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RFID TECHNOLOGY IN FOOD TRACEABILITY SYSTEM

RFID technology in Food Traceability System

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ABSTRACT

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Due to many catastrophic food crisis and outbreaks, people start raising the awareness towards the food supply chain process, the origins of raw materials, how food is produced, stored and distributed to the consumers. Understanding the concerns of citizens, many regulations have been enacted to assure consumers about the safety of food commodities, by the mandatory implementation of traceability system in the food supply chain. Thanks to the evolution of technology, RFID technology is adopted to the system to improve the efficiency of traceability process, hereby be able to deliver transparent, accurate and instant track and trace solution.

Thus, based on the writer's personal desire to acknowledge the impact of traceability system on ensuring food safety, the thesis aims to introduce traceability system and the most-implemented technology – RFID technology. In order to reach the purpose, theoretical research and interviewing method will be conducted, to acquire both the theory knowledge and real-life scenario. The interview is done with Long Nguyen – IT manager of PERP JSC company, which provides traceability solution to feed processing corporate, for better understanding on the current situation in Vietnamese market, where the company is located.

Keywords: traceability, transparent, agriculture, radio frequency identification, intelligent packaging, food safety, food labelling, traceability certificate

Table of Contents

1 INTRODUCTION

In today's world, along with the development of a living standard, food safety has become one of the vital priorities to consumers (U.S. Department of Health and Human Services 2020, cited 18.12.2019). People start to have awareness of the food provenance, from its origin, the way food is produced, the entire process from - farm - to - fork concept, due to recent experimenting of food fraud, chemical contamination, adulteration, etc. For most of consumers, knowing in detail the raw ingredients and food production behind the factory is the guarantee for them to assure that they are provided with reliable, healthy and high-quality product.

The EU Food Fraud's monthly report (European Commission 2019, cited 15.12.2019) shows that in May 2019, there are almost ten cases related to counterfeited food, adulteration and mislabelling that have been recorded so far. Tragically, one of the world's worst outbreaks of E.coli in Germany caused death to more than 30 people and led to thousands of illness (Sample 2011, cited 18.12.2019.) The crisis has shocked consumers for a long time about the safety of the food process. Moreover, a significant horse meat scandal in 2013, which is widen on a European scale that affected large retailers like IKEA and Tesco, has strengthened consumer's need for the food guarantees more than ever (Lawrence 2013, cited 18.12.2019).

Various legislations and regulations have been enacted to minimize societal concerns regarding food safety and also to ensure that business have transparent and efficient production to deliver accurate information. Significantly, there are regulations from the EU Food Law, as well as Japan and The United States that obligate food corporates to have traceability system in their food supply chain, which strictly follow the International Standardization Organzation (ISO) in order to be qualified with global trading activities (Pigini and Conti 2017, cited 20.03.2020)

Since then, the ability to provide a traceable and transparent supply chain is a must for every food corporate, not only for the proven to customer's concern but also for the business itself to gain competitive advantages in the market. With traceability system, raw materials introduced in the system are guaranteed to have good quality, as well as the ability to detect faulty goods quickly. Thus, consumers are delivered with the reliable end-product that is gained certificate and accreditation from the public authorities. Identification of the finished products, all along with the

manufacturing chain will be remain transparent to save public health. (Espiñeira & Santaclara 2016, cited 25.12.2019.)

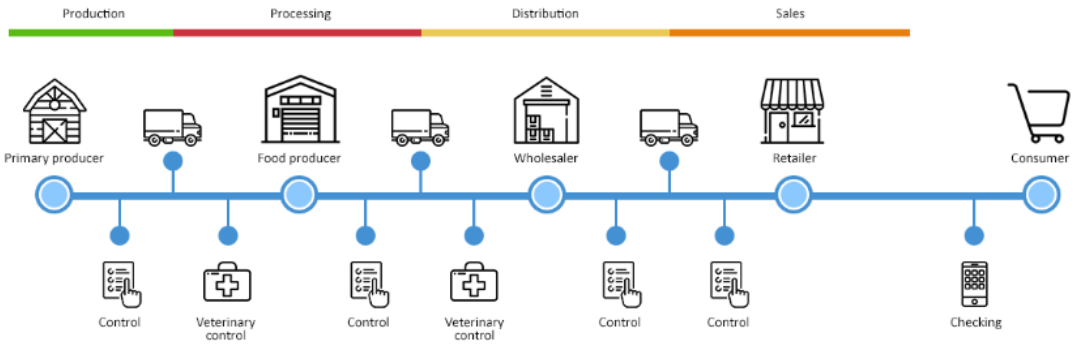

Figure 1. A general diagram of the food supply chain (Kyriakides 2018, cited 27.03.2020)

As showed in figure 1, food supply chain is a complex system, where the massive amount of data is stored in every single stage of it, from manufacturing, processing, distribution to sales. Besides, an effective traceability system relies completely on the amount of information involved in it. The more detailed data it has, the better the system perform its advantage and benefit. Therefore, the ability to deliver the transparency and traceability aspects is not a simple task. However, with the implementation of technologies, the process is faster, smoother, more accurate and more transparent.

These reasons above have led to the development of food production traceability system, wherein customer is provided with transparent information about the food that they consumed. In that situation, this thesis aims to deliver comprehensive information regarding traceability theoretical framework, along with the technologies that have been implemented in real life so far for the consumers and corporates to gain the fundamental knowledge about its potential in the business.

The paper is divided into three parts, first is what traceability means, in which the definition of traceability system will be addressed all along with the specific legislations that affect the process, food labelling, certificate and advantages when having efficient traceability system. In the second part, the paper is going to introduce the RFID technology, which has been widely implementing in the traceability system. Lastly, the interview with company that provided the traceability services

will be outlined in the next section of the thesis to explore about the recent situation and predicted future of traceability system.

2 TRACEABILITY SYSTEM

Implementing food production traceability in the food supply chain has become compulsory in recent years. It presents the ability to track and trace the source of ingredients, the unique identifier of each food items, as well as every single stages of food movement in case of food contamination, food crisis to prevent catastrophic situation. Ideally, the effective traceability system will result in the advanced risk management, rapid responses time, optimized production, accurate and timely delivery of information and determination of desirable product characteristics. (Storøy, Thakur & Olsen 2012, cited 05.03.2020.) Supporting to this, government has published various legislations and regulations to ensure that consumers are safe and protected by forcing organizations to implement traceability system. For example, under Regulation 178/2002/EC, organizations are required to implement traceability system in their food supply chain. (GOV UK 2004, cited 03.03.2020.) Also, it is mandatory for coporates to follow the international standard ISO 22005:2007 with required standard food labelling and compulsory certificate needed for food production and regional, national and global food trading (ISO 2007, cited 25.02.2020.)

2.1 Definition

Since ages, various definitions of the term “traceability” has been defined, included the definition from the International Standardization Organization (ISO), EU General Food Law and abundant reliable scientific papers.

2.1.1 By International Standardization Organization (ISO)

Almost three decades ago, the International Standardization Organization defined “traceability” as “the ability to trace the history, application or location of an entity by means of recorded identifications” in the ISO 8402 (ISO 1994, cited 10.12.2019). To break down the definition, it is clearly determined that the origin, application and place are objects that going to be traced, through the process of documenting entity’s identities. However, this definition was withdrawn and

superseded by another definition in 2007, ISO 22005 that specifically applied in food and feed supply chain: " the ability to follow the movement of a feed or food through specified stage(s) of production, processing and distribution" (ISO 2007, cited 25.02.2020). The ISO 22005:2007 comprehensively explicates the definition of the term "traceability", as well as general requirements for designing and implementing traceability system, particularly in the food and feed manufacturing industry.

2.1.2 By EU General Food Law

In 2002, EU General Food Law laid down the Regulation (EC) 178/2002 to ensure food safety through general principles, requirements and procedures that applied to all food and feed business in European. In the regulation, the term "traceability" is defined 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 (EU 2002, cited 22.12.2019).

This definition has clearly outlined all the activities in traceability process which are tracing and following, both back and forwar, as long as what is tracked down and located and where to execute those.

2.1.3 Kinds of traceability

Generally, traceability system is a tool to:

- Collect, identify and store information of food items that received from the food partner (suppliers, retailers, etc.). Then, be able to track and trace all the information involved in the food items.
- Identify and trace internal information within the food corporation regarding raw ingredients, how and when it is made
- As well as identify, track and trace the destination of the food item to supplier. (Food Standards Agency, cited 10.04.2020).

In order to achieve and maintain traceability through the supply chain, every parties involved must perform both internal and external traceability.

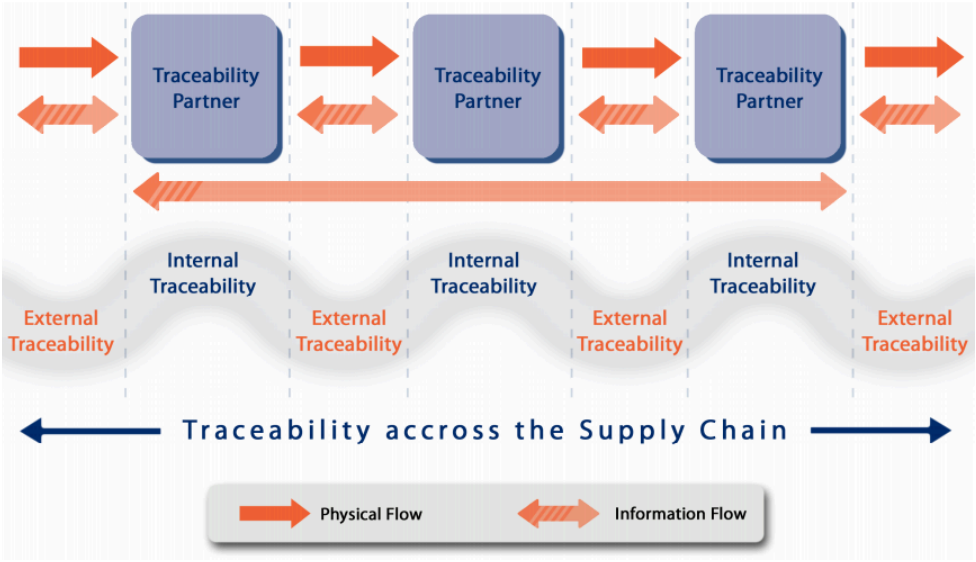

Figure 2. Traceability across the supply chain (GS1 2006, cited 16.04.2020)

External Traceability

External traceability takes place when the food businesses receive the information of trading commodities from their partner. (GS1 2019, cited 16.04.2020) As shown in figure 2, external traceability refers to the ability to trace the movement of information between multiple partners.

Internal Traceability

Figure 2 demonstrates that internal traceability refers to traceability activities happen in the enterprises level, a single manufacturer or a warehouse (Food Standards Agency, cited 10.04.2020.) For example, figure 3 illustrates the common internal traceability process within the manufacturer. Information of raw material A and B, intermediate and final product which is imported, exported and manufactured is all stored in the internal traceability system, as well as all the manufacturer's records.

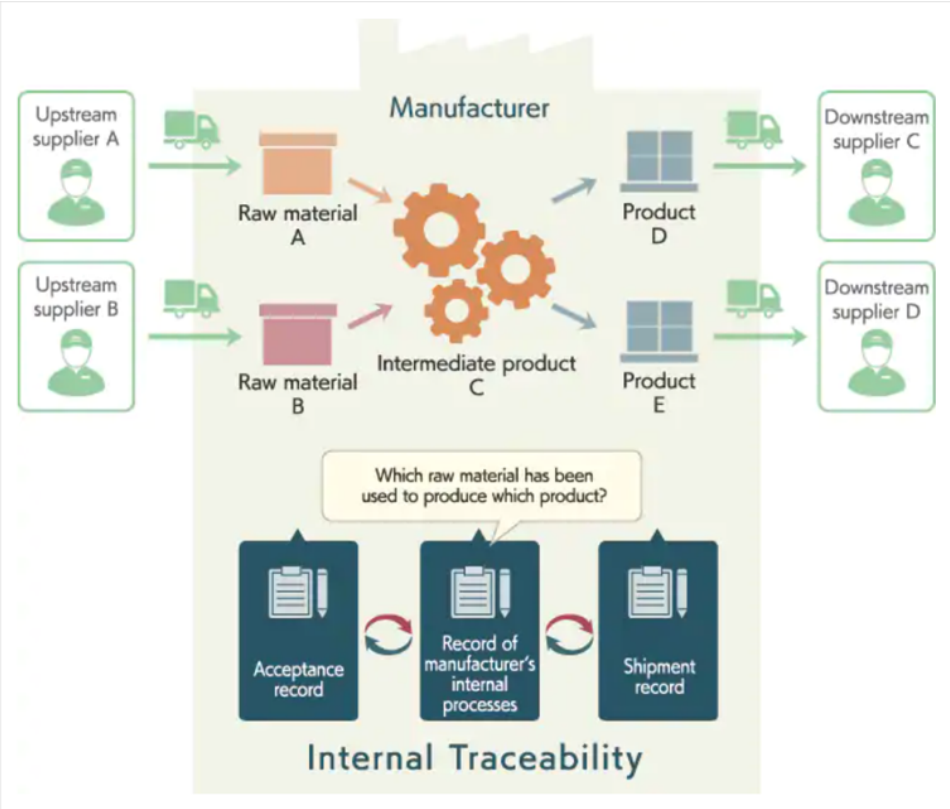

Figure 3. Example of internal traceability within a manufacturer (Keyence 2020, cited 13.04.2020)

2.2 Legislation

The safety and quality of the food item are top concerns that food production organizations have to genuinely focus on. However, this is a complex process due to its characteristics that included many different stages from different production places to the distribution to various markets around the world, which could be international across continents. Since then, several requirements for global standard of traceability system has been developed to ensure that every product meet the international demand for food safety and quality to be able to trade globally between countries and continents. In this sector, some popular regulations of popular imported country will be demonstrated: the European General Food Law from Europe, the SFCR Safe Food for Canadians Regulations from Canada and Beef Traceability Act from Japan that were laid down specifically for traceability system. In addition, there is also regulations from Europe related to food labelling that is obligated to applied to exported products. (Pigini and Conti 2017, cited 10.03.2020)

2.2.1 The European General Food Law Regulation (EC 178/2002).

Published in January 2005, the EC regulation 178/2002 aims to ensure public's health is protected and also the interests of consumers. The regulation applies to all stages in the food supply chain, to prevent any medical problems and gain customer confidence through the confirmation and control of public authorities. It lays down the fundamental principles and requirements for food law, as well as the production process related to the safety of food products by establishing the European Food Safety Authority. (GOV UK 2004, cited 03.03.2020.)

Particularly, the definition, scope and implementation of food traceability are determined in article 18 of EC 178/2002. This is the first regulation that obligate all food businesses to implement the traceability system. Specifically, the Article 18 demonstrates that companies are required to have in place the ability to "identify from whom and to whom a product has been supplied" and the "systems and procedures that allow for information to be made available to the competent Authorities upon their request." (GOV UK 2004, cited 03.03.2020.). It means that whenever one need to trace the origin of product, food operator is demanded to provide immediately the suppliers, customers and the whole producing process of the product.

According to the Article 18, EC regulation EC 178/2002, food traceability system is implemented under these requirements:

- The ability to identify and deliver specific customers and supplier's information of specific items immediately.
- The system of internal traceability is encouraged to develop within the food organization, follow precisely every activity inside the corporate include processing, storages, etc.
- Meet the minimum period of time of keeping the records in some cases. For example, products without specified shelf life (e.g. wine), companies should keep the information for the minimum of 5 years.
- Quick reaction to deliver accurate, reliable data in order for quick handling in case of food crisis. (GOV UK 2004, cited 03.03.2020.)

2.2.2 Ministry of Agriculture, Forestry and Fisheries

Due to several recent food crises related to food contamination, faulty products, the need for high-quality and reliable items is among the top concerns for Japanese consumers, producers and government. In order to meet the Japanese consumers' demand, policies and regulations have been enacted to ensure the safety of the food supply chain, the quality of food items (Charlebois 2014, cited 01.03.2020).

Specifically in beef industry, Japan has experienced a serious crisis related to cow infection in September 2001, whereas the Ministry of Agriculture, forestry and fisheries (MAFF) was motivated to lay down the "Beef Traceability Act" in June 2003 to frame a standard legal traceability system. The system is meant to deliver transparent production and marketing activities, raise the consumer's confidence on food products and based on the identification number tagged on animals, consumers are allowed to track and trace the beef supply chain online (Charlebois 2014, cited 01.03.2020.). In addition, Japan also has a different regulation called "Rice Traceability Act" that demands producers and importers to record at least the information about "name, country that rice was harvested, amount of commodity, date of purchasing, location of storage, name of counterpart and limitation of use" for three years (Godo 2017, cited 02.03.2020.)

2.2.3 Safe Food for Canadians Regulations (SFCR)

The SFCR became valid on January 15, 2019 to strengthen and ensure the food safety system in Canada. Under the regulation, most food business, except for restaurants, cafeterias or similar business, is obligatory to apply for a licence to be able to import, export food internationally. Besides, implement the system to be able to trace one-step backward and forward the food items is mandatory for most food business. For instance, the food business which slaughters animals is required to trace one-step back to the suppliers, or one-step forward to a retailer. (Canadian Health Food Association 2019, cited 15.04.2020.) In order to meet the regulation, the traceability documents must contain the name of food commodities, the manufacturing which produces,

prepares, keeps and makes packaging. The information has to be stored for at least two year. (Government of Canada 2019, cited 15.04.2020)

2.3 Food labelling

As a needed element for traceability system to effectively function, labelling is one of the crucial parts that all systems are required to implement. In every label, information such as manufacturer, country of origin, and so on, which vary based on laws applied for each commodity, are involved to accelerate the tracing process. Whenever there is a food crisis which demand for recalling or in case of food emergency, labelling is the first and convenient mean to obtain information about food items (Charlebois 2014, cited 01.03.2020.)

Since then, the new regulation EU 1169/2011 was enacted in December 2014 to determine food labelling requirements to all pre-packaged food and imported food in EU. Besides, there are also several laws regarding food labelling, Directive 2000/13/EC, EC 104/2000 and EC 1760/2000 was specially laid down for food labelling and advertising, fish and beef products respectively (European Commission, cited 05.03.2020). Thus, in order for company to import or export food products, these regulations must be conscientiously applied in the system (Charlebois 2014, cited 01.03.2020). Particularly, in EU regulation 1169/2011, food business operators are obligated to follow these requirements for labelling:

- All processed foods are required to have mandatory nutritional information
- The allergen lists must be determined next to or right after the list of ingredients (For instance: soy, nuts, glutens, lactose), including non-pre-packaged food in restaurants and cafes.
- For unprocessed food such as pigs, goats or poultry, labels are obligated to show the history of the items,
- Minimum text size must be applied for better legibility (European Commission, cited 05.03.2020). For instance, the x-height of characters is required to be equal to 1.2mm or greater (Food Safety Authority of Ireland 2019, cited 27.03.2020.)

Meanwhile in United States of America, most prepared foods are mandatory for labelling under the FDA regulation, with the following information such as name of food, list of ingredients and nutritional, allergens, name of manufacturer (Charlebois 2014, cited 01.03.2020.) However, for raw products or fisheries, nutritional labelling is voluntary. And for imported products, the country where foods come from was one of the mandatory information to show in the label under the regulation of the U.S. Customs and Border Protection Service.

2.4 Certificate

Japan Agriculture Standard (JAS) certification.

A program to give certificate to the traceability system of imported food was founded in Japan called "Japan Agriculture Standard" (JAS) by a Ministry of Agriculture, Forestry and Fisheries. This program aims to accredit traceability system with the national certification to ensure that every consumer is offered with high-quality and reliable products through informative and rapid system (Ministry of Agriculture, Forestry and Fisheries, cited 08.03.2020.) The JAS certification is optional. However, if food producers are able to obtain the certification, they are likely to win the market because consumers are more likely to believe in certified products. Moreover, JAS certification is now become the essential method for Japanese consumers to make any decision on food products, it is encouraged for any foreign producers to achieve the certification to stand out in the Japanese market and demonstrate their commitment on quality food items. In order to gain the certification, information about date of birth, sex, breed, owner, date and location of fattening and slaughtering, especially all feeds and pharmaceuticals in the manufacturing process are compulsory to present on the system. (Clemens 2003, cited 10.03.2020.)

2.5 Benefit

The most important driven-factor for implementing traceability system in the food supply chain is to **ensure the food safety**. Due to various food crises and outbreaks, consumer is growing attention and doubt to the food industry, demanding transparent information and rapid actions from both

government and food businesses. (Nga, Bogason, Arasonm Arnason and Matthiasson 2010, cited 20.04.2020). Since then, there has been plenty of regulations are enacted globally, and consumer is now guaranteed with **reliable and quality food items** from the food industry. Even if there are any doubts or risks, customer is able to prevent those by themselves firstly (Fisher 2015, cited 21.04.2020.)

In addition, customer can **minimize cost of food quality verification** thanks to traceability system that allows them to access food information rapidly (Nga et al. 2010, cited 20.04.2020.) On the other hand, beyond meeting regulations and consumer demands, implementing traceability system promotes more benefits and competitiveness to food industry generally and food businesses particularly. With the development of new technologies in recent years, the electronic-based traceability system has efficiently managing the food supply chain, results in the **cost reduction in the logistic process** (Food Marketing Research and Information Center 2008, 22, cited 08.03.2020). For instance, less shrinkage cost and food waste, as well as cost of procurement, storage and distribution is decreasing because that product tracing and inventory management is more efficient and accurate.

Besides, thanks to the **rapid and readily in tracking information**, traceability tool reduces delay in recall management and performs timely and accurately business decision. This system also delivers customers the higher chance to approach to reliable and transparent information regarding their food commodities. Thus, food businesses are able to improve their customer services, strengthen consumer confidence on their products and build positive relationship with customer. (Nga et al. 2010, cited 20.04.2020).

Traceability system also supports the **decrease in insurance and liability cost**. Olsson and Skjöldebrand noted that producers were likely to be blamed whenever bad events happened, therefore implementing the traceability system not only comply with the international regulations but also prevent any unwanted lawsuits from customers or food partners. (Olsson and Skjöldebrand 2008, cited 20.04.2020). Performing and maintaining good traceability actions such as meeting country regulations, increasing consumer confidence will result in the expanding of markets and acquiring new customers. Thus, food business is able to strengthen reputation, grow revenue and increase market shares. (Fisher 2015, cited 21.04.2020).

3 RFID (Radio Frequency Identification)

RFID refers to radio frequency identification, a technology that invented to automatically identify and track information through radio waves. RFID was first introduced and used during the Second World War period to identify aircraft whether it is a Friend or Foe system (Kumari, Narsaiah, Grecwal and Anurag 2015, cited 15.12.2019). Later then, it is widely employed in the corporate business process, particularly in supply chain management to maximize capabilities yet deliver minimum changes in an organization. It represents the evolution of technology in traceability system that performs the ability to connect all the parties (objects, people and data), identify and trace them through a real time process. Especially, RFID plays an important role in the effective and efficient development of end-to-end traceability systems, even in SMEs with a small operating cost (Magalhães, Rossi, Zattar, Marques and Seleme 2019, cited 20.12.2020). In this section, the components of RFID will be analyzed for better understanding about the technology, as well as its benefits in the system, limitations and applicable industries. Especially, the global standard of a RFID technology for companies to follow while purchasing and implementing.

3.1 Components

Each system contains three main components: **tags** (transponder), **readers** (interrogator) and a **software**. **Tag** is conventionally seen as the heart of RFID system that attached to the object, which is used to store data. There are different kinds of tags, such as passive or active, which differentiated by the power supply in order to serve various purposes such as keeping communication regard or regardless of distance. Meanwhile, **reader** has the responsibility to collect the information from tag to be managed later by the specific **software** (Kumari et al 2015, cited 15.12.2019). Figure 4 demonstrates the standard architecture of the Radio Frequency Identification system.

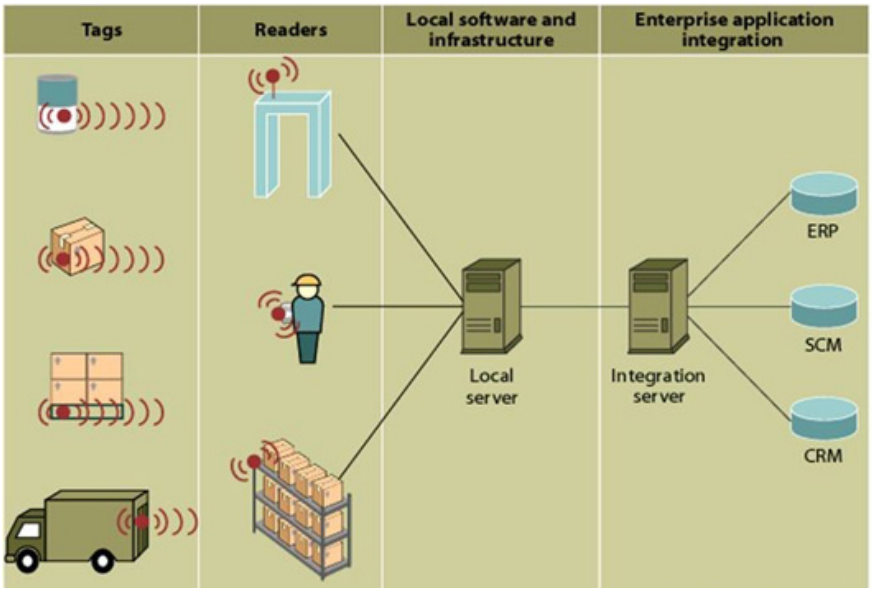

Figure 4. Architecture of a RFID technology. (Mansuri, cited 27.03.2020)

3.1.1 Tag (transponder)

There are two elementary components that every RFID tag contains: Tag antenna and internal circuit integrated in it (IC, Chip). With the activation from internal, or external power, a tag begins to transfer information which is collected from a tagged object to the reader through the antenna.

In details, tags are categorized into passive, active and semi-passive tag commonly based on the power supply attached to them (Brooks, cited 20.12.2019):

- **Passive Tag**: Embedded power supply-free tag, which is powered within the inductive field generated by the radio signals from the reader. It can be used in badge ID for attendee tracking, assets tracking, etc.
- **Active Tag**: The always active tag with built-in battery to remain continuous in communication with reader.
- **Semi-passive Tag**: Tag that only communicate when activated by the reader yet having embedded battery used for activating circuit chip.

With simple structure and light design that does not contain active components, **passive tag** has unlimited lifetime and the ability to work under extreme environmental conditions efficiently. For instance, some tags are capable of suffering extreme acid environments or high temperature up to 200 Celsius degree and above. Also, passive transponder is more affordable than others type of tags and requires no maintenance at all. However, it results in short reading range (under 9 meters) due to the elimination of internal power supply. Thus, the reader is required to place nearby in order for it to be active and transmitting information (Nguyen, cited 20.12.2019).

Active Tag is always active with the built-in battery to communicate with reader at any time. With its own IC, sensor and I/O porters integrated inside, active tag is able to measure and provide accurate and instant environmental temperature. Then identify different parameters related to the object such as its validity to transmit to the reader. Thus, active tag is normally used in cold chain or climate change monitoring application (Kumari et al 2015, cited 15.12.2019). Yet, active tag is bulkier and more expensive due to above embedded components.

Semi-passive Tag is a tag that has battery to energize itself but utilizing power from the interrogator to transmit data. This is more superior than passive tag because of its wider reading range that can communicate up to 30 meters (Nguyen, cited 20.12.2019.)

3.1.2 Reader (Interrogator)

There are two kinds of reader, **Stationary reader** and **Hand-held Reader** that are classified by its ability to move.

Stationary reader is unmovable, fixed reader, which is mounted on the wall, installed in fixed place nearby the gate or somewhere suitable within the reading range. In contrary to tag, readers cannot tolerate extreme environmental conditions. Thus, it is recommended to place reader indoor, or it has to be properly installed if placing outdoor. For instance, *portal reader* is one of the popular applications of stationary reader which is commonly used nowadays (Atlas RFID store, 2020. Cited 27.03.2020). It is designed to identify tag come in and out. Usually, this kind of application is used in the warehouse, where the large number of items are moved frequently for effectively track and

trace purpose. With this RFID system, readers and antennas are installed into the frame that creates the optimized and high-performance RFID-reading zone. For application in threshold read-zone such as attendance, inventory or entering/ exit tracking, portal reader is able to perform its best advantages. Figure 5 shows the illustration of portal reader.

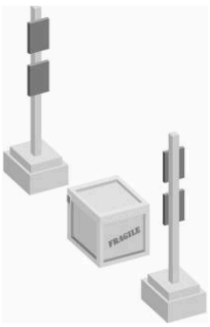

Figure 5. Application for Stationary Reader as a portal (Nguyen, p.51, cited 20.12.2019).

Hand-held Reader is the mobile reader that can retrieving data from transponder on the go by the internal antenna. It is not widely used like stationary one, due to its expensiveness. Yet, mobile reader is cheaper thanks to the evolution of technology nowadays. Figure 6 shows the application of hand-held reader.

Figure 6. Application for Hand-held Reader (Nguyen, p.51, cited 20.12.2019.)

3.1.3 Software (Middleware)

Middleware is an intermediate entity which placed in the middle of reader and database application to create a network that connects various objects to the enterprise system (Tounsi et al 2016, cited 05.01.2020). Because there is no guarantee that all the data gathered from readers are clean and

formatted in the same language, the installation of specified middleware is a must to any RFID system. Thus, it is responsible for managing and ensuring the flow of transferring, filtering, formatting and allocating data retrieved from reader to the host software system to optimize processing. To do so, as shown in figure 7, RFID middleware is generally divided into three sub-layers: Data transmission to control and communicate sets of various readers and transponders, then Operating sub-layer to break down different tags then collect them into suitable group and Business sub-layer refers to the remain departments in the whole RFID system that support the processing (Grande & Vieira 2013, cited 20.12.2019).

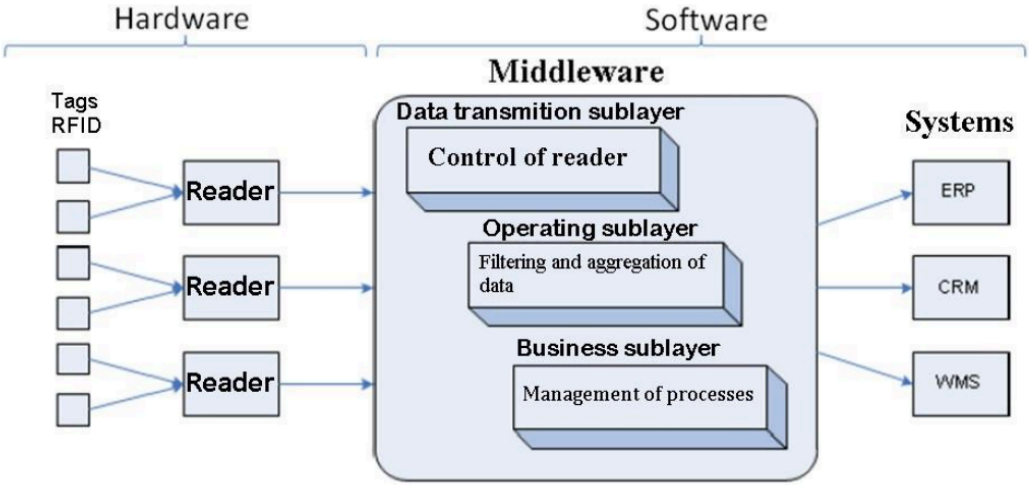

Figure 7. General architecture of RFID middleware (Grande & Vieira 2013, cited 20.12.2019.)

3.1.4 Communication Frequencies

For different communication purpose, RFID devices utilize specifically different bands of frequency to conform properly to requirements, not any single frequency is perfect for all purposes. Usually, RFID tag operates in the electromagnetic spectrum with Low Frequency (LF), High Frequency (HF), Ultra High Frequency (UHF) and Microwave. System operates in LF has short reading range and slow transmission process yet least interference with objects contain liquids or metals, while system is more sensitive to radio waves interference if function in HF (Kumari et al 2015, cited 15.12.2019).

Specifically, Low Frequency band operates between 125kHz to 134 kHz, which means it has very short reading range up to 50 centimetres with limited data transmission speed. However, it has a bunch of advantages such as not being sensitive to radio wave interference, flexible in various areas of functioning as well as the affordable production cost. It operates ideally in tracking animal, cold chain monitoring or access controlling. One of the popular frequencies is High Frequency which functions in 13.56MHz, delivers better reading range with faster data transmitting speed. Thus, more pools of data are able to be transferred efficiently within the range. Popularly, this frequency is operated in the identification of objects or merchandise management. In addition, Ultra-High Frequency (860 MHz-960 MHz) is also a commonly frequency that used in logistic and distribution thanks to its wide reading range and fast data transferring characteristics. It has wide reading range, as well as the ability to transfer information faster. However, due to its expensive manufacturing price, UHF is utilized only in long-term devices. Besides, there are either bands operate in 2.45GHz or 5.8GHz that popularly used in Microwave Frequency. This frequency promotes highest rate of data transferring and better identification ability. Yet, limited in higher cost and shorter reading range. (Kumari et al 2015, cited 15.12.2019.)

3.2 RFID Standards

RFID system is required to follow the global standards and regulations in order to ensure safety and interoperations when trading across nation. Moreover, having standards also beneficial in the development of the whole market generally and each parties particularly. Every manufacturer follows the same instruction of making products, specifically tags and readers, to ensure that different parts came from different vendors will interoperate smoothly. The famous standard developer, International Organization for Standardization (ISO) has created a set of standards, applied to many parts of the RFID technology. For example, the ISO 11785 has been created to define the standard of communicating between tags and readers, or ISO 11784 to specifically determine how data is structured on a tag for animals (Violino 2005, cited 22.01.2020).

3.3 Advantages

RFID technology has been using for many years now and still having its position in the industry, thanks to its advantages to the production in the supply chain generally. One of the benefits RFID brings to corporate is to **promote the visibility of the supply chain**, particularly in the food industry. In other words, all the information throughout the food chain can be able to access, track and trace anytime, by anyone. (Zelbst, Green, Sower and Bond 2019, cited 02.01.2020). For instance, the shipper is able to track the goods information and the shipment status in real time to increase the efficiency of food supply chain.

Besides, the convenient characteristic that RFID technology offers is the remote control, which **does not require line-of-sight scanning** (Micheal and McCathie 2005, cited 22.04.2020). Multiple RFID readers and tags can communicate at the same time, from any orientation. This also increase the accuracy of tracking information. Since tags are read anytime and anywhere by the remote readers, the system records exactly when and where the item leaves or enters the warehouse, for example. It is especially important for delivering fresh food commodities, which requires instant record to maintain the food quality throughout its path (O'Brien 2019, cited 22.04.2020). Furthermore, without the in-time checking on food condition, damaged or expired food is more likely to be distribute to customer, which can possibly explode food crisis and destroy the food business itself.

Other driven factor for implementing RFID technology is to **save the labor costs**. Comparing to the older technique which records on paper, the automatic supply chain requires less human interaction on the process. Most of the activities such as scanning, checking or detecting are now executed by the automatic system, which also prevents any errors and risks made by human. For example, distribution centers now can remove the large amount of labors for managing stocks and inventories, which accounts for 50-80% of the distribution costs. (Micheal and McCathie 2005, cited 22.04.2020).

Later on, good practices in implementing RFID will **maximize the business opportunities**. When the product is accurately followed anytime to anywhere, businesses is likely to improve their

forecast for new market trends, which helps to deliver faster responses to the customer demands and enhance the customer experiences. (Zelbst et el 2019, cited 02.01.2020).

3.4 Limitations

Despite its benefits, RFID still remains some limitations regarding their tags and software. One of the challenges that companies are presently facing is **high implementation cost**, which includes cost of devices and operation cost. For tags, price vary depending on how tags are used, type of tags or how many tags are purchased. A passive tag that is normally attached to pallets or cases costs around 15 cents to 75 cents, depending on volume. (Barcoding Inc. 2020, cited 01.05.2020) Each tag is affordable; however, it is a considerable amount if companies need to tag all items. Price may even increase up to 50 dollars per an active tag with built-in battery, or sophisticated sensor. For readers, price vary from 3000 to 20,000 dollars each, depending on kind of readers. Fixed-position readers are more expensive. (Watson 2013, cited 03.05.2020).

Beside cost, **the privacy and security of the RFID technology** is considered as one of the biggest challenges for its success. Due to the inherent nature of RFID technology that allows tags and readers to communicate in broad area, location and movement of the tagged product is still tracked even when it leaves the supply chain. Thus, privacy advocates concern that customers are likely to be followed, either by the retailers or hackers. Furthermore, even if customers are warned about the issue, RFID tags are not simple to be removed or turned off since it is carefully mounted to the object to prevent any damage. There are several approaches to the problems, however, the solution remains unclear (Micheal and McCathie 2005, cited 22.04.2020). **Security threat** is also one of the limitations of RFID technology. Different sources of attacks such as eavesdropping, or cloning are always likely to exit simultaneously. It happens when an unauthorized reader communicates with the tags on the chain, collect the data to take advantage of the gathered information. Hackers can either reproduce the tags, duplicate or create new tags that may destroy the system to make it out of service. (Beqqal 2017, cited 25.04.2020.)

Moreover, problem regarding **its technical capability** is seen as a questionable topic. Tags that are not able to store enough data, to process in high speed or readers that overlap with other

readers would be a huge problem to the deployment of RFID system. (Beqqal 2017, cited 25.04.2020). Reader that energizes the large amount of tags may face the confusion and stop the scanning process, for example. Strong data management is mandatory for RFID system to operate smoothly between multiple facilities.

3.5 Application

There is a fact that RFID technology appears everywhere around our daily activities, in almost every industry such as retail, logistic or hospitality. The RFID technology is applied in the payment process of public transports and tolls, the asset management in hotels or hospitals to track items and patients, or the movement of goods in supermarkets (Trade ID 2017, cited 10.04.2020).

Specifically for the development of agriculture industry, RFID technology has proved its advantages in plenty of applications like animal identification and tracking, in cold chain management and so on. (Garcia and Lunadei 2010, cited 15.04.2020.) For busy farmers and ranchers who are looking for remote controlling, high rate of identification, large storage memory, RFID technology would become the effective tool for the improvement of farm productivity. (Gao RFID 2015, cited 20.04.2020.)

RFID technology has now been used in many farms to track and identify animal information. Conventionally, ear tags or tattoos are frequently used to track animals. However, the old techniques require lots of human activities for manually detecting and recording that could lead to human error, slower the process and increase the labor cost. With RFID tags that is implanted under animals' skin, farmers are able to record instant activities across their farm to improve the farm productivity and prevent animal thefts. Furthermore, implementing RFID technology will deliver the transparency to the production process, help farmers to improve customer confidence on the food products by publicly showing the origins of feed products, pharmaceuticals and other information regarding its movement until the food is reaching consumer's hand.

Cold chain management refers to the supply chain management that has temperature-controlled system. Commonly, it is used to maintain the high quality and safety of perishable products such

as food, pharmaceuticals or vaccines. As a second-most dangerous driven factor for the exploding of food crisis, temperature in the supply chain is in a high-control to reduce the amount of spoiled items and amount of food waste. Throughout all the production, transportation, storage and distribution stage, RFID tags will help track and manage the temperature of all elements such as truck or warehouse. In order to monitor the goods temperature, semi-passive or active tags with the built-in sensor is frequently used, to mounted on the walls, pallets or boxes during transportation (Prakash, Pravin and Venkatalakshmi 2012, cited 28.04.2020).

Figure 8 demonstrated the example of how RFID operates in food traceability system. In food manufacturer, RFID is labelled on goods, then on each package or pallet to deliver to distribution centres. For vegetable products such as seed or grain of corn that cannot be tagged on individual objects, specified RFID is tagged on bales of hay to collect data about date of harvesting, or field ID, temperature, or even nutrition information. In distribution centre, goods with RFID tags moved through the RFID portal then RFID portal collect and update data to the traceability system. Then in the retailers, they usually utilize RFID – POS (Point of sale) to collect and manage sales information (Hong et al 2011, cited 10.05.2020).

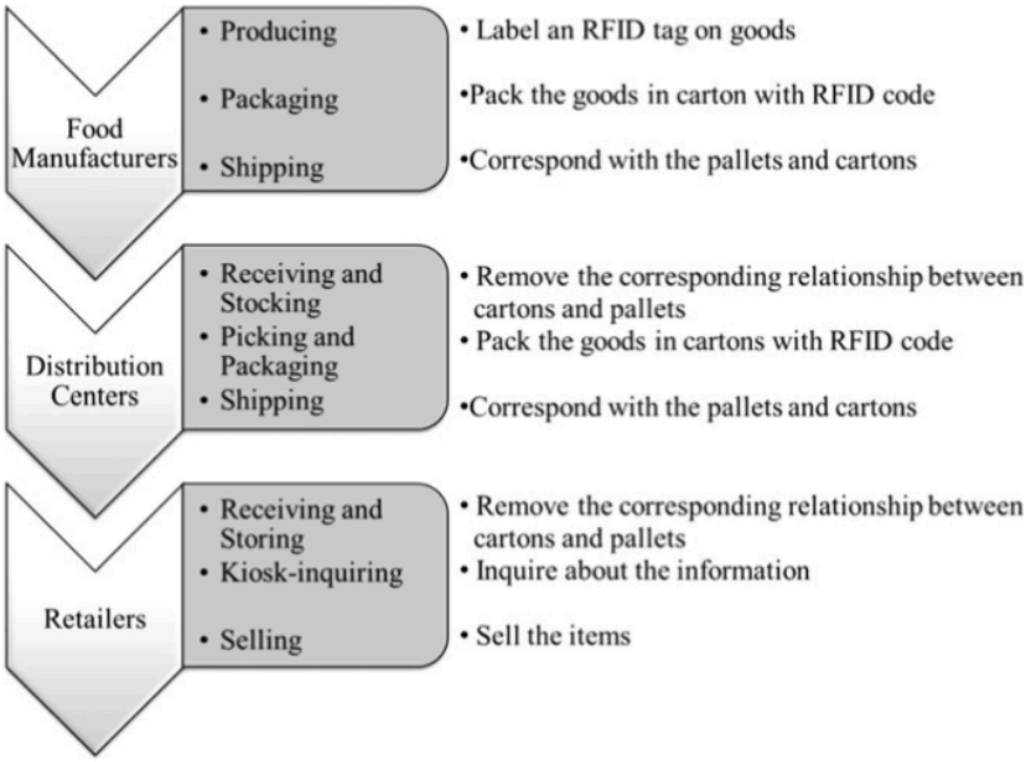

Figure 8. Example of food traceability system operation. (Hong et al 2011, cited 10.05.2020).

4 INTERVIEW WITH PERP JSC. COMPANY

4.1 Background

PERP JSC is an IT – based company which was founded in 2007 in the South of Vietnam. Company provides Enterprise Resource Planning (ERP) solution, as well as Supply Chain Management (SCM) and Human Resource Management (HRM) system. The company headquarter is located in Ho Chi Minh city, with branch office for North region in Hanoi- the capital of Vietnam.

The main product of PERP JSC is the ERP solution, which has almost 20 years development to meet not only the demand of customers but also maximize the capability of businesses. Customers of PERP JSC come from various industries, includes Airline, Railway, Transportation, Retail and Healthcare. Beside developing management solution, PERP JSC also offers courses, events and workshops for SME business about updated knowledge about IT management, ERP infrastructure, SCM and HRM to educate and create motivation for adopting new technology. (Perp JSC 2016, cited 20.05.2020).

Comprehending the important of traceability system in the food supply chain, PERP JSC is developing a project with its partner – an animal nutrition and feed manufacturing company – to promote the Vietnamese consumers' confidence on the food safety through the transparent chain. The project aims to apply traceability in the partner's supply chain, collaborate with partner's customers (farmer, etc.) to create the concept "from farm to fork" chain. Through the project, all the parties, especially farmer, are valued from the benefits along the chain by improving the sustainability of food production, through the inherent nature that deliver real-time data to make insights, predications and improvements of the traceability system.

The interviewing is conducted with the IT manager – Long Nguyen – who is in charge of the development of the project. The interview was held on first of May 2020 at the company headquarter.

4.2 Interview questions

During the interview, these questions were asked to understand more about present traceability in the area, how it has changed and the future of it from the interviewee's perspective.

1. What do you think about chances in implementing electronic – based food traceability system in Vietnam in the present?
2. What kind of technology that has been applying to build the system?
3. Challenges that company has faced when implementing the system? How has the company solved the problems?
4. What do you think about the future of traceability system?

4.3 Result

Question 1: What do you think about chances in implementing electronic – based food traceability system in Vietnam in the present?

According to Long, not many Vietnamese food businesses are adopting new technology in their food traceability system due to various reasons. Generally, as a developing country, the living standards of most the Vietnamese are not in the stable status. Therefore, consumer's concerns are not always about knowing in detail the information along food chain, but the price of food items. Moreover, consumers tend to purchase food directly from the wholesale or local market, which is not regularly certified but fresher and cheaper. Consumer buying behavior is consequently becoming one of the reasons for the situation. Apart from that, Long demonstrated that high implementation cost affects farmers' decision in some way. His team has been doing interview with many farmers, however, many of them refused to adopt new technique to due financial reason. They also expressed their worries regard the increase in price of food products, which has always been their competitiveness in the market.

On the other hand, Long also had his confidence in the rising of new technology adopted in the system. Many enormous food corporates has already been adopting new technology in their supply chain, as well as some small businesses which want to export their products oversea are getting

more interests in the benefits of the system on their production chain, for example complying with the regulations, meeting oversea consumers' demands and creating competitiveness. Long believed that applying new techniques in the food supply chain as well as in ERP system definitely increase the standout competitiveness to every food business.

Question 2: What kind of technology that has been applying to build the system?

The product was introduced to be built based on the combination of RFID (Radio Frequency Identification) technology and Cloud Infrastructure to ensure the efficiency of both food supply chain management and traceability management. By using RFID technology that applied to machineries in the supply chain, company can easily monitor and examine the operating process. The system is able to detect and predict in case malfunctions or breakdowns happen. Long mentioned that implementing sensor in RFID tag is beneficial in managing temperature, humidity, etc. to maintain the quality of products. On the other hands, PERP JSC uses Cloud Infrastructure to store data along the chain. Utilizing cloud infrastructure promotes business agility, enhance the process of making business decision to create competitiveness in the market. With the WIFI connection, partner is able to access to the enormous data pool despite geographical boundaries to store, identify or monitor in any time, without any interruption.

Question 3: Challenges that company has faced when implementing the system? How has the company solved the problems?

Long indicated that he and his team had difficult time dealing with the problems during the project. While testing the system, he found that the lack in technical knowledge of farmer has created a big challenge. Most of farmers were having confusing time inputting data and learning how the system is operated. They tended to prefer staying with their conventional management method, which was a paper-based system. Furthermore, Long noticed that the application was not friendly to low-tech users. It was mainly built for users who are likely to experience smart devices beforehand. To solve the problems, the team has to redesign the user interface to maximize experiences, even to farmer who not familiar with technology. Since the project is still in the progress, Long expected that there would be more troubles his team need to face.

Question 4: What do you think about the future of traceability system?

It is undeniable that traceability system has brought a huge impact on the development of food business nowadays. In Long's perspective, it has evolved and will be in the future thanks to the adoption of high technology. It delivers a quicker and more accurate track and trace solution to the food business, prevents delay in recalling by the ability to narrow the detected area to identify objects rapidly in high accurate rate. At the moment, there has already been many applications of RFID, IoT or blockchain technology, for example. Those technologies have proved their advantages in improving and enhancing the supply chain process. He expected to an evolution of new technology, which will solve the existed problems of high cost, data transmitting speed or customer privacy.

5 CONCLUSION

The purpose of thesis was to widen writer's knowledge in food market and food safety through the research about technology that is implemented in the traceability system as well as the impacts of it on ensuring food safety. Moreover, writer was first noticing the potential of food exported industry and having the desire to know in detail what would be the requirements and competitiveness that food business needs to aware of.

Ultimately, the thesis has basically fulfilled the writer's needs by introducing the foundation of traceability system definition, the legislations from European Food Law, Japanese ministry of Agriculture, Forestry and Fisheries and Safe Food Canadian Regulations, along with the European labelling, or Japanese certifications requirements and its benefits. Thesis showed that beside ensuring food safety, traceability system is also seen as a tool to guarantee consumers with quality and reliable products, minimize food verification and logistic process expenses by the rapid in identifying objects; improve customer services to maintain positive relationship and expand market internationally.

Beside gathering traceability system knowledge, writer was introduced to the components of RFID, which includes tags, readers and management software. Thesis showed the importance of each component, how different parts interoperate with each other despite international boundaries through global standards. Furthermore, the applications of RFID on various fields in agriculture industry, its benefits and limitations are described, for readers to consider adopting RFID technology in the food supply chain system. RFID was studied to promote supply chain visibility, allow monitoring remotely, rapidly and accurately. Thus, result in reducing operation cost in terms of labor, recall activities, insurance and liability expenses.

The result of the interview surprised writer about how Vietnamese food business think about adopting latest technology in traceability system. Farmers seemed not to have enough knowledge about the application of new technology, and it has limited their businesses development. Otherwise, high cost was demonstrated as the boundary which most businesses faced when applying new technology, as expected in the theoretical research. Traceability system is predicted

to have bright future, thanks to the evolution of technology. Interviewee is looking forward for the invention of new technology, which is able to solve the limitations of existed one.

6 DISCUSSION

The thesis aims to introduce food traceability system as a tool to promote food safety and RFID technology, the most-utilized technology to achieve the highly efficient food supply chain management. Theoretical research has been an interesting and helpful method for me to learn more about the topic. I have gained knowledge regarding traceability and RFID technology, not only its beneficial on food traceability system but also why is it mandatory to apply such a complex system in different area in the world. On the other hand, thanks to the interview with PERP JSC, I am able to understand more about Vietnamese market in the perspective of professionals.

The interview has supported my view in Vietnamese traceability system, however a little bit different. Since my background is an urbanist, I found myself and my family is more likely to purchase products in the supermarket with certifications. For example, when purchasing vegetable, my mom tends to purchase in authorized supermarket. In which she is able to check the barcode of the products to know where it is come from and the company that produced it. Thus, specifically for me, I found the huge potential of traceability system in the market as a powerful tool for business.

I am looking forward for the development of the thesis in terms of the evolution of technologies, or particular method to apply traceability system in the food supply chain. Perhaps the study in how certified food products affect consumers purchasing behavior, for instance. Since the thesis indicated that consumers are likely to choose products with legit certifications, it would be interesting to learn further about how and in what aspects it has impacted the social buying behavior.

In addition, the thesis is perhaps beneficial for new start-up who want to do food business. It provides helpful information for those who are interested in expanding their market internationally with regulations in top food imported countries and what certificates are needed. I also suggest the thesis for businesses that needs technology in their conventional traceability system, to consider RFID technology based on my research about its advantages, disadvantages, and structure.

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