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Abstract

In the beginning of 2005 came in force the EU General Food Law (178/2002), where a system is required from food processors for identifying the origin of raw materials of food products and the destination of final products i.e. one step forward and one step backward in the production chain. According to this law, ‘traceability’ means 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. In addition to the EU regulation, several countries have enacted specific legislative measures. In addition to increased requirements of legislation, consumer demands for transparency have also increased which has led to further development of harmonious traceability systems.

In Finland, the new legislation caused concern, but in reality, old operation modes had already fulfilled the requirements in many cases. Certainly data systems can and should be developed so, that they serve better and faster than earlier systems the needs of traceability. In the report by the Finnish Food and Drink Industries' Federation and the Finnish Grocery Trade Association on food traceability in Finland (2005), three development steps of traceability for food companies have been defined. The ultimate aim is that traceability systems would work totally electronically and with new technologies such as RFID and no paper records would be needed.

Hazards, e.g. pathogenic microbes and allergens in food products, can cause significant health risks for people belonging to risk groups of those hazards and they must be efficiently traced in food chains. The faster the defective product is drawn from the market, the less the company receives negative publicity and the undamage to the image of a company is minimized. Process traceability, i.e. the ability to follow the manufacture of ingredients and materials into a product, is not required in EU legislation. However, the better the process traceability is, the bounded and accurate withdrawal can be performed when necessary. Traceability is a preventive, necessary, supplement of food safety systems, which increases the efficiency of food companies, when used correctly.

Some pioneer companies have been developing their own traceability systems primarily to reduce business risk, but they have been lacking standards, which has resulted in very differentiated systems. As a consequence these systems have been producing different economical results. However, work on standardization has been going on as well as building of general frameworks for setting up traceability systems. Information Technology (IT) has the potential of revolutionizing product traceability. In practice the tools for traceability are labels containing alphanumerical codes (a sequence of numbers and letters of various sizes, generally "owners" codes), bar codes and automatic radio frequency identification (RFID), of which bar codes seem to be the most frequently used systems currently. RFID is a very promising technique, but problem is still the high cost of TAGs used in these systems, even though the prices have decreased significantly in recent years.

In traceability investigations often the origin of plant or animal based raw material is sought, e.g. if genetically modified organisms (GMO's) have been used as raw materials or if product contains components hazardous for consumer health or e.g. raw materials of wrong quality. It is very difficult to determine the geographical origin of a food, the requirement imposed by the EU regulation 178/2002. Universal scientific methods for the determination do not exist and indirect methods have to be coupled. Modern analytical techniques in analyzing the origin of foodstuffs can be categorized into two types: the physicochemical techniques and biological techniques. The main problem in all these techniques is the need of data banks.

Contents

1. Introduction

Incidences of food crisis during last year, the variety of additives used in products and on the other hand the consumer requirements of as natural products as possible, the emergence of genetically manipulated products onto market and questions on environmental protection have urged up the requirements for better transparency and traceability in the food production chains. Food chains are increasingly becoming global and information technology has developed fast during last years. Besides the increased requirements of legislation, these have been important motivating factors for further development of harmonious traceability systems (Opara and Mazaud, 2001).

The publication describes the characteristics, requirements and gaps of traceability systems used in food industry, as well as methods used for tracing various hazards (e.g. allergens and pathogens). Additionally the current state of art in traceability in Finnish food industry is discussed. This review has been written in a Finnish project ”Risk assessment and traceability in production safety management in food industry” (1.10.2003–30.6.2007).

2. Traceability in food industry

2.1 Definitions of traceability

Definitions of traceability

'Traceability' means 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. This definition is from the Regulation (EC) No. 178/2002 of the European parliament and the council laying down the general principles and requirements of food law (article 3, point 15). Much used definition, also suitable for food industry, is also the definition of ISO 8402:1994 standard: "The ability to trace the history, application or location of an entity by means of recorded identifications" (Furness and Osman, 2003).

According to an international ISO-standard (ISO 9002, 4.8 – Traceability) a manufactured product must be traced through the various stages of its production and delivery. This is crucial to help identify the stage and hence the cause of any product failure. Where and to which extent traceability is a specified requirement, establish and maintain documented procedures for the unique identification of individual products and batches. The identifications should be recorded. In this definition two essential elements are identification of products and the ability to trace through the records (Opara and Mazaud, 2001).

Traceability downstream in food chain means the ability to trace the products in question, e.g. defective or contaminated products, easily from the production chain and to find all necessary information regarding the process from the beginning to the end, to be able to find the sites where contamination/failure has happened. It should be possible also to be able to trace upstream in the food chain i.e. to recognize all the end-products containing e.g. contaminated raw material or foreign bodies and to locate them to be able to perform a fast withdrawal (Deasy, 2001). Traceability downstream (back) can be called **"tracing"** and upstream (forward) **"tracking"** (Schwägele, 2005; Foster, 2006).

Traceability can be divided to contractor, customer and process traceability (Table 1).

Table 1. Division of traceability to contractor, customer and process traceability (ETL/PTY, 2005).

Traceability		
Contractor	**Customer**	**Process**
The ability to know the contractors of all the ingredients and packaging materials	The ability to know the delivery of the products one step forward in the delivery chain or farthest to the final consumer	The ability to follow the manufacture of ingredients and materials into a product

Definition of lot

Lot identification marking or code is a basic element in traceability (ETL/PTY, 2005). In the article 18 in EU regulation 178/2002 it is stated, that food or feed which is placed on the market or is likely to be placed on the market must be adequately labelled or identified to facilitate its traceability, through relevant documentation or information in accordance with the relevant requirements of more specific provisions. In Finnish legislation food lot is defined as a group of trade units of food product, which have been produced, manufactured or packed in similar conditions (KTM, 2004). A lot is processed from same raw materials in same processing conditions. A lot has usually been limited to at most the size of one day's production (ETL/PTY, 2005). In EU directive 89/396/EEC a model for general identification system of food lots is presented (Pettitt, 2001).

2.2 Benefits obtained from good traceability practise

Traceability is a preventive, necessary, supplement of food safety systems, which increases the efficiency of food company, when used correctly. In practise traceability means collection, documentation, maintenance and application of information related to all processes in the supply chain, which guarantees for the consumers the information on origin and life history of a product (Opara and Mazaud, 2001).

According to Samuelsson and Skjöldebrand (2004), traceability is about collecting relevant information and using it to visualize, improve and optimize the operational processes in a food processing plant.

Traceability is needed:

- in controlling crisis situations and in enabling bounded withdrawals
- in delivering precise information to consumers and controlling authorities

- for safety of consumers, products hazardous to health can be withdrawn quickly from the market
- for safety of operatives; faults can be found and corrected quickly
- for information acquisition of authorities
- for prevention of unnecessary big market disturbances.

(EVIRA, 2007a)

According to published information from the US, the average cost for recalling product from the market is about 540 000 USD. Negative image resulting from withdrawal may, in extreme cases lead to bancrupcy or a company to be forced to stop its activities. Effective, quick tracking is a matter for trademark protection (Samuelsson and Skjöldebrand, 2004). The faster the defective product is drawn from the market, the less the company receives negative publicity and damage to the image of a company is minimized. In order to be able to withdraw the food product in crisis situation as fast as possible, the company must be immediately and accurately able to identify the lots in question and the delivery area of them. Additionally it should be able to identify those process steps, where the problem has evolved and to show the scope of documents. At this step a functioning, real-time traceability system is necessary and indispensable tool (Deasy, 2001). Good traceability system helps also in process management and implementation of GMP (Morrison, 2003). When traceability system is included into quality control systems such as HACCP, the system makes it possible to show, that product fulfils the quality requirements and it also enables tracing of possible contamination sources (Opara and Mazaud, 2001). According to Opara and Mazaud (2001) the benefits and applications of traceability are the following:

- increase of customer and consumer confidence
- regulatory compliance
- demonstrable integrity of food supply chain
- minimization of and transfer of risks
- promotion of best allocation of responsibilities
- facilitation of internal controls
- validation and resolving of complaints
- facilitation of effective product recalls.

3. Legislation and standardization at EU- and international level

Legislation

Since the beginning of 2005 a system has been required from food processors for identifying the origin of raw materials and the destination of final products i.e. one step forward and one step backward in the production chain. This was stated in EU regulation 178/2002, which includes the following clear requirements for traceability:

1. The traceability of food, feed, food-producing animals, and any other substance intended to be, or expected to be, incorporated into a food or feed shall be established at all stages of production, processing and distribution.

2. Food and feed business operators shall be able to identify any person from whom they have been supplied with a food, a feed, a food-producing animal, or any substance intended to be, or expected to be, incorporated into a food or feed.

To this end, such operators shall have in place systems and procedures which allow for this information to be made available to the competent authorities on demand.

3. Food and feed business operators shall have in place systems and procedures to identify the other businesses to which their products have been supplied. This information shall be made available to the competent authorities on demand.

4. Food or feed which is placed on the market or is likely to be placed on the market in the Community shall be adequately labelled or identified to facilitate its traceability, through relevant documentation or information in accordance with the relevant requirements of more specific provisions.

The requirement for one step backward – one step forward traceability are similar in the US (Foster, 2006). For food exported to the US, the requirements for documentation and traceability are even more detailed, due to “The Bioterrorism Act of 2002” which came in force on August 12th 2004 (Storøy et al., 2006). In addition to the EU regulation, several countries have enacted specific legislative measures, e.g. in Italy standards for design and development of traceability systems (Regattieri et al., 2007). Most experts believe that it is only a matter of time before process traceability is made explicitly obligatory, as is the case already in Belgium (Madge, 2005). However, although the EU regulation has come in force, the regulatory situation is confusing. There is currently no general legal requirements for the establishment of traceability systems in food chains. The only mandatory traceability systems enforced throughout a complete food chain concerns beef on sale within EU, which must to be traced back to where it originated. Neither the EU regulation nor previously published documents give any precise requirements that would help in fulfilling the requirements (Regattieri et al., 2007).

Since 18.4.2004 the regulation 1829/2003/EU on genetically modified foods and feeds, the regulation 1830/2003/EU on the traceability and labelling of food products made from genetically modified organisms, and the directive 2001/18/EU on the deliberate release of genetically modified organisms into the environment and repealing Council Directive 90/220/EEC, have been applied in EU. Use of genetically modified material in foods and feeds is still subject to permission in EU and the permission is given by The Comission. This material must be able to be traced at its all production steps from the end products to the raw materials (Leminen, 2004).

Legislation in Finland

One of the aims of the Finnish national food law, Food Act 23/2006 is to ensure the traceability of food products. According to this law, food manufacturer must have a system to connect information of received lots to departed lots, with sufficient accuracy with regard to the purpose of the law. Besides the requirements on traceability in EU regulation 178/2002, other regulations have also been set. These include:

- Act on traceability of beef meat (regulations 1760/2000/EU and 1825/2000/EU, Decision of Ministry of Agriculture and Forestry 1203/2001)
- Act on traceability of eggs (Directive 4/2002/EU and Regulations 2295/2003/EU, 2052/2003/EU)
- Act on traceability of genetically modified food components (Regulation 1830/2003/EU)
- Act on traceability of organically-grown food products (Regulation 2092/91/EU, Ministry of Agriculture and Forestry 346/2000, changed with Regulation 127/2001)
- Regulation on materials and articles intended to come into contact with food (1935/2004/EU).

Besides the European legislation there are several national regulations and guidelines for application of the regulations on packaging labelling of beef and other food products in Finland (EVIRA, 2007b).

Standardization

As the implementation of traceability systems is greatly voluntary, some pioneer companies have been developing their own traceability systems primarily to reduce business risk, but they have been lacking standards, which has resulted in very differentiated systems. As a consequence these systems have been producing different economical results (Regattieri et al., 2007).

International organization for standardization (ISO) introduced in the beginning of 2006 two new standards that define the requirements for a traceability system within a food safety management system and the data that needs to be retained (ISO 22000:2005 – Food safety management systems – requirements, and ISO 22519 – traceability system in the agriculture food chain – general principles for design and development) (Folinas et al., 2006). ISO's technical comittee 34 Food Products is also establishing a standard ISO/FDIS 22005: "Traceability in the feed and food chain – General principles and basic requirements for system design and implementation", which is currently at approval stage (http://www.iso.org). International organisation Codex Alimentarius has dealt with questions on traceability during the last years. It uses the definition of international standardization organisation (ISO) for traceability: ISO 8402:1994 or ISO:2000 series of Quality Management Standards. Codex Alimentarius and European committee for Standardization (CEN) have established the following standards:

- Alimentarius CAC/GL 60-2006 Principles for Traceability / Product Tracing as a Tool Within a Food Inspection and Certification System
- CWA 14659:2003 Traceability of fishery products – Specification of the information to be recorded in farmed fish distribution chains
- CWA 14660:2003 Traceability of fishery products – Specification on the information to be recorded in captured fish distribution chains
- CEN/SS C01 – Food Products prEN ISO 22005 Traceability in the feed and food chain – General principles and basic requirements for system design and implementation (ISO/FDIS 22005:2007).

GS1, a global not-for-profit organisation, has recently published a global traceability standard, the GS1 Traceability standard. GS1 is dedicated to the design and implementation of global standards, technologies and solutions to improve efficiency and visibility in supply and demand chains and is formed as a result of the merger of EAN International and the Uniform Code Council. The standard defines the minimum requirements and business rules to be followed when designing and implementing a traceability system. It divides this process to five sub-processes:

1. "Plan and Organize" determines how to assign, collect, share and keep traceability data.
2. "Align Master Data" determines how to assign identifications to the parties, physical locations, trade items and assets as well as how to exchange master data with trading partners.

3. ”Record Traceability Data” determines how to assign, apply and store data during the physical flow.
4. “Request Trace” sub-process determines how to initiate and respond to a traceability request and
5. “Use information” enables the use of the previous processes to take appropriate action to meet legal and business requirements.

(Mitic, 2006)

GS1 Traceability Standard is based on existing business practices and there is no need to purchase, create or integrate new systems. It uses a common language, the GS1 System of identification and bar coding, GS1 EANCOM® and GS1 XML messaging. GS1 Standard has a global approach as it is used in over 150 countries around the world. The standard is thorough, covering the fundamentals of traceability. It is also flexible, recognizing that circumstances vary within and between sectors and individual retailers and manufacturers (Foster, 2006).

4. Traceability systems

4.1 Characteristics and requirements of systems

Traceability systems are constructions, which enable traceability. There are six essential elements of traceability constituting an integrated agricultural and food supply chain traceability system (Opara, 2003). These elements are:

1. **Product traceability** – defines the physical location of a product at any stage in the supply chain.
2. **Process traceability** – ascertains the type of activities that have affected the product during the growing and post harvest operations (what, where and when).
3. **Genetic traceability** – determines the genetic composition of the product and includes information on the type and origin (source, supplier).
4. **Inputs traceability** – determines type and origin (source, supplier) of inputs, e.g. fertilizers, additives used for preservation or transformation of the raw materials into processed products.
5. **Disease and pest traceability** – traces the epidemiology of microbiological hazards and pests, which may contaminate food products.
6. **Measurement traceability** – relates individual measurement results through calibrations to reference standards and assures the quality of measurements by observing various factors which may have impact on results (such as environmental factors, operator etc.).

A good identification system for a product must be unique, legible, resistant to damage, easy to ’capture’ for records, tamper-proof and incapable of reuse (Opara and Mazaud, 2001). It must fulfil the requirements of legislation. By means of a traceability system, unnecessary package markings could be avoided, e.g. ”may contain traces of nuts”. Effective traceability is the result of structured data acquisition, that the acquired data is accessible and searchable, and that it can be presented in an understandable way with reports, trends and descriptions of production flows within seconds of searching. It should be remembered that traceability in the whole food chain is as strong as its weakest part (Riihikoski et al., 2005).

Basic requirement for traceability is, that products are properly labelled (with e.g, bar code) (Opara and Mazaud, 2001). The product flow and a basic traceability based on bar codes is presented in Figure 1 on a general level.

In the report by Finnish Food and Drink Industries' Federation and the Finnish Grocery Trade Association on food traceability in Finland (ETL/PTY, 2005) are described generalized traceability systems for the food industry and retail. According to the report the handling of traceability information at primary production, food production, distribution centers and transport consists of the following essential components in each step:

1. **Lot identification** – lot information
2. **Reading and handling of the information** – automatic or manual
3. **Storage of information** – electronic, papers; content of lot information
4. **Transformation of the information to customers** – electronic, papers; content of lot information.

(ETL/PTY, 2005)

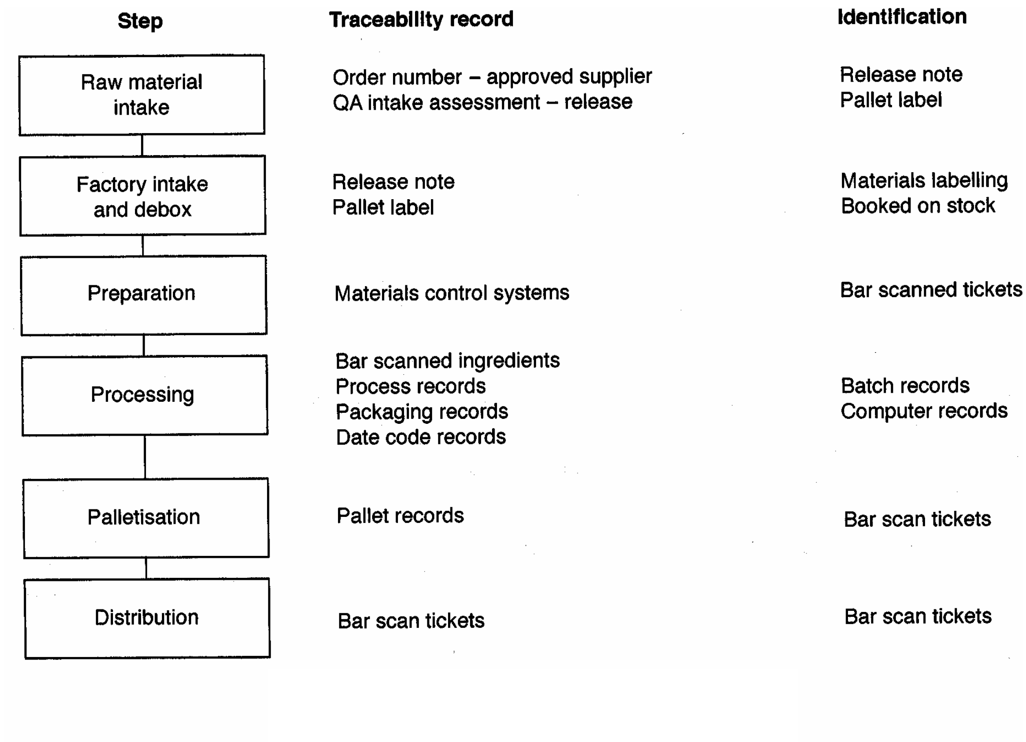

Figure 1. Traceability of a product in food processing chain (Morrison, 2003).
QA = quality assurance.

Problem with traceability systems is often, that part of the important information is still stored as papers, not electronically. Documents which are on paper only, are insufficient in crisis situation, are often unclear, missing or inaccurate and are not available at many places at the same time (Deasy, 2001). The systems are also often not completely continuous, e.g. traceability of grain breaks at most farms into storage silo (Anon. 2004b).

4.2 Building a traceability system

Regattieri et al. (2007) described a general framework, based on product identification, data to trace, product routing and traceability tools, for product traceability (Table 2). They suggested this framework to form a starting and reference point for the design phase of a food supply chain. The "Product identification" is fundamental part containing product characteristics. "Data to trace" contains characteristics of the information that the system must manage. A product traceability system must take the production process into account and record product life along the supply chain and through both production activities and movement or storage activities ("Product routing"). The data accuracy and reliability required and also cost guide the selection of the traceability's tools.

Table 2. Framework for product traceability (Regattieri et al., 2007).

Product identification	Data to trace	Product routing	Traceability's tools
– dimensions	– number	– production cycle	– compatibility vs. process
– volume	– typology	• activities	– no. of data readings
– weight	– degree of detail	• lead times	– no. of data writings
– surface conditions	– dynamism	• equipments	– degree of automation
– shortness	– data storage requirements	• manual operations	– data accuracy
– perishability	– confidentiality and publicity	• automatic operations	– data reliability
– packaging	– checks and alarms	• movement systems	– company's knowledge
– cost		• storage systems	– cost of system
– life cycle length			
– bill of material			
– structure			

According to Opara and Mazaud (2001), when starting to build a traceability system, it should be considered, what and why is traced. This should be done by performing a detailed hazard or risk analysis and this task could be included into hazard identification part of HACCP-system. In building a traceability system, the following roadmap can be followed (Opara and Mazaud, 2001):

1. Draw a flow chart of the product supply chain, from farm to plate and include sources of material inputs (e.g. ingredients).
2. Name a responsible person who is also responsible of product quality.
3. Conduct a hazard analysis of the supply chain using HACCP principles.
4. Document the reasons for embarking on the traceability of the products.

5. Write down which data must be recorded and traced back at each step in the supply chain.
6. Specify the responsible persons for collecting and recording the data.
7. Develop a unique labelling system or bar code for easy identification of the product.
8. Document how the trace-back is to be carried out (include a diagram).
9. Test, validate and verify the traceability system.
10. Document all decisions and actions.

"Good Traceability Practice" guide and TRACE-project

In Europe large projects on development and harmonization of traceability have been and are currently running (See http://www.trace.eu.org/library/links.php). These projects include e.g. TRACE, a five-year project ending 2009, which aims to improve the health and well-being of European citizens by delivering improved traceability of food products. TRACE will develop cost effective analytical methods and develop a "Good Traceability Practice" guide for food production systems (http://www.trace.eu.org) by the end of the project. According to a hearing version of this guideline, it will contain definitions and fundamentals of traceability. It will present the TraceFood Framework, the main objective being enabling traceability through a complete supply chain, preferably in electronic form. The origin and first application was in the seafood sector with the TraceFish standards and recommendations (www.tracefish.org). The guide will include instructions for implementation of process traceability and chain traceability (supplier and customer traceability) according to TraceFood principles as well as a guide how to implement TraceCore^{XML}, the electronic language used for coding and exchanging information about food products. TraceCore^{XML} is based on the concept of request and response messaging, where the communication is reduced to a minimum and is a very costly form of data exchange. The concept of **traceable units** is a key concept in chain traceability in general, and in the TraceFood standards in particular. **A Trade Unit (TU)** is defined as "any item upon which there is a need to retrieve predefined information and that may be priced, or ordered, or invoiced at any point in any supply chain. **A logistic Unit (LU)** is defined as "an item of any composition established for transport and/or storage that needs to be managed through the supply chain". **A production batch** is the traceable unit that raw materials and ingredients go into before they are transformed into products placed in new Trade Units and Logistic units (Storøy et al., 2006).

According to Storøy et al. (2006) a complete infrastructure for chain traceability should cover the following parts:

- Unique numbering of traceable units
- A harmonized vocabulary (glossary)

- Standard rules for electronic coding and transmitting of relevant data
- A common practice for measuring and capture of traceability data
- Good Traceability Guidelines.

4.3 Examples of traceability systems

GS1 has implementation guides of the GS1 Traceability Standard for beef, fresh produce, fish, bananas and wine (www.gs1.org).

Meat

Traceability systems are developing at different rate but in many countries they have been first instituted in the beef supply chain. Most exporting countries have been adopting some kind of traceability system in response to mandatory systems introduced in important importing countries such as Japan and EU. These countries have the most precise traceability systems. Australia and Brazil, where the beef export is important, as well as Argentina and Canada have recently adopted mandatory traceability systems but not as extensive as those in EU and Japan. In 2005 US had not adopted mandatory traceability systems, however several voluntary systems have been operating and new systems being developed. Animal traceability is completely dependent upon successful identification of individual animals or groups/lots of animals first, and origin-and-movement records thereafter (Smith et al., 2005).

4.4 Teleinformatic implementation of traceability systems

General

One of the major weaknesses of the agricultural industry is the information gap among entities in the supply chains originated either by unwillingness to share information or by inability to do so due to lack of sufficient means and sophisticated technologies that allow efficient and transparent information flow. An integrated traceability system must be able to file and communicate information regarding product quality and origin and consumer safety. The main features are the following:

- adequate filtration of information
- information extracting from databases that already exist for supporting food quality and safety standards (HACCP, ISO, GMP)
- harmonization with international codification standards EAN-UCC
- harmonization with internet standards and up to date technologies.

These features make the framework simple in use and enable communicating information through commonly accessible means such as the internet, e-mail, and cell phones (Folinas et al., 2006).

Information Technology (IT) seems to have the potential of revolutionizing product traceability. In practice the tools of traceability are labels containing alphanumerical codes (a sequence of numbers and letters of various sizes, generally “owners” codes), bar codes and automatic radio frequency identification (RFID), of which bar codes seem to be the most frequently used systems currently. The data accuracy and reliability required as well as cost can guide the selection of the traceability tool (Regattieri et al., 2007).

Two types of traceability information flow models in the supply chain can be identified. Most of the food businesses follow the **"one step up-one step down" information flow model**, which is also suggested by EU Regulation 178/2002. In cases when it is necessary for the consumer to have immediate access to information related to all stages of production and treatment (e.g. for organic products or fresh fish or meat for which particular treatment methods have been followed), **aggregated information flow model** is followed. Traceability data can be distinguished to **static** and **dynamic**. Static data refer to product features that cannot change, e.g. country of origin or size. Dynamic data refers to dynamic features that change over time while moving in the supply chain, e.g. lot/batch number or order ID. Traceability data can also be distinguished to **mandatory** and **optional** (Folinas et al., 2006).

Programs

Many companies have implemented their own traceability systems by effectively automating paper-based traceability records. Others have extended their existing enterprise software applications and a growing number of users of the SAP ERP system have also adopted the SAP traceability module. Products have emerged that combine traceability with other record-keeping and control functions. Programs used for controlling and following the process can also simultaneously be used for collecting and maintaining the traceability data. E.g. a system known as FoodReg provides operational execution of the HACCP plan at the same time as ensuring product and process traceability. This and another system called TraceTracker integrate process and chain traceability (Madge, 2005). An example of a traceability program is Food Trak, which has been developed by a private company in Great-Britain. By means of this program, the retailer can see the history of a specific product already from the beginning of primary production of raw materials. Internet is used as a tool in transmitting the data. Problematic are overlappings between these programs and utilization of the data between the programs. (Pettitt, 2001).

A practical risk quantification model, HYGRAM®, has been developed for small and medium-sized enterprises to analyze and quantify risks of different processes, and to compare them. The model makes the user familiar with the HACCP principles by software-assisted guidance through the procedure, connecting special microbiological hazards, good hygiene practice, and other prerequisite programs to HACCP® (Tuominen et al., 2003; http://hygram.vtt.fi/). In a new, recently launched second version (Sunila-Elosuo et al., 2007), it is also possible to make a description of the traceability system used in the company and to assess the risks caused by gaps in traceability at different processing steps.

New solutions

Currently problem with attaching the traceability data to product is, that standard codes exist, but are rarely in use. The candidate codes are GTIN+ (GS1 code, extension to the existing GTIN product type code (GTIN = Global Trade Item Number), in practice carried on a GS1 128 bar code) or ePC (new electronic product code, in practice carried on a RFID-chip, RFID = Radio frequency identification). Currently when the information is sent by putting it on the label and in accompanying documentation, while a better system would be keying the data to the unique identifier and sending an electronic message beforehand in standard form (XML). The weakest link of the chain currently is the receiving of the information, as it may be in the form which is meaningful to the sending company only. An information loss of 80–95% may occur at this step (Storøy et al., 2006).

Folinas et al. (2006) introduced a generic framework (architecture) of traceability data management to act as guideline for all entities/food business operators involved. The traceability system is based on the implementation of XML (eXtensible Markup Language) technology. In the first stage, the necessary traceability data are identified and categorized. In the second stage, the selected data are transformed and inserted into a six-element generic framework/model, using PML (Physical Markup Language), which is a standard technology of XML. The main feature of this framework is the simplicity in use and the ability of communicating information through commonly accessible means such as internet, e-mail and cell phones. XML is data-centric, unlike document-centric typed or electronic reports as pdf's or html pages, allowing information to be structured in a way that is readily accessible for the final users. It is designed with internet in mind. Physical Markup Language (PML) is an XML-based technology which is proposed to be the common language for describing physical objects/products in the examined supply chains.

1. The first element presents static and inherent data of the product.
2. The second element presents the process properties/characteristics of the product in a node hierarchial syntax, which is simply a nested collection of node elements as product moves across the various levels of the supply chain. The PML node structure captures the organization of physical objects.
3. The third element describes all the corresponding information of the tracing process recording the movement history of a product, as it moves through the supply chain. Ownership, roles and responsibilities of each business entity that own or manage a product in the supply chain, are the information that is provided by the fourth element.
4. The fourth element provides the information on ownership, roles and responsibilities of every business entity (people, companies or organizations) that own or manage a product in the supply chain.
5. Fifth element provides the properties of means of production or manufacturing that are being used on the product.
6. The sixth element includes information about the data measurement about location of the product in the supply chain, time/duration measurements and the measurement units of mass, temperature etc.

These elements provide an integrated description of a product using PML. These data can be stored and processed using RFID technology.

4.5 EAN and other bar code systems used in traceability

General

In consequence of development of data processing methods, it has become unavoidable to individualize products with a product code, to be able to e.g. develop management routines in production and delivery. Product code has usually been defined for the needs of a specific company, and the length, construction and input have consequently varied. In the delivery chain a common product code, when applied in all documents of exchange of goods, spares work due to avoidance of recoding and data can be transferred directly in machine coded form (Anon., 2004c).

There are several regulations for recognizing and numbering single products. EAN Numbering Organisations EAN.UCC system was developed to provide a simple standardized system for recognizing units in national and international food chains (Anon., 2004a). EAN comes from the words "European Article Numbering". With this code a product can unambiguitely be recognized at retail at different stages of delivery chain. This "social security number" consists of two parts, number individualizing the product and machine readable bar code corresponding the number. EAN-code was originally directed to daily consumer goods, but it can be used in other goods as well. Mainly the manufacturer or packer gives product numbers according to EAN-system (Anon., 2004c).

The decision on use of UPC-code (Uniform Product Code) and related optically readable symbolic marking of the code in product packing in the US affected so, that in Europe a need was seen for similar system so, that e.g. with a prefix the continent, country or other area could be identified. An offical organization, the **European Article Numbering Association (EAN)** was launched. After enlargement outside Europe, the name was changed to EAN International, consisting currently of approx. 100 countries (Anon., 2004c) and when this organisation and **the Uniform Code Council (UCC)** merged, **GS1** was launched (Mitic, 2006).

EAN-UCC codes

In Europe usually a 13-digit EAN-code is used (Figure 2) and in the US and Canada a 12-digit UPC-code is used (UPC-A). A marking code used for packed products in delivery packages is EAN-128, which can be used when additional information is needed for packages (e.g. best-before date/measuring data/lot- and serial numbers etc.) and which is consequently a more flexible system than EAN-13 (Morrison, 2003). EAN-14 (DUN-code) is a transport packaging code based on consumer code EAN-13 (Anon., 2004d).

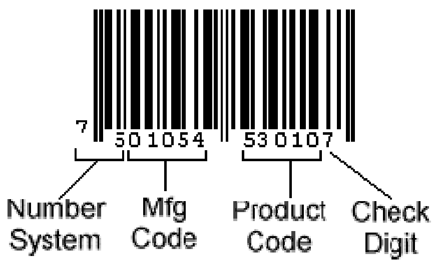

Figure 2. Code EAN-13 (Anon., 2004e).

In electronic tracking and tracing systems, EAN-UCC (2002) is universally accepted as an identification and communication system which uniquely identifies products, locations, services, and assets and also includes a series of standard data structures known as Application Identifiers (AIs), which allow secondary information about a product such as batch, expiry and lot number to be encoded. The system consists of three components:

1. **Identification numbers** – used to identify a product, location, logistic unit, service or asset.
2. **Data carriers** – the barcodes or RFID Tags used to represent these numbers.

3. **Electronic messages** – the means of connecting the physical flow of goods with the electronic flow of information.

(Schwägele, 2005)

GS1 has, together with industry, retail, transport companies and GS1 member organizations developed a standardized bar code label, European Logistic Label (ELL). Logistic units consist of products, which have been packed for transport and delivery. By using GS1 bar code label, the units can be recognized uniquely. GS1 bar code label contains three fields; one for informal information, one for information of the logistic unit in alphanumerical form and one for information in bar code form. The only obligatory requirement is, that each logistic unit to be recognizable by a unique serial number, Serial Shipping Container Code (SSCC) (Anon. 2007a).

Other bar codes

So called Interleaved 2/5 code is generally used in the industry. With this code, only numbers (0–9) can be coded. What makes the use of this code a little difficult, is that one code marking corresponds two numbers in the code (00-->99) (Anon., 2004d; Anon. 2007c).

There has been developed a two dimensional bar code (2D, PDF). Their advantages compared to 1D linear bar codes are smaller size and larger capacity for data (Anon. 2007c).

Even though the traditional bar codes are mostly used systems in marking the products, newer technologies, enabling more data to be included, are becoming more popular. Disadvantage in using barcodes is, that they must be red in a certain position which requires human intervention (thus time and effort) and there is a possibility for error and inefficiency. It is also easily damaged (Regattieri et al., 2007). Another new method for product identification, radio frequency identification (RFID)-system, is described in the following paragraph.

4.6 Radio frequency identification (RFID) *(Kaarina Aarnisalo and Kaarle Jaakkola, VTT)*

In radio frequency identification, a transponder or ‘a tag’ is attached to a product. The tag consists of two parts: a microchip with memory and other electronics and an antenna that enables the electromagnetic coupling between the microchip and a reader device. The tag memory is typically used for storing product information; either direct information in readable format or a product code, using which the information can be retrieved from a database. Most of today's tags have reprogrammable memory, so that the memory content can be changed or added in various parts of the product chain. Although being commonly referred to as 'a reader' reprogramming is made wirelessly using the same device. To secure the tag data from unauthorized reprogramming, parts of the tag memory can be locked or protected with a password. The radio waves are able to penetrate the normally used packaging materials such as paper, cardboard or plastic and thus any line of sight between the tag and the reader is not required. In the products, no identification code (e.g. bar code) is needed to be shown.

RFID systems reduce labor costs as no manual scanning operations are required. RFID reader can scan numerous tags at the same time. Identification is very simple and rapid, and additionally more effective resulting in reduction of profit losses caused by e.g. employee and customer theft, vendor fraud or administrative error. For especially food industry, RFID provides improved management of perishable food items (continuous monitoring of item routing reduces waste and improves customer service levels); Improved tracking and tracing of quality problems by using individual product codes; as well as improved management of product recalls (Regattieri et al., 2007). RFID Tag is also more durable and enables reading in e.g. dirty and cold conditions, which may in case of bar codes be almost impossible. Its larger memory enables individual recognition of products (Kettula, 2005).

The main limitation of RFID is the costs of tags being approx. 0.08–10€ each. (Madge, 2005; Regattieri et al., 2007) For a low-price food product the cost may be too high. There has been a great lack of standardization for all technical systems (numerical, or bar codes or TAGs), but the situation has been substantially improved. In the end of 2004 a ISO-standard 18000-6C came in force for UHF tags used in RFID technology. The standard is known by name EPC-Gen2. This increased the use and sale of UHF tags quickly followed by reduction of price to approx. 8 c. For inductive Tags using 13,56 MHz frequencies, the standards are much older, they were just included in to standard 18000-3 in 2003.

The use of this method will increase substantially in the US in near future. IDC-research center has predicted, that the use and sell of RFID-tags and reading devices will grow from 91.5 million dollars in 2003 to almost 1.3 milliard dollars by 2008. The research applied to US market, but similar trend is to be expected in Europe as well (Anon., 2004f). Wal-Mart, the largest volume retailer in the US, required its top 100 suppliers to ship the goods to it with radio-tagging technology (RFID), by the beginning of 2005. Despite the expenses and difficulties, 98 out of 100 of the suppliers managed to fulfil the requirement; only few if any can afford to ignore RFID. Other major retailers in US and Europe have been following (Smith et al., 2005). In Finland e.g. brewery Sinebrychoff has tested use of RFID tags in their plastic beer baskets. A major advantage was better recognition of single beer baskets enabling more accurate withdrawals. Logistics were clearly enhanced as the recognition of baskets was faster. Recognition reliability was 99.87% for 13.56MHz RFID-Tags (Nurminen, 2005).

EPCglobal is a nonprofit organisation which develops and implements business and technologic standards for the electronic product code. It aims at establishing an EPCglobal network and promoting the expansion of standardised, RFID-supported processes. EPCglobal was founded in 2003 by the international organisations for global standards.

4.7 New technologies for improvement of the traceability chain *(Kaarina Aarnisalo and Kaarle Jaakkola, VTT)*

In the near future, RFID-based systems will be used, in addition to tracking the goods, also to monitor the quality of the products and the supply chain itself. RFID-based remote sensing will enable e.g. the online spoilage detection of vacuum-packed food products and the continuity of cold chain.

As an alternative to conventional barcodes and RFID, new electrically readable coding techniques have also been developed. These electrically readable codes are cheaper than RFID tags but still have some major benefits of RFID technology. Electrically readable code can be attached to a product using conventional printing techniques combined with special inks. Electrical code itself can be invisible and is not as sensitive to dirt and other visible disturbances as a conventional barcode is. It is also possible to embed some sensor properties into these codes as with RFID tags. Read range and flexibility of the system is not comparable with RFID, though.

Innovative technology utilizes microscopic, edible bar codes that can be applied directly onto foods to make them more secure, safer, and also less expensive by replacing “one step forward, one step back” traceability protocols with reach-through and real-time documentation of the origin and subsequent history of a product. E.g. polylactic acid or celluloses can be used for producing food markers by extrusion. The size and concentration of these markers must be such that they have no detectable effect on the tare or the texture of the marked product. The information has to be encoded on the surface of a fairly rigid microscopic particle and the particle attached to food by either (1) electrostatic attraction, (2) use of wetting agents, proteins, or lipids as adhesives, or (3) mixing the particles into a material that is subsequently mixed into or applied to a food. Generally binary codes are scored and embedded onto and within a fibre. When placed on/ in food, the markers by definition become Food Additives and must be safe for consumer at maximum level at which a consumer would be exposed. In some cases, it may be useful to use a marker that dissolves after a particular amount of time, or after it has been heated to a particular temperature (Nightingale and Christens-Barry, 2005).

5. Traceability in Finnish food industry

5.1 Traceability systems

In Finland a thorough report on food traceability by the Finnish Food and Drink Industries' Federation and the Finnish Grocery Trade Association was finished in the beginning of 2005. In this report the systems used, example systems for different food areas, legislation, the functionality of traceability and the lacks and further development needs and steps were described for the industry and retail. The “starting level of traceability”, presented in the report, already fulfils the requirements of legislation. Many companies were, already at the time when the report was made, on the “second starting level” of development, where automatic reading and writing of information in possible; Product- and customer information are recorded into data systems and the products are labelled according to EAN Finland guidelines with bar codes. Lot information is mainly based on daily production, except for most risky raw materials, where lot information can be connected to product lots based on best-before-dates (ETL/PTY, 2005).

In the three further “development steps of traceability” presented in the report the traceability systems will be improved by more accurate lot information with regard to use of raw materials, packing materials and products. Lot information should be recorded in to EAN 128 (SSCC) identifiers which can be connected to customer information. The ultimate aim is, that producer sends the information on products beforehand in electronic format (EDI/DESADV) to customer, who identifies and records the information from products with new technological solutions, e.g. RFID-technique, and no paper records are needed. The timetable of implementation of the development steps depends from the company, but the report provides this model for aims of development (ETL/PTY, 2005).

The Finnish Food and Drink Industries' Federation and the Finnish Grocery Trade Association carried out in 2004 an investigation on how the product traceability between industrial companies and retail could be further developed to serve better possible withdrawals. A wholesome approach, integration of information of each operation has been of interest and thus traceability culminates to examination of compatibility of company’s data management systems and data systems. Traceability systems are a part of larger systems, by which the companies manage the manufacturing processes and the supply- and delivery chains. In all of the companies, data systems for storage and handling of traceability data were in use. The systems were, however, not usually built thinking of traceability needs. Because of this, different applications and updates were added to them (Riihikoski et al., 2005).

In all companies the supplier traceability was working. The lots and suppliers were identified and recorded at raw material receiving. In some of the companies lot information was recorded by automatic equipment for data collection and in some of the companies, manually by writing. The EU regulation 178/2002 does not require process traceability, but it recommends the companies to develop it as it improves the accuracy of withdrawals. As a lot identification, usually date of production or use-by date was used. This information can be expanded with time of packaging, information on packaging line and number of shift. In addition to the date information a letter code is used, which changes if a critical raw material changes (Riihikoski et al., 2005).

Customer traceability was working in all of the companies. It was known and recorded, to which following point of delivery chain the products were delivered. All deliveries from storage to retail delivery centers were identified. In many companies, however, the units delivered are pallets, which may contain smaller delivery units, one production lot may then be divided to several pallets. It was not always known, which specific production lot was delivered to specific point at retail (shops, kiosks etc.) (Riihikoski et al., 2005).

5.2 Current state of art in Finland *(Seppo Heiskanen, ETL)*

Implications by the new legislation

When the requirement of traceability was established in General Food Law (178/2002/EU) as well as in Finnish food law (2372006), it was a new topic. Following, threats were connected to implemention. In reality, old operation modes had already fulfilled the requirements in many cases. Cross-ruled paper worked as well as earlier. The old data systems worked also in most cases. Certainly data systems can and should be developed so, that they serve better and faster than earlier systems also the needs of traceability.

It is required in the legislation, that a company knows, from whom it has purchased raw material lots and to whom it will sell products. Companies are usually able to collect the supplier or customer information very fast. Each company has already, based on book keeping law, follow-up information on raw materials used for production and their suppliers as well as products and customers. This information must be stored at least five years according to the legislation. This same time is applied as general guide in storage of information related to traceability. The delivery times of the raw materials and products can also be shown from the book keeping at least for some time. For easily spoiling food products, meant for short time storage, six months after best-by-date has been considered in legislation sufficient time for storing the information.

Process traceability has been under development in the companies. According to the Food Law, the companies must know with sufficient accuracy, which raw material, purchased at a certain time point, has been used for a specific product lot. Purchased packed raw materials and products at retail have lot markings. In case of raw materials bought from and stored in tanks and silos, lot markings are replaced by documents related to delivery. The companies generally follow the first-in first-out (FIFO) principle. By this way, with help of their records on raw material storage and processing and lot markings of products, they can usually find out with sufficient accuracy, which purchased raw material lot has been used in producing a specific product lot.

In many companies the data system used for control of production, supply and follow-up of storage, has been developed so, that the start-up of a new raw material lot is always registered. This enables consideration of start-up of new lot in product lot number. In some companies similar records have been and still are kept also manually with markings made into note books or other documents.

The development of process control systems and process traceability are closely connected in companies. What is sufficient accuracy today, may not be sufficient after 10 years.

The aim is to increase safety and to minimize costs in problematic situations

The innermost aim of traceability requirement is to increase product safety and to specify and quicken possible product withdrawals. The product lot markings have already served this purpose. It has been possible to target withdrawal to a specific production lot / production lots. If the reason for withdrawal has been a specific raw material lot, timing of production, or a specific production line, it has been possible to implement the action within a reasonable time period and keep it fairly limited, based on storage, production and book keeping on sales.

In connection with the set up of the General Food Law in EU, there was a discussion about how long time period is acceptable for implementation of a withdrawal. The conclusion was, that a company must be able to hand over to authorities the information concerning the supplier and customer as well as the delivery dates immediately. For providing additional information, such as proving internal traceability (production/product- lot connection), a time period that is needed for the company to collect the information within a reasonable time frame, was considered sufficient.

By means of new data management systems a company can, within a few minutes, trace product lots where a specific raw material has been used and customers, to whom products have been delivered. As Finnish Food and Drink Industries' Federation it sees, several Finnish food companies are already at this point. Best is the situation at large and business-to business companies. In the guideline by the EU Comission, all food industry operators are encouraged to develop their activities for improving the traceability systems to be as fast as possible.

In addition to control of own processes, also customer traceability is being developed by the industry

The Finnish Food and Drink Industries' Federation and the Finnish Grocery Trade Association carried out in 2004 an investigation on how the product traceability between industrial companies and retail could be further developed to serve better possible withdrawals. As an essential point came out the informing of the lot numbers of products in a delivery from the industry to retail. By this way both the industrial company and retail would immediately know if the lot in question has been delivered to them.

According to a follow-up investigation made by the Finnish Food and Drink Industries' Federation during 2006, already over 40 % of the companies included the lot numbers of products in delivery to the paper delivery documents. In the delivery information in electrical form, the lot numbers were given in already 60 % of all deliveries. As respondents in this investigation were most of all large companies, the results are expected to be more positive than they actually are. It does, however, show that more and more the possible withdrawal can be implemented very fast and accurately.

Further development is constant and considered

The requirements of legislation are already being fulfilled by the industry. However, further development of traceability is supported by the requirements from the customers during the next few years as well as requirements for increasing efficiency of processes. The aim is, that all lots and pallets at retail have the information according to SSCC-code both alphanumerically and by bar codes. Respective information are included to electronically sent delivery messages.

5.3 Examples of traceability systems in Finland

Meat

Meat must be traceable from the selling point to the animal of origin. In Figure 3 is presented the traceability system of meat in Finland. Records begin from the farm, where each calf must be marked with an earmark. In the slaughter house a label is produced during classification, in which the information of the animal is stated (origin, birth identification, date of slaughter and no. of slaughter house) This label follows the carcass to the cutting room. In the cutting and packaging step of the meat the birth identifications of the animals are combined to a lot identification, which is on the consumer package (Finfood Lihatiedotus, 2004).

Barley

For barley, traceability from ”seed to seed” is impossible, as during production in various steps barley lots are collected as bigger amounts or divided smaller. All actions during the chain should be thoroughly recorded and documented and the information be easily accessed (Kotaviita, 2004). The systematic traceability of domestic grain has, however, been developed. ProAgria, association of agricultural centers, has developed national quality data bank, where the aim is, that retail and industry would be able to see, when necessary, the cultivation information of the lots they have bought, e.g. from which cultivation sector the grain originates (Anon., 2004b). The retail supplying agricultural products, and the processing industry gets important information to quality control of raw materials. In marketing of the products, clear benefits can already be seen of the ability to be able to accurately show the origin and manufacturing method, when needed (Anon., 2007b).

Vegetable oil based unripened cheese spread and oatmeal (Kaarina Aarnisalo VTT and Eva Landor, Ravintoraisio Plc.)

In the national project ”Risk assessment and traceability in production safety management” during 2003–2007 in Finland, traceability systems of vegetable oil based unripened cheese spread and oatmeal were analyzed. The company produces normal oatmeal and glutein-free oat meal. The characteristics of traceability systems of these products are described in Appendix 1.

In both systems the legislative requirements are fulfilled, traceability one step backward and one step forward is realized. In the case of oat, the traceability is, however, ultimately at seasonal level, as the grain lots are mixed in the silos. Problematic in traceability of normal oat is the collection of different grain lots into raw material silos and the following mixing of lots; as also production of various oat meals on same production lines, which leads to risk of mixing of grains. In the spread product, challenging for traceability is the large amount of components and their transfer to different product lots. Essential factor in case of both of these products is the correctness of packaging markings (especially in product packages, but also in cartons and pallets), as with help of this information the withdrawals are performed when needed.

Already a few whey or barley seeds contaminate one kg of oat so, that the most sensitive persons with celiac disease may suffer from it. E.g. one whey seed in one kg of oat causes the exceeding of glutein limit (20 ppm) of naturally glutein-free products. Thus growing of ”pure” glutein-free oat requires special actions. Cultivation is done at contract farms and by using very pure oat seeds. In neighbouring fields no other grain is grown. The purity is checked at farm during the growing season. Foreign grains are weed from the field and are not handled at the farm. The production chain of pure oat from seeds to products contains many analyses and contamination has to be prevented at each production step (Figure 4) (Raisio Oyj, 2007).

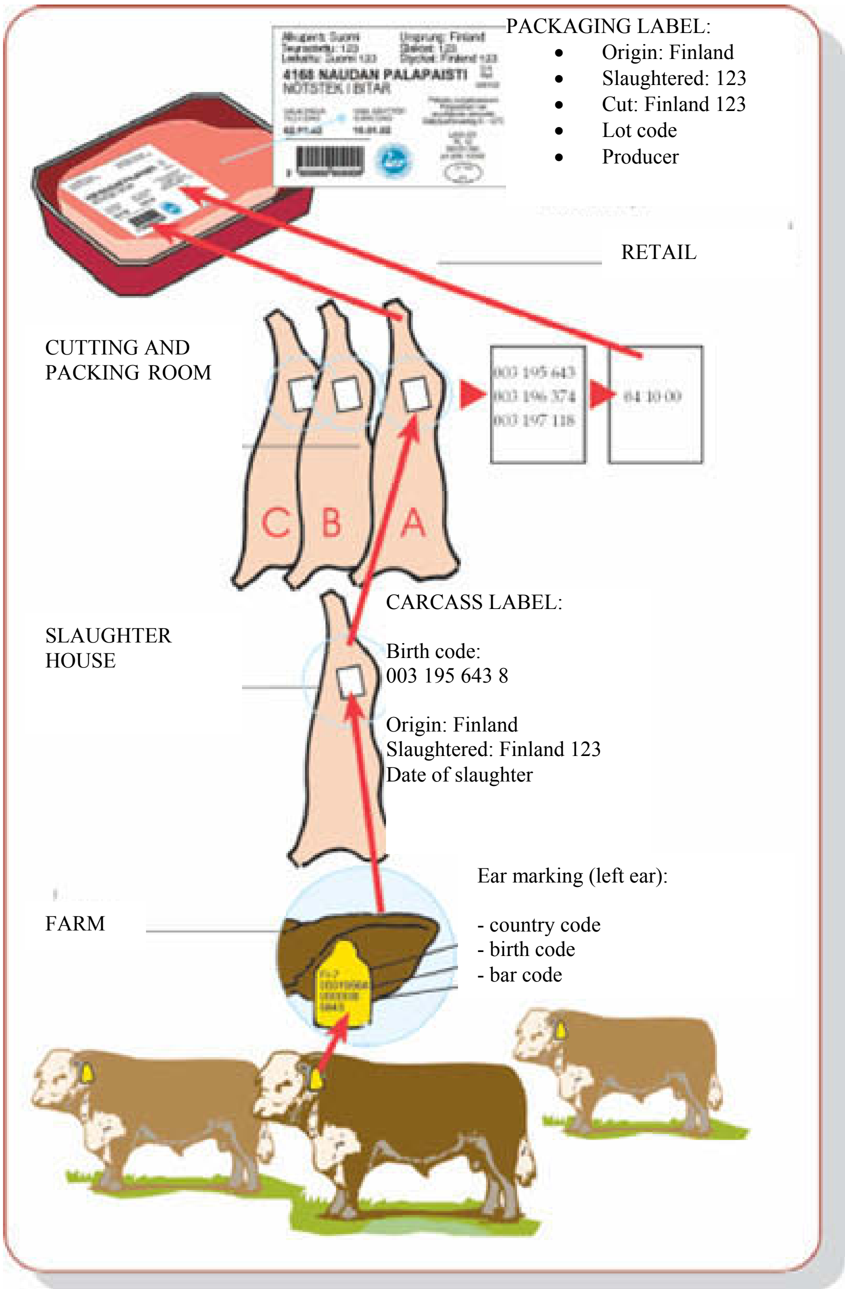

Figure 3. Traceability system used for meat in Finland (Finfood Lihatiedotus, 2004).

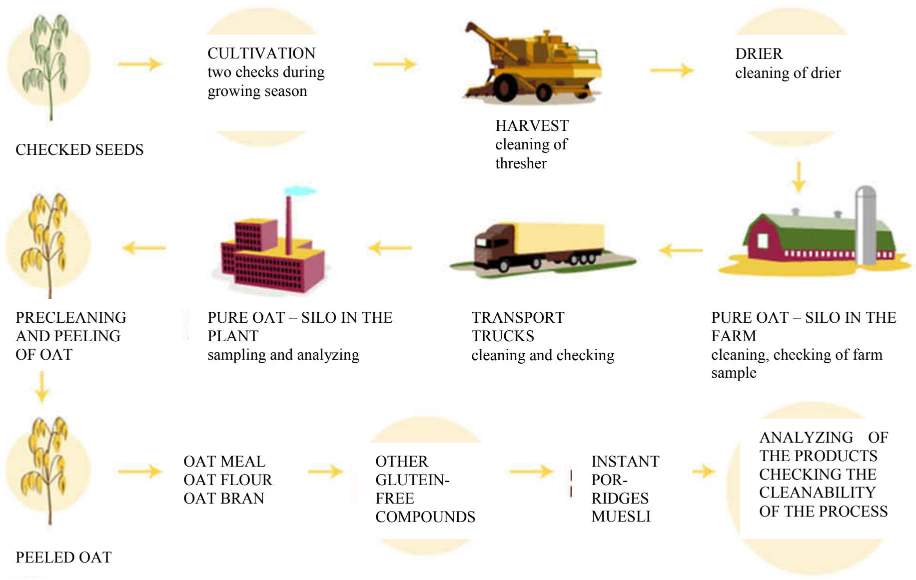

Figure 4. Production chain of pure oat (Raisio Oyj, 2007).

Eggs

Information on all poultry houses producing eggs for retail are collected and registered in Finland. This register is maintained by information service center of Ministry of Agriculture and Forestry (TIKE). This register is the basis for labelling of the eggs. From the beginning of 2004 the origin of eggs can be traced with help of labelling on the packing or egg shell. To the eggs going to retail, a code indicating the production method, country of origin and producer number must be labelled. The regulations are valid in all EU-countries. Each egg going to retail is labelled with identification code of nationality and place of packing. The identification code of poultry house is explained in the package. In the package must be stated the number of eggs, size and quality class (A), best-before-date, production method and average weight. The information of packaging place and that the products must be stored as cooled, are also labelled (Finfood, 2004).

6. Analytical methods used in traceability investigations

6.1 General

In traceability investigations often the origin of plant or animal based raw material is sought, e.g. if genetically modified organisms (GMO's) have been used as raw materials or if product contains components hazardous for consumer health or e.g. raw materials of wrong quality (e.g. wrong kind of grain). Modern analytical techniques, especially molecular biology techniques, can determine the plant of animal species present in a foodstuff. However, it is very difficult to determine the geographical origin of a food, the requirement imposed by the EU regulation 178/2002. Unfortunately so far universal scientific methods for the determination of geographical origin do not exist and indirect methods have to be coupled. The methods in analyzing the origin of foodstuffs can be categorized into two types: the physicochemical techniques (using the variation of the radioactive isotope content of the product, spectroscopy, pyrolysis or electronic nose) and biological techniques (using the analysis of total bacterial flora through many techniques such as Denaturing Gradient Gel Electrophoresis (DGGE) or DNA chips). Methods permitting the analysis of the microenvironment of food are very promising. They are based on the principle that the environment has an effect on the bacterial ecology of food. The bacteria can differ by their quantity, species and characteristics. These methods include traditional biochemical techniques (such as API galleries, analysis of antibiotic resistance and ELISA tests) and molecular biological techniques (such as DGGE or Single Strand Conformation of Polymorphism (SSCP)) (Peres et al., 2007). The main problem in all these techniques is the need of data banks containing representatives of various origins (Peres et al., 2007).

6.2 On-line methods

There is a growing need for use of real-time sensors for quality and safety assurance in food industry. Physical and chemical properties can be measured with sensors, such as electronic nose. This technology is based on absorption and the desorption of volatile chemical substances. The detection system can be composed of gas sensors or a mass spectrography together with statistical processing system for classification of the odours. Electronic nose is used in various applications e.g. in the determination of the origin of olive oil and orange (Peres et al., 2007). Biosensors have a biological identification part, such as antibodies, cells, reseptors or nucleic acids (Patel and Beveridge, 2003). E.g. enzyme sensors have been developed for on-line monitoring of disinfection processes in the food industry (Moody et al., 2001) and for detection of diacetyl in beer (Vann and Sheppard, 2005). In the future, biosensors will most probably be used for various use, e.g. detection of mycotoxins, bacteriocides, allergens or contaminating microbes. By now (2003), there are no commercial applications of biosensors used for detection of residues or contaminants. A few methods used on analysing product composition are available. As industrial applications, the costs of biosensors should be reasonable and the results should be available fast and they should additionally be easy to use (Patel and Beveridge, 2003).

6.3 Laboratory methods

PCR-based methods

With Polymerase Chain Reaction (PCR)-method the desired DNA- (or RNA-) sequence can be multiplied fast and selectively even to million-fold with probes and thermostabile DNA-polymerase (Jalava and Skurnik, 1994). DNA can then be compared to desired DNA with various techniques. Methods based on DNA-analysis, especially PCR (Polymerase Chain Reaction) and following gel electrophoresis are essential methods for analysing the food and their raw materials (Garrett, 2004). PCR-techniques have many applications in identifying food components e.g. identifying genetically modified organisms in foods, identification of breed or cultivar; or origin (Marmiroli et al., 2003; Peres et al., 2007) (See typing methods, 6.5 or analysing PCR-products electrophoretically in DGGE or SSCP, 6.1).

Microarrays and other DNA-based methods

DNA-microarrays provide possibility to investigate several target sequences simultaneously. Hundreds, even thousands, different target sequences can be immobilized to small glass surfaces. Bonded DNA-sequences are then analyzed using fluorescent markers and DNA-chip readers. An example of this kind of method is FoodExpert-ID®-system of bioMérieux, which can be utilized for analyzing a number of mammal-, fish- and bird species in foods and feeds. One of the newest DNA-applications is microsatellite genotyping, which can be utilized for tracing the origin of an animal through the whole food chain. Another novelty is use of DNA-markers in prevention of product forgeries and tampering. In this method a certain DNA-sequence is impregnated into product package and misuse can be detected with help of it (Garrett, 2004).

Enzyme-immunological methods

Immunochemical methods are based on the ability of antibodies (immunoglobulins) to recognize three-dimensional constructions, immunogens or antigens. These methods are used mainly in confirmation of authenticity of meat and meat products and milk and milk products. The method is fast and it is possible to get quantitative results. A limited amount of commercial applications are available (Märtlbauer, 2003).

Near-infrared (NIR) analyses

With NIR (near infra-red)-technology typically e.g. moisture-, protein- or sugar content can be measured from flour, various grain- or milk products or coffee, but also such factors as alcohol content of drinks, ripeness of peas or thickness of food packages. In future the measuring will be performed more and more on-line and NIR is well applicable for this purpose. The biggest limitation of using NIR is the limited penetration of the radiation to product. Infrared-light is fairly low-energetic electromagnetic radiation, which causes internal vibrations in atoms because of interactions between molecules. Molecules (especially OH-, NH- and -CH-molecules) absorb radiation in different ways and begin to vibrate at a certain wave length. Groups of molecules absorb different amount of radiation and the absorbed amount is directly proportional to amount of desired substance in product (Benson, 2003).

Nuclear Magnetic Resonance (NMR)-spectroscopy

Nuclear Magnetic Resonance (NMR)-technique is currently increasingly used in analysing food products and it has been used for composition analysis of very different, mainly liquid but also semisolid foods (e.g. plant oils, fish and meat, milk, etc.). It has been used for separation of different kinds of fruit juices (Belton et al., 1996, Le Gall and Colquhoun, 2003) or milks (Belloque and Ramos, 1999, Le Gall and Colquhoun, 2003). Handling and measurement of sample is easy. NMR-spectra is the ”fingerprint” of the sample. The hight and area of peaks of NMR-spectra vary depending on the sample. The equipment required for the method is expensive but it is probably the best available method for analyzing extracted foods (Le Gall and Colquhoun, 2003).

Spectrophotometry

In methods based on spectrophotometry, ultraviolet light (UV), visible light (VIS) or infrared light (IR) is utilized. The methods are based on the impact or production of electromagnetic radiation in substances. UV-spectroscopy is usually combined with HPLC-technique. IR-spectroscopy is currently the most used spectrofotometric method in authenticity and traceability investigations of food products. Less known fluorecens and so called Raman spectroscopy as sensitive and specific methods, which may provide an alternative for UV- and IR-methods in the future (Meurens, 2003).

Gas and liquid chromatography

Chromatography methods are based on partition and absorption of molecules between a mobile and a stationary phase. The separation is based on different size absorption ability or different molecule partitions between different phases. In gas chromatography (GC) gas is the mobile phase. The method is used e.g. for investigating flavour substances. The capacity of the method is big, it is rapid and repeatable and additionally only a small amount of sample is needed. The biggest part of the molecules are, however, not volatile. Problematic is also the contamination of samples and colon (Forgács and Cserháti, 2003). High pressure liquid chromatography (HPLC)-techique is very sensitive and rapid method and the resolution power is good. In HPLC the mobile phase is liquid and stationary phase solid. For investigating phenolic compounds, antosyanins and organic acids, this method is idealic. Combining HPLC-technique and mass spectrometry (MS) enables better separation efficiency and opens new and wide horizons (Nollet, 2003).

6.4 Traceability of allergens

Allergens

A compound causing immune reaction in body is called **antigen** and antigen causing the allergic reaction **allergen**. Even the smallest amount of allergen can cause problems and almost any food can cause allergy or symptoms of hypersensitivity. In Europe, e.g. the following substances and their derivatives typically cause hypersensitivity reactions: grain products containing glutein, fish, crustaceans, eggs, peanuts, soya, milk and milk products containing lactose, nuts, celery, mustard, sesame seeds and sulfites (Anon., 2004g). The Directive concerning packaging markings of food products came in force in member states in November 2004. After this all ingredients in food products must have been marked onto the package with a few exceptions (exceptions do not include any allergens) (Leminen, 2004).

Examples of traceability of allergens

People being allergic to cow milk may suffer when goat milk has been adulterated with cow milk. Molecular composition of milk from different animal species varies and this is the primary characteristic used for being able to distinguish them. Various electrophoretic, chromatographic and immunochemical methods can be used for finding the differences. Grease composition can be analyzed with FA-analyses (FA = water soluble fatty acids) or with help of TG-profile (TG = triglyceride). Separation of milk proteins with various techniques based on electrophoresis is one of the most used methods in ensuring the origin.

DNA-based methods have been used for testing allergens of plant origin. Quantitative PCR has been used for detecting wheat, barley or rye from glutein free food. A PCR method based on Lectin Le 1 -gen, has been developed. With this method it can be demonstrated, if meat contains 1% or more soya. A sensitive method (detection limit 10 ppm) for detecting traces of hazelnut from foods is available, based on amplification of gen coding for nut allergen (Holzhauser et al., 2002; Lenstra, 2003). Enzyme-immunological methods are emerging methods for analyzing allergens such as almonds and hazelnuts (Märtlbauer, 2003).

6.5 Traceability of pathogenic microbes

For tracing contamination routes of microbes, various molecular microbiological methods based on analysing genotype and phenotype of a microbe can be used. With these methods can be traced, from which products are found corresponding microbes that were found from patient samples or from which process steps can be found microbes corresponding those found from the products. For each microbe, best method for typing varies and should be selected. Methods based on analysing phenotypes include biotyping, serotyping, phage- or bacteriocin typing. Various molecular typing methods exist, e.g. Pulsed Field Gel Electroproresis (PFGE), ribotyping and PCR-based typing methods such as RAPD (Randomly amplified polymorphic DNA) and AFLP (Amplified fragment length polymorphism) (Jay, 1996; Hielm et al., 1999).

7. Conclusions

- From the beginning of 2005 a system has been required in legislation from food processors in Europe for identifying the origin of raw materials of food products and the destination of final products i.e. supplier and customer traceability. In addition to the EU regulation, several countries have enacted specific legislative measures. Increased requirements of legislation and consumer demands have led to further development of harmonious traceability systems.
- In Finland, the requirements of legislation are fulfilled by the industry. The process traceability, i.e. the ability to follow the manufacture of ingredients and materials into a product, is not required in legislation, but has been continuously developed further.
- The better the process traceability is, the bounded and accurate withdrawal can be done when necessary.
- The ultimate aim is that traceability systems would work totally electronically and with new technologies such as RFID and no paper records would be needed.
- Standards and general frameworks for setting up traceability systems have been launched during recent years. E.g. ISO introduced in the beginning of 2006 two new standards that define the requirements for a traceability system within a food safety management system and the data that needs to be retained. Other international and European organizations (Codex Alimentarius, CEN, GS1) have also launched standards for traceability.
- The tools for traceability are currently labels containing alphanumerical codes (a sequence of numbers and letters of various sizes, generally “owners” codes), bar codes and automatic radio frequency identification (RFID), of which bar codes are the most frequently used systems currently.
- RFID is a very promising technology, but problem for use in food products is still the high cost of TAGs especially for low-cost food products. In the near future, RFID-based systems will be used, in addition to tracking the goods, also to monitor the quality of the products and the supply chain itself. RFID-based remote sensing will enable e.g. the online spoilage detection of vacuum-packed food products and the continuity of cold chain.
- Another innovative technology utilizes microscopic, edible bar codes that can be applied directly onto foods to make them more secure, safer, and less expensive.
- In traceability investigations often the origin of plant or animal based raw material is sought. However, universal methods do not exist and indirect methods have to be coupled.
- Modern analytical techniques in analyzing the origin of foodstuffs can be categorized into physicochemical techniques and biological techniques.
- In the future, biosensors will most probably be used for various use, e.g. detection of mycotoxins, bacteriocides, allergens or contaminating microbes.

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Appendix 1: Traceability systems of vegetable oil based unripened cheese spread and oat meal

<table>
<tr><td colspan="2"></td><td>Vegetable oil based unripened cheese spread</td><td>Oat meal</td></tr>
<tr><td colspan="2">Supplier traceability</td><td>Purchasing department has information on raw material suppliers and their contact information.</td><td>Accepted suppliers and their contact information are recorded in own data management system and can be accessed whenever needed. In case of glutein-free oat meal the origin or the grain is known with accuracy of specific field area.</td></tr>
<tr><td colspan="2">Customer traceability</td><td colspan="2">Is known until the next step in chain (via wholesales can be received the information to which single retail shops the products have been delivered)</td></tr>
<tr><td colspan="2">Withdrawal</td><td colspan="2">A flowchart has been done from the withdrawal process. Mainly the product manager has the responsibility, ultimately the sales- and production managers. The product manager has responsibility also outside work hours. Information of product lot no. can be sent to wholesales and retail shops within 24 h, to which product has been delivered directly from the plant. The withdrawal takes days/weeks.</td></tr>
<tr><td colspan="2"></td><td colspan="2">PRODUCTION PLANT</td></tr>
<tr><td colspan="2">Responsibilities</td><td>Ultimately the factory manager;The raw material controllers, process operators, the operators in palleting room</td><td>Ultimately the factory manager; (farmer), manager + personnel of grain storage, production manager, millers, packers, palleting room operator</td></tr>
<tr><td colspan="2">Identification of products</td><td>Best-before-date (lot identification), time, health mark, EAN-code, identifications of cartons</td><td>Best-before-date (lot identification) and time, bar code stick-on label from own data management system containing e.g. EAN-code</td></tr>
<tr><td rowspan="2">Data storage</td><td>electrical</td><td>Records of process runs, 1–2 yrs., in Excel-format</td><td>In both own data management system and in manual records min. 5 yrs, glutein-free oat meal min 5 yrs; Lims laboratory data management system</td></tr>
<tr><td>paper</td><td>Form for follow-up of weights of products, 2–5 yrs</td><td>Manual records in production</td></tr>
<tr><td rowspan="2">Data transport</td><td>manual</td><td>Arrival labels, maps, booking of information into paper records of process runs, and in Excel</td><td>Manual records in production, note pads</td></tr>
<tr><td>automatic</td><td>Records of process runs, transfer of information of cartons automatically into production control- and storage system</td><td>own data management system for incoming grain (input manually); Lims-laboratory data management system</td></tr>
<tr><td colspan="2"></td><td colspan="2">STORAGE</td></tr>
<tr><td colspan="2">Responsibilities</td><td colspan="2">The person responsible for the storage</td></tr>
<tr><td colspan="2">Identification of products</td><td colspan="2">Pallet label: SSCC –code</td></tr>
<tr><td rowspan="2">Data storage</td><td>electrical</td><td colspan="2">Place of pallet in production plant and intermediate storage: operational system SAP, min. 2 yrs.</td></tr>
<tr><td>paper</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Data transport</td><td>manual</td><td colspan="2">Transport consignment note</td></tr>
<tr><td>automatic</td><td colspan="2">Reading the SSCC</td></tr>
<tr><td colspan="2"></td><td colspan="2">TRANSPORTS</td></tr>
<tr><td colspan="2">Responsibilities</td><td colspan="2">Transport contracts, lorries chosen by wholesales are in use, responsible persons are the Head of logistics and the drivers</td></tr>
<tr><td colspan="2">Identification of products</td><td colspan="2">Paper records containing information of the load, and dispatches</td></tr>
<tr><td>Data storage</td><td>electrical</td><td colspan="2">operational system SAP</td></tr>
</table>

	paper	Paper records containing information of the load, and dispatches are stored as papers or scanned
Data transport	manual	Paper records containing information of the load, and dispatches are stored as papers or scanned
	automatic	
		WHOLESALE
Supplier traceability		Contact person and accurate contact information are known from the supplying company, and connection can be made immediately - within one hour.
Customer traceability and withdrawal		The specific retail shops where product has been delivered, can not directly be traced. From the operational system (e.g. SAP) can be found the requested best-before-dates and information on retail shops, where products have been delivered. The contact information are easily available. Contacts are made with e-mail, intranet, fax or phone. There is an accurate flowchart of the withdrawal and the responsible persons have been defined. The withdrawal is based on an accurate product name, best-before date (lot identification) and EAN-13- code. The information reaches the retail shops within 30 min-2 days. Time for return depends on the case. If the product causes health risk, immediately, otherwise 1-3 weeks.
Responsibilities		In withdrawals responsible person is Product group manager/Head of product research and development/ Buyer. In the receiving room the responsible person is the receiver or the person in charge of quality
Identification of products		The most important identification are the dispatches of suppliers and pallet identifiers. EAN pallet labels are in use (they contain EAN- and SSCC -codes, but usage of SSCC-code is incomplete). Additionally may be given short ID -identifier for pallet.
Data storage	electrical	In operational system (e.g. SAP). Storage time depends from the document: for invoices 5 yrs.; for dispatches the selling time of the product + 6 months; truck control system
	paper	
Data transport	manual	
	automatic	With operation control system (data input manually) and with truck control system
		RETAIL SHOPS
Responsibilities		Shelving is done by the Compartment responsible/Product group responsible/in some retail shops the whole personnel is shelving in turn. The person who is shelving or the Compartment responsible is in charge of sensory – and best-before-date checks done in connection with the shelving. Shop manager is responsible for withdrawals.
Identification of products		best-before-date and EAN -code
Data storage	electrical	Many shops have computer programs, by which the raw materials are ordered and the recipes are controlled. The information on raw material suppliers and supply dates are also registered to these programs. The information of traceability of the products are usually stored at least until the best-before-date + safety marginal (usually 6 months) time
	paper	At shop level, there is no storage book keeping, the information on suppliers of products and lot information can be found from the filed delivery documents or from the products themselves
Data transport	manual	Delivery records and load books
	automatic	The basic information of products

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Title

Traceability of foods and foodborne hazards

Abstract

In the beginning of 2005 came in force the EU General Food Law (178/2002), where a system is required from food processors for identifying the origin of raw materials of food products and the destination of final products i.e. one step forward and one step backward in the production chain. According to this law, 'traceability' means 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. In addition to the EU regulation, several countries have enacted specific legislative measures. In addition to increased requirements of legislation, consumer demands for transparency have also increased which has led to further development of harmonious traceability systems.

In Finland, the new legislation caused concern, but in reality, old operation modes had already fulfilled the requirements in many cases. Certainly data systems can and should be developed so, that they serve better and faster than earlier systems the needs of traceability. In the report by the Finnish Food and Drink Industries' Federation and the Finnish Grocery Trade Association on food traceability in Finland (2005), three development steps of traceability for food companies have been defined. The ultimate aim is that traceability systems would work totally electronically and with new technologies such as RFID and no paper records would be needed.

Hazards, e.g. pathogenic microbes and allergens in food products, can cause significant health risks for people belonging to risk groups of those hazards and they must be efficiently traced in food chains. The faster the defective product is drawn from the market, the less the company receives negative publicity and the undamage to the image of a company is minimized. Process traceability, i.e. the ability to follow the manufacture of ingredients and materials into a product, is not required in EU legislation. However, the better the process traceability is, the bounded and accurate withdrawal can be performed when necessary. Traceability is a preventive, necessary, supplement of food safety systems, which increases the efficiency of food companies, when used correctly.

Some pioneer companies have been developing their own traceability systems primarily to reduce business risk, but they have been lacking standards, which has resulted in very differentiated systems. As a consequence these systems have been producing different economical results. However, work on standardization has been going on as well as building of general frameworks for setting up traceability systems. Information Technology (IT) has the potential of revolutionizing product traceability. In practice the tools for traceability are labels containing alphanumerical codes (a sequence of numbers and letters of various sizes, generally "owners" codes), bar codes and automatic radio frequency identification (RFID), of which bar codes seem to be the most frequently used systems currently. RFID is a very promising technique, but problem is still the high cost of TAGs used in these systems, even though the prices have decreased significantly in recent years.

In traceability investigations often the origin of plant or animal based raw material is sought, e.g. if genetically modified organisms (GMO's) have been used as raw materials or if product contains components hazardous for consumer health or e.g. raw materials of wrong quality. It is very difficult to determine the geographical origin of a food, the requirement imposed by the EU regulation 178/2002. Universal scientific methods for the determination do not exist and indirect methods have to be coupled. Modern analytical techniques in analyzing the origin of foodstuffs can be categorized into two types: the physicochemical techniques and biological techniques. The main problem in all these techniques is the need of data banks.

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Food safety risks increase with globalization and increased travel and trade, and foodborne hazards can easily spread to geographically distant countries and affect the health of people in numerous regions at the same time. Furthermore, the traceability of foods has become vastly more complex, and the ingredients of many processed and ready-to-eat foods may come from countries with different foodborne hazards and risks. Urbanization, changing consumer habits and climate change also affect food safety. Food can become contaminated at many stages of the food chain, beginning in the environment a Food traceability has been associated with food safety procedures for many years, but recent high-profile cases of food fraud around the world have given traceability a different strategic purpose. Focusing solely on dairy products, our survey results offer a glimpse of consumer perceptions of traceability as a means to preserve food integrity and authenticity. This study explored the various influences that market-oriented traceability has had on dairy consumers.Â Traceability is an integral requirement in the agri-food sector especially due to the perishable nature of food and the potential for health risks through transmission of bacteria. There are various traceability systems that allow companies to keep track of their products both upstream and downstream. "Looking for trouble" Traceability Improved monitoring of foodborne disease and risk assessment Transparency Improving food hygiene in commercial catering and in the home Recommendations References. Introduction. Most countries with systems for recording foodborne disease have reported significant increases in the incidence of diseases caused by pathogenic micro-organisms in food over the past few decades.Â Food production, processing and other handling operations should be analysed with a view to identifying hazards and assessing associated risks. This should lead to the identification of critical control points and the establishment of a system to monitor production at these points (i.e. the Hazard Analysis and Critical Control Point - "HACCP" approach).