SESSION 3

Traceability working group:
advancements acquired and activities carried out

Traceability of food products

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1. Introduction

One of the characteristics of the present agriculture of the developed countries almost worldwide is the conversion from agrarian, local, fully integrated food systems to industrialized, monocultured agricultural production. While no attempt will be made in this paper to analyze this transformation and explore the roots of the industrial takeover, there is a wide consensus that this process has brought a number of negative effects. It manifests itself, among others, in contaminated soils and ground waters, polluted air, foodborne illness, toxic chemicals in foods, animal feed and fiber and myriad other environmental problems that effect, not only quality, but more important, food safety **[1]**. Moreover, the industrialized food production has created a distance between the consumer and food production, resulting in consumers lining up in supermarkets and array of slickly food products about which they know very little.

Food labels often do not provide enough information to allow a consumer to know what is in our food and how and where it is produced. No labels are required that inform consumers about the pesticides and other chemicals used on crops, or the residues still left on those foods at time of purchase. Similarly, there is yet no mandatory labeling of the geographic origin of foods, despite the wishes of growing number of consumers who prefer to choose produce from a specific origin, and/or avoid purchasing produce from certain regions. At the same time, consumers are becoming more involved in food marketing systems, demanding levels of safety assurance, purity and authenticity and even information on production or environmental practices. Some means to protect the consumer are already part of legislation existing in most European and associated countries. However, the public has been aware of some cases where these legal and enforcement systems did not provide an adequate protection. Thus, there is an increased demand by the consumers for an accurately documented history of any product in the food chain to ensure food safety and make food producers and handlers accountable for their product.

Out of this demand emerged the relatively new buzzword **'Traceability'**, triggered primarily by the consumers concerns about 'Mad Cow Disease', dioxin in chicken feed, Salmonella and Listeria in fresh produce and bioengineered food products (GMO's). However, since then, traceability has become more than a food production buzzword, but a necessary component of the food production process. Yet, a clear definition is still missing regarding what products, what information and which agri-food chains are to be traced, in order to develop the appropriate traceability protocols, both within and between chains. While a lot of work has already been done worldwide, primarily in developed countries **[2]**, many gaps are still remaining wide open. Since engineering offers a major tool for closing many of the gaps, the objective of this presentation, prompted by the Club of Bologna, is to briefly describe the WHAT, WHY and HOW of traceability and suggests the possible contribution of engineering to this process and the role the Club of Bologna can play in the implementation of the traceability process.

2. WHAT? WHY ? HOW?

2.1 What is traceability?

According to the Webster's Dictionary, 'Traceability' is "the ability to follow or study out in detail, or step by step, the history of a certain activity or a process". A more rigorous and targeted definition was provided by the International Organization for Standardization (ISO standard 8402:1994) and supported by EC regulation 178/2002, which defines 'Traceability' as "the ability to trace and follow a food, feed, food-producing animal or ingredients, through all stages of production and distribution" **[3].** Under this regulatory framework, starting in 2005 a much higher burden of responsibility will be placed on all links of the production chain of food for human consumption, starting with the farmers and food producers and ending up at the market. Thus, traceability is generally viewed as a potential risk management tool for public health purposes.

Traceability enables consumers to be provided with targeted and accurate information concerning products. This is especially important in cases where the consumer is willing to pay a higher price for products that are produced under certain guaranteed circumstances such as organically produced food or that coming from a desired origin. Thus, source verification, supported by proper labeling, is part of the traceability process and provides the ability to trace products from their initial components (for example, from seeds) through a production and distribution system to the end user.

Traceability should provide a verifiable documentation for an effective food control system and should aim at limiting the discontinuity of the information throughout the food supply chain. In practice the term traceability stands for a system of record keeping and documentation by operators that enables tracking of the movement of a product or ingredient through the food chain.

2.2 Why traceability?

Recent records on food safety show that about seven million people a year are affected by food borne illness (Food Engineering International Report, Feb. 1998). This results in strong loss of confidence towards production processes from the consumer side. There is a general belief, primarily in the EU view, that consumer confidence will be restored if food products are clearly labeled and ingredients can be traced backward to the source and forward to the customer. Breakdowns in food safety can have far-reaching repercussions, and withdrawals of particular foods are sometimes necessary to protect public health. It is much easier, straightforward and certain process for the industry, if the batches of food in question can be identified and their process of production tracked and verified **[4].** Furthermore, many researchers endorse the premise that the further away from the true biological cause a measurement system gets, the more likely it is that the effect can be the result of other causes. Thus, a traceability capability is required to ensure that all the chain process effects are addressable and measurable. Measurement of only down-stream effects would impair the consumer's capability to identify the various "players" accountability for the safety of the product. Unfortunately, no rigorous tool is available today to certify the quality of food production, thus giving no mean for the consumer to choose upon safety criteria.

A recent study carried out by the British Food Standards Agency suggested that robust traceability systems in the food chain allow food, ingredients, feed and animals to be effectively and reliably traced and thus, play an important role in protecting consumer's interests with regard to food safety and public health **[3].**

2.3 How

The system of traceability should allow for an effective tracking methodology from the source materials to the farm gate – " from seed to table", which will include traceability models to ensure the products' compliance with the established requirements. It consists of collecting all relevant data pertaining to the history of a product and the development of an easily accessible information system that will cover all stages of the growing, processing and distribution cycles of both fresh and processed plant and animal products. Thus, it is a major issue of knowledge management, which in essence is a question of collecting and then connecting the dots.

Collecting all the relevant data entails a measuring capability of all relevant factors that relate to safety issues. Thus, it entails use of proper instrumentation and sensors, capable of recording and monitoring many physical, chemical and microbiological processes and handling information throughout all the operating phases. It should be characterized by fast and cost-effective performance, user's friendly and remote sensing if necessary. All the information from the various sources will be part of the database and a network platform. This network needs to be transparent, accessible to all the stakeholders with provisions for auditing, verification and certification to ensure the accuracy and reliability of the information inputted and compliance with the established requirements.

3. Current status of the traceability process

3.1 Legal and Regulatory Aspects

Unfortunately, there is currently no general legal requirement for the establishment of traceability systems in the food chains. The only mandatory traceability system currently applying to a complete food chain enables beef on sale within the

EU to be traced back to where it originated **[5,6].** However, the EU General Food Law Regulation will introduce a broad non-descriptive traceability requirement from 1 January 2005. A Concerted Effort Framework – 'FoodTracE' has been established by the EU in 2000 aimed at developing a practical framework for traceability of food and develop the means to plan, model, validate and implement the traceability process. In addition, many of the large food manufacturers, retailers and food service companies have already established traceability arrangements, primarily to reduce business risk. Some limited degrees of food safety regulations related to traceability are already required by several countries (or regions) under a number of separate measures.

In 1985 a UN General Assembly resolution gave rise to the *Guidelines for consumer protection*, published in 1986. These guidelines identify food as one of three priority areas that are of essential concern to the health of consumers. The Codex Alimentarius evolved from these guidelines and was selected as the reference point for these guidelines with regard to food **[7].** While this codex deals also with quality issues, it reflects an emphasis on ensuring that consumers receive products that are safe and do not present a health hazard. It contains more than 200 standards, including those dealing with labeling, food hygiene, food additives, contaminants and toxins. The Codex documents have been disseminated to nationally based consumers' organizations for comments as required.

The European Food Law has also established its legal basis for traceability in the 'one-up one-down' model. In 2002 the U.S. became concerned about GMO's and the potential impacts of traceability legislation on international trade in food. Its Department of Agriculture Economic Research Service published "Traceability for Food Marketing and Food Safety: What's the Next Step". The paper set out the case for voluntary traceability within the food industry. It maintains that traceability can have a number of practical purposes for private firms including product differentiation and food safety control. The paper argues that government should ensure that the private sector meets performance targets for food safety but, above and beyond this, it is much more cost-effective for firms and supply chains to introduce their own traceability schemes to minimize the impact of food safety problems, to maintain market credibility for their products, and to provide consumers with information they are prepared to pay for (at more than marginal cost). Following this approach, the U.S. National Institute of Standards and Technology (NIST) of the U.S. Commerce Department has developed NIST Policy on Traceability, which presents the definition of measurement traceability used by NIST, and clarifies the roles of NIST and others in achieving traceability of measurement results. Thus, the primary role of NIST is to assist its customers in establishing traceability of their measurement results and to assess the claims of traceability made by others.

While the EU and the U.S. seem to adopt different approaches, in practical terms the European and the American positions on food safety/security and traceability are remarkably similar: a mandatory requirement on operators to maintain records for 'product tracing', sectoral requirements enforceable by inspection and extension of traceability to other attributes of interest to processors/retailers/consumers including composition and processing.

In addition to a EU proposed (yet unendorsed) regulation, several countries have introduced their own regulations on traceabilty. In Italy, for example, the Italian Standards Institute (UNI) has enacted specific legislative measures. Two specific standards have been issued: UNI 10939 "Traceability system in agricultural food chain – General principles for design and development" of April 2001, and UNI 11020 "Traceability system in agri-food industries – Principles and requirements for development" of December 2002 **[8,9].**

Other legislative acts have been introduced in several European countries, such as France, Spain and Greece, but they relate primarily to quality issues, rather than food safety. Their certification implies to characterize the produce and communicate objective advantages (specifications like maturity for harvesting, level of sugar, etc.).

Identity preservation (IP), which represents only one aspect of the traceability process. It also has attracted great interest in several other countries, which have developed mandatory labeling laws for foods containing ingredients derived from genetically modified (GM) crops. To comply with these labeling laws, food manufacturers must be able to document the genetic purity of both GM and non-GM ingredients. This can be accomplished by either preserving the identity of a crop from seed to final product (IP), or by tracking back from the final product to the crops from which ingredients were manufactured (traceability). Likewise, on May 13, 2002, President Bush signed into law the Farm Security and Rural Investment Act of 2002 (the 2002 Farm Bill), which requires country of origin labeling (COOL) for beef, lamb, pork, fish, perishable agricultural commodities and peanuts **[3]**. Efforts are underway to expand COOL to include poultry. The new COOL law forbids USDA from mandating a specific tracking system. At the same time, USDA is required to guarantee that any system used by any food processor can be audited for accuracy.

3.2 Traceability in Practice

The realized great importance of traceability has prompted the development of many systems, mostly locally established, following specific procedures and set of rules that may differ from each other. While non of these systems offer a truly comprehensive traceability procedure, certain codes and procedures have already been established, such as the MRL, GAP and HACCP systems, which may, or may not be part of a future developed common procedure for traceability.

Apart from the legal aspects, the two major issues of traceability, - measuring and sensing of the various contributing factors and database generation and processing have been only partially dealt with.

The issue of knowledge management pertaining to traceability is a major one, since it involves dealing with an exceptionally high volume of data. It has been already addressed in part by several companies and organizations in different places in the world, but unfortunately, with no contact, cooperation, or attempts to coordinate the development work. Nevertheless, the results of some of these uncoordinated works have been implemented already in their respective countries and may be incorporated in the future in a universally accepted information management system, if and when developed.

An on-line management network – ***'AGROSAFE'*** has been developed, for example, in Israel, to assist all levels of the agricultural production chain in the monitoring and documentation conforming to the EUREPGAP standards, as well as facilitating daily crop management. It is an innovative, internet-based system, designed to provide a multi-directional flow of data, shared (upon predetermined authorization) between growers, packing-houses, marketing chains and consumers.

The National Food Research Institute in Japan has developed the ***'SEICA'*** (http://seica.info), which is the XML web service system, in which any grower can easily create a catalogue of his produce on the web site. The system issues a unique catalogue number for each registration of the catalogue. With the catalogue number and web site address of SEICA attached to the produce, product identification is achieved at any place and any time.

Two data collecting system addressing the safety of the product have been developed in France. **'Tracenet'** is a database which defines a unique standard of potato production with respect to the safety of the product; and the **Agri Confiance ®** scheme: the ***'SIREME'*** project, developed by CEMAGREF **[10,11]** aimed at organizing traceability between organizations of growers.

The European Commission of Standards (CEN/TC) published a pioneering work of a traceability protocol in October 2002 in its standard for the "Traceability of fishery products – Specification of the information to be recorded in captured fish distribution chains". The *Tracefish* concept, an electronic system of chain traceability, was developed under the patronage of the European Commission in its Concerted Action Project QLK1-2000-0064.

As its starting point, the TraceFish team adopted the ISO definition of traceability and applied it to sea fish and farmed fish chains. The ISO definition is far more powerful than that in the EU principles of food law, as it includes the constituents and processing history of products – what the food is made of and what has happened to it, not merely where it has been. This is crucial for food safety and for a number of other reasons such as labeling.

The outbreak of the BSE disease prompted the initiation of several systems for tracking livestock, especially beef, and some of them are well advanced. However, a structured, universally accepted traceability protocol for beef production is not yet available, to the best of our knowledge. Nevertheless, certain criteria have been already identified, and major beef producing countries, such as Brazil, Argentina, Australia, UK and Ireland, has agreed upon specified, and proposed regulations **[12]**. These include identification (classification- type, gender and age; origin) labeling (name of cut; weight; price; packaging date); information procedure -data collected, processed, stored and made publicly available whenever necessary, and certification and auditing.

The milk sector has also been active in putting in place a number of traceability systems. Some of the large distribution companies of milk in Italy and their derivatives, are already offering a product traceability systems that keep track of: storage tanks used for handling the milk; milk hauling in the farms and management of the herd at the farm of origin and even the processing of milk products. Likewise, the application of radio frequency identification (RFID) technology to the consumer goods supply chain in the U.S. is approaching a major milestone. By attaching tiny microprocessors and antennas to products and packages, goods can be tracked throughout their path in the supply chain. Ultimately, each item can be identified by a unique electronic product code (EPC) contained in the memory of the chip. While this technology is not available yet to a single food produce (but applicable to food packages), it is conceivable that with further development, primarily in the nanobiotechnology area, all food products could be included. However, no solution is available yet to the data proliferation, which is more than can be handled by current networks, once the technology is broadly applied at the item level.

None of the aforementioned examples, however, conform to the real meaning of traceability. They are either, site specific, product specific and do not provide, neither a general comprehensive and accessible database, nor the listing of the necessary measuring techniques.

4. The missing links

While traceability is both recognized, and the concept established by the European Union, the U.S. and several other countries, the means of achieving full traceability has not been determined. A clear definition is still missing on what products, what information and which agri-food chains are to be traced. Traceability, where and if applied, is nationwide in scope with different approaches, not only between Europe and the U.S., but also within the EC countries. Many non-EU countries see traceability as disproportionate and thus claim that it is unlikely that there will be any international agreement on mandatory traceability in the near future. Many claim that governments should no longer be the primary gatekeepers of the safety of a food supply that has grown internationally more diverse and exotic. Instead, consumers should increasingly rely on those selling food to keep it safe.

Moreover, a great disparity exists between developed countries, which recognize the importance of food safety (and are ready to pay for it) and less developed countries for which the mere availability of food takes priority over food safety.

There is also a concept mix up of quality with food safety issues. These two have obvious links, but food quality is primarily an economical issue decided by the consumer, while the food safety is a governmental commitment to ensure that the food supply is safe for consumers and that food and feed meet foreign and domestic regulatory requirements. Unfortunately, no coherent, uniform, well-established and internationally accepted procedure is yet available. In fact, there is already inflation in standards, leading to duplicity, cost increase and a lot of confusion on the part of all the stakeholders. A prudent implementation of the traceability process entails the establishment of a common approach to all aspects of traceability. Subsequently, the development of a generic framework, based on a range of simple principles that will take existing systems into account and ensure smooth and efficient transfer of information through every stage of the chain.

An efficient transfer of information requires both, diverse capabilities for measurement-methods and instrumentation, and appropriate IT procedures. Both, unfortunately, are not adequate at present. Existing measurement technologies are, in many cases, time consuming, labor intensive, expensive, incapable of performing on-line measurements, or even unable at all to address certain issues of food safety. In addition, many food products usually carry claims for having a certain food components with certain beneficial effects to the consumer. These may, or may not be true, and in some cases may jeopardize the food safety. In order to verify these claims and validate the food safety aspects, we need to be able to sense and measure the existence of the said food components. Unfortunately, the technologies to perform these measurements are inadequate, or even totally unavailable yet. In addition, a judicious use of traceability protocols entails routine monitoring to provide data for risk assessment, enforce laws, ease international trade and help verify food labeling. While tremendous progress has been achieved already in the development of reliable measurements techniques, sensors and cost-effective diagnostic tools, many issues still remaining un-

solved and thus impair the implementation of a viable traceability process.
Likewise, a user-friendly, reliable data collection and archiving system is yet not available. The desired system should be comprehensive, but at the same time easily accessible and transparent to all the "players".
Finally, a universally accepted regulatory framework is still not available and is essential for implementing a viable procedure for traceability. Traceability protocols could, in principle, be controlled within the confines of one's own organization and facilities. But, they can prove difficult, or even impossible, to manage across unrelated entities and widespread geographies. Administering these protocols across these different entities may prove to be quite challenging.
Since traceability is linked to both economical and political considerations, some major, yet unanswered issues need to be addressed. For example, can traceability be internationally accepted, will it be voluntary or mandatory and if mandatory, will it be enforceable? Who will pay for the extra cost involved and will the tracing process be tamper-proof? While the EU appear to favor a statutory imposition of traceability, the US seems reluctant to enforce legislative actions and the LDC's are in no position at all to implement a monitoring and control systems, at least not in the foreseeable future.

5. Engineering Aspects of Traceability - The Role of the Club of Bologna

Realizing the importance of the traceability issue on one hand and its link to mechanization on the other hand, the Club of Bologna addressed these two linked together issues in two separate sessions held respectively in July 2002 in Chicago, U.S.A at the ASAE/CIGR meeting and November 2002 in Bologna, Italy at the 13th meeting of the Club of Bologna, on the occasion of the 33rd EIMA show. While it is beyond the scope of the club's activities to address all the issues of traceability, as an internationally think-tank group on strategies for the development of agricultural mechanization, it has sought to identify the possible contribution of mechanization to the process of traceability.
Traceability involves the inputs from many disciplines, such as the recording and monitoring of all the field operations; chemical, physical and microbiological analysis throughout the production chain; genetic fingerprinting (labeling) and marketing studies; and the data processing of these inputs in a manageable, transparent and meaningful way. All these inputs are inherently engineering oriented. Thus, engineering issues play an important role in the traceability process **[13].** They affect the various stages of the production chain and have the capabilities to measure and sense the various conditions relevant to traceability. Thus, for example, the quality of the work of the machine, machine settings, malfunctions and interaction with the operator - for all the mechanical operations from cultivation to final handling - are all- important factors affecting overall traceability. Moreover, meaningful traceability entails the measurements of both, the environmental and climatic conditions occurring naturally, that may affect the food safety. Temperature; humidity; radiation and wind conditions of the environment; quality of irrigating water; air and soil pollutants and air-borne pathogens, are some examples of important factors that need to be measured and quantified. In addition, circumstantial sensing of various parameters of production operations are additional examples of the needed engineering contribution to the traceability process. Examples are gas composition in fruit storage rooms; temperature and relative humidity of grains during harvesting or in grain storage silos; gaseous conditions inside of animal's housing and identification and quantifying of contaminants in plant and animal product, both external and internal. Product characterization is another vital element of the traceability process, requiring identification (origin), analysis of product constituents and possible residues (contaminants). Without the capability to measure and the availability of suitable instrumentation the implementation of traceability is doubtful. While significant development has been done in recent years, a lot still need to be done. A thorough study is therefore required, which could be initiated by the Club of Bologna to identify the technological gaps in the traceability process. This should include a thorough analysis of the present situation of tractors, agricultural machinery and processing plants and their effect on traceability. Since the reliability of the technical aspects of the tracing system depends very much on the equipment design, a fresh look at current equipment design should be initiated to consider, among other parameters also the traceability aspects. The availability of electronic and

mechanical devices required for the traceability process should also be evaluated, to be followed, subsequently, by suggestions of possible solutions based on recent and forecasted developments **[12,13,14].** Such study may be carried out in the form of an EC Concerted Effort initiative, EC PF6 program, or sponsored by FAO and may serve as a stimulant for both, researchers and industry to address yet unsolved problems. Since this approach represents primarily medium-long solutions, one should consider also more immediate, simplified, low-cost and users-friendly solutions, to allow a short-term traceability process.

Many food components are biologically active molecules. Thus, one approach to measuring biological molecules in food is to mimic the detection strategies of cells.

Thus, for example, highly specific electronic sensors have already been developed for biomolecules. Nan biotechnology offers a potential powerful tool for diagnostic purposes, providing better methods for addressing food safety issues. Researchers at Stanford University, for example, have demonstrated the potential diagnostic application of nanotube-based sensors for detecting proteins selectively from solution. Other examples also exist (in different stages of development) of biosensors, which utilize biochemical reactions to determine the presence of specific compounds, offering the food industry rapid and relatively inexpensive types of monitoring devices with high sensitivity.

Another issue where the Club of Bologna can play an important role is the need for standardization in the measurements required for the traceability process. Traceability is the property of a result of a measurement whereby it can be related to appropriate standards through an unbroken chain of comparisons. However, the administrative system to confirm traceability depends on the country to which traceability is sought. Thus, an attempt should be made to develop a universal standard.

Finally, the Club of Bologna could contribute to the educational aspects of traceability by taking the initiative and collaborating with both national and international organizations to introduce the concept of traceability.

6. Conclusions

Traceability is becoming understood as a method of connecting producers to consumers, and of providing increased security around food supplies. There is almost a world consensus that a traceability system has a potentially useful and important role to play in helping to protect the interests of the consumers in relation to food. However, many still question the practicality of such a system because of the complexity of supply chains and the multi-national food supply. The whole process would, undoubtedly, add cost and complexity to the supply chain, and would be reliant upon adequate chain of custody documentation and various testing systems. Thus, in spite of the recognized importance, there are currently no general legal requirements to put such systems in place. Moreover, the means of achieving full traceability has not been determined. Nevertheless, the growing requirement to accommodate the needs for traceability in the burgeoning climate of global trade and consumer demands, has prompted various initiatives to address the needs for traceability. Several (albeit only partial) models have been developed and even implemented on several products. Because of the public pressure to ensure that food supply is safe, it is believed that an ultimate consensus on traceability issues and systems structure could be reached. More work is required to fill up the many gaps in the planned system and a concerted effort to coordinate the work done in different places. Since every traceability scheme will rely heavily on engineering inputs, the Club of Bologna has an important role in promoting the concept of traceability through forum discussions, information dissemination and serving as a catalyst for research and development activities.

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