A Review of Food Traceability in Food Supply Chain

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***Abstract*—This paper conducted a literature review on food traceability issues. About 34 studies, mainly focus on food traceability issues, were reviewed. Based on the review results, driving forces, challenges in implementing food traceability systems, traceability techniques and application of traceability systems have been identified and discussed.**

***Index Terms*—food, research trend, supply chain, traceability**

I. Introduction

FOOD crisis have been with human beings in the past few years. Opara [1] mentioned that there are many food-related health hazards, such as foot-and-mouth disease, mad cow disease, microbial contamination of fresh produce. Only in Europe food borne illness affects about 1% of population (approximately seven million people) each year [2]. In addition, food crises lead to economic loss because of indirect costs of product recall. The loss of the market value and reputation could lead to total bankruptcy of the brand name [2]. Therefore, much attention has given to food traceability in food supply chain.

The objective of this paper was to conduct a literature review on food traceability in food supply chain. There are four parts in this paper, including driving factors for food traceability, challenges behind the implementation of food traceability systems, techniques applied for food traceability purpose and application of food traceability systems.

II. Driving forces for food traceability

Many driving forces behind the implementation of food traceability systems are indicated in Table I.

The drivers can be categorized into five concerns: safety and quality, economic, social, regulatory, technological. Due to these drivers, food traceability has become important issue [3], [4]. In order to satisfy the customers ' demand for variety of the food attributes and comply with the government rules, food companies have to implement traceability systems. Moreover, economic motives have influenced the development of traceability systems in the livestock sector [5]. These are: protect animals from theft; proving that animals possess valuable attributes such as up-to-date vaccination so that the animals deserve higher prices. In addition, the emerging new and cheaper techniques (see section 3) are the factors to motivate companies to develop traceability systems.

TABLE I
Driving forces for food traceability

Major concern	Driving forces	References
Safety and quality concern	High incidence of food-related health hazards(such as foot-and-mouth disease, mad cow disease, microbial contamination of fresh produce); increasing concern over the impacts of GMOs on the human food chain	[1]
Economic concern	The growth of the international trade and the increase of the number of potentially marketable species require reliable and rapid methods to verify the authenticity of the products and their origin.	[6]
	Better market access, better price, better food quality for consumer	[7]
Social concern	The need to identify genetically modified organisms(GMO) and non-GMO agricultural chains	[1]
	Addressing declining consumer confidence in food in the market and public concern about rising incidence of food-related illness and deaths	[8], [9]
Regulatory concern	The introduction of new food safety legislations to maintain market power and stay in business(partners in food supply chain have to have food traceability system to stay in business)	[3], [4]
	Ownership disputes(e.g. protecting animals from theft in the case of animal production)	[5]
Technological concern	Advancement in technology(encouraging traceability)	[10]

III. Challenges in implementing food traceability systems

Food companies have to face many challenges in developing food traceability systems (see Table II). These challenges have been categorized as awareness limitation, economic limitation, information limitation and standard limitation. Due to these constraints, every firm or supply chain has to define which strategies drive its activity and which kind of good or service it is going to provide to the market [11].

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IV. Techniques Applied for Food Traceability Purpose

Table III presents lists of most techniques applied in food traceability system. These techniques are mainly applied for product identification, genetic analysis, quality and safety measurement, environment monitoring, geospatial science and technology and software technology [1].Some researchers discussed these techniques from some aspects, such as applications, limitations and challenges.

V. Application of Food Traceability Systems

Food traceability systems have been used in many fields (see Table IV), such as cereal grain food supply chains, meat supply chains and animal feed. Dong *et al*. [27] has pointed out that several different analytical techniques have been well adopted in geographical origin traceability of cereal grain. Hobbs discussed three broad functions of meat and livestock traceability systems, including an ex post cost reduction function, a liability function, and an ex ante quality verification function. In general, traceability was considered to be an effective safety and quality monitoring system with potential to improve safety within food chains, as well as increasing consumer confidence in food safety [16].

VI. Conclusion

A literature review on food traceability systems (FTSs), which embraces the driving forces, challenges, technologies and applications of FTSs, was conducted in this paper. In order to implement FTSs well, traceability activities can be integrated with food logistics; the communication among partners should be strengthened; effective and efficient traceability technologies ought to be developed. In addition, more attention from society, government agencies and researchers should be given to FTSs. Future research can be focus on how to integrate traceability and logistics well and how to use big data in food traceability systems.

TABLE II
Challenges in Implementing Food Traceability Systems

Category	Challenges	References
Awareness limitation	Considering traceability as a huge bureaucratic load and reluctance in investing in traceability systems and less attention given to link the quality and safety information with product flow	[2], [8]
	Less willingness by some FSC partners to participate in the implementation of traceability systems	[12]
Economic limitation	Traceability is often regarded as a further burden costs and work to producers(e.g. staff motivation and training)	[11]
	Difficulties in coordinating and allocating costs and benefits of traceability system among the actors of the FSC under consideration	
Information limitation	Lack of complete, accurate, timely, and easily accessible information	[13]
	Problem of information asymmetry along supply chain	[14]
Standard limitation	Lack of uniformity(e.g. different companies use different standards information exchange)	[15]
	Different links have different level of accuracy of traceability	[16]
	Data related issues(data protection, trust, privacy/security, and reliability)	[10]

TABLE III
Techniques Applied for Food Traceability Purposes

Description	Techniques	Example of information to be captured	Reference
Product identification	Bar code technology	Item number, packed date, batch number	[17]
	RFID	Product temperature, location	[18-21]
	Electronic IDentification (EID)	Product name, batch/lot number, and price.	[1]
Genetic analysis	DNA typing; DNA tests based on real-time PCR ; DHPLC technique	Genetic origin, evaluate product ingredients; detect and quantify GMOs and other transgenic materials	[1], [22], [23]
Quality and safety measurement	δ2H and δ18O isotopic analyses combined with chemometrics	The geographical origin of products	[24]
	Molecular biology techniques	The authenticity of the products and their origin	[6]
	Smart packaging(PH indicators)	Growth of bacteria	[25]
	Penetrometer, firmometer, twist tester, Instron machine, and Kiwifirm; infrared and magnetic resonance imaging	firmness of fleshy products and other internal quality attributes	[1]
Environment monitoring	Intelligent packaging, gas analyzers and biosensors	Temperature, relative humidity, atmospheric composition of the air, including pollutants	[1], [25]
Geospatial science and technology	The integration of Geographic Information Systems (GIS), Remote Sensing (RS) and Global Positioning Systems (GPS)	Site specific data on animals and their movement	[1]
Software technology	QualTrace, EQM (Enterprise Quality Management) and Food Trak	Integration of technologies for full traceability systems	[1], [26]

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TABLE IV
APPLICATION OF FOOD TRACEABILITY SYSTEMS

Application	Function	Reference
Applied in cereal grain food supply chains	geographical origin traceability	[27]
Applied in meat supply chains	ex post cost reduction, an ex ante quality verification	[28]
Applied in animal feed	characterize the composition of forage and feed	[29]
Increase consumers' satisfaction	Increasing consumers' confidence in food and reducing consumers' complaints	[12]
	Promote food choice	[10]
Manage food crises	Improving crises management in event of hazard incidence	[30]
	Enable the accessibility of integrated data throughout production, storage, distribution, quality control and selling processes	[31]
	Optimize the recall process; reduce food recall costs	[2], [7], [32]
Improve food supply chain management(FSCM)	Increase transparency and adds value to the quality of FSCM by reducing information asymmetries and logistics costs	[4], [33]
	Reinforcing the level of coordination between partners of food supply network	[34]

REFERENCES

[1] L. U. Opara, "Traceability in agriculture and food supply chain: a review of basic concepts, technological implications, and future prospects." *Journal of Food Agriculture and Environment*, vol. 1, 2003, pp. 101-106.

[2] R. Saltini, R. Akkerman, "Testing improvements in the chocolate traceability system: Impact on product recalls and production efficiency." *Food Control*, vol. 23, no. 1, 2012, pp. 221-226.

[3] M. Bertolini, M. Bevilacqua, R. Massini. "FMECA approach to product traceability in the food industry." *Food Control*, vol. 17, no. 2, 2006, pp. 137-145.

[4] I. Hong, *et al*. "An RFID application in the food supply chain: A case study of convenience stores in Taiwan." *Journal of food engineering*, vol. 106, no. 2, 2011, pp. 119-126.

[5] E. Golan, *et al*. "Traceability in the US food supply: economic theory and industry studies." Agricultural economic report, vol. 830, no.3, 2004, pp. 183-185.

[6] M. Espiñeira, F. J. Santaclara, "6 - The Use of Molecular Biology Techniques in Food Traceability", *Advances in Food Traceability Techniques and Technologies*, A volume in Woodhead Publishing Series in Food Science, Technology and Nutrition, 2016, pp. 91-118.

[7] A.M. Donnelly, P. Olsen, "Catch to landing traceability and the effects of implementation – A case study from the Norwegian white fish sector", *Food Control*, vol. 27, no. 1, 2012, pp. 228-233.

[8] M. Heyder, L. Theuvsen, and T. Hollmann-Hespos, "Investments in tracking and tracing systems in the food industry: A PLS analysis", *Food Policy*, vol. 37, no. 1, 2012, pp. 102-113.

[9] J.Hu, X. Zhang, LM. Moga, M. Neculita, "Modeling and implementation of the vegetable supply chain traceability system", *Food Control*, vol. 30, no. 1, 2013, pp. 341-353.

[10] P. Chrysochou，G. Chryssochoidis，O. Kehagia, "Traceability information carriers. The technology backgrounds and consumers' perceptions of the technological solutions", *Appetite*, vol. 53, no. 3, 2009, pp. 322-331.

[11] M. Canavari, R. Centonze, M. Hingley, R. Spadoni, "Traceability as part of competitive strategy in the fruit supply chain", *British Food Journal*, vol. 112, no. 2, 2006, pp. 171-186.

[12] P. A. Liao，H. H. Chang，C. Y. Chang, "Why is the food traceability system unsuccessful in Taiwan? Empirical evidence from a national survey of fruit and vegetable farmers", *Food Policy*, vol. 36, no. 5, 2011, pp. 686-693.

[13] N. Ackerley，A. Sertkaya, R. Lange, "Food transportation safety: Characterizing risks and controls by use of expert opinion", *Plant & Cell Physiology*, vol. 37, no. 10, 2010, pp. 4642.

[14] X. S. Zhang，S. Y. Lv，M. Xu，W. S. Mu, "Applying evolutionary prototyping model for eliciting system requirement of meat traceability at agribusiness level", *Food Control*, vol. 21, no. 11, 2010, pp. 1556-1562.

[15] T. Maitri，D. Kathrynam, "Modeling traceability information in soybean value chains", *Journal of Food Engineering*, vol. 99, no.1, 2010, pp. 98-105.

[16] Kher, V. Swaroop, *et al*. "Experts' perspectives on the implementation of traceability in Europe", *British Food Journal*, vol. 112, no. 3, 2010, pp. 261-274.

[17] H. Ringsberg, "Bar Coding for Product Traceability", in *Reference Module in Food Science*, Elsevier, 2016.

[18] F. Dabbene, P. Gay, and C. Tortia, "5 - Radio-Frequency Identification Usage in Food Traceability A2 - Espiñeira, Montserrat", *Advances in Food Traceability Techniques and Technologies*, A volume in Woodhead Publishing Series in Food Science, Technology and Nutrition, 2016, pp. 67-89.

[19] P. M. Goodrum，M. A. Mclaren，A. Durfee, "The application of active radio frequency identification technology for tool tracking on construction job sites", *Automation in Construction*, vol. 15, no. 3, 2006, pp. 292-302.

[20] S. Li，B.M. Khumawala，C. Zhang，J.K. Visich, "Radio frequency identification technology: applications, technical challenges and strategies", *Sensor Review*, vol. 26, no. 3, 2006, pp. 193-202.

[21] L. Ruiz-Garcia，L. Lunadei, "The role of RFID in agriculture: Applications, limitations and challenges", *Computers and Electronics in Agriculture*, vol. 79, no. 1, 2011, pp. 42-50.

[22] G. Corrado, "Advances in DNA typing in the agro-food supply chain", *Trends in Food Science & Technology*, vol. 52, 2016, pp. 80-89.

[23] A. Giancaspro, *et al*. "Varietal traceability of bread 'Pane Nero di Castelvetrano' by denaturing high pressure liquid chromatography analysis of single nucleotide polymorphisms", *Food Control*, vol. 59, 2016, pp. 809-817.

[24] R. E. De, *et al*. "The use of δ2H and δ18O isotopic analyses combined with chemometrics as a traceability tool for the geographical origin of bell peppers", *Food Chemistry*, vol. 204, 2016, pp. 122-128.

[25] M. Ghaani，CA. Cozzolino，G. Castelli，S. Farris, "An overview of the intelligent packaging technologies in the food sector", *Trends in Food Science & Technology*, vol. 51, 2016, pp. 1-11.

[26] A.K. Evizal, S.K.A. Rahim, T.A. Rahman, S.L. Rosa, "10 - Traceability Software for the Food Industry A2 - Espiñeira, Montserrat", *Advances in Food Traceability Techniques and Technologies*, A volume in Woodhead Publishing Series in Food Science, Technology and Nutrition, 2016, pp. 191-206.

[27] H. Dong, D. Luo, and H. Luo, "16 - Effective Use of Food Traceability in Cereal Grain Food Supply Chains A2 - Espiñeira, Montserrat", *Advances in Food Traceability Techniques and Technologies*, A volume in Woodhead Publishing Series in Food Science, Technology and Nutrition, 2016, pp. 303-319.

[28] J.E. Hobbs, "17 - Effective Use of Food Traceability in Meat Supply Chains A2 - Espiñeira, Montserrat", *Advances in Food Traceability Techniques and Technologies*, A volume in Woodhead Publishing Series in Food Science, Technology and Nutrition, 2016, pp. 321-335.

[29] C. Morcia, G. Tumino, R. Ghizzoni, V. Terzi, "19 - Effective Use of Food Traceability in Animal Feed A2 - Espiñeira, Montserrat", *Advances in Food Traceability Techniques and Technologies* , A volume in Woodhead Publishing Series in Food Science, Technology and Nutrition , 2016, pp. 353-363..

[30] J. L. Salazar，G. Azuara，J. L. Tornos, "Improving RFID traceability systems with verifiable quality", *Industrial Management & Data Systems*, vol. 112, no. 3-4, 2013, pp. 340-359.

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[31] F. Schwägele, “Traceability from a European perspective”, *Meat Science*, vol. 71, no. 1, 2005, pp. 164-173.
[32] T.M.L. Diallo, S. Henry, Y. Ouzrout, “14 - Effective Use of Food Traceability in Product Recall A2 - Espiñeira, Montserrat”, *Advances in Food Traceability Techniques and Technologies*, A volume in Woodhead Publishing Series in Food Science, Technology and Nutrition, 2016, pp. 263-273.
[33] K. M. Karlsen，B. Dreyer，P. Olsen，E. O. Elvevoll. “Literature review: Does a common theoretical framework to implement food traceability exist?” *Food Control*, vol. 32, no. 2, 2013, pp. 409-417.
[34] F. Dabbene， P. Gay, “Food traceability systems: Performance evaluation and optimization”, *Computers and Electronics in Agriculture*, vol. 75, no. 1, 2011, pp. 139-146.

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