The Configuration of Fruit State Monitoring System Using the RFID System

Ki Hwan Eom, Nghia Truong Van, Lin Sen, Kyung Kwon Jung and Joo Woong Kim

Department of Electronics and Electrical Engineering
Dongguk University, Seoul, Korea
Korea Electronic Technology Institute, Seoil University

kihwanum@dongguk.edu

Abstract

Fruit have a variety of vitamins and has the most vitamin C, and so we can know the status of the fruit to the loss of the vitamin C. There are a lot of factors that the loss of the vitamin C, but it is highly dependent on temperature. Therefore, monitoring temperature variability during transport and storage is very important. In this paper, we propose the fruit state monitoring system using the RFID system. The proposed system consists of server, RFID reader, RFID tag, sensor interface, temperature sensor. In order to verify the effectiveness of the proposed system, we performed experiments on the strawberry juice. Strawberry may be considered among the fruit most rich in Vitamin C. The temperature is taken by the sensor and reported through MFC software. Fruit state monitoring was divided into the 5 grade. The experimental results show that was confirmed the performance of the fruit state monitoring system.

Keywords: *Fruit State Monitoring, Temperature Sensor, MFC, RFID System, Strawberry Juice*

1. Introduction

Fruit is very good for health because it has various vitamins, has the most vitamin C, and is delivered to the end customer in an excellent and fresh condition is really important. The required system should control and monitor the fruit conditions in order to ensure quality for consumers and to comply with all legal requirements. Each group of consumers requires different status such as in retail or institution, hospital, school, *etc*. Among environmental parameters during transport and storage, temperature is the most important factor in prolonging the shelf life of the fruit. Also there are a lot of factors that the loss of the vitamin C, but it is highly dependent on temperature. Customers are very necessary to know the status of the fruit with the loss of vitamin C by measuring the temperature. Recently Radio Frequency Identification (RFID) has resulted in a wide variety of applications in food industry [1].

In this paper, we propose the fruit state monitoring system using the RFID system, in order to consumer health. This system consists of server, RFID reader, RFID tag, sensor interface, temperature sensor. In order to verify the effectiveness of the proposed system, we performed experiments on the strawberry juice. Strawberry may be considered among the fruit most rich in Vitamin C. The proposed system, temperature is taken by sensor connect to RFID tag, it is read by Speedway Revolution UHF RFID reader. Kinetic modeling method is applied in order to verify status of vitamin C left, five fruit statuses are reported on server computer by MFC software.

The designed system is easy to control and monitor food status in warehouse center, Vitamin C lose graph and Vitamin C percentage left are displayed, the warehouse can make delivery plan to consumers actively, and change temperature in the store suitably.

2. Proposed Fruit State Monitoring System

2.1. System Overview

The system consist of smart RFID tag and reader connected to server computer, each part of fruit is attached temperature sensor, it was read by reader 900Mhz Speedway R420. Five fruit statuses are very bad, bad, normal, good and very good reported on server computer through MFC software. Operator can know percentage vitamin C left and fruit status, therefore warehouse can make delivery plan to consumer. The system overview is shown in Figure 1.

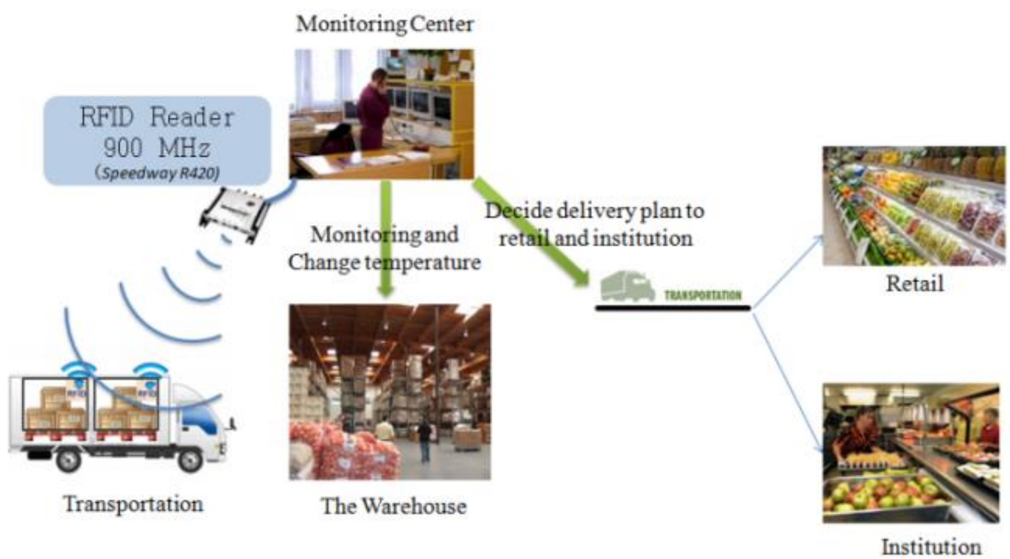

Figure 1. Fruit Monitoring System Overview

2.2. Built Sensor Tags and RFID Reader

The RFID sensor tag block diagram is shown Figure 2. An antenna 900 MHz and impedance matching circuit precede the analog front end. The power harvester block rectifies incoming RF into DC voltage to supply for the system. The demodulator follows the envelope of the RF carrier wave to extract Amplitude Shift Keyed (ASK) [2]. It is read by MSP430 microcontroller (MCU) to receive downlink data from the reader. Uplink data is sent through modulator circuit (FSK) [3].

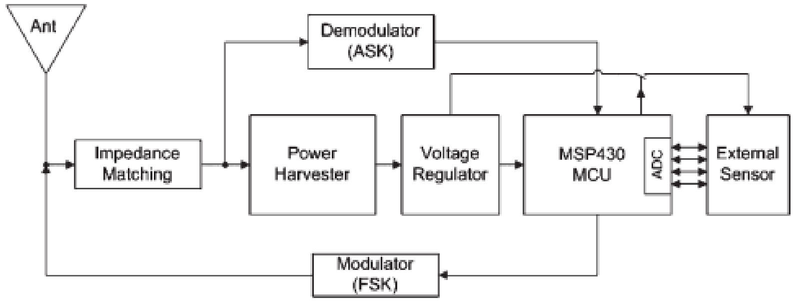

Figure 2. RFID Sensor Tag Block Diagram

The power harvesting and communication circuit of tag is shown in Figure 3 [3]. RFID tag does not actively transmit radio signals. Instead they modulate the impedance of their antenna which causes a change in the amount of energy reflected back to the reader.

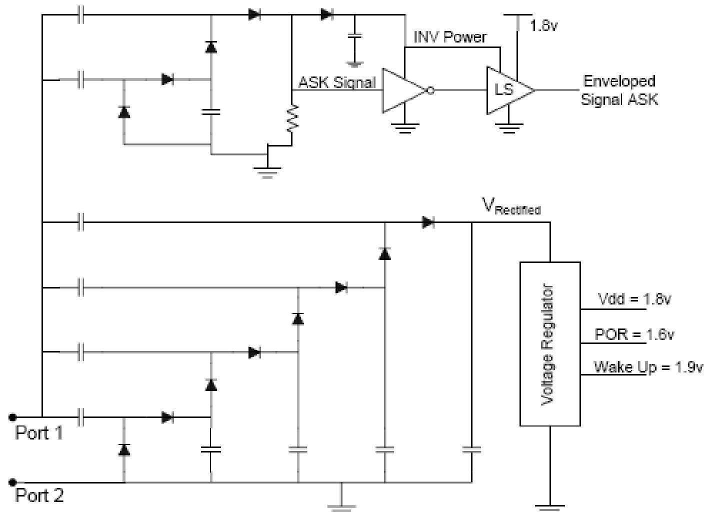

Figure 3. Harvesting and Communication Circuit of Designed Tag

The temperature was used LM94021, it is a precision analog output CMOS integrated circuit temperature sensor that operates at a supply voltage as low as 1.5V. The LM94021's low supply current makes it ideal for battery-powered systems as well as general temperature sensing applications [4], the temperature picture is shown in Figure 4. Detail of fabricated RFID tag is shown in Figure 5.

Figure 4. LM94021 Temperature

Figure 5. Fabricated Sensor Tags

The reader Speedway revolution UHF RFID reader used in the monitoring. By running Speedway connect on the reader and configuring it to export tag reads over TCP/IP port [5]. The reader Specification is shown in Table 1. The RFID reader is shown in Figure 6.

Table 1. Reader Specifications

Item	Specification
Interface Protocol	EPC global UHF Class 1 Gen 2 / ISO 18000-6C
RF Frequency	900Mhz - 930Mhz
RF Range	10cm - 10m
Transmit Power	+10.0 - 30.0 dBm
Power Consumption	24V
Operating Temperature	-20°C - +50°C

Figure 6. RFID Reader

2.3. Kinetic Modeling Method

The Kinetic modeling method is applied in order to verify Vitamin C left in food. Vitamin C loss was found to be described by the equation (1) and (2)

$$C = C_0 e^{-kt} \quad (1)$$

$$ln \frac{C}{C_0} = -kt \quad (2)$$

Where C and C_0 are the concentration of vitamin C at time t and zero. k is the apparent reaction rate of vitamin C loss. The reaction rate is affected by temperature follow equation (3) below

$$k = k_{ref} \exp \left[\frac{-E_A}{R}\left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right] \quad (3)$$

Where k_{ref} is the reaction rate of the vitamin C oxidation at a reference temperature T_{ref}, Ea is the activation energy of the chemical reaction and R is the universal gas constant [6].

The deep knowledge of degradation of vitamin C, such as the kinetic order and rate constant are the basic requirement to define shelf life of fruit juices. In order to verify kinetic modeling method, data of strawberry juice stored at different temperature is referenced [7].

Follow research about strawberry juice, the vitamin C at different temperature as a function of time is shown in Table 2, and degradation parameters of vitamin C obtained by Weibullian model is shown in Table 3 [7].

Table 2. Vitamin C Content of Strawberry Juice Stored at Different Temperature as a Function of Time

Storage Temperature					
5°C		10°C		25°C	
Time (day)	AA content	Time (day)	AA content	Time (day)	AA content
0	1	0	1	0	1
2	0.909	1	0.914	1	0.8791
6	0.815	3	0.850	3	0.5895
7	0.806	4	0.798	4	0.4374
9	0.727	5	0.750	5	0.3100
12	0.663	6	0.712	6	0.2115
14	0.592	7	0.668	7	0.0934
15	0.592	10	0.549	10	0.0934
AA content was expressed as relative variation from raw material (C/Co)					

Table 3. Degradation Parameters of Vitamin C obtained by Weibullian Model

Temperature	b(d^{-1})	r
5	0.0278	0.993
10	0.0480	0.994
25	0.1982	0.981

2.4. MFC Interface Design

Interface software based on Microsoft Foundation Classes (MFC), temperature average is calculate in set time period, vitamin lose percentage is measured by kinetic method. The software flowchart is shown in Figure 7. Interface is designed for convenient operation, in main screen, temperature value, food status and vitamin C percentage left is displayed like Figure 8. Five fruit conditions are inputted by other tab on interface screen.

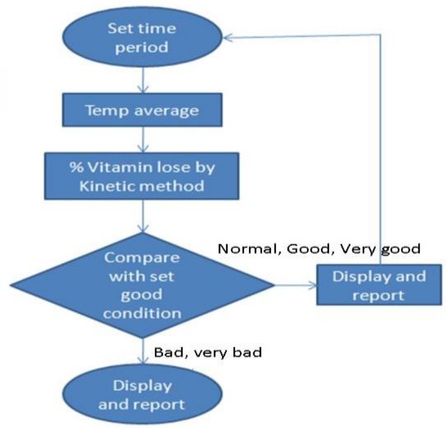

Figure 7. Interface Software Flowchart

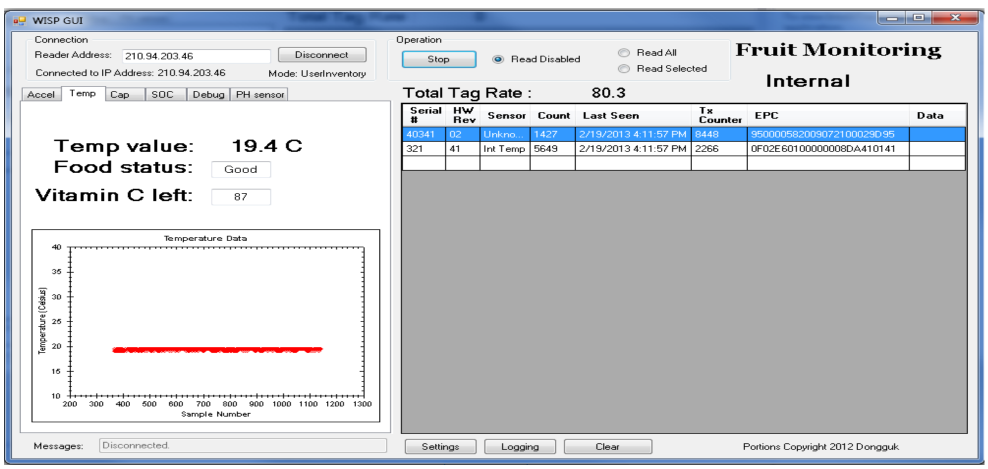

Figure 8. The Main Screen Monitoring System

3. Experiment and Discussion

In order to verify proposed system, strawberry juice was used as fruit juice object, the system was set up Figure 9. The experiment had been implemented for 15 days.

Basic temperature was kept at 5°C. The 3rd day temperature had changed to 25°C for 24 hours. The 8th day temperature had changed to 10°C, and 14th day temperature was 25°C. The Vitamin C lose graph is shown in Fig 10. And the result is shown in Table 4.

When temperature increase the percentage vitamin C left decrease rapidly, at 4th day C/Co decrease about 16%, the monitoring system change from very good status to good status only. At 12th day status from normal to warning bad, 14th day temperature reach 25°C strawberry juice became very bad, risk report at the monitoring system.

Figure 9. System Implementation

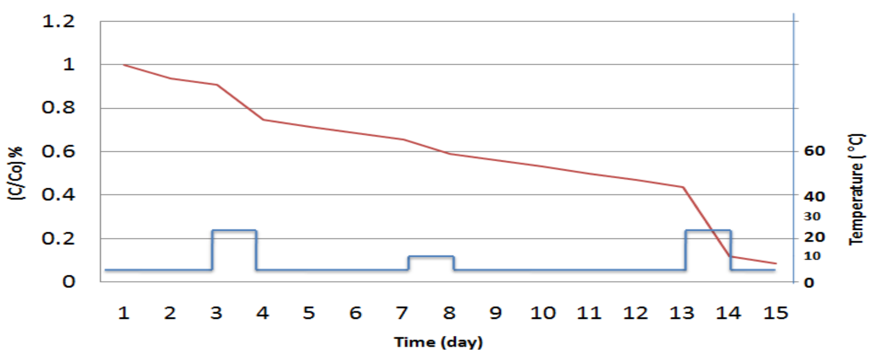

Figure 10. Percentage Vitamin Left depend on Temperature and Time

Table 4. Vitamin C Left for 15 days when Temperature was Changed

Time (day)	Temperature (°C)	C/Co (%)
1	5	1
2	5	93.85
3	5	90.77
4	25	74.80
5	5	71.72
6	5	68.64
7	5	65.56
8	10	59.00
9	5	56.31
10	5	53.23
11	5	50.15
12	5	47.08
13	5	44.00
14	25	12.00
15	5	8.85

The Vitamin lose from first day to third day follow equation (4)

$$y = -0.031x + 1 \tag{4}$$

When temperature increase to 25°C, high Vitamin lose follow equation (5)

$$y = -0.16+1.84 \tag{5}$$

From 7th day to 8th follow equation (6)

$$y = -0.063x + 1.068 \tag{6}$$

Where y is C/Co and x is time.

Vitamin C lose percentage is showed in Table 5, and the status and percentage Vitamin C left are updated on PC.

Table 5. Status follow Vitamin C Lose

% Vitamin C lose	State Grade
100% - 90%	Very Good
90% - 70%	Good
70% - 50%	Normal
50% - 40%	Bad
40% - 0%	Very Bad

4. Conclusion

Fruit have a variety of vitamins and has the most vitamin C, and so we can know the status of the fruit to the loss of the vitamin C. There are a lot of factors that the loss of the vitamin C, but it is highly dependent on temperature. Therefore, monitoring temperature variability during transport and storage is very important. Also customers are very necessary to know the status of the fruit with the loss of vitamin C by measuring the temperature.

We proposed smart RFID fruit monitoring system in order to the health of the customer, provide safe, and high quality. Proposed system consists of server, RFID reader, RFID tag, sensor interface, temperature sensor. Current temperature and fruit vitamin C left are measured and reported to monitoring center. Therefore, warehouse can control temperature suitably and make delivery plan to reach individual customer requirements.

In order to verify effectiveness of the proposed system, we performed experiments on the strawberry juice. The strawberry juice had been tested for 15 days in case of temperature changing from 5°C to 25°C. The temperature was transmitted to server well, percentage vitamin left was calculated by kinetic method, and the strawberry juice status was display on server PC. We state grade is divided in to 5 states. They are very good, good, normal, bad and very bad. The Vitamin C lose graph and percentage of Vitamin lose is reported at control center, the warehouse can make plan to delivery fruits. The proposed system confirmed usefulness through experiments.

This system can apply for any fruit or food. We used strawberry as the object for experiment because of strawberry juice database from other food paper.

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Authors

Ki-Hwan Eom was born in Seoul, Korea in 1949. He received the B.S. and Ph.D. degree in electronic engineering from Dongguk University, Korea in 1972, and 1986, respectively. He was a visiting professor from 1989 to 1990 at Toho University and from 2000 to 2001 at University of Canterbury. Since 1994, he has been with Dongguk University, where he is currently a professor in the Division of Electronics and Electrical Engineering. His research interests are in electronic application and convergence system

Nghia Truong Van received the B.S. degree in Automatic Control Engineering from Hanoi University of Technology, Vietnam, in 2010. And M.S. degree in Electrical and Electronics Engineering from Dongguk University, Seoul, Korea, in 2013.

His research interests are RFID system, Automation system and Management System.

LINSEN received the B.S. degree in Information and Communication from Kwangdong University, Korea, in 2011. His research interests are RFID communication, RFID S/W and embedded system.

Kyung Kwon Jung was born in Korea. He received the B.S., M.S., and Ph.D. degrees in Electronic Engineering from Dongguk University, Seoul, Korea in 1998, 2000 and 2003, respectively. He is currently working as research engineer in Embedded Software Convergence Research Center at Korea Electronics Technology Institute. His research interests are in intelligent systems, digital signal processing and sensor network applications.

Joo Woong Kim received the B.S. degree in Electronics Engineering from Dongguk University, Korea in 1996 and Ph.D. degree from Dongguk University in 2003

He is currently is a professor of Public Health University of the computer electronics. His research interests in: Intelligent Systems, USN, SMPS