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A Mobile Control System of Fermentation Temperature on Winemaking

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Abstract

Fermentation temperature is an important factor which affects success of making fermented foods. Control of fermentation temperature by traditional manual method is not convenient. If fermentation temperature control becomes automatic, the manual working hours can be reduced. In general, one cannot monitor the fermentation temperature anytime and/or anywhere. This makes those who make fermented foods such as glutinous rice wine at home more inconvenient. The purpose of this study is to help those who need to go outside and then cannot monitor fermentation temperature 24 hours a day. This study develops a novel mobile control system for monitoring fermentation temperature and then controlling the cooler and heater for keeping fermentation temperature in the proper range. The process for controlling fermentation temperature will be automatic. The efficiency of making fermented foods at home can be improved. The ideal fermentation temperature can be remotely monitored and controlled.The proposed system will let those who make fermented foods such as glutinous rice wine at home monitors the fermentation temperature anywhere and anytime.

Keywords

Winemaking, Fermentation, Glutinous Rice Wine, Embedded System, Smart Phone

1. Introduction

One needs to maintain the ideal fermentation temperature when making fermented foods. The temperature control is really important for fermented foods such as glutinous rice wine. Poor fermentation temperature control will cause a musty flavor glutinous rice wine and also lead to longer aging period which refers to fermentation time. It is usually aged for about 15 days during winter season in Taiwan. It is time-consuming and inconvenient to maintain the ideal fermentation temperature by using traditional manual methods. This paper will propose a mobile control system for maintaining ideal fermentation temperature. The mobile temperature control system can control and monitor the fermentation temperature anywhere and anytime.

An alcoholic fermentation is a process that the yeast converts sugar into ethanol. Therefore, this process is usually used to make alcohol. During the fermentation process, there are several factors that can influence the success or failure of making alcohol. The temperature on yeast during the fermentation process is one of the most important factors whether making alcohol can succeed. It is quite critical to properly keep the fermentation temperature range for alcohol during fermentation process. The seasonal restriction is also another important factor to the success of making alcohol. For example, people typically make vinegar in hot weather such as summer, while make red yeast rice wine in cold weather like winter. In this study, we will take glutinous rice wine for example. When making glutinous rice wine during winter season in Taiwan, it ferments more than 15 days. But, it only ferments for 10 days during summer season in Taiwan. Therefore, it truly needs less aging period for make glutinous rice wine in summer season than in winter season.

If we can keep fermentation temperature in perfect range, then no seasonal restriction problem exists for making glutinous rice wine. The reason why it needs longer aging period in cold weather is that the fermentation process becomes more slowly in cold weather. Therefore, if one can maintain the fermentation temperature in perfect range, make glutinous rice wine will do effectively at any time of the year. The proposed mobile system can overcome the weather limitation of making glutinous rice wine by keeping the fermentation temperature in perfect range.

In 2015, Weeks [1] proposed an Arduino-controlled brewing system for beer. The process of making beer includes six major steps: mashing, sparging, boiling, fermenting, packaging and aging. Weeks created a low-cost automatic brewing system on the mashing process for beer by using Arduino [2]. The mashing process refers to the saccharification stage which enzymes convert starch into sugar. In 2016, Kuriakose et al. [3] developed a temperature control system for craft beer fermenter which can automatically control temperature of the wort during fermentation process. Boopathy and Ramkumar [4] in 2015 proposed an Arduino-controlled tea drying system. Their system can dry tea leaves automatically which controls the temperature of the drying chamber in different stages of drying. This system also can monitor the temperature by smart phone through the Bluetooth [5]. In 2015, Farineau [6] proposed a brewing system to brew large batches of beer easily in an enclosed space and to get the right balance between cost of brewing process and precise temperature control.

As aforementioned, it is not convenient to monitor fermentation temperature all day long because one maybe goes outside or sleeps. If the process for controlling fermentation temperature can become automatic, the convenience of making glutinous rice wine at home will be improved. This research will improve the efficiency of making fermented foods at home. Furthermore, this study can remotely monitor the fermentation temperature and then control the cooler and heater for keeping ideal fermentation temperature.

2. Material and methods

Different fermented foods maybe require various fermentation temperatures. For example, the optimum fermentation temperatures for the glutinous rice wine and steamed bun are 25℃ to 33℃ [7] and 25℃ to 30℃ (1st fermentation stage) [8], respectively. Therefore, it is important to ferment different foods at different fermentation temperatures. There are six major steps for making glutinous rice wine: rinsing the rice, soaking the rice, steaming the rice, cooling the rice, combining the yeast powder with the rice, and fermenting and aging. The glutinous rice is rinsed by boiled water, because the running water may influence the success of fermenting. It is necessary to soak it for hours before cooking because glutinous rice is hard. As glutinous rice has been soaked, the rice is then placed in steamed cooker and steamed for about 30 minutes. Since yeast is very sensitive to temperature, it is necessary to cool down the hot rice before combining the yeast powder with the rice. If the yeast is straightly put to the rice which are just steamed and the rice have not been cooled down, the yeast will be killed by the heat. After the yeast and the rice have been mixed evenly, the rice will be placed in a jar. In order to let the rice ferment properly, it is important to poke a hole down the middle of jar through to the bottom. The hole can help to create more liquid while aging period. Typically, it ages for 10 days during summer season in Taiwan.

It is really time-consuming to control fermentation temperature by the traditional manual methods through all the aging period. If the process of fermentation temperature can be automatically controlled, the efficiency of making glutinous rice wine will be improved greatly. This study will develop a mobile control and monitor system for fermentation temperature of glutinous rice wine.

The hardware parts of proposed system consist of NodeMCUDevkit board [9], cooler, heater, temperature sensor, display, personal computer, and smart phone. The NodeMCUDevkit board can allow user to develop IoT (Internet of Things) [10] easily and is used to control cooler and heater for keeping fermentation temperature in the range of 25℃ to 33℃. The proposed system employed a thermoelectric cooler [11] and a PTC heater (Positive Temperature Coefficient heater) [12]. The activation of the cooler and heater depends on the temperature measured by a temperature sensor. Therefore, it is important to choose an appropriate temperature sensor. The temperature sensor should be able to provide precise temperature measurement and long-term stability. The DHT11 temperature humidity sensor [13] is selected and it is a precision temperature sensor device. Air conditioner is usually installed in an enclosed space. The cooler and heater work as air conditioner. The air conditioner works by removing heat from one place and to another place. Therefore, a plastic box is served as an enclosed space where fermented foods and temperature sensor are included. A display is added to show current fermentation temperature. The display uses IIC 16x2 LCD (Liquid Crystal Display) display [14]. Compared to standard LCD displays, the IIC LCD display requires fewer I/O pins which are connected to the NodeMCUDevkit board. The IIC LCD display only needs 2 I/O pins. The personal computer is a general purpose computer with Microsoft Windows as its operating system. The smart phone used a phone with Android operating system and 4G (the fourth generation of mobile phone mobile communication technology standards).

The MQTT (Message Queuing Telemetry Transport) [15] is a lightweight and common messaging protocol and is

used for communicating smart phone and NodeMCUDevkit board. The MQTT protocol executes messaging using a publish/subscribe model. This feature makes it suitable for IoT. The Arduino IDE [16] is an open-source Arduino software and easily used to program NodeMCU because its language is similar to C/C++ programming language. Android Studio [17] is one common IDE for Android application and used for coding APP program on smart phone.

3. Proposed mobile control system of fermentation temperature

The block diagram of the proposed mobile control system is shown in Fig. 1. Personal Computer is as the central controller which can control NodeMCUDevkit board. NodeMCUDevkit board can control cooler and heater. Temp. sensor can detect temperature and then NodeMCUDevkit board reads the temperature from it. Smart phone and NodeMCUDevkit board communicate with each other via MQTT broker. The proposed control system consists of two major parts: hardware and software.

The hardware part is composed of Personal Computer, NodeMCUDevkit board, Cooler, Heater, Temp. sensor, and Fermenter. The hardware implementation of the proposed system is shown in Figure 2. Personal Computer can control the NodeMCUDevkit board by using USB (Universal Serial Bus) interface. The NodeMCUDevkit board is connected to WiFi network to publish data to MQTT broker. Users can use smart phone to subscribe the data which the NodeMCU send to MQTT broker via wide area network. The NodeMCU reads the temperature from Temp. sensor and controls Heater or Cooler to keep the fermentation temperature in the proper range. The NodeMCU also receives commands from smart phone by MQTT protocol to control Heater and Cooler. The NodeMCU also shows the temperature on the Display. The thermoelectric fan is used as cooler to cool down the fermentation temperature. The PTC heater is used as heater to raise up the fermentation temperature.

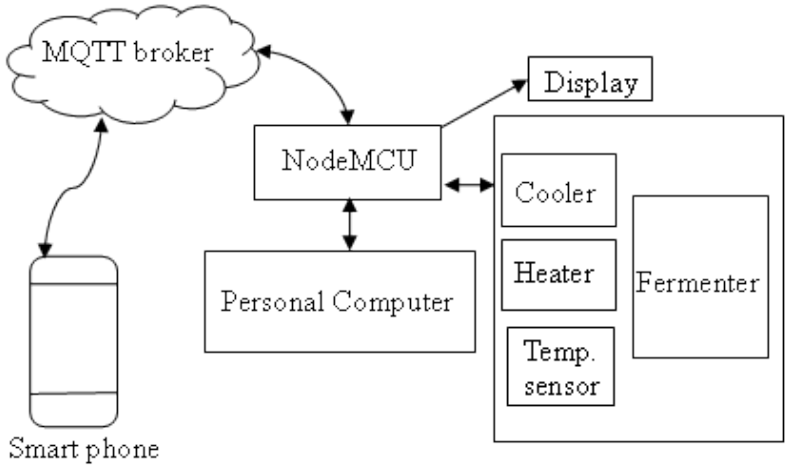

Figure 1. Block diagram of the proposed system.

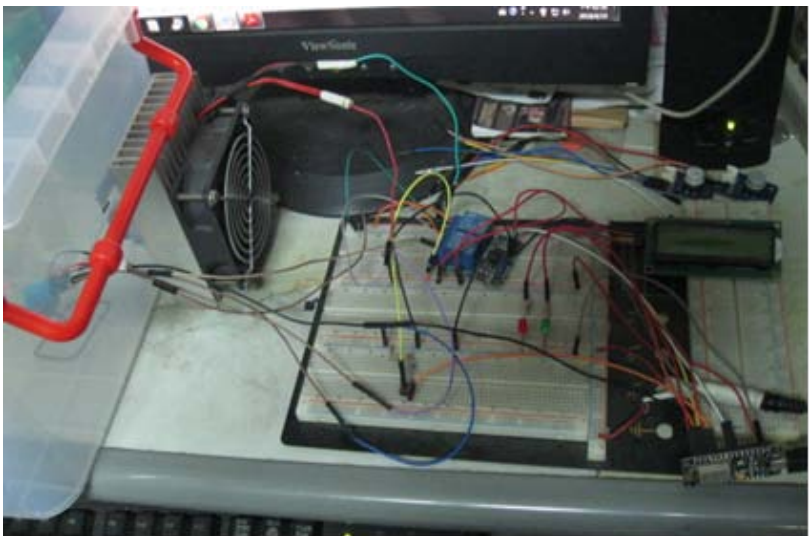

Figure 2. Hardware implementation of the proposed system.

The proposed system uses publish/subscribe model of MQTT to publish the fermentation temperature to MQTT broker from the NodeMCU. One gets the fermentation temperature on the smart phone by subscribing it from MQTT broker. If one can remotely control Cooler and Heater by sending a message to MQTT broker through the smart phone. One publishes a message "0" on a topic, named A, from the smart phone to the broker, and then the NodeMCU will subscribe the topic A. When the NodeMCU receives a message "0", the Heater and Cooler will be turned off. When the NodeMCU receives a message "1", the Heater or Cooler will be turned on depending on fermentation temperature. In other words, the received "0" ("1") message will turn off (on) the Heater or Cooler if it is originally turned on (off).

The software parts of the proposed system include three parts: program on personal computer, program on NodeMCU, and program on smart phone. The software program on personal computer allows one to choose appropriate temperature control options for different fermented foods and then control the fermentation temperature in the proper range by turning on/off Heater or Cooler. The software on NodeMCU can send warning message to smart phone if the fermentation temperature out of proper temperature range. The software on NodeMCU can detect temperature and publish it using MQTT. If the temperature is too high, the software will publish a message "warning" to MQTT. If the NodeMCU receives a message "0", cooler and heater will be turned off. If the NodeMCU receives a message "1", cooler or heater will be turned on.

Figure 3 a user menu of software on smart phone which is developed under Android Studio. The menu allows one to subscribe the temperature from MQTT broker and publish a message to MQTT broker. When users press the button "Subscribe" of menu, it will start to display the temperature subscribed from MQTT broker. Users can press the button "Publish" of menu to publish a message "0" or "1" to MQTT broker. When smart phone receives a message "warning" from MQTT broker, it will start to vibrate for noticing user. The program was built by using Android Studio. It is an Android app development and uses java for coding.

Figure 3. User menu of smart phone (a mobile app).

The operation procedure is listed as follows:
(1) Select one fermented food of menu of personal computer, please see Figure 4.

Figure 4. Operating menu of personal computer.

(2) Press the confirm button to activate the proposed system, please see Figure 5.

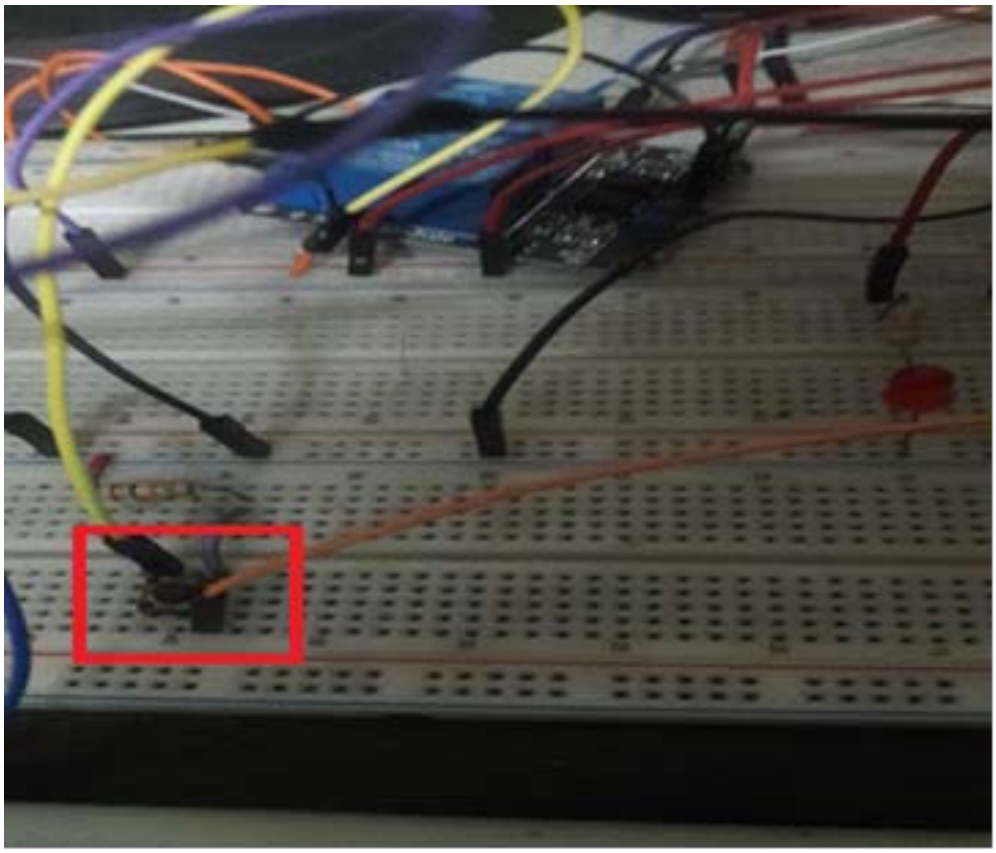

Figure 5. Confirm button.

(3) Press the button “SUBSCRIBE” of menu on smart phone to remotely monitor the fermentation temperature anywhere and anytime, please see Figure 6.

Figure 6. SUBSCRIBE of menu on smart phone.

(4) Enter 0 or 1 in the Payload item and press the button “PUBLISH” of menu on smart phone to turn Cooler and Heater off or on, please see Figure 7.

Figure 7. Payload and PUBLISH of menu on smart phone.

4. Conclusions

A novel mobile control system for remotely monitoring fermentation temperature by controlling the cooler and heater has been developed. The proposed system let those who make fermented foods such as glutinous rice wine at home monitors the fermentation temperature anywhere and anytime. The smart phone can display fermentation temperature which is sent by the NodeMCUDevkit board through MQTT broker. The smart phone also can remotely control the fermentation temperature in the proper range by turn on or off heater or cooler by MQTT through internet.

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