specification for the electronic encoding of the data (Danish Standards Association, 2003b).

In the Tracefish scheme, each trade unit is labelled with a unique ID according to the GS1 identification system. The trade units receive their first unique ID at the source, and as the trade units are transformed along the food supply chain, they are given new unique IDs. Each step in the supply chain must register the trade units they receive and produce and any information related to the trade units. The information related to each unique ID is stored on electronic databases at each step, and the necessary traceability data must be available on demand by the other steps in the chain and the authorities (Danish Standards Association, 2003b).

The Tracefish scheme has created the term “GTIN+” to denote the unique ID. GTIN+ is defined by Tracefish as “GTIN plus a further number to uniquely identify each particular trade unit (e.g. the production batch and serial number or the date and time of production)” (Danish Standards Association, 2003b). Thus, GTIN+ is not identical to SGTIN, which is comprised of the GTIN and a serial number. SGTIN does not contain the production batch.

2.2.2. Tracefood

Tracefood promotes itself as a traceability toolbox. Among other things, the intention is that the toolbox should contain a generic Good Traceability Practice (GTP) and as branches to that, sector-specific GTP guidelines. In addition, the toolbox will contain sector-specific XML standards that build on the generic TraceCore – XML Standard Guidelines mentioned under Tracefish (Tracefood, 2006).

2.2.3. Global Traceability Standard (GS1)

Bar codes: Traceability of Fish Guidelines

The Traceability of Fish Guidelines (EAN·UCC, 2002) specify the minimum requirements for ensuring the traceability of fish and fish products. The guidelines were developed in cooperation with the Tracefish project and are likewise voluntary. As the guidelines fulfill the traceability requirements set forth in the EC/178/2002 regulations, the target groups of the guidelines are the EU member countries, non-EU countries exporting to the EU and countries wishing to follow the EU Regulation. The guidelines illustrate how to implement traceability in the fish industry by using the GS1 system (formerly known as the EAN·UCC system), which is an internationally accepted identification system. Bar codes and their corresponding unique identification numbers form the basis of the GS1 identification system. The unambiguous numbers identify goods, services, assets and locations. Additional information (such as best before dates) can also be encoded with numbers and bar codes. The use of bar codes ensures the possibility of electronic data capture. The GS1 identification system is explained in detail in EAN·UCC (2002), GS1 (2006a) and GS1 (2006b).

RFID: EPCglobal standards

A joint-venture between GS1 and GS1 US, named EPCglobal Inc., (EPCglobal Inc., 2006a) has published seven standards that support the use of RFID and Electronic Product Codes (EPCs) in the supply chain. An EPC is an identification scheme for universally identifying physical objects via RFID tags and other means. For example, the standards define standardized EPC tag data and requirements for an RFID system. The EPCglobal standards use the GS1 identification system as a basis together with RFID tags instead of bar codes. However, in the EPCglobal standards, a serial number has been added to the GS1 identifiers in order to make unique identification at the item-level possible (GS1 Denmark, 2006; EPCglobal Inc., 2006b; EPCglobal Inc., 2006c).

2.3. Commercial traceability solutions

Many commercial electronic traceability solutions have been developed. Some of them are for a particular product or specifically for either small, mid-size or large companies. The programs have varying degrees of customization and varying levels of traceability. They may support integration with bar code printers, scanners and scales, and integration with financial programs, for example. It is also possible to integrate traceability software in Enterprise Resource Planning (ERP) programs (Thompson et al., 2005) and to incorporate traceability into vessel software, as is the case with Seadata Suite (www.seadata.is, www.trackwell.com). Examples of traceability software and solutions are:

- WiseFish™ and FarmControl by Maritech International, www.wisefish.com
- SeaSoft by Computer Associates, Inc., www.caisoft.com
- Softtrace Ltd., www.soft-trace.com
- ParityPro™ Food Enterprise System by Parity Corp., www.paritycorp.com
- FishMonger™ Seafood Software by Disc Design & Data, www.fishmonger.com
- Global Traceability Network (GTNet) by TraceTracker Innovation ASA, www.tracetracker.com
- Traceway by Nesco Ltd., www.weighdata.com/nescoweighing/traceway.php
- TraceAll Online by Traceall Ltd., www.traceall.co.uk
- M3 Trace Engine by Lawson, www.lawson.com
- Marel Production System by Marel hf, www.marel.com
- Catellae™ Solution Suite by Lyngsoe Systems, www.lyngsoesystems.dk

Aside from these, research groups have created traceability software (Pinto et al., 2006) and a model for designing an information system for traceability (Jansen-Vullers et al., 2003). More commercial traceability solutions are mentioned in Rowan (2002) and Duxbury (2004).

2.4. Traceability in the fish industry today

Frederiksen et al. (1997) developed an Integrated Quality Assurance System, which used bar codes to carry information about the fish in the crate, for example the species, the size category, the vessel number, the catch date, and the weight of the fish in the crate. However, this system was only used in the first step of the chain (on the vessel) and the information was not transferred further in the chain. A similar system is described by Denton & Meyers (2003) and is common in the UK fishing fleet. The “Info-fisk” traceability system is, on the other hand, a traceability system for the whole fish supply chain, from the vessel to the retailer (Frederiksen et al., 2002). This system also used bar codes to carry data along the chain. In Japan, a test traceability system has been developed for farmed oyster. Consumers can type an 11-digit number found on the oyster packs into the cooperative’s homepage and obtain information such as the name of the farm, the producer and the day the oysters were processed (Hashimoto & Niwa, 2004).

Seafish, England, is working on a traceability system that uses RFID tags embedded in fish crates (Denton & Myers, 2003). Likewise, Oregon State University Seafood Laboratory is developing a system in which traceability information is stored in a database and can be accessed by all the links in the chain (Morrissey & Almonacid, 2005).

3. Traceability in the pharmaceutical industry

Traceability of prescription drugs back to the manufacturer is a legal requirement in the United States, established by the Federal Food, Drug, and Cosmetic Act, which was amended by the Prescription Drug Marketing Act of 1987 (PDMA), as modified by the Prescription Drug Amendments of 1992. The requirement, denoted a pedigree requirement, entails that any person, who is not the manufacturer or an authorized distributor of the prescription drug, and who engages in wholesale distribution of the drug, must provide to the recipient of the drug a pedigree for that drug. A drug pedigree is a statement of origin that identifies each prior sale, purchase, or trade of a drug (United States Food and Drug Administration, Office of Regulatory Affairs, 2006).

The main purpose of the pedigree requirement in the United States and drug traceability as a whole is to prevent the sale of substandard, ineffective, and counterfeit drugs (Harrop, 2006c; United States Food and Drug Administration, Office of Regulatory Affairs, 2006). Copies of drugs can enter into distribution at any of the many small wholesalers, which then unknowingly sell the drug as the real thing. The pharmaceutical industry fails to obtain earnings and the consumer may be taking a drug which may have no effect or may be lethal (RFID Update, 2005).

The high price of pharmaceuticals justifies the use of item-level tagging in order to make an electronic pedigree system. Bar codes or RFID tags are used to identify each trade item (RFID Update, 2005). For example, Eli Lilly places bar codes on individual vials of insulin (McQuivey & Feehan, 2005).

The drugs that companies have chosen as a pilot to RFID-tag on the item-level are those that are most susceptible to counterfeiting and/or are popular on the black market. Examples of drugs that are being RFID-tagged at present are GlaxoSmithKline’s HIV drug Trizivir, Pfizer’s Viagra, and Purdue Pharma’s painkiller OxyContin (IDTechEx, 2006a; RFID Update, 2005). Each bottle is tagged with an EPC code, which is linked to information about the drug’s manufacturing and shipping history. Manufacturers, wholesalers, and pharmacists can obtain this information by scanning the RFID tag on the bottle and thereby verify the bottle’s authenticity (IDTechEx, 2006a). A “certified chain of custody” can be established and verified on demand (RFID Update, 2005). The information linked to the EPC code also reveals the current location of the product and the status of the item, ie. whether the item is ok, expired or recalled (Montgomery Research & Sun Microsystems, 2006).

Another application of item-level RFID-tagging of drugs is to keep track of the stock of product samples given to medical practices. At the medical facility, a reader is installed in the closet where product samples are kept. The reader registers the type and quantity of the tagged drug samples that are removed and sends this information to a database at the pharmaceutical company (McQuivey & Feehan, 2005).

Monitoring patients’ compliance with their prescriptions is another application of RFID-tagging. When removing a tablet from a blister pack, a printed conductor is broken. The time that this happens is recorded by the silicon chip on each package. Upon receiving the empty package from the patient, the pharmacist can scan the chip with a reader and obtain information about when the medication had been taken, or at least removed from the blister pack. The RFID tag on the package also links the information to the patient that received the unused package (IDTechEx, 2006b; Harrop, 2006b).

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