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Diagnostic model for assessing traceability system performance in fish processing plants

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ABSTRACT

This paper introduces a diagnostic tool that can be used by fish processing companies to evaluate their own traceability systems in a systematic manner. The paper begins with discussions on the rationale of traceability systems in food manufacturing companies, followed by a detailed analysis of the most important indicators in the designing and executing traceability systems. The diagnostic tool is presented in four grids through which fish companies can evaluate their own developed traceability system. The paper argues that if a company operates at a higher level of contextual factors, then design and execution of traceability system needs to be at a higher level as well so as to achieve a higher level of traceability system performance. The paper concludes that companies that are able to systematically assess their own developed traceability systems are able to determine food safety problems well in advance, and thereby take appropriate corrective actions.

1. Introduction

Systems that are linked to quality assurance such as traceability systems have recently attained a lot of attention in the food industry. Traceability systems may provide real time information regarding the location and history of products in the supply chain (Dabbene and Gay, 2011; Van der Vorst, 2003). Similarly, traceability systems can reduce business risks above and beyond legal compliance. They can facilitate product recall and withdrawal; assist companies to comply with regulatory requirements (e.g., Bioterrorism Act of 2002, General Food Law EC 178/2002, etc.) as well as help in brand protection and product authentication (Van der Vorst, 2003). Traceability is also regarded as a risk-management tool that allows food business operators or authorities to withdraw or recall products which have been identified as unsafe (Thakur and Donnelly, 2010).

Two types of traceability systems can be identified in the literature: internal and external (chain) traceability (Karlsen et al., 2011b; Moe, 1998; Tracefish, 2001). Internal traceability is within one company and relates to data about raw materials and processes to the final product before delivery. External (chain) traceability focuses on the product information from one link in the chain to the next. It describes what and how data are transmitted and received. External traceability also refers to the ability to track a product batch and its history through the entire production chain. Chain traceability works between companies and depends on the presence of internal traceability in each link (Donnelly and Karlsen, 2010; Moe, 1998; Tracefish, 2001).

Governments, particularly in developed countries, argue that existing food safety requirements have been ineffective in reducing the growing burden of foodborne illnesses (Kelepouris et al., 2007). As a result, inefficiency of existing food safety systems in combination with the international developments linking food safety with trade, have resulted to new food legislation focused on assuring high levels of food safety (Kvenberg and Schwalm, 2000; Van der Meulen and Van der Velde, 2004). In Europe, the General Food Law EC 178/2002 Article 18 specifically requires each partner in the supply chain to keep track of products during all stages of production and have access on demand to its upstream and downstream trading partners. The regulation seeks to ensure that at each stage of food production, processing and movement through the supply chain steps are taken to maintain safety of products intended for human consumption, at its highest quality. In the United States, the Bioterrorism Act of 2002 requires all companies involved in the food and feed industry to self-register with the Food and Drug Administration (FDA) and maintain records and information for food traceability purposes (FDA, 2001). However, the ability to consistently trace consignments of food, such as fish, through the supply chain is currently inadequate. Traceability

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systems have been developed at company level, however, these systems provide limited traceability, and they are fragmented, uncoordinated and inconsistent in approach (Dabbene and Gay, 2011; Tracefish, 2001). Literature shows that poor design (EAN.UCC, 2005) and poor execution of Food Safety Management Systems (FSMS) are reasons for rework, too high contamination levels, customer complaints, recalls, and foodborne outbreaks (e.g., Holt and Henson, 2000).

Constant pressure from stakeholders (government, retail, and customers) on FSMS, the context in which the systems operate such as product complexities, production process complexities, supply chain complexities and organisation characteristics (Van der Spiegel, 2004) makes traceability system a very important tool. Similarly, the dynamic environment in which systems operate, such as emerging pathogens and changing consumer demands, require that FSMS be systematically evaluated to determine opportunities for improvement (Manning et al., 2006; Van der Spiegel et al., 2006; Wallace et al., 2005a). This paper underpins indicators (elements) that are important in assessing performance of traceability systems, also known as "Track and Trace" or T&T system, in fish processing plants. The main objective of this paper is to develop a diagnostic tool that can be used by fish processing companies or any other food processing company to evaluate their own traceability systems and identify areas that need improvements. The principle of the diagnostic instrument is described first, followed by assessment of important indicators of the diagnostic instrument and discussion of the usefulness of the diagnostic instrument.

2. Structure of the diagnostic instrument

The diagnostic instrument to assess performance of companies' own traceability systems (Fig. 1) has been developed based on broad literature exploration in the fields of food quality management, supply chain management, food safety and traceability systems. A literature review of the journals, books and websites points out that the availability of diagnostic instruments to assess performance and effectiveness of FSMS for food applications is relatively limited (Van der Spiegel et al., 2004; Wallace et al., 2005b). Thus, the need for fish processing companies to have their own diagnostic instrument to help them assess their strengths and weaknesses to attain higher control of food safety problems is imperative. This diagnostic instrument is composed of five main parts: (1) contextual factors, (2) traceability system design, (3) traceability system execution, (4) traceability system requirements, and (5) traceability system performance, and food safety level.

2.1. Contextual factors

Contextual factors are described as the environment in which organisations (e.g., fish processing plants) operate (Luning and Marcelis, 2007, 2009) which directly or indirectly affect the performance level of the traceability system. Contextual factors include product complexity, production process complexity, supply chain complexity and organisation complexity/characteristics (Van der Spiegel et al., 2005). It is assumed that high level (more complex) of contextual factors put a high demand on the design and execution of the traceability system, in terms of requiring; more information collection points, more detailed information and data processing, collection of more samples and collection of samples at a higher level (e.g., at ingredient level). However, the organisational characteristics are considered to be somehow different from other contextual factors. A high level of complexity in an organisation contributes positively to the design and execution of the traceability system and does not put high or low demands on the traceability system. For example, high level of employee involvement does not put a higher demand on the traceability system but positively contributes to the design and execution of such a system.

2.2. Traceability system design

The design of the traceability system has been extensively described in the literature (EAN.UCC, 2003). Various other studies have also demonstrated that a traceability system should be composed of factors such as; type of identification, mode of data registration, location of data storage, mode of information communication and the degree of data standardisation (Loftus, 2005; Tracefish, 2001). Similarly, indicators such as appropriateness of the location of information collection points (ICPs), level of using hazard analysis and critical control points (HACCPs) system during traceability system design and determination of traceable resource units (TRUs) have been argued to enhance the traceability system design (Karlsen et al., 2012; Thompson et al., 2005) and therefore, are included in this model.

2.3. Traceability system execution

Execution process requires a constant interaction between employees and management. For this, case indicators that are linked to employees' performance are included in the diagnostic instrument. Execution involves communication of traceability procedures and instructions. If these procedures and instructions are not well known and communicated (Baron and Greenberg, 2000), the execution process is most likely to be associated with ambiguity ('we do not understand') and uncertainty ('we are not informed'). Consequently, the degree of compliance with regulations and procedures, the degree of accuracy of the traceability system documentations and recordkeeping, validation and verification of the traceability system may be affected. Poor compliance to procedures (Azanza and Zamora-Luna, 2005) and absence of proper documentation and recordkeeping are typical sources of failures on FSMS. Formal communication is important especially when previously established work practices need to be changed. Accurate dissemination of information is essential to avoid guesswork (Holt and Henson, 2000).

2.4. Traceability system performance

A basic requirement for designing an effective traceability system is to determine the information that needs to be traced (Karlsen et al., 2012; Regattieri et al., 2007). Similarly, the actual performance of the system depends on how well it is designed and executed in practice. Performance of the system can also be checked on its capability, reliability, rapidity, and precision/accuracy. Capability is the ability of retrieving the information required without any error and may be determined by the reliability of the tools, procedures, and information sources used. Rapidity refers to speed of responding to information requests regarding the trade items. Rapidity may be determined by the information management, tools used, and their automation as well as the level of cooperation between the supply chain partners. Precision/accuracy is the ability to pinpoint a particular food product's movement. Precision/accuracy may be determined by consistence of batch sizes used in the supply chain (EAN.UCC, 2003). These indicators are fundamental in fish traceability systems and therefore, are included in this diagnostic instrument as well.

3. Methodology

Conceptual process flow diagrams were created for handling, processing, storage, and transportation sectors in the fish value

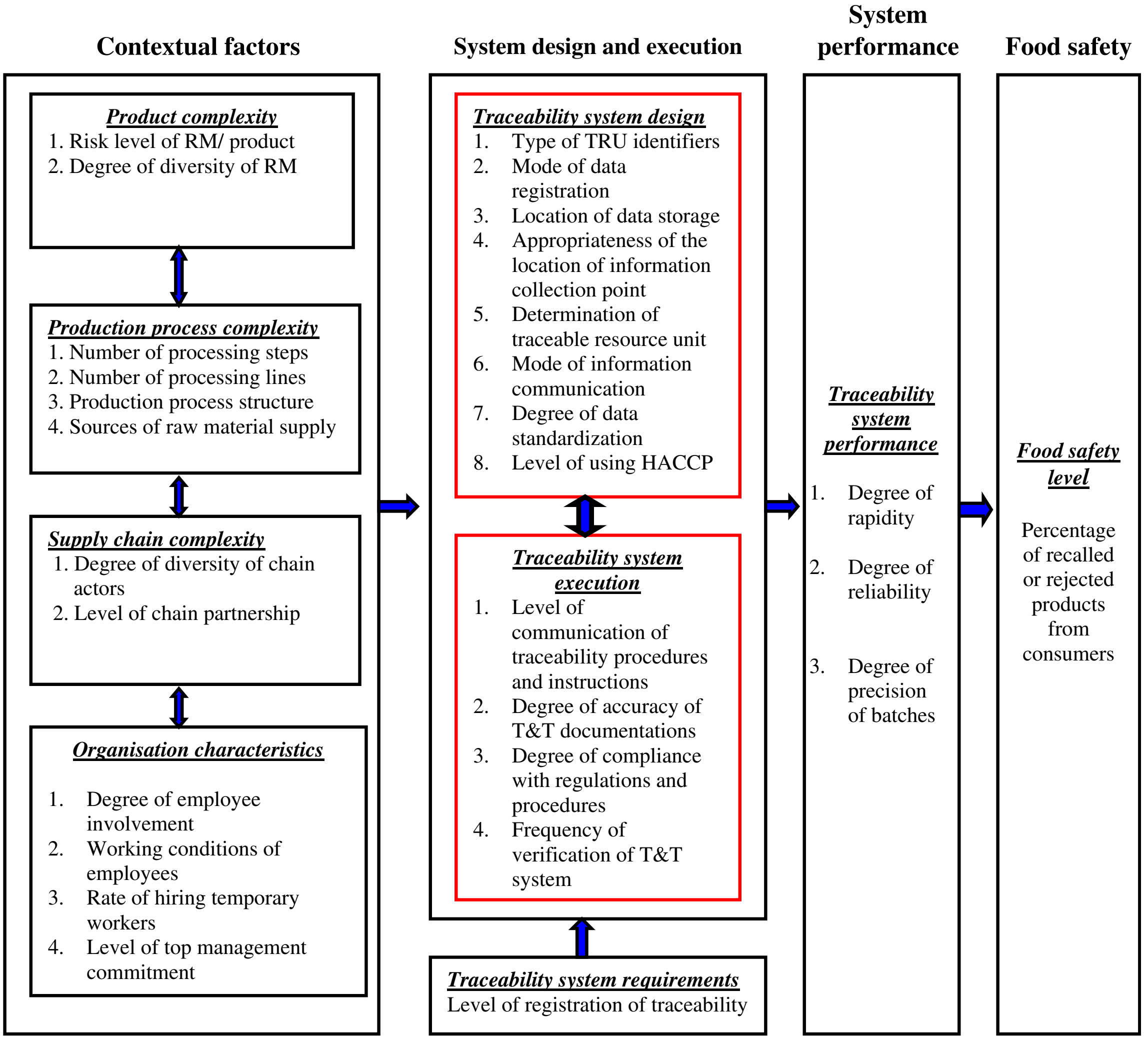

Fig. 1. Diagnostic instrument for assessing traceability system performance in a food processing company.

chain. This process was accomplished through rigorous literature search, discussions with experts in fish processing companies in the Netherlands as well as the author's own experience working in the fish industry. This process enabled the researchers to identify the most important traceability indicators as far as; product, process, organisation characteristics, traceability system performance, and food safety level are concerned. The identified indicators were then assessed as shown in the grids.

4. Results

4.1. Assessment of indicators of the diagnostic instrument

In Section 2 above, we discussed what indicators should be included in a diagnostic tool. In this section, we explain how to assess the most important indicators included in this diagnostic tool. Similar to assessment of core control activities (Luning et al., 2008; Mgonja and Kussaga, 2012), grids to guide the assessment have been developed (Tables 1–4). For each grid, indicators are described how they influence performance of a traceability system in a fish processing plant, and three levels are characterised (low, medium, and high) for each indicators. The underlying criterion to judge each level is indicated in Tables 1–4.

4.2. Assessment of contextual factors

The grid to assess the impact of contextual factors on the designing and execution of the traceability system is presented in Table 1. For the contextual factor "product complexity", three indicators are derived: (1) risk level of raw materials for safety, (2) degree of diversity of raw materials such as many species of fish, and (3) spoilage rate of raw materials. It is assumed that higher levels of product complexity put higher requirements on the design and execution of the traceability system in terms of requiring detailed information regarding the product.

The indicator, "risk level of raw materials for safety" provides an insight on the frequency and the likelihood of contamination from either chemical or microbiological contaminants. Contaminated raw materials from animal and fish origin have been cited as important sources of food safety problems (Ferreira et al., 2009). In this tool, the risk levels of product are indicated in Table 1. The indicator, "degree of diversity of raw materials" focuses on the raw material assortments the company is dealing with. Different species of fish have different potential hazards (FDA, 2001), and so processing many types of fish creates a high demand on the traceability system designing and execution since you need to collect more detailed information from each species. A company dealing with diverse raw materials with various hazards requires more

Table 1
Grid to assess contextual factors.

Indicator/question	Assumed mechanism	Low level (1)	Medium level (2)	High level (3)
Product complexity				
What is the risk level of raw material (RM) for safety in your plant?	If the risk level of the product is high, then detailed information is required to judge the safety level of the product, which put more requirements/demands on the design and execution of the T&T system	The incident is not likely to occur once in 10 years and once it occurs, it is simply about a product being out of specification	When there is a possibility of a repeated incident once in a year and which may result to customer ill health	There is a chance of a repeated incidents several times per year and which results to customer fatality e.g. due to pathogens)
What is the degree of diversity of RM with potential hazards in your plant?	Different species e.g., of fish have different Hazards. The more varied species you have the more detailed information you need to collect. This situation put higher requirements on T&T system	Only 1 or 2 fish species with potential hazards are manufactured throughout the chain	Between 2 and 10 fish species with potential hazards are manufactured throughout the chain	More than 10 species of fish with potential hazards are manufactured throughout the chain
Production process complexity				
How many processing steps do you have for each product in your plant?	Many production steps mean more points for data collection need to be included in the T&T system. Thus, put a higher demand on the design and execution of T&T system	Between 1and 5 processing steps	Between 6 and 10 processing steps	More than 10 processing steps
How many processing lines do you have for each product in your plant?	Many production lines mean more points for data collection need to be included in the T&T system. Thus, put a higher demand on the design and execution of T&T system	Only one processing line	Between 2 and 5 processing lines	More than 5 processing lines
What is the production process structure (convergence and divergence process) in your plant?	Diverging and converging product streams make it difficult to follow the different raw materials that go into the product and all the end products. Thus, put a high demand on the design and execution of the T&T system	Divergence/convergence process occurs within the company	Divergence/convergence process occurs outside the company	Divergence/convergence process occurs inside and outside the company
What are the sources of (RM) supply in your plant?	Having RM from wild sources (e.g., Ocean, lake) you need to do many analyses so as to judge the safety level of the RM. This situation put a higher demand on the design and execution of the T&T system	Less than 20% of raw materials are supplied from wild sources	20–50% of the raw materials are supplied from wild sources	More than 50% of the raw materials are supplied from wild sources
Supply chain complexity				
What is the degree of diversity of the chain actors in your plant?	Having many actors in the chain is associated with receiving and sending more information than when there are only few actors in that chain. This situation put a high demand on the design and execution of the T&T system	Supply chain consists of one RM supplier, one fish processor and one buyer	Supply chain consists of multiple RM suppliers, one fish processor and one buyer or its vice versa	Supply chain consists of multiple RM suppliers, one fish processors and multiple buyers
What is the Level of chain partnership in your plant?	High level of chain partnership is associated with high level of chain collaboration and sharing of all business information on regular bases, which contribute positively on the T&T system design and execution and hence T&T system performance	Partners exchange bits of information (e.g., product information, quantity, price etc.) only upon request	Partners exchange product and process information on a regular basis e.g., prices, quantity, production method etc.	Partners carry out joint planning of all activities and exchange all information about product, process and customers on regular bases
Organisation complexity/characteristics				
What is the degree of employees' involvement in your plant?	Early inclusion of workers in designing T&T system will lead to a better understanding of its purpose and importance. This may contribute to a more positive attitude and a more desirable intention to execute T&T system at a high level	Employees are just informed and instructed about how to work with T&T system during execution	Employees suggestions and opinions are taken into account during designing stage	Employees are completely involved in T&T system from the moment of conceptualisation, throughout the execution process
What are the working conditions of employees in your plant?	Good working conditions such as good ventilation, good smell and provision of feedback information is highly motivating and positively contribute to the design and execution of the T&T system	Poor ventilation, bad smell and no feedback information	Good ventilation but no provision of feedback information	Good ventilation, good smell and provision of feedback information
What is the rate of	Temporary workers lack;	Less than 30% of all employees	Between 30 and 60% of all	More than 60% of all employees

(*continued on next page*)

Table 1 (*continued*)

Indicator/question	Assumed mechanism	Low level (1)	Medium level (2)	High level (3)
temporary workers in your plant?	motivation, commitment, proper training, proper working skills and work experience. Large number of temporary workers will negatively contribute on the T&T system	are temporary employees	employees are temporary employees	are temporary employees
What is the degree of top management commitment in your plant?	Management commitment and support is essential for T&T system. High commitment of the top management is associated with a clear policy about the T&T system design and execution, clear statement regarding the T&T system reviews and personnel responsible for the implementation of the T&T system at the managerial level	T&T system is not stated in the organisations' policy, there is no T&T system reviews and is not stated who is responsible for the implementation of the T&T system	T&T system is stated in the organisations' policy but there is no T&T system reviews and is not stated who is responsible for the implementation of the T&T system	T&T system is clearly stated in the organisations' policy, presence of T&T system reviews and it is clearly stated who is responsible for the T&T system implementation

(Adapted from Mgonja and Kussaga, 2012).

Table 2
Grid to assess traceability system design.

Indicator/question	Assumed mechanism	Low level (1)	Medium level (2)	High level (3)
Types of TRU identifiers, mode of data registration and location of data storage	More advanced types of TRU identification, mode of data registration and location of data storage, puts less demand on the execution of the T&T system	Paper based systems	Barcodes based systems	Barcodes based systems and RFID based systems
Appropriateness of the location of information collection point	The reliable T&T system is linked with collection of all necessary data at Critical Information Points (CIP), resulting in a reliable and efficiency in data collection which contributes positively on the performance of the T&T system	T&T information is collected at all processing steps based on internal discussion	T&T information is collected from selected processing steps only, without detailed/scientific reason as to why information is collected at those points	T&T information is collected at all appropriate CIP and it is based on HACCP system
Determination of the traceable resource unit (TRU)	A highly reliable T&T system can track and trace its products to an ingredient level, in this way a more specific location of a safety problem can be identified	A TRU is a shipping truck containing different batches of different fish	A TRU is a batch of same type of fish	A TRU is a single carton from a particular batch of fish
Mode of information communication	More advanced mode of information communication put a low demand on execution of the T&T system. For example sending T&T information by digital means is faster and less prone to errors compared to printed and oral communication	System design only permits oral communications	System design permits oral and printed material communication	System design allows communication via printed material and via electronically e.g., electronic data interchange (EDI)
Degree of data standardisation	Use of standards optimises T&T data processing and communication within the supply chain	No standards used	Use of printed forms made locally at the company	Use of international standards such as EAN.UCC standards
Level of using HACCP system during T&T system design	Usage of HACCP system in the designing of the T&T system will contribute positively on its performance	HACCP system is not used during designing of the T&T system	HACCP system is only used at the initial stages of the T&T system design	HACCP system is entirely used in all stages of T&T system design and during execution

monitoring tasks to maintain food safety (Panisello and Quantick, 2001). In this tool, the risk levels for this indicator are illustrated in Table 1.

The contextual factor ''production process complexity'' is denoted by four indicators: (1) number of processing lines, (2) number of processing steps, (3) production process structure like convergence/divergence processes, and (4) sources of raw material supply. The indicators, ''number of processing steps/lines'' implies that a company that has many processing steps/lines is associated with many data generation points (large volume of data) because the company has to collect and keep information of what happens in each step. This situation puts a higher demand for designing and execution of the traceability system than when dealing with a low volume of data. Having many processing steps/lines is a common practice in food production (Moe, 1998) and therefore, proper planning is required in order to be able to control product safety and quality (Black and Porter, 1996). Low, medium, and high level scenarios are illustrated in Table 1 for this indicator.

The indicator, ''production process structure'' refers to the position where product mixing is taking place. Production process can be a straight line structure, divergent and/or convergent structure (Trienekens and Van der Vorst, 2006). Diverging and converging product streams make it difficult to follow the different raw materials that go into the product and all the end products that result at the end of the production process. Divergent process (where product flows diverge into a larger number of products) and convergent process (where a large number of product flows converge into a single product) are common practices in food production.

Table 3
Grid to assess execution of traceability system.

Indicator/question	Assumed mechanism	Low level (1)	Medium level (2)	High level (3)
What is the level of communication about procedures and instructions regarding T&T	Clear written instructions prevent misunderstanding of required tasks. Thus, contribute positively on the T&T system design and execution	Only oral communication is used between management and employees	Only written communication is used between management and employees	Both oral and written communication is used between management and employees
What is the degree of accuracy of T&T documentations and recordkeeping	The accuracy of documentations and recordkeeping about ingredient usage, production and dispatch contributes positively for achieving a more robust traceability	Documents are not is a specific place, not complete, not well readable and not arranged systematically	Documents are in a specific place, well readable but often not complete and not arranged in a systematic order	Documents are in a specific place, complete, well readable and systematically arranged
What is the degree of compliance to regulations and procedures	More complete (all steps followed) and accurate (in right way) compliance to regulations and procedures due to full adherence will result in more appropriate decision making behaviour, which will positively contribute to high performance level of the T&T system and hence food safety	Majority of workers execute tasks according to own insights, they are not aware of existence of procedures for certain tasks. They are controlled on compliance on ad hoc basis	Majority of workers are familiar with procedures (but not always exact content); tasks are executed based on habits. Workers are controlled on compliance to procedures on regular basis	All workers are aware of procedures and are consciously following procedures, T&T tasks are internalised. Self-control of compliance to own and international standards
What is the frequency of validation and verification of T&T system	The more frequent is the verification of the T&T system the more reliable is the system and the more it contributes on the performance of the T&T system	No validation and verification is done before implementation of the system	Every time that a change is made on the system e.g., whenever there is a change in supplier or buyer	Verification and validation is done on scheduled basis e.g., once per year and whenever there are changes on the system such as supplier or buyer

Divergence of materials into more products generates a track of numerous lots and more information is required for registration in the traceability system (Moe, 1998). Registering information about the product identity is especially required before and after convergent and divergent processes (Vernède et al., 2003). In this tool, it is assumed that if convergence and/or divergence process occurs within the company, the registering of the necessary information can be done appropriately since the process is within the control of the processor (hence low level). On the other hand, if divergence and/or convergence process occurs outside the company, the registering of the necessary information cannot be guaranteed (hence medium level). However, the convergence and divergence process may occur both outside and inside the company (hence high level) and thus put more demand on the traceability system design and execution. The indicator, "sources of raw material supply" is focusing on where the raw materials are coming from. If the company has many different sources of raw materials supply, more tests are required to judge the safety level of the product. For instance, if the company obtains its raw materials (e.g., fish) from a specific farm, operating with clear specifications, then hazards can well be established and the safety level can be determined. On the other hand, if the company obtains its fish from wild sources (e.g., oceans and lakes) it becomes difficult to establish or predict all the hazards. Therefore, the raw materials have a higher chance of having unknown hazards and thus, more analyses are necessary to be carried out by the company so as to assess the safety level of the final products. Fish originating from wild sources may have a significantly higher level of toxicological contaminants (such as methyl mercury, dioxins and dioxins like PCBs) and thus present the highest safety risk (EFSA, 2005). Raw materials supplied from wild sources therefore, put a higher demand on the design and execution of the traceability system than farmed fish. Risk levels for this indicator are illustrated in Table 1.

The contextual factor "supply chain complexity" is typified by two indicators: (1) degree of diversity of chain actors, and (2) level of chain partnership. The indicator, "degree of diversity of chain actors" denotes the number of actors operating in that supply chain. Each firm in the supply chain is normally positioned in a network layer and belongs to at least one supply chain (i.e. it usually has multiple suppliers and customers at the same time) (Lazzarini et al., 2001). Actor relationships are essential in controlling safety along the whole food supply chain (Manning et al., 2006). A company dealing with many actors in the chain is confronted with stricter and/ or differing demands and so needs to comply with more requirements than a company dealing with few actors. Assessment levels associated with this indicator are shown in Table 1. The indicator, "level of chain partnership" refers to a degree of cooperation among actors. When the level of chain partnership increases, partners dedicate more resources to sustain and further the goals of the supply chain (Spekman et al., 1998), and as a result information is easily exchanged. When the level of chain partnership is low, there is less information to be transferred since partners exchange bits of essential information only upon request. When the level of chain partnership is high, there is more information to be transferred because partners carry out joint planning of all activities and exchange all information on a regular basis. Therefore, a high level of chain partnership is associated with more detailed information sharing, and thus positively contributes to the design, and execution of the traceability system. In this tool, levels associated with assessment of this indicator are illustrated in Table 1.

The contextual factor "organisation characteristics" is denoted by four indicators: (1) degree of employees' involvement, (2) working conditions of employees, (3) rate of hiring temporary workers, and (4) top management commitment.

The indicator, "degree of employee involvement" refers to what extent employees are explicitly involved in the design and actual

Table 4
Grid to assess performance of the traceability system and food safety.

Indicator/question	Assumed mechanism	Low level (1)	Medium level (2)	High level (3)
How long does it take to trace product information within the company	The less time needed to trace the products the higher the performance of the T&T system	More than 24 h	Between 4 and 24 h	Within 4 h
What is the level of reliability of procedures, tools and information used in the company	The more the reliable the tools, procedures and information sources used, the higher the level of traceability system performance	Locally made tools, local procedures and local sources of information are used	Use of both local and international approved tools, procedures and information	All used tools, procedures and information sources are internationally approved (EU/FDA)
What is the degree of accuracy/Precision of product batches	The more precise the size of the batch, the less the time needed for track and tracing the product and so the higher the level of T&T system performance	The actual batch size is not known	The actual batch size is known but is variable from time to time	The actual batch size is known and is constant at all the times

execution of the traceability system. Early inclusion of employees in the designing process of the traceability system can lead to a better understanding of its purpose and importance. If people are not involved they feel less accountable for the traceability tasks they have to execute, which favours unpredictable behaviour. Employees' involvement contributes to a more positive attitude (Heizer and Render, 1993; Ivancevich et al., 1994; Luning et al., 2002) which leads to a more desirable intention to execute the traceability system at high levels. Employee involvement has been argued to increase motivation and affect employees' performance and thus, is considered as an important factor influencing the performance of FSMS (Holt and Henson, 2000; Panisello and Quantick, 2001; Holy von, 2004). The employee involvement situation is judged as low level when employees are just informed and instructed about how to work with the traceability system during the execution stage. Typical for the high level is the situation when employees are completely involved in the traceability system from the moment of conceptualisation, throughout the execution process (Table 1). The indicator, "working conditions of employees" refers to the comfortability of employees in their working places. The environment in which people work can have a positive impact on their ability to perform various tasks in the organisation, whereas if the working condition is good, people will be motivated and their ability to execute various tasks will be higher than the organisation with poor working conditions (Luning et al., 2002). Poor working conditions, such as; loud noisy conditions, bad odours, high humidity and poor feedback are dissatisfying and demotivating. If these conditions are not improved to acceptable levels, they may hinder the traceability system design and execution. Typical levels for this indicator are shown in Table 1. The indicator, "rate of hiring temporary workers" refers to what extent the company is employing temporary workers. Temporary employees are in a constant state of employment flux because they are never guaranteed consistent employment, nor are they assured of a solid start or finish date for their assignment. Temporary workers are incompetent due to lack of; proper training, proper working skills, work experience, motivation and commitment as compared to permanent workers (Foote, 2004). Poor execution of activities during the production process has been largely attributed to incompetence of employees (Fielding et al., 2005). If the company has a large number of temporary workers, it is likely that most activities including traceability activities will not be carried out appropriately. This situation therefore, may contribute negatively on the traceability system execution and thus hinders high performance of the system. Rapid staff turnover, high level of seasonal staff, language problems, and poor motivation due to job status may cause many food safety problems (Walker et al., 2003). Levels to judge this indicator are prescribed in Table 1. The indicator, "level of top management commitment" refers to the willingness of the top management to support a traceability system design and execution. For successful implementation, management must clearly show its commitment to the system. Management commitment is generally considered as a basic condition for any effective FSMS (Holy von, 2004; Luning and Marcelis, 2009; Jacxsens et al., 2009). Top management commitment can be demonstrated by ensuring that; regulatory and legal requirements of the traceability system are understood and appropriately addressed, the organisation's policy about a traceability system is understood and implemented at all relevant levels of the organisation, the traceability system objectives and plans are established as necessary and that the responsibilities of all functions affecting traceability system are clearly defined. Management should make provisions for necessary resources and personnel to maintain the system, including a management representative, who will ensure that requirements of this system are met. Management should review the system annually to determine its effectiveness. The management situation in this tool is considered as low level when the traceability system is not stated in the organisation's policy, there are no traceability system reviews and it is not clearly stated who is responsible for the implementation of the traceability system. Typical conditions for the high level situations include when the traceability system is clearly stated in the organisation's policy, there is presence of traceability system reviews and it is clearly stated who is responsible for the traceability system implementation (Table 1).

4.3. Assessment of traceability system design

The grid to assess traceability system designing is illustrated in Table 2. Three indicators have been selected and discussed in details: (1) appropriateness of the location of information collection point, (2) level of using HACCP system during T&T system design, and (3) determination of the traceable resource unit (TRU). For more information about the indicators, type of TRU identification, mode of data registration, location of data storage, mode of information communication, and degree of data standardisation refer to EAN.UCC (2003).

The indicators, "appropriateness of the location of information collection point and Levels of using HACCP system during T&T system design" refer to specific processing steps in which the company collects the T&T information. Within food manufacturing, it is common to see traceability systems used alongside HACCP to provide verifiable documentation, which monitors the critical control points (CCP) and allows remedial action to be taken if product falls below specified CCP (FSA, 2002). The process of determining the 'why and what' to trace can be accomplished through a detailed hazard analysis (or risk assessment) of all steps and processes in the production of food. By identifying steps that are critical to safety, the type and amount of information that should be recorded and transferred within the supply chain can also be determined (Opara and Mazaud, 2001; Thompson et al., 2005). Comprehensive databases reduce ambiguity and uncertainty in decision-making on assessment of food safety risks (McMeekin et al., 2006). The reliable traceability system is characterised by the collection of all necessary information at critical information points (CIP) of the production chain, resulting in efficiency of the data collection process (Caporale et al., 2001). It is assumed that the level of appropriateness increases if the HACCP plan is based on the quantitative risk assessment. The level of appropriateness is; low when T&T information is collected at all processing steps based on internal discussion and high when T&T information is collected at all appropriate CIP and it is based on HACCP system (Table 2).

Indicator, "determination of the traceable resource unit (TRU)" provides insight on the risk level the company is willing to take. TRU refers to a unit of trade, such as a whole fish, a batch of fish of any size or an ingredient. TRU is the reference unit, which is tracked and traced and is associated with Critical Traceability Points (CTPs). CTP are points at which information about a food item is systematically lost (Karlsen et al., 2010). This can happen when information about a product or process is not linked to a TRU or recorded systematically. TRUs invariably change during processing as new TRUs are being assigned at each step within the food chain. Each firm must develop a system of assigning new TRUs during processing, distribution, and retail (Thompson et al., 2005). The decision on the definition of TRU lies on the discretion of the company. The key is to find the preferable TRU where the benefits exceed the costs. Consequently, the costs and potential benefits associated with implementing traceability at different granularity levels should be identified (Karlsen et al., 2012). Unique identification of TRU is a key requirement to link product and process information to a specific traceable unit (Karlsen et al., 2011a). It is assumed that a highly sophisticated T&T system is the one that can manage to track and trace its products to an ingredient level, in this way a more specific location of a safety problem can be identified. In this tool, determination of TRU is assigned to a; low level when a TRU is a shipping truck containing different batches of fish and a high level when a TRU is a single carton from a particular batch of fish (Table 2).

Traceability can be achieved through the use of paper-based systems (Frosch et al., 2008), bar codes and radio frequency identification (RFID). In a bar code system, each time items are moved from one point to another, their bar code labels must be positioned so that they can be detected and identified by the reader. This characteristic, often called "line-of-sight positioning requirement" requires human intervention during scanning process and is associated with error and inefficiency (Regattieri et al., 2007). As a result, bar codes are less attractive to the food sector, and their application is consequently limited. The use of radio frequency identification (RFID) technology increases chances for effective and efficient traceability system in fish processing. Based on automated data capture, traceability information can be obtained at significantly reduced labour costs (Kelepouris et al., 2007). In our diagnostic tool low level is associated with the use of paper-based traceability whereas high level is associated with the use of RFID system.

The grid to assess execution of the traceability system is presented in Table 3 and is characterised by four indicators: (1) level of communication regarding T&T procedures and instructions, (2) compliance to regulations and procedures, (3) degree of accuracy of T&T documentations, and (4) frequency of verification of T&T system.

The indicator, "level of communication regarding T&T procedures and instructions" focuses on how the top management communicates with employees. Literature shows that communication is most effective when it uses multiple channels, such as both oral and written messages (Baron and Greenberg, 2000), especially when previously established work practices need to be changed, and accurate dissemination of information is essential to avoid guesswork (Holt and Henson, 2000). An advantage of oral communication is that the sender can use the feedback from the receiver to decide whether or not the message has been interpreted correctly. A disadvantage of oral communication is that one cannot remember everything every day. So communication becomes effective if it is both oral and written. The communication situation in this tool is considered as; low level when only oral communication is used between management and employees and high level when both oral and written communication is used between management and employees (Table 3).

The indicator, "compliance to regulations and procedures" focuses onto what extent companies adhere to their own policies, guidelines and instructions as well as international standards. Besides the design aspects of any T&T system, the way it is operating (performance) in practice is critical for the actual realisation of food safety. Performance is commonly analysed by checking compliance against pre-set requirements and procedures. Procedures aim at directing peoples' decision-making behaviour. In practice, however, they are often not properly followed, which may lead to unexpected behaviour and undesirable safety outcomes (Luning and Marcelis, 2007; Walker et al., 2003). Various researchers have studied the reasons beyond non-compliance to guidelines, procedures, and instructions. Such reasons include ability and disposition of people to quality or safety tasks, awareness and knowledge of guidelines and procedures (Azanza and Zamora-Luna, 2005). In this tool, low level is observed when the majority of workers execute tasks according to their own insights, because they are not aware of existence of procedures for certain tasks. A high level corresponds with workers who have a comprehensive understanding of T&T system tasks and its procedures (Table 3).

The indicator, "degree of accuracy of T&T documentations and recordkeeping" refers to the ability of the company to document T&T information accurately and consistently. A wide range of studies have acknowledged that insufficient recordkeeping and documentation (Panisello and Quantick, 2001; Walker et al., 2003) contribute significantly to unsatisfactory performance of quality management systems. Documentation and recordkeeping can be differentiated based on their objectives. Documentation aims at keeping knowledge and information, whereas recordkeeping aims at collecting data. Procedures, manuals, (work) instructions, flow diagrams, research reports, complaints, statistical analyses, etc. are typical sources of information and knowledge for documentation whereas process and product data, specifications of packaging materials, records of distribution and storage are typical sources for the recordkeeping system (Jacxsens et al., 2009; Luning and Marcelis, 2009). Documentation and recordkeeping systems that are superior are able to provide the right information and data at the right place at the right moment which will better support decision making processes in the FSMS (Karlsen and Olsen, 2011; Luning and Marcelis, 2009). Low levels of documentation and recordkeeping are associated with T&T documentation being everywhere in the company (not in a specific place/office), often not complete, not well readable and not arranged in a systematic order. Typical conditions for high levels include T&T documentations located in a specific place, complete, well readable and systematically arranged (Table 3).

The indicator, "frequency of validation and verification of T&T system" provides insight on how often the management validate and verify their T&T system. Studies have identified that lack of validation and verification (Taylor and Kane, 2005) highly contributes to unsatisfactory performance of quality management systems. To provide assurance to stakeholders that safety requirements will be met, the performance of the control system (e.g., T&T system) must be evaluated on its effectiveness and proper execution (in Luning et al., 2009). Validation and verification are two fundamental activities to support the assurance objective (Jacxsens et al., 2009; Kvenberg and Schwalm, 2000; Luning et al., 2009; Wallace et al., 2005a). Validation is defined as obtaining evidence that a control measure or combination of control measures, if properly implemented, is capable of controlling the hazard to a specific outcome. Verification includes the application of methods, procedures, tests and other evaluations; in addition to monitoring to determine compliance with the HACCP plan (in this situation, T&T system). Validation activities involve checking in advance the effectiveness of designed control measures, whereas verification activities concern checking afterwards if control activities are operating in practice as designed (Luning et al., 2009). The low levels for frequency of validation and verification of T&T system are observed when there is no validation and verification prior to implementation of the system. Typical for high levels is the situation where verification and validation is done on a scheduled basis (e.g., once per year) and whenever there are major changes in the system (Table 3).

4.4. Traceability system performance and food safety level

The grid to assess performance of the traceability system is presented in Table 4 and is characterised by three indicators: (1) reliability of procedures, tools and information, (2) accuracy/precision, and (3) time needed for tracing the products. The indicator: reliability of procedures, tools and information, is discussed in more detail.

The Traceability system must be reliable, meaning that it should be capable of retrieving the information required without any risk of error. Overall reliability is determined by the reliability of the tools, procedures and information sources used EAN.UCC (2003). If the tools, procedures and information sources used are reliable (for instance, approved by the EU or FDA), then the performance of the traceability system is likely to be high. The low levels for this indicator would occur when the company uses locally made tools, local procedures and local sources of information. Typical for a high level is when all tools, procedures and information sources are internationally approved (EU/FDA approval) (Table 4). When the company is a worldwide enterprise it is useful for the company to use international standards however, if the company is small, implementation of international standards might not be necessary.

Performance of the traceability system is also determined by the precision of the size of successive batches. A batch or a lot is a defined quantity produced at a certain time and placed in a uniform manner (Petersen and Green, 2005). The size of an individual batch is important in reducing risk and liability for individual companies. In general, the smaller the batch size, the lower the amount of product at risk for food safety issues. High level of precision in size between successive batches leads to high performance level of the traceability system. For example, in case of any problem, product recall and withdraw can be done more systematically than in a situation where there is no precision in batch sizes. Levels for this indicator are shown in Table 4.

Performance of the traceability system is also determined by the speed of obtaining information. The information concerning traceability of items must be obtained rapidly. However, rapidity depends on a number of factors such as the information management tools used, their automation and the level of cooperation between the supply chain partners. Longer reaction times can make contaminated products reach a large number of consumers. If the speed of obtaining the information about the traceable item is high, then the performance of the traceability system can be judged to be high and vice versa.

5. Conclusions

Fig. 1 illustrates how the factors and indicators discussed in this paper are interlinked together. Realisation of our diagnostic tool requires processing plant managers to use Tables 1–4 precisely to calculate the average score for each grid after giving scores in each indicator. If their contextual factors found in Table 1 are on the high or medium level (e.g., all of them or maybe 60% of them), their traceability system should be designed and executed on the high or medium level as well (60% or higher). The managers should then check their average scores in traceability system design (Table 2) and traceability system execution (Table 3) and also Table 4 indicators for further performance. If managers score on average (say 40% or below) on each indicator in (traceability system design and execution) then this paper suggests that they might not be able to trace food safety problems in an efficient manner. Therefore, they will need to redesign their traceability system and execution process to enhance performance of their traceability system.

The General Food Law EC 178/2002 requires traceability throughout the food supply chain. In order to track and trace products throughout the supply chain, food business operators must maintain relevant information from the suppliers, keep track of all products and their transformations through all stages of production and then pass this information to the next link in the supply chain (Donnelly et al., 2009; Thakur and Hurburgh, 2009). One of the biggest challenges in traceability systems is the collection of information in a standardised and systematic format (Thakur and Donnelly, 2010). The use of systematic procedures may allow companies to attain full traceability and fulfil the demands for greater product and process information control (Donnelly and Karlsen, 2010). The T&T system diagnostic tool can be a valuable and inexpensive tool for achieving this objective.

Food processing companies that evaluate their traceability system in a more structured way and according to specific criteria can have a better understanding of actual performance of their traceability system. These companies will be able to obtain actual information and therefore, food safety problems will be more systematically detected. The self-assessment provides insight to the strong and weak points of the current T&T system and supports a food processor in identifying what/ and how to improve in the system. Beyond individual food processors, the tool can be applied at the governmental level as a benchmark for performance of traceability systems as implemented by various food processing companies. In this paper, we argued that high level of complexity of contextual factors require high level of traceability system design, execution and performance. However, due to the nature of this study we did not validate such assertions in our diagnostic tool. We suggest further studies to be conducted to validate such assertions.

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