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Viewpoint

Perspectives on traceability in food manufacture

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Traceability in food manufacturing can range from in-house traceability in production plants to traceability in whole or part of the production chain from raw material to consumer, and descriptors of the product and its history can be few or many as decided. Well thought-out traceability systems are fundamental to achieving optimal benefits from quality control, production control and for fulfilling consumer demands etc. In order to facilitate the discussion of a traceability strategy in food industries this Viewpoint outlines the fundamental theoretical issues of traceability systems and presents a more practical discussion of its extent.

Traceability is the ability to track a product batch and its history through the whole, or part, of a production chain from harvest through transport, storage, processing, distribution and sales (hereafter called chain traceability) or internally in one of the steps in the chain for example the production step (hereafter called internal traceability) (see Box 1 for explanation of terms). Traceability is a generic issue, as its fundamentals are independent of the type of product, production and control system it serves [1].

Traceability must be managed by setting up a traceability system, which keeps track of product routes and of selected data. Manufacturers of vehicles, aircraft and spacecraft have long had highly advanced traceability systems [2, 3]. From early times, the food industry has had simple traceability systems, but with the increasing implementation of Good Manufacturing Practice (GMP) [4] and ISO 9000 quality management [5] in food manufacture, traceability systems have become more advanced covering more information and more steps in the production chain. Recently, the BSE crisis and debates about transgenic soybeans have drawn new attention to chain traceability.

Traceability is an essential subsystem of quality management. The development of advanced internal traceability systems can, however, also be spurred by the search for improving the efficiency of data collection, plant control and quality assurance. That search has resulted in an increasing interest in coupling data from more than one control or management system [6–9], which in turn, requires that a traceability system with a high degree of detail is established.

Traceability is also a system in itself and its establishment should be given proper attention and suited to actual needs using a systematic approach. To do this well requires awareness of the various features of traceability, which are addressed in this paper.

Fundamental features of traceability

We adopt the basic definition of the term traceability found in the quality management and quality assurance standard from ISO [10]: Traceability is the ability to trace the history, application or location of an entity, by means of recorded identifications.

The term traceability can be used in four distinct contexts, each with a different implied sense:

(1) Product; it may relate materials, their origin, processing history, and their distribution and location after delivery [10].
(2) Data; it relates calculations and data generated throughout the quality loop, sometimes back to the requirements for quality [10].
(3) Calibration; it relates measuring equipment to national or international standards, primary standards, basic physical constants or properties, or reference materials [10].
(4) IT and programming; it relates design and implementation back to the requirements for a system [11].

Categories 1 and 2 cover the fundamental concepts included in advanced traceability systems relating to products and their processing. These important issues are somewhat neglected in the literature on food processing and are therefore the subject of this paper.

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Box 1. Terms

A step refers to some discrete operation or location at which some task or process is performed on the product.

A chain is composed of the sequence of these steps.

A product can be any material at any stage of processing. Thus, it may be the whole material in its native harvested form (e.g. an apple), or be part-processed (e.g. blanched apple pieces), or the final product (e.g. canned apple pulp).

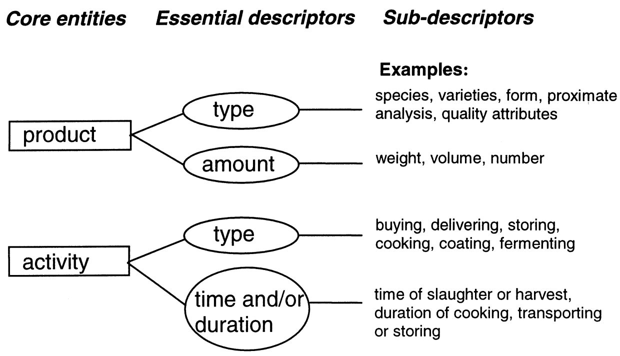

Fig. 1. Fundamental structure of a traceability system.

Calibrating measuring equipment (Category 3) using standards that are traceable to national or international standards is essential to all food business to provide a common base for assessment of product quality and performance in accordance with specification [12]. It is, however, well-discussed in the literature. Since this paper is not about programming, the traceability system Category 4 will not be dealt with here.

Structure of system

Product traceability is first of all based on the ability to identify products uniquely. Product identification can be made by physical marking on the product or its package or by use of records [13]. Records are especially important where information cannot be marked on the product, e.g. in the process.

A traceability system can be split into two elements, namely; the routes of the product and the extent of traceability wanted [13]. Routes describe the path along which, and the means by which, products can be identified throughout the manufacturing, distribution and retail system. Extent defines the scope of traceability. This will be elaborated below.

Core entities

The most advanced theoretical treatment of traceability is that of Kim *et al.* [1]. They describe the fundamental and necessary core in an ideal traceability system as the ability to trace both products and activities. Products and activities are called core entities, an entity being what can be individually described and considered [10]. Activities can mean buying, selling, handling, transportation and thereby describe the route of the product. However, it can also be extended to activities that influence the quality of the product, hence activity in the sense of handling or processing like for instance storing, grating, boiling, packing etc.

To make the concept more operational, we have defined for each core entity a set of essential descriptors that must be included in order to secure ideal traceability of products and activities, (Fig. 1). Each of the essential descriptors is then qualified using sub-descriptors taken from purchase, production, measurements etc.

The extent of a traceability system is determined by the choice of sub-descriptors, the number and content of which can be extended as required, even to include descriptive factors such as quality attributes, environmental loads etc.

Traceable resource unit

Unique identification and traceability in any system hinges on the definition of what is the batch size or, using the terminology developed by Kim *et al.* [1], the traceable resource unit (TRU). For batch processes, a TRU is an unique unit, meaning that no other unit can have exactly the same, or comparable, characteristics from the point of view of traceability [1]. When dealing with continuous processing, the definition of a TRU can be difficult. It may depend on the raw material TRU or on a change in processing conditions, as different activities according to the definition give different TRUs. A consistent definition must be maintained but what constitutes a TRU is decided by the system designer. The identification of a TRU may change during the product route when for example TRUs are pooled. This results in a new TRU which must be given a new identification different from that of any of the original TRUs. The size of a TRU may also change, for instance when one batch is split into several batches. However, the individual TRUs can only keep the identification of the original TRU as long as the activities occurring to the individual TRUs are identical.

Retrospective analysis

Traceability is required to recall what has already occurred and, in use, traceability works backwards [1]. This means that the recordings concerning the TRU must be designed from the viewpoint that they will be interrogated retrospectively. Furthermore, a stable, accessible record system is essential.

Traceability in food manufacture

While traceability in food processing systems is important, some data are essential to fulfil ethical and legal responsibilities of food manufacturers to customers and consumers. Other data are less crucial but also relevant; for instance for consumer information, price setting, optimal processing etc. The desired degree of detail of information (number of sub-descriptors, size of TRUs) varies according to the purpose. For some purposes, e.g. consumer information, a limited number of sub-descriptors are needed (although it is increasing with the rise of the political consumer) whereas for quality and process optimization purposes more product and activity descriptors, and perhaps smaller TRUs are desirable. The processing step is the step in the chain that may be interested in the highest degree of detail of information. Hence, the number of sub-descriptors laid into a chain traceability system may be significantly fewer than the number of sub-descriptors used in an internal traceability system.

Finally, it may not always be possible to establish the ideal traceability system with traces unbroken. Where loss of traceability of a product is unavoidable, effective alternative methods of control should be ensured [13].

System technology

Traceability systems work fine based on pen and paper versions. The use of computers, however, enables a larger amount of data to be handled and thereby it becomes realistic to develop traceability systems with very detailed information about both the product and its processing history. Examples of such advanced traceability systems using information technology (IT) have been described for three large food processing industries [6, 7, 14].

Chain traceability

In principle there are two main ways of managing information in the chain where full traceability is required. 1) information is stored locally in each of the steps in the chain sending only product identification information along with the product. Thereby the product and its sub-descriptors can be traced by going backwards in the chain one step at the time. 2) information follows the product all the way through the chain. The latter is necessary if it is desired to bring information from early steps in the chain to the consumer or to advertise and market special features of a product (e.g. organically grown, free of genetically manipulated materials, fresh fish from a certain area caught yesterday, special slaughtering method used, etc.). In practice most information is stored locally and little follows the product. An example of full chain traceability in a complicated chain with many steps is seen in the Danish pork industry [15].

Many advantages can accrue from establishing chain traceability, and when sub-descriptors concerning quality attributes are included, the advantages are increased (Box 2).

Most food processing companies establish end-product traceability to secure efficient product recall procedures. Product recall systems only require traceability in part of the chain from the production step to the consumer [16]. However, if the problem stems from the supply of raw material, traceability back to the supplier improves the possibility of either correcting faults, avoiding re-occurrence or placing the responsibility there [13]. Recall systems can be established on a minimum of traceability information (e.g. production date), however, the more sub-descriptors that are included (e.g. production time, batch number, production conditions) the more focussed the product recall can be, thereby minimising loss of money and reputation.

The particular aims (or limitations) of one or more of the steps in a food processing chain set the demands (or limits) for the extent of information incorporated in the chain traceability system.

Box 2. Advantages of chain traceability

- Establishes the basis for efficient recall procedures to minimize losses
- Information about the raw material can be used for better quality and process control
- Avoids unnecessary repetition of measurements in two or more successive steps
- Improves incentive for maintaining inherent quality of raw materials
- Makes possible the marketing of special raw material or product features
- Meets current and future government requirements (e.g. confirming country of origin)

Internal traceability

Many advantages can accrue from having internal traceability within a step in the chain (Box 3). A minimum of internal traceability, being able to trace the raw material that went into a final product, is in the interest of most food manufacturers. Establishing internal traceability may be easy enough for pure batch processing, however, for continuous or semi-continuous processing it can be very difficult. Product is not going through as a process flow and any alterations to the

Box 3. Advantages of internal traceability in the production step

- Possibility for improved process control
- Cause-and-effect indications when product does not conform to standards
- Possibility of correlating product data with raw material characteristics and processing data
- Better planning to optimize the use of raw material for each product type
- Avoidance of uneconomic mixing of high- and low-quality raw materials
- Ease of information retrieval in quality management audits
- Better grounds for implementing IT solutions to control and management systems (e.g. Computer based quality management systems, Laboratory Information Management Systems (LIMS), Manufacturing Execution Systems (MES) and others)

processing conditions may result in a delay before stability is returned. Under such conditions the ideal TRU can be very small and therefore many food processers do not have traceability down to the ideal TRU. Instead they have a sort of 'sufficient' traceability where products processed within a period of time are known to come from a certain raw material batch, with some mixing at both ends. However, only an internal traceability system coming close to tracing the ideal TRU can be used as a grid for combining data from process control, quality management and other management systems.

Future trends

The desire for the integration of more and more information in food production management and the increasing demands for information along the food processing chain will set higher requirements for well-structured traceability systems in the future.

There is a need for more work on analysis of the fundamental and practical aspects of traceability in food manufacture. From this, guidelines that can help companies to assess their particular need for the degree of detail in their internal and chain traceability systems can be made.

In the future, the information flowing in the food manufacturing chain might provide a competitive advantage since it can be sold along with the product.

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