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# An Overview of Agricultural Traceability Systems: How to Track Products from Farm to Fork

# Un Aperçu des Systèmes de Traçabilité Agricol: Comment Suivre les Produits de la Ferme à la Forchette

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**Résumé :** La traçabilité agricole est un sujet crucial pour les agriculteurs, les consommateurs et l'environnement. En effet, la traçabilité permet de suivre le parcours des produits agricoles depuis leur production jusqu'à leur consommation, en passant par la transformation et la distribution. Cette transparence offre de nombreux avantages, notamment pour la sécurité alimentaire, la qualité des produits, la protection de l'environnement et la confiance des consommateurs.

La traçabilité agricole est un enjeu majeur pour les agriculteurs, les consommateurs et l'environnement. La mise en place d'un système de traçabilité fiable et transparent est essentielle pour garantir la sécurité alimentaire, la qualité des produits, la protection de l'environnement et la confiance des consommateurs. Les avancées technologiques et les initiatives des acteurs de la filière agricole offrent des solutions pour améliorer la traçabilité et répondre aux besoins de toutes les parties prenantes. Il est donc important de continuer à sensibiliser et à encourager les agriculteurs, les transformateurs, les distributeurs et les consommateurs à adopter des pratiques responsables et durables pour assurer un avenir meilleur pour l'agriculture et la planète." Dans cet article, nous allons explorer les enjeux de la traçabilité agricole et les solutions pour améliorer sa mise en œuvre.

**Mots-clés :** Traçabilité, le secteur agricole, les stations d'emballages et les entreprises agricoles, filière de tomate, Théorie des parties prenantes, responsabilité sociale des entreprises.

**Abstract:** Agricultural traceability is a crucial issue for farmers, consumers and the environment. Indeed, traceability allows to follow the path of agricultural products from their production to their consumption, through processing and distribution. This transparency offers many benefits, including food safety, product quality, environmental protection and consumer confidence. Agricultural traceability is a major issue for farmers, consumers and the environment.

The implementation of a reliable and transparent traceability system is essential to guarantee food safety, product quality, environmental protection and consumer confidence. Technological advances and initiatives by agricultural industry players offer solutions to improve traceability and meet the needs of all stakeholders. It is therefore important to continue to raise awareness and encourage farmers, processors, distributors and consumers to adopt responsible and sustainable practices to ensure a better future for agriculture and the planet." In this article, we will explore the challenges of agricultural traceability and solutions to improve its implementation.

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## Introduction

Global supply chain traceability has become an increasingly important issue in recent years, with calls for increased oversight and transparency (Steven, 2015; MacCarthy et al, 2016).

Governments, media, industry groups, suppliers, customers, and the companies themselves are all interested in better understanding how companies manage their global supply chains in terms of information sharing (Silverstro&Lustrato, 2014), quality control (Chen et al, 2014), supplier management (Handfield et al, 2015), disruption prevention (Kleindorfer& Saad, 2005), and risk management (Grötsch et al, 2013).

Recent supply chain safety and security issues in different industries, including food service, pharmaceuticals (e.g., Heparin issue 2008), consumer foods (e.g., e-coli in hamburgers), have further exacerbated the requirements of companies to improve supply chain traceability.

As a result, companies have begun to increase and improve product traceability throughout their global supply chains in order to have information readily available for internal use and to satisfy stakeholder demands (Shafiq et al, 2014).

In addition, traceability is an important benefit for companies in terms of managing product quality control and safety, tracking product recalls, and optimizing reverse logistics processes (Chen et al.

Recently, more and more research has focused on tools to effectively manage traceability in the supply chain.

Information technologies such as RFID have become important enablers for tracing products/services throughout the supply chain, as they promise improved speed, transparency, and security of information sharing (Jakkhupan et al, 2015; SAE, 2015; U.S. House of Representatives, 2007).

Yet, for all its purported benefits, traceability can be difficult to implement both internally and across the supply chain.

Companies often struggle to obtain critical, accurate, and up-to-date logistics information from supply chain partners (Mattevi& Jones, 2016).

In addition, the extent to which companies receive and use information differs from company to company and supply chain to supply chain (Mattevi& Jones, 2016).

1. Definitions and importance of traceability :

1.1. Definition:

The term traceability, from the root "trace", was first defined in 1987 in the XF 50-120 standard. Traceability is "the ability to trace the history, location or use of a product by means of recorded identification".

In 1987, the traceability was defined Standard NF X 50-1201. This national standard is recognized as equivalent to ISO 84022 Time. Then, traceability is defined as Below: "Product traceability is the ability to find historical, location or use of the product of a means of identification recorded. "

In 1995, the ISO 8402 resume this definition by introducing the concept of entity. In 1998, the traceability is as the "possibility of following a product at the various stages of its production, its transformation and its marketing, in particular in the food chains" (The definition in the Petit Larousse and the Robert). For the standard ISO 9000: 2000, the traceability is "the ability to find the history, the implementation, the location of what is examined".la norme ISO 9000: 2000

Traceability was introduced in companies in the 1980s, in the context of Total Quality Management (Moe, 1998; Souza Monteiro and Caswell, 2009). With the mad cow crisis in 1996, traceability is a concern for companies especially in the agri-food sector (Viruega and Vernet, 1999; Loureiro and Umberger, 2007; Galliano and Orozco, 2011). Under the effect of European regulations (eg. EC 178/2002 for traceability in the food industry in Europe, REACH), companies are complying and developing traceability practices, formalized in quality procedures. The first theoretical and empirical work appeared in sectors where products are "vulnerable" (food, biochemistry, health) (Jansen-Vullers et al, 2003).

The definition of traceability presents traceability as the ability to retrieve information about an entity by means of recorded identifications. This definition reminds us that the word traceability is constructed in the same way as power, namely the contraction of the ability to do something.

Traceability is the ability to trace an entity. This entity is little defined and it was only specified in the standard X 50 120 that it could be a product. In fact, the definition of the entity is made by the place of the definition of traceability. This definition is found in the quality standards of industrial systems and more precisely in the section control of the processes. We can conclude that the entity is an element of the process or which passes in the process and which is to be taken into account in a system of quality assurance. This entity can be a raw material, a machine, a finished product or a transformation step.

Therefore, traceability is the ability of a production system to follow the entities of this system. A trace is an identification of the path taken by this entity inside or outside a process. Here is what the terms, locations, and historical uses refer to.

ISO 8402 definition (ISO 8402, "Vocabulary for Quality Management and Quality Assurance," AFNOR 1994.) of traceability Complete the NF X 50 120 definition. "Traceability is the ability to find the history, use or location of an item or activity, or similar activity, with a recorded identification. "

So to conclude, many definitions are put forward, both by current regulations and by some reference authors. However, to date, there is no real consensus on the definition.

Variations in the definition of traceability are also widespread in the academic literature. In a study aimed at understanding the extent to which recall improvement, market response and regulation impact the perceived benefit of traceability, Dessureault (2006) applied the ISO definition, arguing that it is the most widely used. Golan et al, (2004), however, criticized the broad ISO definition on the grounds that it lacked specification standards on measurement and tracking as well as on the information, technology and accounting process flow. Thus, they developed a definition of traceability that means a record-keeping system designed to track the flow of products or product attributes through all stages of production, processing and distribution.

Although Golan et al, (2004) attempted to narrow the meaning of traceability in their research to develop a framework for how the private sector meets the social goals of traceability, they proposed a definition that appears to perceive traceability from the distribution channel to the consumer. Dickinson et al, (2003) also addressed the meaning of traceability as the ability to track the inputs used to produce food products to and from their sources at different levels of the marketing chain. This definition incorporates the identity preservation required for provenance certification while Hobbs (2004) introduced an element of distinction between ex-ante traceability as the provision of information about process attributes that verify product quality, and ex-ante traceability as the process of tracing a product back to the source.

In light of the imperfect information exchange in the food supply chain, traceability studies have been addressed at different levels. Traceability can be done to the processor stage or to the final consumer stage, also referred to as farm-to-fork. A number of studies on traceability have concluded that traceability should be from farm to processing (Bertolini et al, 2006; Bollen et al, 2007; Regatierri et al, 2007). However, Ammendrup and Barcos (2006), in a study on the main purpose of traceability, its characteristics and depth, concluded that the application of the farm-to-fork or consumer stage is the most revealing of the traceability concepts. Other studies (Baggio, R. and Cooper, C. (2010),) supported Ammendrup and Barcos' (2006) view and concluded that traceability can only be established at the final consumer stage. Above all, the fact remains that achieving a robust traceability system in the food supply chain is a complex task and often not replicable across sectors. Despite this, traceability is the method for achieving end-to-end provenance in the food supply chain.

The first example of traceability is proof of passage to a particular location or certificate of origin. The interpretation of the negative hands affixed to the cave walls, decorated with the Cosquel of Lascaux and the Chauvet of Altamira, is certainly bold as the signature of certain passages of our ancestors. The following table shows the different definitions proposed by practitioners:

**Tableau 1: Reports on the plurality of definitions of traceability found in the selected references, reflecting the diversity and richness of this concept.**

| Auteurs | Definition | Reference definition second Main |
|---|---|---|
| Bendaoud(2008) | Ability to reconstruct, in whole or in part, the life cycle of the object in question. p. 146 | |
| Fabbe-Costes et Lemaire(2001) | We call total traceability, the traceability ensured on the scale of a chain of supply (...) It is thus a question of following as well the physical flows (batches of materials, components, products, logistic units) and the documents which are associated to them, as the actions which allow their transformation (production, assembly, conditioning, etc.) or their movement (handling and/or transport).p.3-4<br>Traceability in logistics consists in being able to locate physical flows (or entity flows) at any time, to reconstruct ex post or in itinere the history of the flow, to provide a holographic vision of the supply chain. p. 4 | |

| | | |
|---|---|---|
| Fabbe-Costes(2006) | Traceability in logistics consists in being able to locate physical flows (or entity flows) at any time, to reconstruct ex post or in itinere the history of the flow, to provide a holographic vision of the supply chain. p. 4 | |
| Fabbe-Costeset Lemaire(2010) | Total traceability (...) refers to the traceability of the whole chain, in its inter-organizational and global vision. p.3 | |
| Baillette et al. (2012) | It allows to follow and thus to find a product since its creation (production)<br>creation (production) to its destruction (consumption).<br>Traceability has not only the ambition to follow a product from its creation to its distribution (traceability of objects), but also to follow the activities of the people who implement these products to follow the entire production process (traceability of activities). | |
| Golanetal.(2004) | Traceability systems are systems of record that track products or their attributes throughout the production process or supply chain.p.1 | |
| Jansen-Vullers et*a l*. (2003) | Tracking a product and its history through all or part of the value chain. Traceability is defined as active or passive. p. 401 | |
| Karâa et Morana (2008) | Traceability implies the ability to represent, describe but also locate products, in real time.p.2 | |
| Karâa et Morana (2011) | Traceability makes it possible to trace the origin of a product or an activity, highlighting its history, its components, the conditions of production, planning/design and the operations of storage, packaging and distribution.p.15 | Cheng et Simmons, 1994 |
| Moe (1998) | Ability to follow a batch and reconstruct its history from its origin to its marketing, thus providing information related to the activities of harvesting, transport, storage, processing, and distribution (supply chain traceability) but also information related to internal traceability (e.g. production stages).p.211 | |
| Pellaton et Viruega (2007) | One will speak about a system of total traceability to qualify a system of traceability which allows at the same time to trace the products and the processes. | |
| Romeyer (2001) | To ensure the possible follow-up in real time, of the flows (trans-functional even inter-organizational) of multidimensional information (spatial and temporal) associated with the physical flows within the logistic chain. p. 44<br>Traceability integrates the activities and consists in ensuring the follow-up of the activities (and information relating to these activities) and the information flows (associated with the physical flows within the logistic chain) connecting these various activities. p.68 | |

| | | |
|---|---|---|
| Ta (2004) | Definition1: "Ability to trace the history, implementation or location of what is being examined".<br>Definition2 : Upstream traceability : or supplier traceability " Procedures or tools put in place to be able to find what happened before the economic actor (company or processing site) becomes legally or physically responsible for the products ".<br>Definition 3 : Internal traceability: or traceability of the manufacturing process " Traceability set up in the company throughout the manufacturing process of the products, since the reception of the raw materials, until the forwarding of the manufactured products ".<br>Definition 4 : Downstream traceability: or traceability since the company towards the customers " Procedures and tools set up to be able to find what occurred after the transfer of property or after the physical transfer of the products manufactured by the company towards a third ".<br>Definition 5 : Upward traceability " It is the capacity, in any point of the supply chain to find the origin and the characteristics of a product starting from one or more given criteria ". | Définition 1:NF EN ISO 9000:2000 |
| Viruega et Vernet, (1999) | "Traceability is the ability to trace the history, use, or location of an item or activity, or similar activities, through recorded identification."<br>Process traceability is based on the three meanings of ISO 8402:<br>- in the sense of placing on the market, it applies to a product or service;<br>- in the sense of calibration, it applies to the connection of measuring equipment to national or international standards, to primary standards or to basic physical constants and properties<br>- in the sense of data collection, it links the calculations and data produced along the quality loop to the products or services p. 83-85<br>Origin traceability characterizes the use of traceability to determine and guarantee the origin of products. p.87 | ISO 8402 |

Source : auteurs

1.2 Importance of traceability :

Although traceability has become a common term in the vocabulary, its origin would date from little. According to Pellaton and Viruega (2007), it was in 1998 that the French dictionary referred to it (in 1994 for the English translation: traceability). However, as early as the 1970s, we find the first writings emphasizing the importance of product tracing and recall as a source of competitive advantage (Fisk and Chandran, 1975). In doing so, it should be appreciated that since antiquity, tracing practices have existed through - for example - the application of seals on administrative acts, the marking of animals both to specify the name of the owner and in a sanitary context. Nowadays, it is in the constraints resulting from the agricultural and agro-alimentary sectors that traceability finds a place of choice. And it is mainly by relying on the standard ISO 8402: 1994 that traceability is defined: "the traceability of the product is the aptitude to find the history, the localization or the use of a product by means of a recorded identification". As such, traceability is then seen either as a tool, a means to the management of a supply chain (Romeyer, 2000; Fabbe-Costes and Lemaire, 2001; Colin, 2005), or as an approach in its own right (Viruega, 2005; Pellaton and Viruega, 2007).

As such, traceability applies to both people and things. In the case of people, it replaces the quarantine, which is currently difficult to apply because of the "easy opening" of borders (Torny, 1998), but also through the social security number that identifies each individual. Applied to the company, traceability makes it possible to trace the origin of a product or an activity, by highlighting its history, its components, the conditions of production, planning/design and operations (Cheng and Simmons, 1994), its storage, packaging and distribution. In this respect, Hermitte (1996) distinguishes three main uses for traceability:

**a.** A fight against illicit use where we find the idea of counterfeiting and/or the use of illegal products such as drugs,

**b.** A safety tool a posteriori which refers to the recall of the dangerous product after a marketing.

**c.** A risk prevention tool through the edition of product lists as in the medical sector.

In its practice, two functions are attached to the traceability: the tracking (follow-up in real time of the flows) and the tracing (memorizing this follow-up). These two functions are all the more important as traceability is linked to the ever increasing accumulation of information.

According to this process, traceability seeks to synchronize a set of physical and informational flows which, when driven in an integrative way, lead to improve the coordination and competitiveness of all the actors of a logistic chain, in order to create value for the final customer. And to meet this challenge, traceability calls daily on Information and Communication Technologies (ICT). Although induced in all industrial sectors, traceability finds its foundation in the agri-food sector in an objective of sanitary security (Lehu, 2000; Viruega and Venet, 2000; Barre, 2004; Lecomte et al, 2004; Tuffery, 2005). The various crises require the marking of products. The objective is to clarify the role of each stakeholder in the supply chain. The aim is to know who did what, when and where. The topic of agri-food traceability thus seems particularly important and timely. In short, the ultimate goal of any traceability approach is to ensure the safety and quality of the products concerned, which is at the heart of EU and global trade policies. And in the extension of this reasoning, third countries will be forced to apply equivalent rules of traceability before being able to export their products to the European Union.

The traceability allows to know where a product comes from, and to follow its logistic course among other things the conditions of supply, the conditions of storage, and finally of distribution

The globalization of trade has increased consumer demands for information on the origin and quality of the products they buy

The traceability of origin is today at the heart of the issues of transparency desired by a growing number of consumers and companies, and cases such as those of mad cow disease and the pseudo Spanish cucumber.

## 2. The typologies of traceability :

Professional news and academic research (press, professional journal) show that academic research a general enough introduction to traceability to ask relevant questions.

The traceability then has several typologies to know:

- The internal traceability
- The downstream traceability
- The upstream traceability
- The ascending traceability
- The descending traceability
- The traceability of products

2.1. Internal traceability :

The internal traceability (or traceability of manufacturing processes) concerns the part of the process within the company producing or processing the product in question. That said, the implementation of internal traceability presents certain difficulties due in particular to the passage of the entity by several platforms, workshops of production and storage. Then the internal traceability concerns all the stages that have in the company and this very important traceability and that which makes the role of quality control and it is the task for which was created the traceability.

2.2. The downstream traceability :

Downstream traceability is to trace a product by following the chronology. When a defect is detected on certain parts, for example, it is possible to identify the products containing these parts to make a precise recall. This is an effective way to prevent recalls and defective products.

Downstream traceability (or traceability from the company to the customers), as opposed to upstream traceability, refers to all the tools and procedures allowing to follow the delivery of the goods to the final customer, i.e. to follow the product at the various stages of its production and its transformation until its delivery to the customer. (Ta 2002, 2004; Lecomte et al, 2006).

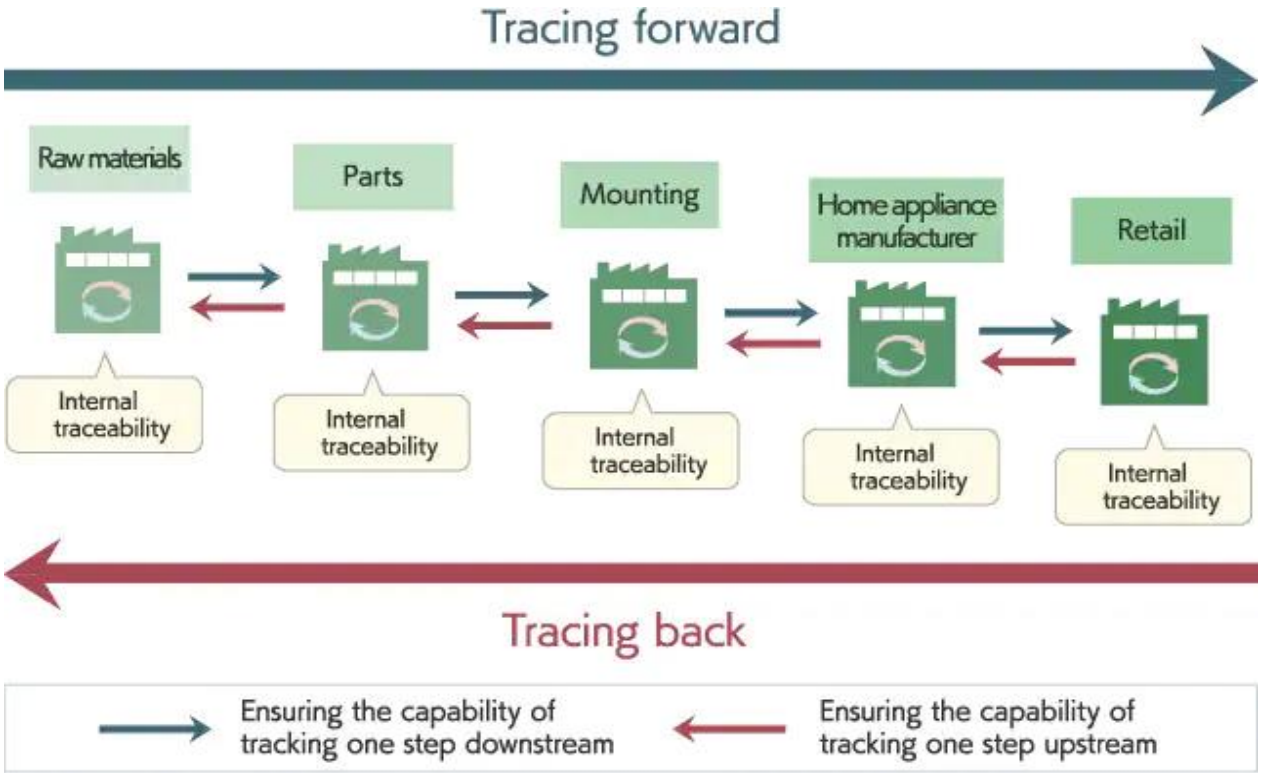
2.3 Upstream traceability:

Upstream traceability, mandatory for certain sectors of activity such as the food industry or the pharmaceutical industry.

Upstream traceability according to Ta 2004 or supplier traceability "Procedures or tools put in place to be able to trace what happened before the economic actor (company or processing site) becomes legally or physically responsible for the products" (Definition 1: NF EN ISO 9000:2000). Upstream traceability (or traceability from suppliers to the company) also refers to the routing of raw materials from the supplier to the company, so everything related to the first phase.

And the figure n°2 shows the first typology of upstream/internal/downstream traceability. However, according to us, this diagramming of Ta (2002) is very simplified compared to what occurs in reality. The step of traceability is indeed, much more complex and just to understand well this type of traceability.

**Figure 1:** La première typologie traçabilité amont et en aval




**Source : Lecomte et al. (2006)**

2.4. Ascending/descending traceability :

A second distinction can be made between upward, downward traceability. The traceability first, as a general rule; it grants to identify the origin of a product, that allows to recognize the problem if there is, to know the causes of a defective product and to avoid that replicates: it is about the ascending traceability.

- If the consumer is not satisfied with the quality of the product, the consumer can inform the consumer services by indicating the lot number of the product concerned.

- This marking allows the company to quickly identify the product concerned.

Upward traceability is a legal obligation that allows you to go back from the final product to the raw materials used in its production, and therefore has the following objectives

- Identify those responsible for health problems is very important.

- To improve the safety of consumers.

- To learn the quality process.

- To improve the logistic flow.

- To comply with effective regulations.

The ascending traceability concerns all the food industrial sectors...

Moving now to the downward traceability this type of traceability is allows to follow the course of a product in different stages of its manufacture to its consumption, it allows the companies to know the exact place where is located a given product, for these reasons :

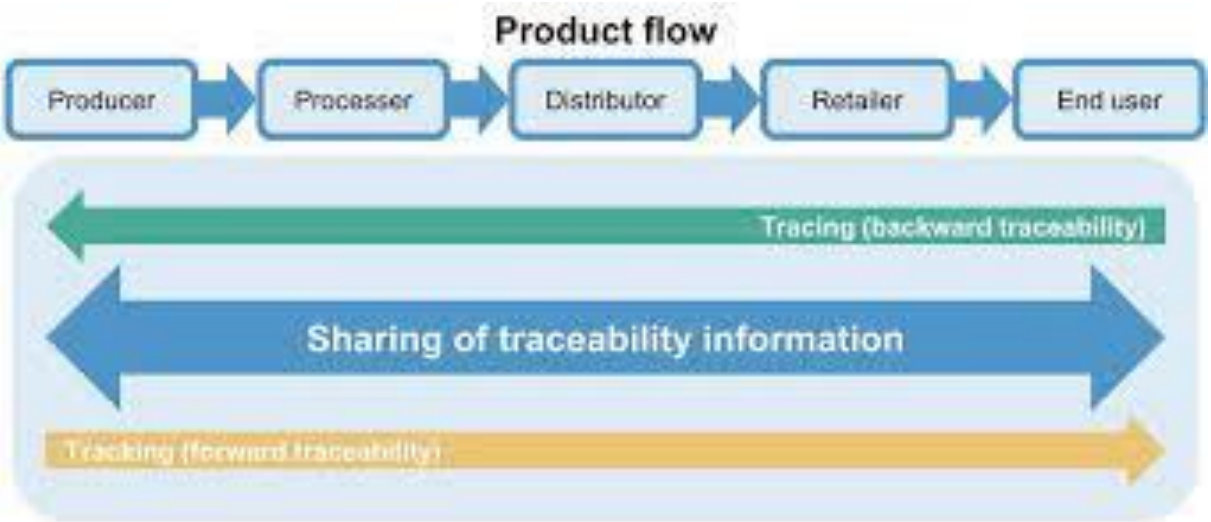
- Companies can intervene quickly by recalling products or batches and withdrawing them from the market as soon as they detect non-conformities.

- It is therefore a quality approach that the company must adopt to ensure consumer safety and product quality.

The downward traceability is to guarantee the company and also the consumer and it is there that a consequently, the downward traceability is used when a company must withdraw a product or a batch of products from the market, in particular when a problem of nonconformity is detected. The company knows the exact location and destination of the product and can act without delay thanks to this type of traceability. And with top-down traceability, companies can:

- Prevent the risks associated with manufacturing defects.
- Know all the steps of the production and marketing process.

Figure 3: The different types of traceability




**Source : auteurs**

2.5. The traceability of products :

The traceability of products is the monitoring that concerns especially the agri-food sector, it is a guarantee of quality for the consumer and moreover is part of the quality approach and the image of a company, is also the identification of the causes of a quality problem and also to trace a product and control its quality in the various stages of production transformation distribution and also consumption.

We can in this kind or this type of traceability asks the following question, Why the traceability of products?

Then to answer the following question one can say that the traceability of the products is very important and also the traceability of the products it is the common point between all the sectors and what very important it is that the state imposes the respect of standard quality always more rigorous and the installation of techniques of traceability always more powerful. For the company as well as for the consumer, it is a question of :

- To seek techniques to ensure the safety of products on the market;
- To answer the high requirements of the customers and especially the foreign customer because this customer and more requirement by contribution with other;
- To answer to a strict and hard regulation;
- To find the identification of the causes of a quality problem.

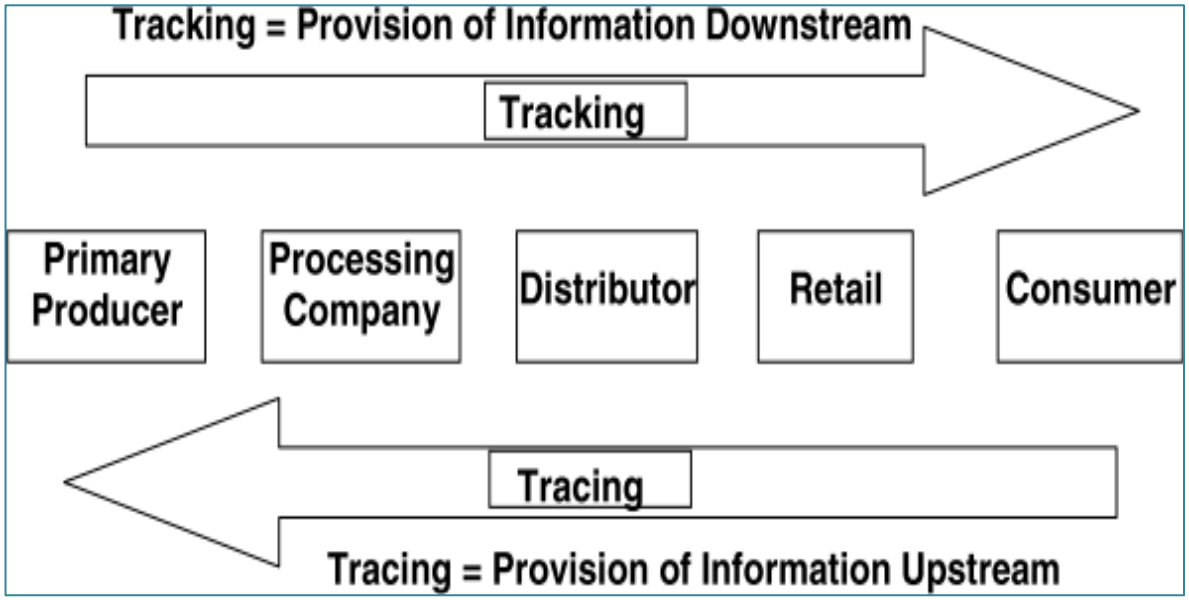
The traceability of the products allows the company to defend itself in case of problem it works to detect where there is a problem by bringing the proofs that it has well respected all the regulation during the manipulations of the product at the time of its supply until its distribution detects where there is the problem and hold the concerned person the responsibility.

## 3. The follow-up and the tracing

### 3.1 General :

Van Dorp (2002) points out that there is no uniform understanding of tracking and tracing. Definitions vary depending on the dimensions of the type of activities included and the organizational context in which they are performed. Stefansson and Tilanus (2000) indicate that tracking generally means following the entity on its path from A to B, while tracing means finding the entity between A and B. Schwägele (2005) defines tracking as "the ability to follow the path of an item as it moves down the supply chain from beginning to end," and tracing as "the ability to identify the origin of an item or group of items, through records, up the supply chain."

**Figure 4 shows the flow of tracking and tracing information through the supply chain.**




Source : Davies, C. (2004) 'Preparing for New EU Traceability Laws', pp. 24.

Although the quality of the transport process can be very high, a tracking and tracing system could still provide benefits in other ways. According to Stefansson and Tilanus (2000), it could be applied for administrative purposes, e.g. as a basis for payments to transporters. In addition, the data collected could be statistically processed and integrated into an information system to confirm whether the quality of the process is maintained at a satisfactory level. Traceability also covers everything about the products before, during and after the manufacturing, packaging and distribution process, which involves ingredients, processes, tests and test results, environment, resources used, transportation methods, etc. (Schwägele, 2005).

Based on the findings of van Dorp (2002), considering the variation in quality of tactical and operational levels of production, two types of definitions of tracking and tracing could be established, tracking and tracing in the narrow sense and tracking and tracing in the extensive sense (van Dorp, 2002). The characteristics of each type can be found in Table 2. The main difference between restricted tracing and extensive tracking and tracing is that the latter encompasses the former and allows traceability information to be used in multidimensional environments. Supply chain domains instead of focusing solely on product tracing.

**Tableau 2:** Deux types de suivi et de traçabilité (van Dorp, 2002)

| **Suivi et traçage au sens large** | **Suivi et traçage au sens restreint** |
|---|---|
| ➢ Includes tracking and tracing in a limited sense<br>➢ Information is used in the control and management of successive stages of production<br>➢ Provides dynamic batch allocation<br>➢ Optimizes and controls processes within and between the different links in the supply chain | ➢ Provides real-time visibility and disposition<br>➢ Creates a history for component traceability and usage of each final product<br>➢ Provides upstream and downstream traceability |

3.2. Tracking and tracing principle:

Stefansson & Tilanus (2000) emphasize that a track and trace system should include the interface between a physical transportation system and an information system. They classified tracking and tracing systems according to eight attributes:

Commodity identification technology: e.g., alphanumeric codes, bar codes, RFID, etc.

- Tracking and traceability system scope: Tracking and traceability system scope is defined by the three dimensions of transformation: transportation (location transformation); storage (time transformation); and conversion processes throughout the supply chain (form transformation).

- Timing and placement of entries : Sometimes tracking is done at discrete times and places that need to record time and place. For example, when possession of the shipment moves from one carrier to another, which may involve different modes of transportation, in this situation the time and location must be recorded to maintain the completeness of the transportation information.

- Hierarchical Level: A discrete record instance may refer to different hierarchical packaging levels and different hierarchical assembly levels.

- Recorded Attributes: A tracking and tracing system can record three attributes: entity identity, current location, and current time. Additional entity attributes such as quantity (if the shipment is complete when the shipment consists of multiple units) and quality (if observable damage has occurred).

- Information system organization: The information system that stores tracking and tracing data may be centralized or shared by multiple participants.

- Information system accessibility: A tracking and tracing system should allow interested parties to track and find entities traveling from A to B. There are two types of information system accessibility. Non-automated, queries must be made and answered manually; automated, queries can be made automatically whether the information is centralized or decentralized, via EDI or the Internet.

- Tracking and tracing system activity level: A passive tracking and tracing system records entities at fixed locations as they arrive or depart. An active track and trace system monitors the entity's progress from one control point to the next and notifies the user if anything unexpected is recorded.

4. Motivations for adopting traceability systems

Traceability systems typically track the flow of products and services from suppliers through production, distribution, and retail to the last customer. Bourkalis et al, (2011) argued that financial information and purchasing data, which flow in the opposite direction of product and service flows, also constitute traceability. European Union food legislation (178/2002) considers all other ingredients intended for use in the production of food products. These may include fertilizers, herbicides and other inputs as part of the traceability system. Information asymmetries in international commodity supply chains can significantly affect product traceability. To ensure the efficient functioning of markets and gain competitive advantage, transparency and information exchange remain key. A number of studies have analyzed the emerging concepts of trust, transparency, and traceability in food chains, but it is still unclear what drives the adoption of traceability systems in supply chains.

Theuvsen et al, (2005) identified six factors as important drivers for the adoption of traceability systems. These drivers were confirmed by Dessureault (2006) as follows:

- market differentiation strategies;
- business process improvements
- risk management strategies;
- stakeholder demands;
- certification system requirements; and
- legislative requirement.

These are now expanded upon below.

### 4.2. Market differentiation strategies:

Product differentiation is one of the important factors mentioned in the literature as a reason for implementing traceability systems (Asioli et al, 2011). For homogeneous products such as tomatoes, effective product differentiations in supply chains depend largely on the origin and traceability attributes that are communicated to consumers. Casewell et al. (2002) reported that changing consumer perceptions of product quality and increased demand for differentiated products have provided greater impetus for traceability and private labeling of foods.

Thus, traceability has gained importance as a market differentiation strategy in international commodity trade. Product origin and traceability labels provide information cues that help consumers form opinions and make purchasing decisions. Country of origin is a common resource in product differentiation and has a strong cultural link to product quality (Tregear and Gorton, 2005). A number of studies have concluded that consumers value traceability when purchasing a product. Caporale and Monteleon (2001) reported that providing information about the sources of a product significantly increased its acceptability and created a positive perception of quality.

Loureiro and Umberger (2003) concluded that the willingness to pay more for a traceable and labeled American steak and hamburger, for example, led to an increase in consumption of 38% and 58%, respectively. Other studies in Europe have also confirmed that consumer expectations underpin the adoption of traceability in supply chains. Roosen et al, (2003), in a market study in Germany, France and Great Britain, concluded that traceability, among other factors, is a high demand attribute. Decisions about market differentiation and competitive positioning in product markets influence the decision to adopt traceability. Bernues et al, (2003) found that the most important information for the European consumer includes nutritional elements and attributes such as traceability. This allows firms and retailers to escape price competition to some extent by creating product niches and distinct brands.

### 4.3. Business Process Improvement

In a survey of the food industry, Gawron and Theuvsen (2007) reported that the adoption of a traceability system has a positive relationship with internal and external business processes, including logistics, inventory control, and quality improvement. Business process improvement as a determinant of traceability is influenced by a company's size, internal organization, location, and industry (Galliano & Orozco, 2008). Larger firms generally have better access to financial resources and benefit from economies of scale. Large firms also have a diverse workforce and range of skill levels, and are receptive to technology and innovation compared to small firms. Firm size also determines the power to negotiate with suppliers and the ability to implement supply chain improvement systems such as traceability. Rabade and Alfaro (2006) thus conclude that the traceability activities employed by a firm are related to its size and resources.

The internal and external organizational structures of firms are important drivers of business processes and traceability. Companies whose organizational structure relies on information technology as a tool to gain competitive advantage and improve business processes have a greater propensity to implement traceability systems. The multi-unit, multi-site structure of companies plays a positive role in the adoption of traceability as a measure of supply chain improvement and control. The environment in which a company is located can determine the willingness to adopt innovations to improve business processes.

In addition, the level of specialization in the area where a company is located could influence network relationships and collaborations with other companies. This collaboration, when extended to suppliers, can serve as a pathway for the adoption of traceability to improve business efficiency. A company's industry, including upstream and downstream stakeholder relationships, and industry characteristics also influence traceability adoption.

Supply chain characteristics and product codes play a role in selecting innovations to gain competitive advantage. The roles of suppliers and downstream distribution, as well as civil society regulations, remain an important element in the adoption of traceability systems. Companies consider the general rules of operation in a market as well as civil governance norms in the design of traceability systems and other supply chain processes.

4.4. Risk Management Strategies:

Although the topic of risk has been introduced into supply chain design, it is useful to explain the concept of risk as a motivation for implementing traceability systems. Risk, in decision theory, is a variation in the distribution of potential outcomes and the probability of their occurrence (Arrow, 1965). However, definitions and measures of risk in the literature vary from field to field. To cope with the globalization of food marketing and simultaneously meet changing consumer demands, commercial companies tend to collaborate with suppliers and consumers within the supply chain. The risks and uncertainties become even greater and more complex in the international supply of raw materials such as tomatoes (Doeg, 2005).

To mitigate supply chain risks, companies are motivated to adopt traceability systems as advanced risk management tools to mitigate the effects of public product recall and the resulting consequences (Doeg, 2005). Public product recalls are often accompanied by legal payments and compensation that affect the company's profit. Crisis communication within the supply chain and disposal of defective products also requires significant media and process investments. Unstructured product recalls result in reduced brand value, lower customer loyalty and a weaker competitive position for the brand. Traceability systems, however, tend to establish product identity and pathways that identify inputs, sources of defects, and locations of affected products. Traceability as a transparency measure in tomato supply chains tends to minimize recall incidents and thus strengthens tomato supply chains. Figure 5 shows the risk management process

**Figure 5: Risk Management Process**

Source : Sacks, A. M. and Johns, G. (2010) Organizational Behaviour, 7th Edn. Ontario

### 4.5. Stakeholder demand

Regulatory states have been developed as a feature of modern governance in the global economy. This is where states seek to extend their governance using civil society and other non-governmental organizations. The private sector is passively directed to effectively self-regulate the supply chain within legal boundaries and standards. In Europe and other developed economies, traceability and certification of origin are at the heart of food chain governance reform, which is taken up by civil society, consumer groups and other stakeholders. Manufacturers can be compelled by stakeholders to implement or improve traceability systems for supply chains (Fritz and Hausten, 2008).

Powerful supermarket and retail chains can impose traceability and its standards on processors and suppliers in the food chain. Commodity finance regulations in the banking sector, for example, emphasize operational risk in the context of lending and require a certain level of traceability to influence the cost of capital of supply chain participants. Other stakeholders, such as non-governmental organizations, are engaged in various campaigns to promote the adoption of traceability. These stakeholder actions, in line with state regulatory concepts, drive the adoption of traceability in supply chains. In the tomato supply chain, consumer groups have actively campaigned against social and environmental issues regarding child labor and pesticide residues in tomatoes. This has led to a resurgence of certification bodies monitoring the supply chain to report incidents of negative practices.

### 4.6. Certification System Requirements:

The requirement for food certification is based on ethical and safety concerns in the supply chain and the aftermath of consumption (Fritz and Canavari, 2010). While food safety issues are largely measurable, ethical concerns involve a range of subjective and objective values, against which certification standards are set. A measurement system for tangible and intangible values applicable to a particular sector can help foster sustainability in a commodity supply chain. As an overarching concept, sustainability aims to protect the environment to build economically viable and socially acceptable food chains (ICCO, 2007).

All consumers need safe food that meets their dietary needs, but not all consumers have access to safe food. Ensuring safe food requires that all processes in the food supply chain be transparent, verifiable and certified. A traceability system is needed to track and trace products for which certification standards are required. Traceability for certification purposes has taken on an international dimension, reflecting the length and depth of specific food chains. Retailer-led traceability certification standards have spread rapidly through the supply chain and have tended to become mandatory for suppliers and thus an incentive for adoption (Trautman et al, 2008).

4.7. Legislative requirements:

Chemical and physical contamination of food, as well as contamination by biological agents, remains a risk in many countries around the world. Civil society's demand for ethical and high quality food has prompted governments to adopt regulations to ensure food safety (Trautman et al, 2008). A number of OECD countries, including the European Community, the United States, Japan, and Canada, have enacted food safety laws and regulations to influence the entire food and food product supply chain.

Legislation such as the European Food Safety Act EC 178/2002 (EC, 2002), the United States Bioterrorism Act 2002 (US Congress, 2002) and the Japanese Food Safety Basic Law 2003 (Yokohama, 2007) emphasize that traceability is fundamental to food safety and assurance of credibility. The complex nature of international supply chains therefore requires suppliers to comply with domestic market legislation in all export destinations. In a competitive international market environment, suppliers are required to focus not only on their own country's regulations, but also those of other countries where their food or food products are consumed.

The need for traceability in the global food chain has become imperative for suppliers in other parts of the world. A number of mandatory and voluntary traceability systems exist in many countries. These schemes are governed by laws or certification systems that define operating standards. These systems often focus on animal products because of their propensity for contamination.

In conclusion, changing consumer perceptions of food quality and increased demand for transparency in food supply chains have contributed to the growing literature on traceability. The ISO protocol for food defines traceability as the ability to trace and link the origin of inputs, the processing history, and the distribution location of the product after delivery (ISO, 2007).

However, the debate over a commonly accepted definition continues to evolve in both policy and academic circles. The fundamental characteristics and functionality of traceability systems include product identification, traceable data, product route identification, and traceability tools. Data storage and exchange processes can be performed using basic paper-based handwritten systems, higher capacity two-dimensional barcodes/matrices, and advanced radio frequency identification (RFID) systems. Theuvsen et al. (2005) and Dessureault (2006) have identified factors such as market differentiation strategies, business process improvement, risk management strategies, stakeholder demands, certification system requirements, and legislative requirements as motivating the adoption of traceability systems in supply chains.

Advantages and efficiencies of setting up a supply chain :

5.1. The advantages :

The implementation of a supply chain has several advantages namely the optimization of the storage space of the costs of supply and thus of the transport, also better traceability of the products, an advantage of increase of the productivity, the reduction also of the handling costs by an allocation of the material and human resources less, and the improvement of rate of customer satisfaction, to know well its expenditure and its costs allows the company to better control them. Thus, your strategic decisions become more relevant.

Beyond financial indicators and profitability, an increasingly important notion is appearing: the ecological footprint. The notion of eco-logistics performance, competitiveness and respect for the environment. It is a question of integrating in the rate of customer service, the cost of obtaining the product and the impact on the environment.

KLS offers different WMS/TMS solutions (WMS: Warehouse Management System; TMS: Transport Management System)

To get the most out of your logistics management. Please note that these solutions can be integrated with other offers of the market if you already have a WMS or TMS tool. Indeed, to be efficient, the Supplychain must be treated from A to Z.

In other words, it is necessary to optimize the supply of raw materials or finished products up to the shipments.

The advantages of logistics management are multiple:

- Optimization of storage space,
- Reduction of supply costs and therefore of transport costs,
- Reduction of handling costs by allocating less material and human resources,
- Better traceability of products,
- Increased productivity,
- Improved customer satisfaction rate.

Knowing your expenses and costs allows the company to better control them. Also your strategic decisions become more relevant. The Supply Chain is the management of the supply chain and the smooth running of a company. Thanks to it, it is possible to control the production and supply of a product, or to follow its journey from the producer to the consumer. It is therefore a key service for a healthy company.

5.2 Efficiency of traceability systems

The new European regulation on food safety makes traceability mandatory in the agricultural sector. The objective is to be able to contain the destabilizing effects of a possible food safety crisis on the markets. The ambition is very high, but the public authorities do not want this traceability to result in costs that would weigh on the competitiveness of companies and sectors or that would be passed on too heavily to consumers.

Conclusion

In conclusion, agricultural traceability is a key concept for ensuring food security, sustainability and transparency in modern agriculture. The theoretical and conceptual underpinnings of agricultural traceability include supply chain management, corporate social responsibility, and sustainable development. By tracking every step of crop production, from planting to harvesting to treatments and fertilizers used, farmers can ensure that crops are produced in a sustainable and environmentally friendly manner. Agricultural traceability also provides increased transparency for consumers who want to know where their food comes from. Ultimately, agricultural traceability is a key element in ensuring a sustainable future for agriculture and food security.

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