

## Fresh Agricultural Product Export Environment Analysis Using IP-RFID-based Reefer Container Monitoring Equipment

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### Abstract

*Recently in far eastern Russia, the demand for fresh Korean agricultural products has been increasing. To meet this ever-increasing demand for fresh agricultural products, maritime transport that uses reefer containers is necessary. However, in reality, most of the fresh agricultural products are exported using short air transport method because it is impossible to monitor their conditions during the long maritime transport period. This study introduced the IP-RFID-based reefer container monitoring system and monitored the temperature change of the fresh agricultural products during maritime transport using the system. In addition, this study also monitored the temperature change of the fresh agricultural products that were exported to the same region during the air transport and compared it with the temperature change during maritime transport. The study result showed that the fresh agricultural products maintained better conditions during the maritime transport by retaining the Cold Chain during the entire transport process. In addition, maritime transport was more efficient than air transport because the strawberries could be directly sold to consumers without additional works.*

**Keywords:** IP-RFID, Reefer container, Agricultural product, Export environment, Monitoring

### 1. Introduction

Recently in far eastern Russia—such as Vladivostok and Maritime Province—the demand for fresh Korean agricultural products has been increasing. To meet this ever-increasing demand, maritime transport for fresh agricultural products using a reefer container is necessary. [1-2] However, most of the fresh agricultural products are exported using short air transport method because the current reefer container monitoring technologies, such as PCT and 4-pole, cannot accurately monitor the condition of the fresh agricultural products during the long maritime transport period. [3-4]

This study introduces the reefer container monitoring system using IP-RFID, which it independently developed. This reefer container monitoring system consists of the IP-RFID Tag that collects information such as a reefer container's internal temperature, humidity and vibration during transport, Smart Point that transmits the status information collected by the IP-RFID Tag to the Internet, and the Service Platform that provides suitable information to users using the collected information.

This study applied the aforementioned reefer container monitoring system to the strawberry cargo transported from a Korean port to Vladivostok in far eastern Russia to monitor the temperature change during the maritime transport process. Also, this study

monitored the temperature change of the strawberry exported to the same region during the air transport using the IP-RFID Tag and compared/analyzed the result.

The study result showed that maritime transport could maintain the optimum storage temperature of fresh agricultural products during the transport, while air transport allowed the decay of the agricultural products to some extent because they were exposed to room temperature during the transport.

This study will introduce the IP-RFID technology and the IP-RFID-based reefer container monitoring system in Chapter 2, deal with the maritime and air transport paths of the strawberry in Chapter 3, compare and analyze the monitoring results of the two transport paths in Chapter 4, and will provide the conclusion in Chapter 5.

## **2. Introduction to IP-RFID-Based Reefer Container Monitoring System**

### **2.1. IP-RFID Technology**

The existing RFID system is mainly used to allow the tag perceive the attached objects from the reader installed at the base, which makes it unsuitable to use the communication protocol requiring many system resources such as TCP/IP. However, to make the RFID Tag play the role of one information provision entity in global network, it is necessary to use the IP technology. [5-6]

IP-RFID is a technology that combined RFID (Radio Frequency Identification) technology with minimum IPv6 technology, which can make the remote management / control of the moving tags possible by extensively expanding the perception range of the RFID tags and guaranteeing their mobility using the existing IP infra by embedding the IP in the RFID tag (Hyung Lim Choi, 2010).

### **2.2. IP-RFID-Based Reefer Container Monitoring System**

The maritime shipment of fresh Agricultural products use reefer containers that maintain the temperature at set point throughout the process.

At present, reefer containers do not provide real-time monitoring of its inside conditions. Upon request, the shippers can receive only limited information about the temperature history logs after the products have reached their destination.

The temperature information of the current reefer containers is recorded to the control units of the reefer containers, and the shippers can check the records using the monitoring programs provided by the manufacturers of the reefer containers.

The currently used remote monitoring service is the Power Cable Transmission (PCT) method, which is recommended by the International Maritime Organization (IMO). However, this method is not widely used because it requires a separate PCT communication infrastructure and is susceptible to data loss problems because of the use of power cables. [7-8]

A monitoring technology that collects data from the data ports inside the reefer containers and transmit them through wireless communication, such as RFID and Wi-Fi, is under development. Despite this, however, this has not been made commercially available. [9-10]

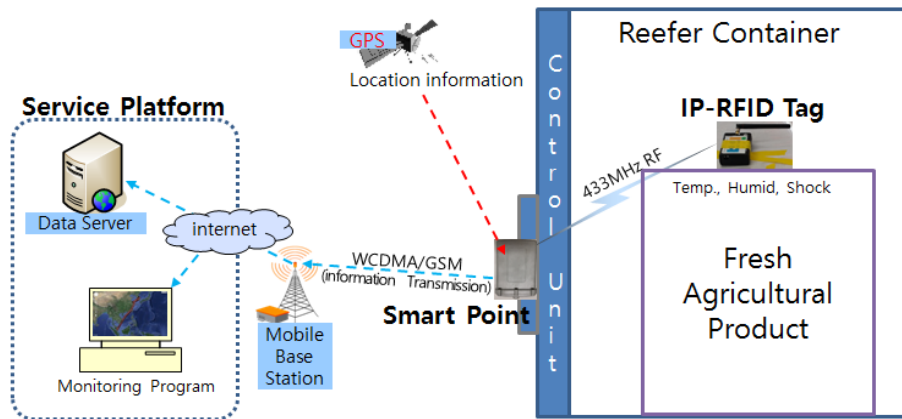
Table 1 summarized the characteristics and limitations of current methods to monitor reefer containers. [11-12]

**Table 1. Summarized the Current Reefer Container Monitoring Methods**

Method	Monitoring Information	Feature	Problem
Periodic check	Power On/Off, Defroster status, Refrigerator status, Current temp. in container	Check the Reefer Container Display Panel with human eyes	Record error, hard work in night and rough weather
4-pole	Power On/Off, in range status, Defroster status, Refrigerator status, Alarm info	Need to connect 4-pole cable	Only display with 4-pole interface system
PCT (PLC)	Set temp., Return temp., Supply temp., Container ID, Defroster status, Alarm info	Send the information of container with PCT	Need to add PCT modem weak
Current Check	Power On/Off, Defroster status, Refrigerator status	Applicable all of reef container	Only check the Simple process of reef container status
RFID Based	Set temp., Return temp., Supply temp., Container ID, Defroster status, Alarm info	Use the Interrogate Port to get information of reef container RF Based communication	Rough installation Need the RFID Machine for sending information

Figure 1 below shows the IP-RFID based Reefer Container Monitoring System introduced in this study.

This system consists of the IP-RFID Tag attached to the cargo inside the reefer container, which senses the temperature, humidity, and impact around the cargo, and transmits them to the outside using 433MHz RF communication system. Meanwhile, the Smart Point installed inside of the control unit box that collects the status information of the cargo transmitted from the multiple IP-RFID tags and after the collection, transmits the data again to the remote service platform on a real-time basis after adding the location information of the reefer container using GPS technology. The Service Platform that receives the reefer container status information transmitted from Smart Point then stores it in the database and provides this information to users.

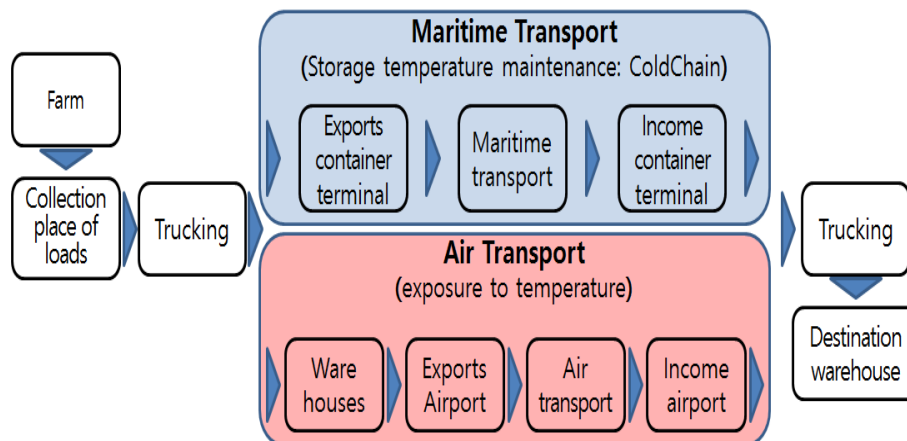


**Figure 1. Reeper Container Monitoring System**

The Smart Point was made to allow users at home and abroad to access the global network through automatic roaming using WCDMA/GSM technology, as well as to receive the IP-RFID Tag information in the Service Platform through the TCP/IP communication system.

### 3. Introduction to Fresh Agricultural Products Export Paths to Far Eastern Russia

The fresh Korean agricultural products export paths to far eastern Russia include the maritime transport method using a ferry vessel departing from Donghae Port in Gangwon Province and the air transport method using a cargo plane departing from Incheon International Airport.



**Figure 2. Maritime and Air Transport Path**

Figure 2 shows the important bases during maritime transport and air transport.

When the fresh agricultural products harvested in production sites arrive at the collection place of loads equipped with precooling facilities, the sorting and packaging process is carried out at optimum storage temperature. Then, the fresh agricultural products that are to be exported by maritime transport are loaded in a reeper container that can maintain optimum temperature during transport, transported to Donghae Port, and loaded on a ferry vessel for export to Vladivostok Port of Russia. During this process, the reeper container maintains the temperature of 1°C, the optimum storage temperature for strawberry, by receiving power from the car generator during inland transport and from the ferry vessel during maritime transport for a period of four or five days [11].

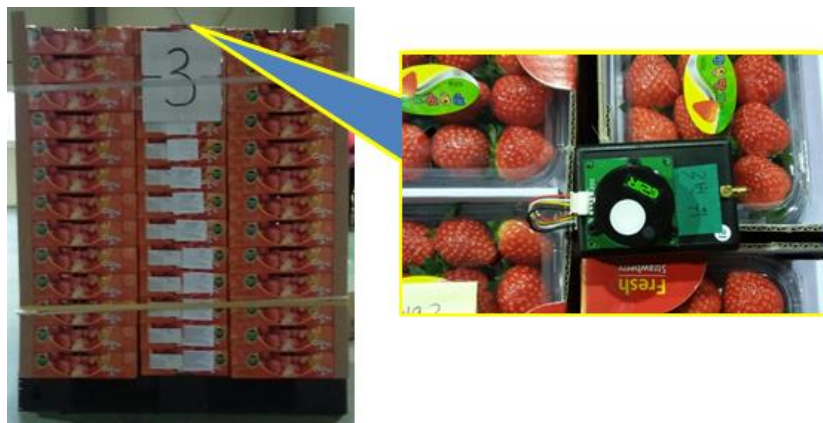
When the harvested fresh agricultural products to be exported by air transport arrive at the collection place of loads, which is equipped with precooling facilities, they go through the sorting and packaging process. Then, they are transported by trucks to warehouses near the airport. In the warehouses, they are repackaged to fit the containers (ULD) that can be loaded on airplanes and transported to Vladivostok International Airport using cargo planes. The fresh agricultural products are exposed to room temperature from the moment they are repackaged in the warehouse near the airport. Also, the entire air transport process takes an average of two or three days.

The time gap between maritime transport, where the fresh agricultural products are transported while maintaining optimum temperature, and air transport, where they are exposed to room temperature, is an average of two days.

#### 4. Export Environment Monitoring for Fresh Agricultural Products Exported to Far Eastern Russia

Targeting the strawberry exported using the maritime transport method and the air transport method from Korea to Far Eastern Russia, this study monitored the export environment through the application of the IP-RFID-based reefer container monitoring system introduced in this study for strawberry cargo [12].

For monitoring of maritime and air transport environment, this study installed three IP-RFID Tags and one Smart Point at the strawberry reefer container for e maritime transport, and five IP-RFID Tags at the strawberry cargo for air transport from Korea to Vladivostok Port / Airport of Russia.



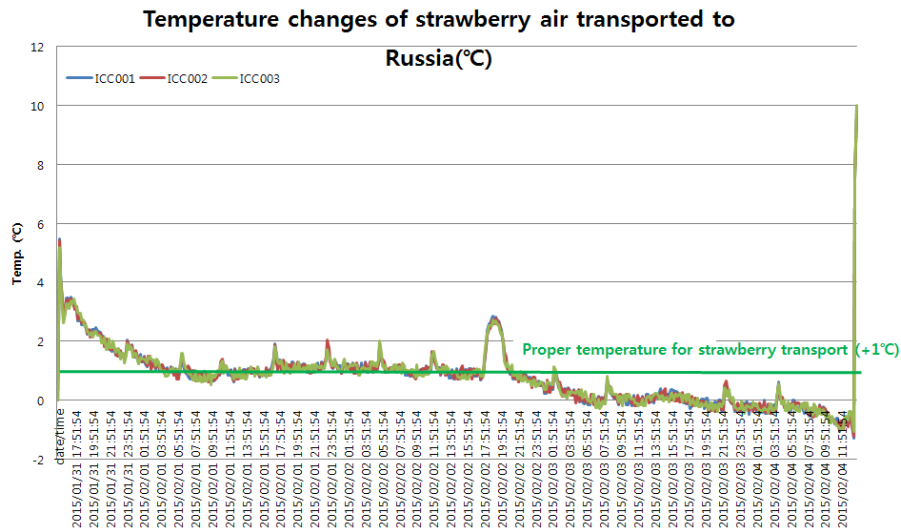
**Figure 3. Strawberries Packaged and Attached Sensor**

For monitoring, strawberries produced in Paju, Gyeonggi-do and Nonsan, Chungcheongnam-do were used. After harvesting about 85% of the ripened strawberries for export, 500 g were placed in each plastic box for export. Then, they were packaged with paper boxes in four plastic box bundles. The paper boxes were subsequently piled on 1,100 × 1,100 mm standard pallets, and the final wrapping was conducted to ensure that they can be loaded in the container.

##### 4.1. Strawberry Export Environment Monitoring through Maritime Transport

Maritime transport using a vessel took about 5 days from Jan. 31 to Feb. 4, 2015, and the temperature change during the transport process is shown in Figure 4 above.

During the export process using maritime transport, the temperature of the reefer container was set to 1°C and the Cold Chain was maintained in the entire export



**Figure 4. Maritime Transport Temperature Monitoring Result**

section from domestic transport to arrival at the warehouse of the Russian buyer, while the reefer container’s internal temperature was maintained at  $-0.5\text{--}3\text{ }^{\circ}\text{C}$ , which is close to the optimum storage temperature for strawberries, during the actual transport process. Consequently, the strawberries could be able to maintain their freshness even five days after their arrival at Russia and they could be directly sold to Russian consumers without sorting-out process.

#### 4.2. Strawberry Export Environment Monitoring through Air Transport

Air transport using a cargo plane took about 3 days from Mar. 24 to Mar. 26, 2015. Also, temperature change during the transport process is shown in Figure 5 below.

During the export process using air transport, the strawberries could be transported in a low-temperature condition in domestic sections by using trucks equipped with refrigerating facilities, however they could not maintain  $1\text{ }^{\circ}\text{C}$ —the optimum storage temperature for strawberries—during the air transport process because they were exposed to room temperature from the moment they arrived in domestic warehouses.

In particular, the Cold Chain was not maintained in the Incheon Airport warehouse, the Russian Airport, and the Russian inland transport sections. Moreover, they were transported while being exposed to room temperature of  $6.2\text{--}18.2\text{ }^{\circ}\text{C}$ . Even after the strawberries arrived at the warehouse of the Russian buyer, the warehouse was unable to promptly reduce the temperature to the optimum storage temperature for strawberries.

Consequently, the quality of the strawberries was reduced even though the transport time was about two days shorter than the maritime transport and they could be sold to Russian consumers only five days after the shipment, the same time as the maritime transport, after the decayed strawberries were sorted and the strawberries underwent the repackaging process.



**Figure 6. Strawberries Result of Spoilage through Air Transport**

## 5. Conclusion

This study introduced a reefer container monitoring system composed of the IP-RFID Tag, Smart Point, and Service Platform based on IP-RFID technology that can extensively expand the perception range of the tags and guarantee their mobility by combining RFID technology with IPv6 technology. In addition, to identify the system's performance, this study also monitored the transport environment of the strawberries produced in Korea and exported to Vladivostok using the introduced system.

The monitoring of the export environment was carried out for two paths—maritime transport and air transport. The monitoring result showed that the strawberries were transported by maritime transport for about 5 days while maintaining close to 1 °C, the optimum storage temperature for strawberries. The air transport took about 3 days, which is 2 days shorter than the maritime transport, but it was identified that the strawberries lost their freshness during the transport because they were exposed to room temperatures of 6.2–18.2 °C and that the quality of some strawberries was reduced because they became spoiled during the transport process.

The above monitoring results of maritime transport and air transport show that the prompt transport of the fresh agricultural products is definitely important, however maintaining the Cold Chain, the optimum storage temperature, is more important during the transport of fresh agricultural products.

Further studies need to be carried out with regard to the future of communication between the Smart Point and reefer container control units so that reefer container temperature can be controlled based on the temperature information perceived by the IP-RFID Tag attached to the cargo using real-time control technology, an advantage of IP-RFID technology.

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