Fermentation Food Monitoring System using the Smart RFID Sensor Tag

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Abstract

People in the world made a unique fermented food for a long time. These fermented foods have been increased interest to people health in recent years. These fermented foods can be caused a disease in the event of misunderstood difference between fermentation and putrefaction. In addition consumers can't know degree of different between fermentation and putrefaction. Therefore, the monitoring system which can predict a fermented foods change is needed in the distribution process in order to ensure quality and maturity. In this paper, the system which the can be monitored maturity and quality for fermented foods was proposed for consumers' health and safety. We measured the pH and temperature in order to maturity and quality of fermented food. The proposed system consists of RFID Tag, pH sensor, temperature sensor, RFID reader and server. In order to we confirm the usefulness of the proposed system, we are monitored fermented state and quality about a kimchi and a rice wine of Korea representative fermented foods.

Keywords: *Fermentation food monitoring system, Maturity, Quality, Smart RFID sensor tag*

1. Introduction

Fermentation technology is that humanity has learned one of the oldest foods a storage technology. People in the world made a unique fermented food for a long time. These fermented foods have been increased interest to people health in recent years. Typically Food can be fatal food spoilage according to mycotoxin producing mold and Microorganisms that contain toxins. On the other hand, food can be converted into fermented foods that contain useful ingredients by the action of microorganisms [1]. These fermented foods can be caused a disease in the event of misunderstood difference between fermentation and putrefaction. In addition consumers can't know degree of different between fermentation and putrefaction. Therefore, the monitoring system which can predict a fermented foods change is needed in the distribution process in order to ensure quality and maturity. Also, pH and temperature is a very important factor that affects quality and maturity of fermented foods than the other factors [2, 3]. However the technology concerning safety of food distribution and quality is limited presently to Simple barcode, TTI and RFID technology.

In this paper, the system which the can be monitored maturity and quality for fermented foods was proposed for consumers' health and safety. We measured the pH and temperature in order to maturity and quality of fermented food. The proposed system consists of RFID Tag, pH sensor, temperature sensor, RFID reader and server. RFID tag is 900 MHz and Passive Tag. And the PH sensor uses ISFET. In order to we confirm the usefulness of the proposed system, we are monitored fermented maturity and quality about a kimchi and a rice

wine of Korea representative fermented foods. We confirm fermentation through a pH measurement and display a degree of fermentation to three grade. And we confirm quality through a temperature measurement and display a quality to three grade.

2. Proposed System

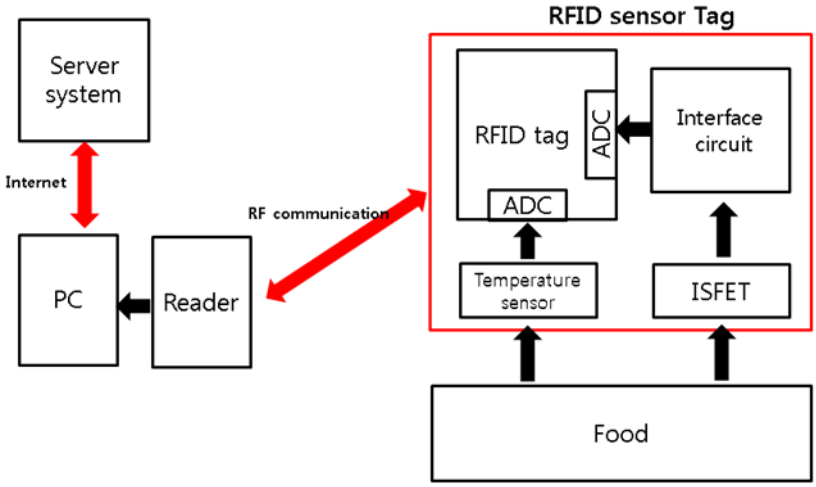

Figure 1. Block diagram of proposed system

The proposed system consists of RFID Tag, pH sensor, temperature sensor, RFID reader, and server. This system is provided with maturity and status information of the food using measured data from smart RFID sensor tag. The food pH and temperature value is measured by RFID sensor tag according to the around environment. The pH value outputs voltage via interface circuit and a temperature value outputs voltage. The scalable voltage is changed into output voltage through amplifier. And the voltage is converted a digital signal through ADC. The digital data which is transmitted reader at RFID tag is stored at server. When consumers buy food, proposed system shows information that is stored at food status. Block diagram of proposed system is shown in Figure 1.

2.1. 900 MHz RFID tag

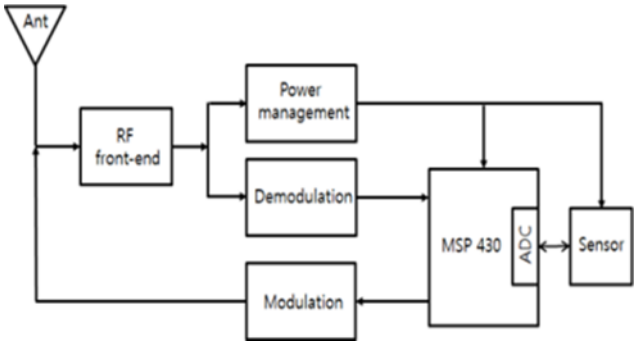

Figure 2. Block diagram of 900 MHz RFID tag

The Block diagram of the manufactured 900 MHz RFID tag is shown in Figure 2. Tag is composed of 900 MHz antenna, RF front-end, Power management, Demodulation, Modulation, temperature sensor and micro-processor (MSP 430). RF front-end took impedance matching using the variable capacitor. Power management supplies DC power that is changed RF energy through step five doubling circuit[4]. Demodulation changes digital signal through comparing the length of incoming signal of the antenna. Modulation is that digital signal sends on reader using backscatter method. Microprocessor is used to MSP430 that is able to operating low-power mode. Sensor tag is passive type tag that can operate power of RF signal. The photo of manufactured smart RFID tag shows in Figure 3.

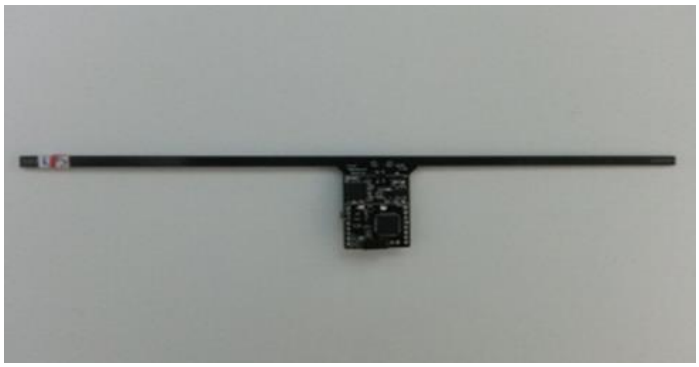

Figure 3. The photo of manufactured Smart RFID tag

2.2. Temperature Sensor

Figure 4. Temperature Sensor

The proposed system temperature sensor was used a commercial product which produced in the National Semiconductor. It shows in Figure 4. Characteristics of temperature sensor are shown in Table 1.

Table 1. Characteristics of temperature sensor

Characteristics	Content
Supply Voltage	1.5V to 5.5V
Supply Current	9 μA (type)
Temperature Accuracy	20°C to 40°C ±1.5°C −50°C to 70°C ±1.8°C −50°C to 90°C ±2.1°C −50°C to 150°C ±2.7°C
Operating Temperature	−50°C to 150°C

2.3. PH sensor (ISFET)

Figure 5. PH sensor (ISFET)

ISFET sensor is used a commercial product. It has a structure similar to a MOSFET [5]. Because operation of sensor responds to the H+ ions (solution exists) and an insulating layer (Ta2O5) surface, the electrochemical potential difference occurs [6]. In this regard the potential difference is a function of the ion concentration, ISFET channel conductance can change. Therefore, the ion concentration in the solution appears as a change in the current flowing in the drain. PH sensor includes a temperature sensor that is necessary for temperature compensation. It was shown in Figure 5. Characteristics of temperature sensor are shown in Table 2.

Table 2. Characteristics of ISFET

Characteristics	Content
Sensitivity	55mV/PH
Range	PH1 ~ PH 12
Accuracy	0.05 pH
Operating temperature	-45°C ~ 120°C
Response time	10s

2.4. RFID reader

Figure 6. RFID reader

The proposed system reader was used a commercial product which produced in the IMPINJ (Speedway Revolution UHF RFID reader). It is shown in Figure 6. The reader is connected Ethernet and it can be transmitted data by PC. Reader of the specification is shown in Table 3.

Table 3. Characteristics of RFID reader

Characteristics	Content
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

2.5. Interface circuit

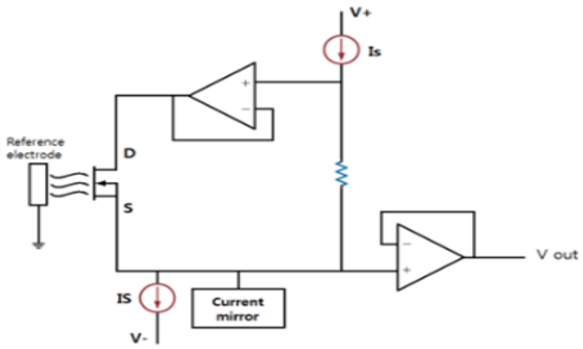

Figure 7. Interface circuit Schematics

The configured circuit schematic is shown in Figure 7. ISFET is formed the gate region of the channel in response to changes in the hydrogen ion concentration. Channel formation in the area of the gate changes Ids. Because Rds keep uniformly voltage and current, Vs is changed through ISFET of the gate channel. Therefore, Vgs variation indicates directly changes in hydrogen ion concentration [7]. FET's input or output using the buffer circuit has remove noise. Because FET is influenced by the ambient temperature, we make a constant current bias using Miller circuit. Designed circuit is shown in Figure 8.

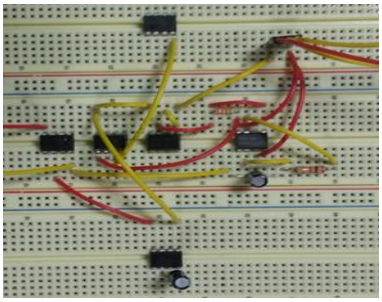

Figure 8. Designed interface circuit

3. Experiment

3.1. Maturity of fermentation food according to pH changes

Figure 9. Experimental environment

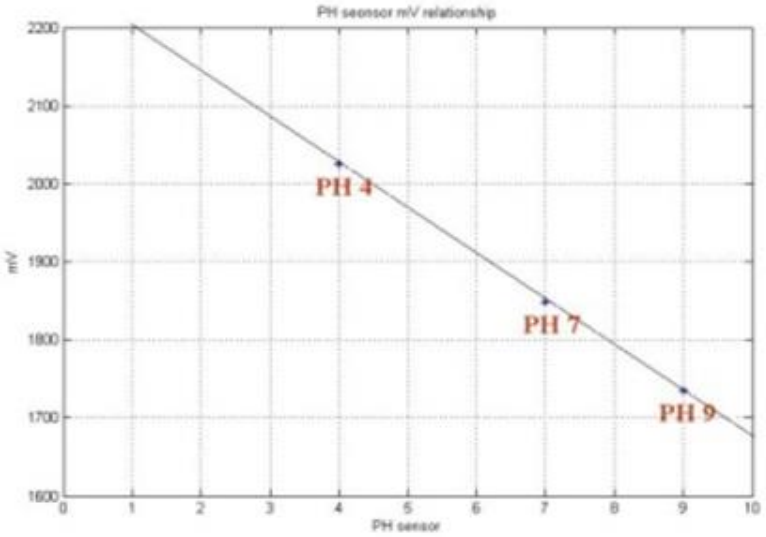

Figure 10. pH sensor output graph

The experimental environment is shown in Figure 9. Smart RFID sensor tags confirm accurately pH value through the experiment. pH of the comparison target like as Figure 9 is used to 4, 7 and 9 pH standard solution. Room temperature experiments were conducted at 25 degrees. Experimental result shows a linear change like as Figure 10. Consequently, the pH sensitivity of ISFET could be checks the change of 55mV/pH. Equation (1) is derived by graph of Figures 10.

$$\text{pH Value (pH)} = (2180(\text{mV})-\text{Vout}) / 55\ (\text{pH}) \quad (1)$$

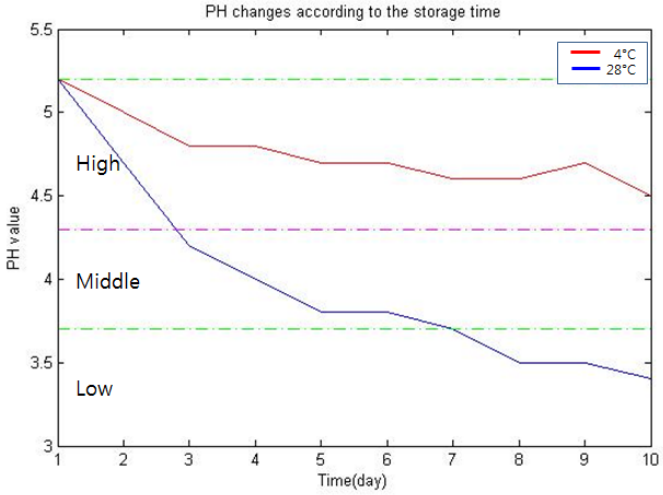

Figure 11. The kimchi fermentation process of pH

In this paper, the proposed system would experiment with using kimchi. The degree of fermentation of kimchi can be confirmed through pH [8]. Experiment temperature is composed of room temperature (28 ~ 29 ° C) and refrigerated temperature (4 ° C). Experimental temperature observes a change in PH during a 10 days. The experimental result shows in Figure 11. We could confirm the fermentation status of kimchi according to pH changes through sensory evaluation. Grades 3(High, Middle, Low) can be expressed.

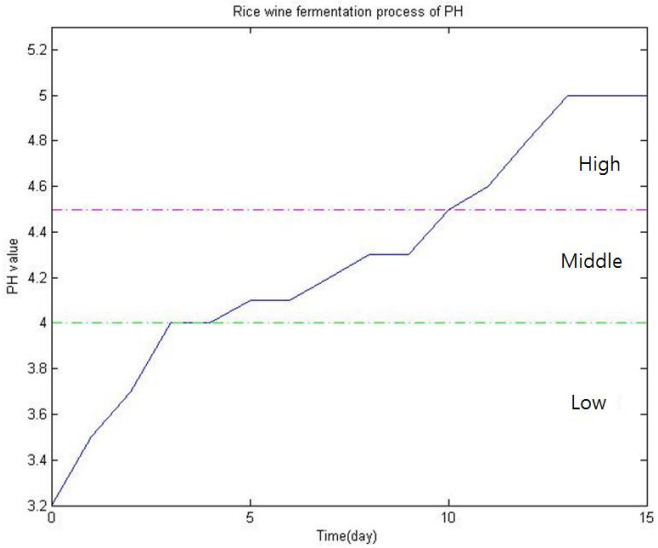

Figure 12. Rice wine fermentation process of PH

Figure 12 is the result of experiment using a rice wine. The experimental environment of rice wine pH changes was observed at 28 degrees for 15 day. We could observe fermentation and a corruption of rice wine through sensory evaluation. The fermentation state of rice wine is indicated high, middle, low. And bad grade are corrupt state.

3.2. State of food quality according to temperature

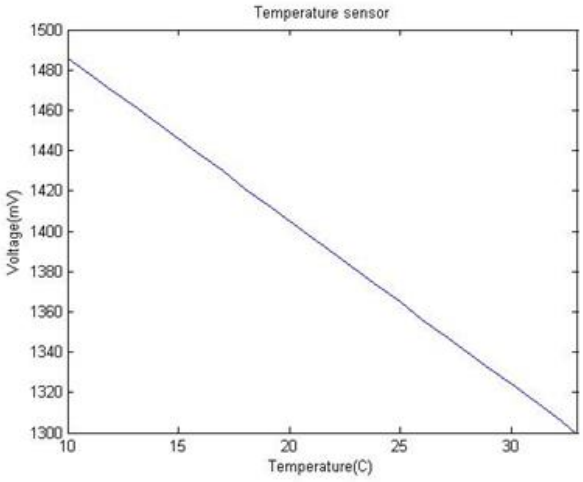

Figure 13. Temperature output graph

The sensor output value according to the temperature change was confirmed by experiments. We were able to confirm linear output is shown in Figure 13. Equation (2) is derived by graph of Figures 13.

$$\text{Temperature Values } (^{\circ}C) = (1567(mV) - Vout) / 8\ (^{\circ}C) \quad (2)$$

The kimchi of vegetables-fermented food is the important nutrient of the vitamin C content [9]. So many researchers have been conducted study about changes of kimchi fermentation of vitamin C content. We can know the most abundant vitamin content through research when the kimchi has properly matured [10]. The vitamin C content of Kimchi fermentation temperature is shown in Table 4 [11].

Table 4. Vitamin C content of Kimchi fermentation temperature

Temp	5		15		25	
	Time(day)	Vit C(mg%)	Time(day)	Vit C(mg%)	Time(day)	Vit C(mg%)
	2	16.3	2	14	2	16.3
	4	16.3	4	17.8	4	16.3
	6	18	6	19	6	18
	8	18.1	8	18	8	18.1
	10	18	10	18	10	18
	12	18.8	12	18	12	18.8
	14	19	14	18.2	14	19
	16	18.5	16	17.5	16	18.5
	18	18.7	18	17.2	18	18.7
	20	18	20	17	20	18
	22	18.5	22	16.7	22	18.5
	24	16.3	24	16.2	24	16.3
	26	16	26	16.1	26	16

We observed a vitamin C according to changes in the temperature and time of kimchi using the data in Table 4. The temperature changes were set at between 4 degrees of a

refrigerated temperature the 28 degrees of a room temperature. The quality of kimchi according to the set temperature is shown in Figure 14. We can be confirmed the best quality at the 12 days of the food through output value. We can see that fell the poor quality of the food after 12 days.

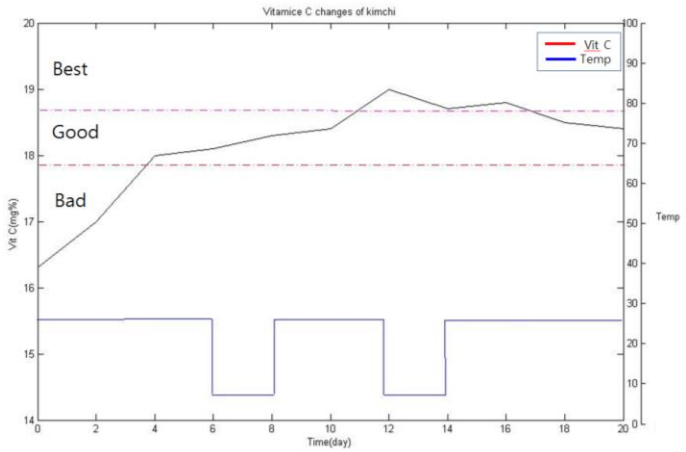

Figure 14. Quality of kimchi according to the set temperature

The rice wine made a polysaccharide saccharification using fungal enzyme. And it is fermented through yeast. Therefore, the reduction of yeast will be caused degrade the quality of rice wine [12]. The rice wine yeast changes in each preservation temperature over time are shown in Table 5 [13].

Table 5. Rice wine yeast changes in each preservation temperature over time

Temp	**4**		**27**
Time(day)	Yeast cell number	Time(day)	Yeast cell number
1	4.8	1	4.8
2	4.5	2	4.2
3	4	3	3.8
4	3.7	4	3.3
5	3.2	5	2.9
6	3.2	6	2.6
7	3.18	7	2.3
8	3.15	8	2
9	3.14	9	1.8
10	3.1	10	1.5
11	3.05	11	1.47
12	3	12	1.45
13	2.92	13	1.42
14	2.85	14	1.4
15	2.8	15	1.38
16	2.7	16	1.3
17	2.6	17	1.25
18	2.5	18	1.2
19	2.4	19	1
20	2.3	20	0.9

We were observed the changes in the number of yeast using Table 5 according to temperature and time. The temperature changes were set at between 4 degrees of a refrigerated temperature the 28 degrees of a room temperature. The quality of rice wine according to the set temperature is shown in Figure 15. We can be confirmed that it is decreased rice wine quality over time. Also, we can be confirmed uneatable quality food after 9 days.

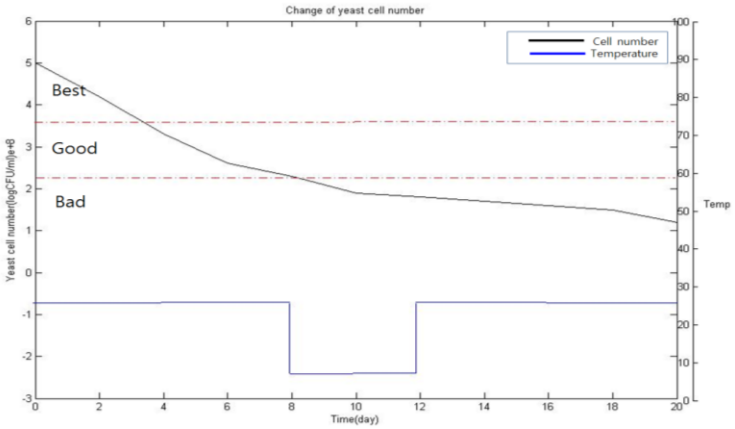

Figure 15. Quality of rice wine according to the set temperature

Figure 16. Experimental environment

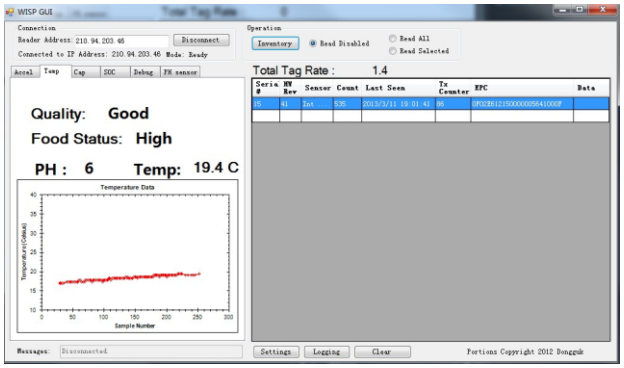

Figure 17. Test program

Experimental environment is shown in Figure 16. The proposed system of test program is shown in Figure 17. Test program is saved pH value and temperature changes of fermented Foods. The program outputs maturity of the food through the stored pH information. Also, we outputs state of the food that the measured temperature and changes quality information is calculated. Proposed program is conducted experiment five times. Sensory test had a survey of recruit graduate students of ten. We were able to confirm the changes that occur in the process of distribution of food through sensory evaluation applied system.

4. Conclusion

These fermented foods have been increased interest to people health in recent years. These fermented foods can be caused a disease in the event of misunderstood difference between fermentation and putrefaction. In addition consumers can't know degree of different between fermentation and putrefaction. Therefore, the monitoring system which can predict a fermented foods change is needed in the distribution process in order to ensure quality and maturity. Also, pH and temperature is a very important factor that affects quality and maturity of fermented foods than the other factors. In this paper, the system which the can be monitored status and quality for fermented foods was proposed for consumers' health and safety. We measured the pH and temperature in order to maturity and quality of fermented food. The proposed system consists of RFID Tag, pH sensor, temperature sensor, RFID reader, and server. RFID tag is 900 MHz is Passive Tags. And the PH sensor uses ISFET. In order to we confirm the usefulness of the proposed system, we are monitored fermented maturity and quality about a kimchi and a rice wine of Korea representative fermented foods. We confirmed fermentation through a PH measurement and display a degree of fermentation to 3 grades. And we confirmed quality through a temperature measurement and display a quality to three grade. We could be monitored fermentation state of kimchi and rice wine with 3 grades through sensory evaluation and pH changes. Also we applied the quality changes table of fermented foods by measuring the change in temperature over time. As a result, we could be displayed status of the quality of food (3 grades) and fermentation of food (3 grades). The proposed system can give to consumers at real-time of maturity and quality through measured pH and temperature changes of fermented foods.

Acknowledgements

This research was supported by the Agriculture Research Center program of the Ministry for Food, Agriculture, Forestry and Fisheries, Korea.

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