
Volume 29, No. 2 pp. 83–158
February 2013
ISSN 0924-2244
ELSEVIER
TRENDS IN FOOD SCIENCE & TECHNOLOGY
Modelling in the food cold chain
Pulsed electric fields processing effects on plant-based foods
Tasting as a presentation method for sensory stimuli in conjoint analysis
Food safety challenges associated with traditional foods in the Middle East
Increasing use of barley and barley by-products
Equilibrium water activity of dry powder mixtures
How to define traceability?
Use of data mining techniques to discover knowledge from animal and food data

ELSEVIER

Trends in Food Science & Technology 29 (2013) 142–150

TRENDS IN FOOD SCIENCE & TECHNOLOGY

Viewpoint

How to define traceability

Petter Olsen[a,*] and Melania Borit[b,1]

[a]Nofima, Muninbakken 9-13, Breivika, Postboks 6122, N-9291 Tromsø, Norway (Tel.: +47 776 29231; fax: +47 776 29100; e-mail: petter.olsen@nofima.no)
[b]University of Tromsø, Norwegian College of Fishery Science, N-9037 Tromsø, Norway (e-mail: melania.borit@uit.no)

While food product traceability has become increasingly important in recent years, there is no consensus on what the term "traceability" means, and several conflicting definitions exist. This paper gives an overview of relevant traceability definitions, outlining similarities, differences, and the consequences of choosing one definition over another. To ascertain which definitions are most commonly used, 101 scientific articles relating to food traceability were reviewed. All the definitions commonly referred to in these articles are shown to have weaknesses. By combining the best parts of the existing definitions, this paper offers a new possible definition of traceability as pertaining to food products.

Introduction

Background

In recent years there has been an increased focus on product traceability in food supply chains. Around the turn of the century the main driver for improved food product traceability was the many tragic and costly food scandals that received wide media attention around the world at that time. These included the Bovine Spongiform Encephalopathy (BSE, or mad cow disease) case in the early and mid-nineties (Wales, Harvey, & Warde, 2006), the massive Hudson Foods recall in the US in 1997 (USDA, 1997), and the dioxin contamination of chicken feed in Belgium in 1999 (Bernard *et al.*, 2002), to mention but a few. These scandals resulted in massive press coverage, and increased demands from business partners and consumers relating to documentation and traceability of food products. As a result, traceability requirements appeared or were strengthened in national legislation and in commercial standards for food production. In recent years, electronic systems and standards for food product traceability have improved a lot. This has led to a potential for benefits associated with investing in better traceability systems, beyond reducing risk and meeting requirements. These potential benefits typically include:

- Reduced cost and labour related to better information logistics and less re-punching of data internally.
- Reduced cost and labour related to exchange of information between business partners through better integration of electronic systems.
- Access to more accurate and more timely information needed to make better decisions in relation to how and what to produce.
- Competitive advantage through the ability to document desirable product characteristics, in particular relating to sustainability, ethics and low environmental impact.

This means that traceability has become an important tool in a variety of areas and sectors, and traceability is being referred to in many disciplines and scientific articles. Unfortunately, as this article shows, the definitions used and the respective interpretations of what traceability is are neither precise nor consistent. This article discusses the various ways traceability is defined, what the definitions mean and entail, and also offers a recommendation for how traceability, as pertaining to food products, should be understood and defined.

For the rest of this article, "traceability" should be understood to have the suffix "as pertaining to food products". There are many other meanings and applications of the term, including "measurement traceability" and "transaction traceability", but this article does not attempt to analyze or expand the term "traceability" in contexts other than the one just specified.

Structure of this paper

As we cannot assume that the reader is familiar with all the various definitions of traceability that exist, we begin by listing each of them in Section 1.3. The methodology for the systematic review of scientific papers published in the

* Corresponding author.
[1] Tel.: +47 776 20934.

http://dx.doi.org/10.1016/j.tifs.2012.10.003

area of food product traceability is described in Section 2. Section 3 outlines the outcome of the literature study, and based on this five existing definitions are chosen for further study. This section also includes a brief overview of definitions of -, and references to traceability systems in scientific articles, and the properties these systems have. In Section 4 the definitions of the term "traceability" are analyzed in more detail and compared with the properties and functionality commonly assigned to traceability systems, as outlined in Section 3. Finally, by combining parts of various existing definitions, a new definition is suggested; a definition hopefully without the weaknesses present in the existing alternatives.

Existing definitions of traceability

When we started our investigation we did not know exactly which definitions we would find in frequent use, but to increase consistency and readability we have chosen to include all the pre-existing definitions referred to in this article in this section. This includes traceability as defined in international standards, in legislation, in some dictionaries, and also the most cited standalone definition formulated in a scientific article according to our literature review.

Traceability as defined in international standards

Traceability defined in ISO 8402. An old, practical and often used definition of traceability is found in the International Standardization Organization (ISO) 8402 (ISO, 1994) where traceability is defined as: "*The ability to trace the history, application or location of an entity by means of recorded identifications.*" This definition clearly states what should be traced (history, application and location) and also how the tracing should be done (by means of recorded identifications). It suffers, however, from recursion and thus incompleteness related to the fact that "traceability" is defined by using the term "trace", and the term "trace" is not defined here. It has this recursion in common with many other definitions, as indicated below. In this paper, and in particular related to the definitions we analyze, we understand "trace" to mean "find", "follow" or "identify". An additional problem is that ISO 8402 was withdrawn by ISO and superseded by ISO 9000 which uses a different definition of traceability.

Traceability defined in ISO 9000 and ISO 22005. ISO 9000 (ISO, 2000) has a slightly less specific definition of traceability: "*The ability to trace the history, application or location of that which is under consideration*". Note that in this newer definition, the fragment "*by means of recorded identifications*" has been removed, and this has consequences as discussed in Section 4.

The ISO 22005 (ISO, 2005) definition is word for word the same as the ISO 9000 definition, but ISO 9000 is a standard for quality management systems in general whereas ISO 22005 is a specific standard for traceability in the food and feed chain. ISO 22005 adds that "*Terms such as document traceability, computer traceability, or commercial traceability should be avoided.*"

For all these ISO definitions (ISO 8402, ISO 9000, ISO 22005), there is an additional clause which states that when relating to products, traceability specifically entails "*the origin of materials and parts, the processing history, and the distribution and location of the product after delivery.*"

Traceability defined in Codex Alimentarius. The Codex Alimentarius Commission Procedural Manual (FAO/WHO, 1997) defines traceability as "*the ability to follow the movement of a food through specified stage(s) of production, processing and distribution*". This definition reduces traceability to the following of the movement only, and if taken literally, this definition is very different from all the others outlined here which use at least potentially more comprehensive verb phrases. Codex Alimentarius is recognized by the World Trade Organization as an international reference point for the resolution of disputes concerning food safety and consumer protection, so the traceability definition there is of special importance, even though it is (as shown in Section 3) not commonly referred to, at least not in scientific articles.

Traceability as defined in legislation: the EU GFL (Regulation 178/2002)

The EU General Food Law (EU, 2002) defines traceability as "*The ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution*". This definition is often referred to in scientific articles, and it is quite detailed with respect to what should be traced and followed, and where. It is, however, less detailed when it comes to describing what type of properties are relevant or how the traceability might be implemented. Also, substituting the "trace" phrase used in other definitions with "trace and follow" does not solve the recursion problem.

Standalone definitions of traceability in scientific articles: traceability defined in Moe (1998)

The most commonly referred to definition of traceability that comes from a scientific paper is in Moe (1998). It says "*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*". Moe specifies that this is "chain traceability", and defines "internal traceability" as the same thing, but "*internally in one of the steps in the chain*"; a useful distinction not made in most other definitions. "Track" is used as the verb here which avoids recursion, but does not really add clarity as the term is not clearly defined. "Product batch" is that which is being traced here which introduces the question related to what a product batch is, and whether all food product traceability is necessarily done on product batch level. For further discussion on this, see Section 4.

Traceability as defined in dictionaries

While dictionary definitions of traceability in general are too imprecise for our purposes and not frequently referred to in scientific articles, we decided to perform a brief examination of these definitions anyway, to get an indication of what the general meaning of the term "traceability" is.

Most dictionaries offer only generic definitions of traceability, and typically "traceability" is only defined as "the ability to trace". This is the case of Dictionary.com (Dictionary.com, 2012), The Free Dictionary by Farlex (Farlex, 2012), Merriam-Webster (Merriam-Webster, 2012) and the Oxford Dictionaries Online (Oxford University Press, 2012). The verb "trace" in turn has a plethora of meanings, and the most relevant for our purposes are "*to follow the footprints, track, or trail of*" and "*to follow or study out in detail or step by step*" (Merriam-Webster, 2012). "Trace" is reported as being a word where the first known use is in the 14th century and the origin is from the Anglo-French *tracer* (Merriam-Webster, 2012), the Vulgar Latin *tractiare* – to drag, and the Latin *tractus* – past participle of *trahere* – to pull (Farlex, 2012).

Only a few dictionaries offer relevant definitions of "traceability" beyond "ability to trace". Cambridge Dictionaries Online (Cambridge University Press, 2012) defines the term as "*the ability to discover information about where and how a product was made*" which, while being fairly generic, is still a suitable definition for our purposes, and it manages to avoid the recursion present in many other definitions.

The most extensive dictionary definition of "traceability" is found in Webster's Online Dictionary (WOD) (Webster's Online Dictionary, 2012), where domain definitions, speciality expressions and extended definitions are given. Under the domain "Environment" WOD mentions "*The ability to trace the history, application, or location of an item, data, or sample using recorded documentation*", which is very close to the ISO 8402 definition, recursion included. Under "Extended definitions" WOD adds:

1) "*Traceability refers to the completeness of the information about every step in a process chain.*"
2) "*Traceability is ability to chronologically interrelate the uniquely identifiable entities in a way that matters.*"
3) "*Traceability is the ability to verify the history, location, or application of an item by means of recorded identification.*"

Extended definition 1) in particular seems to be a fair attempt at avoiding the recursion while still providing a non-trivial definition. Extended definition 2) pre-supposes uniquely identifiable entities which, in the context of food products, is beyond definition and into implementation of traceability. Extended definition 3) is in contrast with common usage of the term "verify" as pertaining to attributes of food products; see discussion on this in Section 4.

Methodology

Literature search strategy

The key objective of this paper is to examine the use of the term "traceability" in scientific articles relating to food products and food production, and to point out relevant definitions, including their properties and mutual inconsistencies. To establish which definitions are used in scientific papers, a systematic literature review was needed. To accomplish this, a search strategy was developed as outlined in Table 1. Given the search criteria in the table ISI Web of Knowledge provided in total 243 hits and all were included in the preliminary documents list. Google Scholar and Science Direct delivered too many results; therefore 100 articles were picked out randomly from the top hits of each list. After eliminating documents that did not meet the inclusion criteria listed in Table 2, 101 articles remained for analysis. These remaining articles were then investigated using the coding scheme outlined in Table 3, and the data was recorded in a database. The final coding question was expanded as the literature study proceeded. Initially ISO 22005 was not a separate option, but as several papers referred to it, it was given a separate code in the investigation.

Results

Overall results of the literature search

Most of the analyzed articles (65%, $n = 101$) mentioned a traceability definition, which means that one third of scientific articles in this field took the definition of traceability for granted, at least in that they did not provide a definition for the term. Out of those referring to a definition, 66% used a single definition, while the rest referred to at least

Table 1. Databases, keywords, and search strategy used to identify scientific articles to be included in the review of traceability definitions.

	Database	Keywords	Where	When
1	Google Scholar	a. Products, traceability, definition	Articles and patents AND legal opinions and journals	All times
		b. Food traceability	Articles and patents AND legal opinions and journals	All times AND since 2008
2	ISI Web of Knowledge	a. Food traceability	In topic AND title	All times
		b. Food traceability AND traceability	In topic AND title	Since 2005
3	Science Direct	a. Food traceability	In all fields	All times

Table 2. Criteria used to include scientific articles in the final analysis list. Documents not fulfilling these criteria were excluded.

Inclusion criteria	Why this criterion?
Published in English language	English is by far the most common language for scientific publication in this field
Published as an article in a scientific journal	Articles published in scientific journals have passed a rigorous quality control
Refers to food and food products	This paper refers to traceability as pertaining to food products
Includes references to traceability	This paper is about traceability

two definitions. The fact that more than 20% of all scientific articles in this field referred to at least two definitions might indicate that the definition of traceability should not be taken for granted. The most common definition used in all the assessed documents was EU GFL (24%), followed by ISO 8402 (17%) and ISO 9000/ISO 22005 (8%/5%). It is worth noting that the ISO 8402 definition continued to be used even after the standard was withdrawn in 2000, as indicated in Fig. 1. 14% of the articles provided their own definition of traceability, and 14% of the articles referred to definitions found in other scientific articles. Among these, the one devised by Tina Moe in 1998 was the most referred to (5%); no other definitions from scientific articles were referenced in more than two papers. Despite being an international reference point for the resolution of disputes concerning food safety and consumer protection the Codex Alimentarius definition of traceability was referred to in only 5% of the articles. For a discussion on the Codex definition of traceability and its limitations see Section 4.

An additional observation from the literature study is that in several scientific papers, the term “traceability” was used in a way which does not correspond to any of the definitions listed above. Phrases like “labels with different degrees of traceability information” and “to find out about the traceability of a product” were not uncommon. From the context, it was clear that many of these articles used the word “traceability” when they meant “product properties”, in particular properties relating to origin. We have chosen not to provide a reference to these articles here, partly because there were many of them and singling out a few would be unfair, but also because the concept of traceability is not trivial and the definitions are contradictory, so some confusion is understandable. However, a shared feature of all the definitions above is the fact that traceability is not a type of information; it is the means by which information is retrieved and hence also stored and arranged. Conceptually, a traceability system is quite similar to a filing cabinet in that they both deal with systematic storing and retrieving of data. Importantly, neither a traceability system nor a filing cabinet care about what types of data are being stored. There is no special relationship between traceability and origin; information relating to the origin of a food product should be recorded along with any and all other types of information. In some articles, the terms “traceability information” or “traceability data” were used to refer to the product properties recorded in a traceability system, and this also has the potential to cause confusion. The reason is that practical implementation of traceability necessitates the introduction of codes or numbers whose sole purpose it is to provide identification and enable traceability, and these codes are often referred to internally as “traceability codes” or “traceability numbers” and collectively as “traceability data”, and this is then of course a different meaning of the same term.

Table 3. Coding questions and guide used to analyze the scientific articles included in the systematic review of traceability definitions.

1.	Does the article include or refer to a definition of traceability? *Yes/no.*
2.	If yes, is it one single definition or several? *Single definition/multiple definitions.*
3.	If yes, which definition(s) does it include or refer to? *ISO 8402/ISO 9000/ISO 22005/Codex Alimentarius/EU General Food Law/other author's definition/own definition/other.*

Properties of a traceability system

The scientific articles included in the systematic literature review described above contained several detailed descriptions of traceability systems in various food sectors. Many of the articles went into great detail outlining what properties these traceability systems could or should have, and in this area there did not seem to be significant disagreement. Opara (2003) indicates that “*With respect to a food product, traceability represents the ability to identify the farm where it was grown and sources of input materials, as well as the ability to conduct full backward and forward tracking to determine the specific location and life history in the supply chain by means of records*”. For this to happen in a supply chain, a traceability system must have the following properties:

1. Ingredients and raw materials must somehow be grouped into units with similar properties, what Moe (1998) and Kim, Fox, and Grüninger (1999) refer to as “traceable resource units”.
2. Identifiers/keys must be assigned to these units. Ideally these identifiers should be globally unique and never reused, but in practice traceability in the food industry depends on identifiers that are only unique within a given context (typically they are unique for a given day's production of a given product type for a given company). Expanding on this issue is beyond the scope of this paper; see Karlsen, Donnelly, and Olsen (2011) for a more detailed discussion on this.

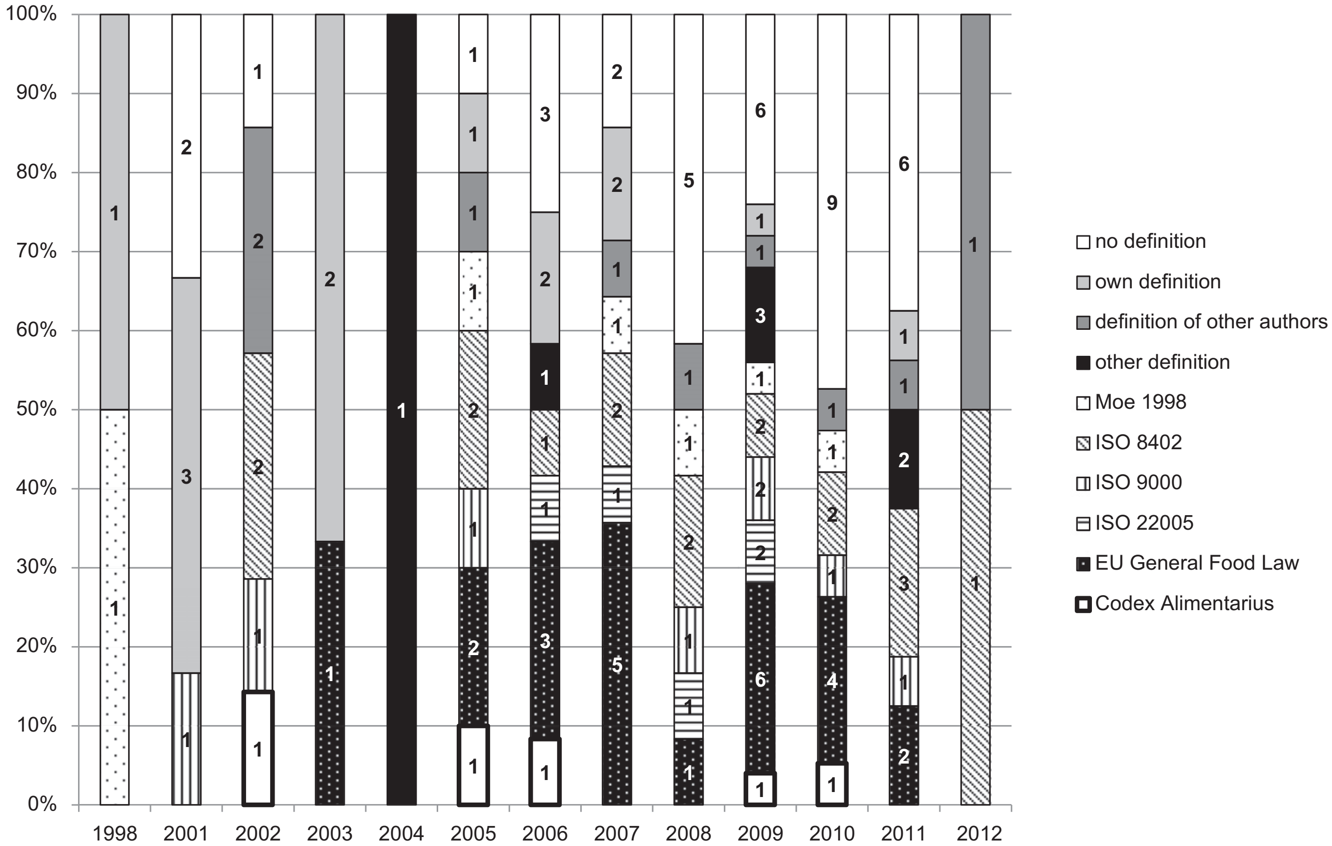

Fig. 1. Traceability definitions and their usage in scientific articles. The numbers in the columns indicate how many articles were using that specific definition. A total of 101 articles were analyzed.

3. Product and process properties must be recorded and either directly or indirectly (for instance through a time stamp) linked to these identifiers.
4. A mechanism must exist to get access to these properties.

All these requirements are necessary for food product traceability. If there is no grouping of ingredients and raw materials; if no distinction is made between what one uses or produces today and what one used or produced many years ago, there is no traceability. If no identifiers are assigned to the traceable resource units, one can only access immediate properties physically attached to the units (for instance on the label), and all properties that one wants to have access to would have to be copied every time a process converts an input to an output. This could work for very short and simple supply chains, but in general traceability depends on assigning identifiers to units, and recording properties that are linked to these identifiers.

This overview of traceability system properties provides us with a benchmark for the traceability definitions. There is general consensus on what a traceability system is, and what properties it could and should have. As basis for our discussion we compare the traceability definitions with the properties of a traceability system. A traceability definition can be classified as too narrow if it does not include or allow for functionality that must be provided by a traceability system. A traceability definition can be classified as too broad if it allows for systems that do not satisfy the minimum requirements for a traceability system.

Discussion

As basis for our discussion, it is useful to make a structured comparison of the different definitions, see Table 4.

As an aid to evaluating the differences between these definitions, we describe two hypothetical systems which offer at least some degree of food product traceability.

Hypothetical system 1 (HS1) – A perfect online location tracking system for food products and all their ingredients. This could in theory be implemented by a multitude of GPS transponders (Zhang, Liu, Mu, Moga, & Zhang, 2009), which would identify location of all products and ingredients at any given time so the ability to follow the food product geographically would be perfect. HS1 would include the functionality for continuous monitoring and permanent recording of the position data, so that even after the fact one could see exactly where a product and all its ingredients came from and went.

Hypothetical system 2 (HS2) – A rapid instrument for accurate analysis of all analytically verifiable properties a food sample may have. This could be implemented if one managed to combine into one instrument all the

Table 4. Selected traceability definitions broken down in constitutive elements.

Defined in	Verb phrase	Product properties	Trace what	Trace where	Trace how
ISO 8402	Trace	History, application or location	An entity	–	By means of recorded identifications
ISO 9000 and ISO 22005	Trace	History, application or location	Of that which is under consideration	–	–
Codex	Follow	Movement	A food	Through specified stage(s) of production, processing and distribution	–
EU GFL	Trace and Follow	–	A food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed	Through all stages of production, processing and distribution	–
Moe (1998)	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 or internally in one of the steps in the chain	–

methods and instruments currently in use to measure analytical properties of food products, such as DNA fingerprinting (Ogden, 2008), Magnetic Resonance (Renoua *et al.*, 2004), and Isotope analysis (Renoua *et al.*, 2004).

The question now becomes: if one has either one or both of these instruments, does one then have traceability?

Very few would argue that HS1 could be a good enough food traceability system in itself. The only properties HS1 could give us access to would be exact location at a given time, and according to most definitions that is only one aspect of traceability. It is worth noting that if we used the Codex Alimentarius definition of traceability, HS1 would offer traceability as defined there, which serves as an illustration of how narrow that particular definition is.

HS2, especially if combined with HS1, would give a much broader picture. If we look at the "Product properties" column in Table 4, HS1 would give location, and HS2 would give quite a lot of information about origin, application and life history. Still, regardless of how good HS2 was, it would be limited to giving information about the analytically verifiable properties of the food sample. For many applications of traceability, it is relevant also to have access to food product properties that cannot be analytically verified. These include properties such as identity of food business operator or owner at various stages in the chain, processing conditions that did not directly influence the food properties, data on yield and economics, properties relating to ethics, sustainability and legality, and so on. HS1 + HS2 would only partly satisfy the ISO definitions; there are aspects of "history, application or location" relating to a food product that you cannot get through tracking movement and instantaneous measurements. Moe (1998) also refers to "ability to track ... history", so again HS1 + HS2 would not be sufficient. The EU GFL definition does not indicate which properties the traceability system should provide access to, but the same regulation that contains the traceability definition also contains the legal requirements for traceability of food products in the EU in general. In the EU GFL "Article 18 – Traceability" these requirements include "... *identify any person from whom they have been supplied with a food, ...*" and ... *identify the other businesses to which their products have been supplied*." Identification of persons and businesses cannot be done analytically (at least not in this context), so it is clear that a system consisting of HS1 + HS2 would not satisfy any of the definitions analyzed here (with the exception of Codex Alimentarius). Note that HS2 is an instrument for instantaneous measurement; one gets to know the properties of a food sample by measuring it there and then. This is as opposed to a system of record keeping throughout the chain (the "recorded identifications" mentioned in the ISO 8402 definition) where one assumes that if A has some property and A goes into B, then B will also have this property, and one knows this without needing to measure B. Note also that the analytical methods, when utilized, provide data that it is very relevant to record and attach to the food product for future reference. This means that record keeping is not something one does instead of using analytical methods; it is something one does to keep track of all data, including the data that comes from using an analytical method or instrument.

Looking at the many examples of traceability systems described in the analyzed scientific articles, it seems clear that even the combination of HS1 and HS2 would not be sufficient for a perfect or even adequate food product traceability system and that access to the properties that HS1 + HS2 could not provide us with is essential in modern food production. With this as a basis, we can conclude that a traceability system for food products should have the following properties:

- It should be able to provide access to all properties of a food product, not only those that can be verified analytically.
- It should be able to provide access to the properties of a food product or ingredient in all its forms, in all the links in the supply chain, not only on product batch level.
- It should facilitate traceability both backwards (where did the food product come from?) and forwards (where did it go?).
- The traceability must be based on systematic recordings and exchange of these; there are many relevant properties that will be lost if there is no record-keeping system and a way of distributing/sharing the information.
- In practice, this means that a unit identification system or numbering scheme must be present; without it one cannot achieve many of the goals listed above.

It is worth noting that when traceability is based on systematic recordings and record-keeping, there is no guarantee that the recordings are true. Both error and fraud may lead to untrue claims with respect to properties of the food product. There is a clear need to verify these claims, and in this area analytical methods and instruments play a crucial role. See Borit and Olsen (2012) for a discussion of this issue.

Given these properties of a traceability system, we can go back to the traceability definitions and evaluate them against the list outlined above. This evaluation is included in Table 5.

Some comments on this evaluation:

- Ideally, the verb phrase should not be recursive, and if it uses a different verb than "trace" it should explain it, or refer to an explanation of it.
- It may be relevant to keep track of any or all properties a food product may have. Therefore the definition should not limit this.
- It may be relevant to keep track of the properties of any unit size, so "of that which is under consideration" is good, whereas focussing only on products or product batches is an unnecessary limitation.
- It may be relevant to keep track of the properties of these units anywhere in the supply chain.
- There is no traceability without recorded identifications and a record-keeping system, and a good definition should spell this out clearly, in order to avoid confusing the issue.

In the choice between the definitions above, ISO 8402 is the only one which has incorporated this final and essential property, so of these it is the recommended definition to use. Nevertheless, as already mentioned, ISO 8402 suffers from the recursive verb phrase, and also from the fact that the standard has been superseded, so an ideal definition does not currently exist. Such an ideal definition should combine the best parts of the definitions above, and could be phrased as follows:

Traceability (*n*)

The ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications.

This definition has the following advantages:

- It does not suffer from the weaknesses outlined above, associated with the other definitions.
- It closely matches the properties of traceability systems as used in the production industry in general, and in the food production industry in particular.
- It states that one needs to make recorded identifications if one wants to call what one is doing traceability, and also that one needs to provide access to these recordings. This is in line with the properties that traceability systems used in the production industry have.
- It can serve as demarcation between different scientific disciplines. There is a significant difference between having traceability ("ability to access any or all information") and verifying the claims in a traceability system. Both are very useful tasks and interesting scientific disciplines, but they are quite different. The literature search revealed that many articles did not make this distinction, and it was easy to get the impression that if one wanted traceability, one needed analytical tools and methods. Our view is that if one wants traceability, one has to systematically record properties of "that which is under consideration", and some of these properties can be verified by analytical tools and methods (and indeed some of these properties are obtained through using analytical tools and methods). The point

Table 5. Evaluation of the traceability definitions against the properties of traceability systems. Light shading indicates a problem as identified in Section 4; darker shading indicates a significant limitation or shortcoming in the definition as compared to the properties of a traceability system.

Defined in	Verb phrase	Properties	Trace what	Trace where	Trace how
ISO 8402	Recursive	All	A general food related entity	–	Recorded identifications
ISO 9000 and ISO 22005	Recursive	All	A general food related entity	–	–
Codex	Vague	One only	"Food" is undefined	Specified stages	–
EU GFL	Recursive	–	A general food related entity	All stages	–
Moe (1998)	Vague	–	A product batch	All stages	–

is that it is the recording of information, and the giving access to the recorded information that constitutes traceability, and this definition spells this out in detail.

Note that this definition is similar to the old ISO 8402 definition, and like ISO 8402 it can potentially apply to traceability of any products, not only food related.

While recording of information in itself is not too difficult, getting access to the information later on might be challenging in practice. This is especially true for products with many ingredients, for large production runs with many inputs, for deeply processed products with extensive supply chains, and for products where it is difficult to link inputs that go into a production process to the respective outputs. In all these cases tracing back from a finished product to all its ingredients and raw materials and all the associated recordings will result in an overwhelming amount of information which will be difficult to communicate or analyze (Olsen and Aschan, 2010). Therefore computerized traceability systems are needed to keep track of this information, as well as tools for data mining, analysis and visualization. Process re-engineering can help significantly with this problem, especially if it involves introducing smaller production batches with fewer and more clearly defined inputs. However, this practical problem does not change the fact that if one wants access to all properties a product and its respective ingredients and raw materials have, then extensive record keeping is needed.

Conclusion

Traceability is not a trivial term, and the systematic literature review shows that even in scientific papers there is a lot of confusion and inconsistency. With basis in the properties of a traceability system for food products as described in numerous articles, we have concluded that record keeping is an essential aspect of traceability, and that attempts to implement or define traceability without record keeping will lack significant components. Of the definitions analyzed here, the only one to specify that record keeping is an essential part of traceability is ISO 8402, so with respect to phrasing, it is the most accurate definition. Unfortunately, the ISO 8402 standard has been withdrawn, and the definition suffers from the fact that it defines traceability as "the ability to trace", without defining the term "to trace". This means that currently scientific papers do not have an existing standard or definition without obvious weaknesses to refer to. By combining parts of existing definitions, we have suggested our own definition which hopefully will be seen as an improvement over the alternatives that currently exist.

Acknowledgements

The discussion that underlies this paper started in the Nordic Council of Ministers project "Traceability and electronic transmission of qualitative data for fish products" and the EU 5FP TraceFish project. It continued in the EU 6FP projects Seafood Plus and TRACE where arguments were repeated and refined several times until finally there was some consensus on various terms and their meanings, at least within the respective projects. Thanks to the Nordic Council of Ministers and the European Commission for funding these projects, to the Norwegian Ministry of Fisheries and Coastal Affairs for funding a significant part of the writing of this article, and special thanks to the project members who were most eager and willing to exchange views on this issue; in particular Tina Moe, Jostein Storøy, Marco Frederiksen, Paul Brereton and Heiner Lehr. The second author wishes to thank the EWMA project (Norwegian Research Council project number 195160) for facilitating this work.

References

Bernard, A., Broeckaert, F., De Poorter, G., De Cock, A., Hermans, C., Saegerman, C., et al. (2002). The Belgian PCB/dioxin incident: analysis of the food chain contamination and health risk evaluation. *Environmental Research, 88*, 1–18.

Borit, M., & Olsen, P. (2012). Evaluation framework for regulatory requirements related to data recording and traceability designed to prevent illegal, unreported and unregulated fishing. *Marine Policy, 36*, 96–102.

Cambridge University Press. (2012). *Cambridge Dictionaries Online*. http://dictionary.cambridge.org/ Last access date 15.05.12.

Dictionary.com. (2012). *Dictionary.com*. LLC. http://dictionary.reference.com/ Last access date 15.05.12.

EU. (2002). Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. *Official Journal of the European Communities, 31*, 1–24.

FAO/WHO. (1997). *Codex Alimentarius. Joint FAO/WHO Food Standards Programme*. Rome: Codex Alimentarius Commission.

Farlex. (2012). *The Free Dictionary by Farlex*. http://www.thefreedictionary.com/ Last access date 15.05.12.

ISO. (1994). *ISO/TC 176/SC 1 8402:1994, Quality management and quality assurance – Vocabulary*.

ISO. (2000). *ISO/TC 176/SC 1 9000:2000, Quality management systems – Fundamentals and vocabulary*.

ISO. (2005). *ISO/TC 176/SC 1 22005:2005, Traceability in the feed and food chain – General principles and basic requirements for system design and implementation*.

Karlsen, K. M., Donnelly, K. A. M., & Olsen, P. (2011). Granularity and its importance for traceability in a farmed salmon supply chain. *Journal of Food Engineering, 102*, 1–8.

Kim, H. M., Fox, M. S., & Grüninger, M. (1999). An ontology for quality management – enabling quality problem identification and tracing. *BT Technology Journal, 17*.

Merriam-Webster. (2012). *Merriam-Webster Inc*. http://www.merriam-webster.com/ Last access date 15.05.12.

Moe, T. (1998). Perspectives on traceability in food manufacture. *Trends in Food Science & Technology, 9*, 211–214.

Ogden, R. (2008). Fisheries forensics: the use of DNA tools for improving compliance, traceability and enforcement in the fishing industry. *Fish and Fisheries, 9*, 462–472.

Olsen, P., & Aschan, M. (2010). Reference method for analyzing material flow, information flow and information loss in food supply chains. *Trends in Food Science & Technology, 21*, 313–320.

Opara, L. U. (2003). Traceability in agriculture and food supply chain: a review of basic concepts, technological implications and future prospects. *Food, Agriculture & Environment, 1*, 101–106.

Oxford University Press. (2012). *Oxford Dictionaries*. http://oxforddictionaries.com/ Last access date 15.05.12.

Renoua, J. P., Bielickia, G., Depongea, C., Gachonb, P., Micolc, D., & Ritzd, P. (2004). Characterization of animal products according to geographic origin and feeding diet using nuclear magnetic resonance and isotope ratio mass spectrometry. Part II: beef meat. *Food Chemestry, 86*, 251–256.

USDA. (1997). *Food Safety and Inspection Service*. United States Department of Agriculture, Consumer Education and Information, Releases no. 0272.97, 0276.97, 0283.97. http://www.fsis.usda.gov/ Last access date 15.05.12.

Wales, C., Harvey, M., & Warde, A. (2006). Recuperating from BSE: the shifting UK institutional basis for trust in food. *Appetite, 47*, 187–195.

Webster's Online Dictionary. (2012). *Webster's Online Dictionary*. http://www.websters-online-dictionary.org/ Last access date 15.05.12.

Zhang, J., Liu, L., Mu, W., Moga, M. L., & Zhang, X. (2009). Development of temperature-managed traceability system for frozen and chilled food during storage and transportation. *Journal of Food, Agriculture & Environment, 7*, 28–31.