Freshness Guard Patch: The Little Guardian of Food Safety Perception for the Blind

Abstract

Food spoilage is one of the important factors affecting the quality of life and health of the blind. For the blind, the lack of visual perception ability makes it difficult to judge the degree of food spoilage through conventional methods. Seeking new indicators of food spoilage changes and designing them into portable devices is the key to solving the problem. This study explores the key points of the problem through interviews and surveys, and studies the pattern of pH changes during the process of food spoilage through experimental research. The results show that as the degree of spoilage deepens, the pH value gradually decreases. This study uses this chemical law to design a portable representation device with sensor linkage, and constructs a theoretical closed-loop system combining pH sensors and sound release devices. The device can provide sound reminders for different stages of spoilage, thus helping visually impaired people conveniently and safely judge the degree of food spoilage. It solves the problem of traditional methods being unable to capture critical changes in time, and realizes humanitarian care and social benefits for the visually impaired group.

Keywords: Food safety; Visually impaired people; Sensor

1. Introduction

Food safety is a focus of people's daily life, and food spoilage is one of the causes threatening people's health. Usually, "observing appearance" is an important way to judge food spoilage. When food spoils, there are usually some changes in appearance, such as color change, loss of luster, appearance of mold spots or stringiness, and liquid food may become turbid. Or even through the shelf life on the packaging bag, we can also judge whether the food is fresh. The initial stage of food spoilage is not so easy to judge, especially for the blind. Without vision, it is difficult to distinguish the quality of food through the subtle touch or smell in the initial stage of food spoilage. Therefore, once visually impaired people identify food spoilage through touch, smell and other methods, they have already been exposed to toxins, which will cause certain health damage to their bodies. In addition, visually impaired people are afraid of food spoilage and throw it away before the shelf life expires, which also causes waste of resources.

Members of this research team have long participated in public welfare organizations and worked as companions for visually impaired runners on weekends. During this process, they came into contact with many visually impaired people. Through communication with them, they learned about this trouble and thus had the idea of designing a lightweight and portable tool to help visually impaired people identify food spoilage.

Taking fruits as an example, their freshness directly affects eating safety and nutritional value. In actual storage, fruits do not go directly from fresh to spoiled, but go through the transition stages of "approaching spoilage" and "being spoiled". For the blind, the lack of visual perception ability makes it difficult to judge whether fruits have entered these stages, which may lead to eating food with reduced quality or even harmful food. Through literature retrieval and experimental verification, the research team designed a portable food safety perception device based on the variation of characteristic indicators of food spoilage, which solves the problem that traditional methods relying on smell or touch cannot timely capture the subtle changes of fruits when they are approaching spoilage, and realizes humanitarian care and social benefits for the visually impaired group.

2. Preliminary Research

2.1 Literature Review

2.1.1 Current Situation of Food Safety Problems for the Blind

Food safety has always been a focus of attention, and it is even more critical for the blind who cannot observe through vision. During the storage, processing, transportation and other processes of food, due to changes in environmental conditions, its original characteristics and quality undergo irreversible changes, which will lead to food spoilage. Food spoilage not only reduces the nutritional value of food, but also may produce various toxic and harmful substances, causing human poisoning. The main causes of food spoilage include microbial action, enzyme action, oxidation reaction and external environmental factors.

The visually impaired group still faces many challenges in detecting spoiled food. Firstly, most of the existing detection technologies and equipment require visual operation, which is not suitable for visually impaired people. Secondly, the cost of some auxiliary equipment is relatively high, which limits its popularization among the visually impaired group. Finally, the lack of special food spoilage detection training and education for the visually impaired group makes it difficult for them to effectively apply the existing detection methods in real life. Therefore, it is necessary to further develop detection technologies and equipment suitable for the visually impaired group, improve the accuracy and convenience of detection, so as to ensure the food safety and health of the visually impaired group.

2.1.2 Existing Solutions

For the detection of spoiled food, traditional detection methods include sensory identification, chemical identification and microbial identification. Sensory identification mainly judges whether food is spoiled by observing the color, smell and tissue state of food. Chemical identification evaluates the freshness of food by detecting changes in trimethylamine, histamine and pH value in food. Microbial identification reflects the degree of microbial contamination of food and whether it is spoiled by determining the number of microorganisms in food. However, these traditional methods have shortcomings such as cumbersome operation, poor timeliness or low

sensitivity, which are difficult to meet the needs of modern rapid and accurate detection (Wang Zhenjie et al., 2015), and are very unfriendly to the visually impaired. They cannot judge whether food is spoiled by visually observing the appearance and color changes of food, so they need to rely on other senses or auxiliary equipment. At present, some studies are exploring the use of computer vision technology and Internet of Things technology to monitor the quality and spoilage of food in real time. These technologies can predict the occurrence of spoilage through complex algorithms, providing more reliable detection methods for the visually impaired group (Shubham, 2023; Shadman, 2024). In addition, the development of new packaging materials also provides new possibilities for food preservation and spoilage detection. However, these new detection methods usually require manual operation, which also limits the application of such technologies in the visually impaired group.

During the process of food spoilage, the typical changing indicators can directly reflect the spoilage process of food. Therefore, the detection of characteristic indicators is the key to characterizing food spoilage. When food spoils, under the action of microorganisms, acidic and alkaline substances such as hydrogen sulfide, biogenic amines, nitrogen-containing compounds and harmful acids will be produced. At present, the chemical methods for detecting these spoilage substances include high-performance liquid chromatography, liquid chromatography-tandem mass spectrometry and enzyme-linked immunosorbent assay (Shijiao, 2022; Emin, 2023). As mentioned above, these methods usually rely on large-scale equipment and may require pretreatment, so they are not suitable as portable detection methods designed for the visually impaired.

During the above-mentioned food spoilage and microbial action process, intermediate metabolites will cause changes in the pH value of food (Vivaldi, 2020; Noor, 2019). For example, the pH value of common spoiled fruits will decrease, and the pH value of spoiled meat and seafood will also decrease.

Based on this, the research team selected pH value as the indicator parameter for food spoilage, studied the law of pH value change caused by food spoilage, and designed a portable sensor device based on this to help visually impaired people timely and accurately identify the spoilage state of food. This research project has certain scientific research value and practical application value.

2.2 Interview Survey

In order to explore the concerns and actual needs of the visually impaired group regarding food safety issues, the research team designed a questionnaire to collect information in the following aspects:

a. The frequency of visually impaired people misjudging the degree of food spoilage;

b. The common types of food with misjudgment, such as fruits, meat, vegetables, cooked food, pastries and bread;

c. The general experience of visually impaired people in judging food spoilage, such as touch, taste;

d. The form of identification device that visually impaired people expect, such as touchable labels, detection rod devices, mobile phone apps;

e. The frequency of use of this device predicted by visually impaired people;

f. The form of food spoilage alarm signal that visually impaired people hope the device will send, such as touch texture, smell reminder, sound reminder;

g. The specific needs of visually impaired people for this device, such as price, function.

Considering the difficulty for visually impaired people to answer questions by themselves in either paper or electronic form, the research team adopted the form of interviews to obtain feedback. On weekends, they participated in offline group activities of visually impaired people such as blind running groups, and interviewed 12 visually impaired friends in total.

The interview results show that visually impaired people generally report that they often encounter the problem of misjudging the degree of food spoilage, and the common types of food include fruits, meat, cooked dishes and various processed products. Most visually impaired people judge food spoilage by squeezing, touching and sniffing. They generally hope to have a portable identification device that works by connecting to a mobile phone probe or mobile phone camera, and have requirements for the device to be easy to operate and cheap. At the same time, they generally hope that the device can broadcast the spoilage situation of food through sound.

Based on the above survey information, the research team adjusted the experiment and design plan accordingly. We added the detection of pH value of meat in the experiment. In addition, an intelligent AI image recognition and analysis detector was added to assist the pH indicator parameter for identification, so as to improve the accuracy of judgment and avoid the limitations of manual operation.

Figure 1 Example of Interviewing the Visually Impaired Group

3. Innovative Scheme

3.1 Target Audience

The target audience of this project is visually impaired people who cannot accurately identify food spoilage in daily life, and it can be extended to ordinary people who pay attention to food safety and expect to obtain a portable characterization device.

3.2 Experimental Methods

According to the preliminary literature research, the research team plans to select pH value as the indicator parameter for food spoilage response, and study the law of pH value change caused by food spoilage through experiments. The research team takes fruits that are easy to obtain in daily life and easy to spoil as experimental objects, and conducts experimental tests on typical types such as intact fresh fruits, fruits that have just started to spoil, and seriously spoiled fruits to detect their pH values, so as to obtain the law of pH change of fruits.

There are many methods for pH detection. In this project, the research team plans to use a pH probe to characterize the pH value inside and on the surface of food. In order to facilitate the determination and improve the accuracy of experimental data, the research team uses both easily available pH instruments in daily life and high-precision pH instruments in professional chemical laboratories to summarize the law and verify each other. The following experiments are designed and carried out respectively:
(1) Use portable, easily available and fast precision pH test paper as the detection method, and test the pH change of apples and oranges as examples.
(2) Use a commercially available household pH pen as the detection tool (as shown in Figure 1) to detect the daily pH values of common fruits, including apples, mangoes, kiwis, figs, oranges and cherries, and study their change trends.

Figure 2 Process of Detecting Fruit pH Value with a Commercially Available Household pH Pen

(3) In a professional chemical laboratory, pretreat and quantitatively calibrate fruit samples such as apples, oranges, kiwis, bananas and cherries, and use a laboratory-grade pH meter to test and compare the pH values before and after spoilage (as shown in Figure 2).

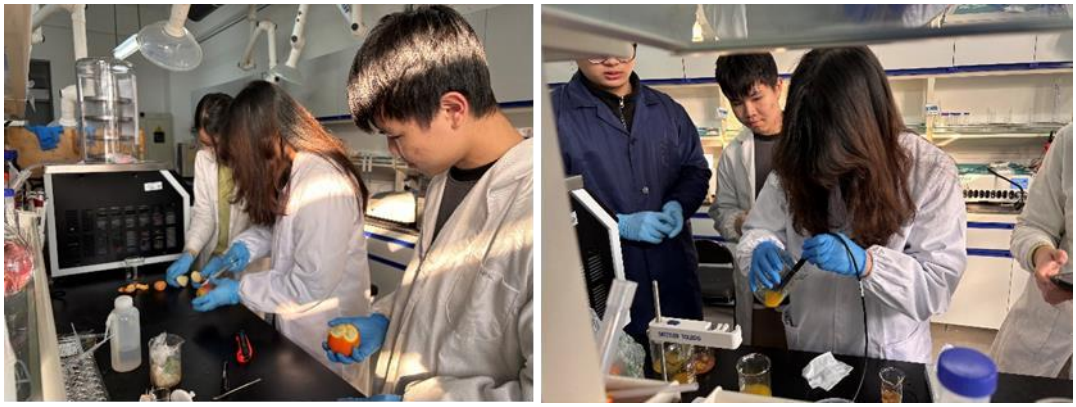

Figure 3 Chemical Laboratory Test Process

(4) According to the survey results, adjust the parameters of the types of substances to be tested, add meat as the research object, and test the pH values inside and on the surface of meat. The pretreatment process for testing the pH value inside meat is the same as that for testing fruits. For testing the pH value on the surface of meat, clean the surface with 50 mL of deionized water respectively, and test the pH value of the rinsing water.

The test data results are obtained through the above experimental processes, and the data are processed to quantitatively analyze the law of pH change.

3.3 Overall Scheme

To help visually impaired people conveniently and safely judge the spoilage situation of food, based on the above-mentioned changes in pH value during food spoilage, the research team designed a portable characterization device and constructed a theoretical closed-loop system combining pH sensors and sound release devices, so that the device can provide sound reminders for different spoilage stages. The main structure and functions include the following parts:

(1) pH Detection Module:

The core detection component is a high-sensitivity pH probe, which is used to detect the pH value change on the surface or in the liquid of food. The probe converts the change of pH value into an electrical signal through electrochemical reaction, and conducts real-time data analysis with the built-in microprocessor. Through literature research and experimental verification, the pH value of different types of food will change significantly (usually decrease) during spoilage, and the sensitivity setting of the probe ensures that these subtle changes can be detected.

(2) Signal Conversion:

When the change range of pH value exceeds the set threshold, the microprocessor will trigger a feedback mechanism through the signal processing module. The feedback method is designed as a multi-modal sound warning, combining a beep (short high-frequency prompt) and voice broadcast (such as "Abnormality detected, please pay attention to food freshness"). The voice prompt can be connected to the user's mobile phone or earphone via Bluetooth to meet the use needs in different environments. To further ensure the effectiveness of the prompt, the device can be equipped with a vibration motor to generate vibration reminders when an abnormality is detected.

(3) Image Acquisition and AI Analysis Module:

To avoid insignificant pH changes caused by factors such as food oxidation or different degrees of fruit ripeness, the device is also integrated with a high-definition micro camera to collect images of the inside and appearance of food. The captured images are preprocessed through image processing algorithms, such as denoising and contrast enhancement, and then directly

sent to the embedded AI module for real-time analysis to identify mold spots or uneven color spots formed inside the fruit, so as to assist the characterization of pH characteristic parameters and improve the characterization accuracy.

(4) Portability and Operability Design:

The overall design of the device is small and lightweight, supporting both hand-held and fixed use. The shell is made of waterproof and oil-proof material, and is equipped with a detachable probe sleeve for easy cleaning and replacement. The button operation of the device is simple: long press to start, and single press to switch modes, which is convenient for visually impaired users to operate with one hand.

(5) Detection Results and Reactions:

Abnormal pH Value: If the pH probe detects that the change range of the pH value on the surface or in the juice of the food exceeds the threshold, the device will issue a vibration and sound warning, and prompt "The food may have spoiled".

Abnormal Image: When the camera and AI module analyze the image and detect spots or mold forms, the device will vibrate and broadcast the specific problem by voice, such as "Internal spots found, please eat with caution".

Example

Fruit Detection: For example, during the spoilage process of bananas, the pH value decreases from 5.12 when fresh to 4.85 after spoilage, and at the same time, image analysis detects spots inside the peel. The device will prompt "The food has spoiled".

4. Result Analysis

4.1 Experimental Result Analysis

The obtained data are classified, counted and deeply analyzed. The relationship between pH value change and the degree of food spoilage is analyzed.

4.1.1 pH Test Paper Test

First, precision pH test paper was used to test the fruits, and the results are shown in Figure 3. The results show that the change of pH value is small, so the color change of the test paper is very unobvious and difficult to distinguish with the naked eye. At the same time, because the juice of the fruit itself has color, it will interfere with the color development of the test paper. Therefore, pH test paper is not convenient to prove that the pH value of fruits changes with the degree of spoilage.

Figure 4 Comparison of pH Values of Fresh and Spoiled Oranges and Apples

4.1.2 Household pH Pen Test

The research team used a household pH pen to test apples, oranges, mangoes, kiwis, figs and cherries. First, the pH values of these fruits in a fresh state were tested. After a week of spoilage, the pH values of these fruits were tested again. From the test results (Figure 4), it can be seen that the pH values of various fruits decrease during the spoilage process.

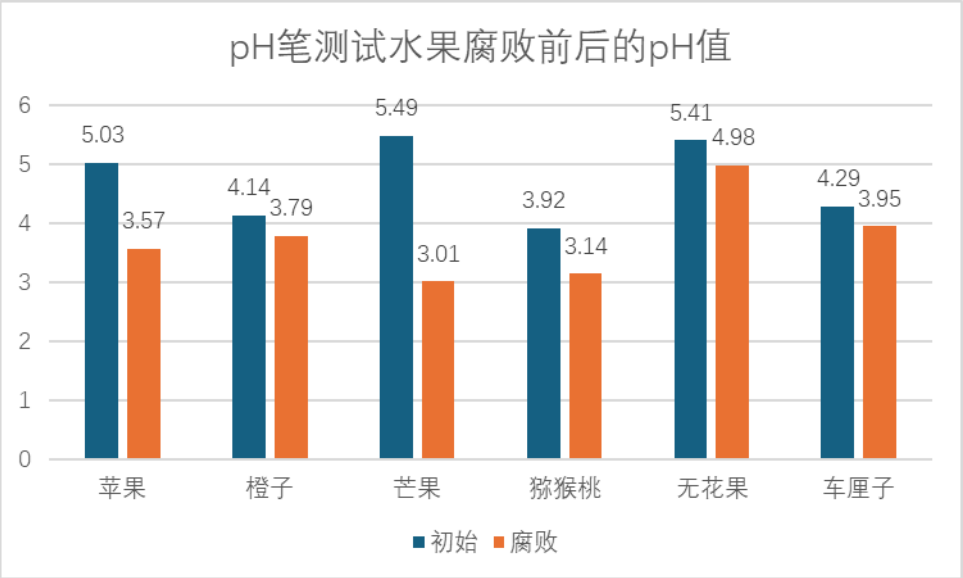

Figure 5 pH Values of Fruits Before and After Spoilage Tested by Household pH Pen

4.1.3 Chemical Laboratory pH Meter Test

In a professional chemical laboratory, the fruit samples were pretreated by crushing and suction filtration, and the fruit juice samples were taken for testing. To prevent experimental errors caused by sample oxidation, the samples were tested immediately after pretreatment, and the samples that could not be tested in time were temporarily stored in a vacuum drying oven. For the determination of the surface pH value of meat samples, the surface was cleaned with 50 mL of deionized water respectively, and the pH value of the cleaning water was tested to characterize the surface value of the food. The pretreatment and storage processes of the water samples were the same as before. The experimental results are shown in Figure 5. The results show that the pH values of most fruits and meats decrease after spoilage.

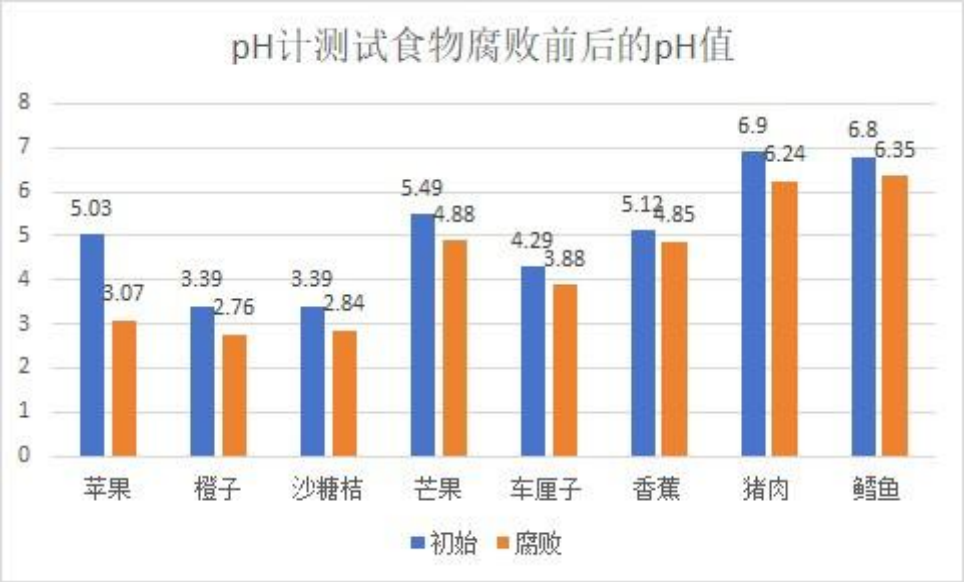

Figure 6 pH Values of Food Before and After Spoilage Tested by Laboratory pH Meter

Both experiments can verify that the pH value of food changes after spoilage, and at the same time, the pH value is indeed convenient to test. Therefore, it is feasible for the research team to select the pH value as the variable to be tested in the design.

4.2 Design of Food Safety Perception Device for the Blind

Since it is difficult for the visually impaired group to distinguish the quality of food through the subtle touch or smell in the initial stage of food spoilage, the research team hopes to design a lightweight and portable tool to help visually impaired people identify food spoilage. After various preliminary studies, we decided to use the pH value as the variable for our test, because it is easier to implement than other variables and does not require large-scale equipment.

Based on the above experimental results, combined with the design scheme and ideas of the food safety perception device for the blind in Section 3.3, the research team designed a set of circuit diagrams for the food safety perception device for the blind, as shown in Figure 6. The pH probe is used to detect the pH value inside or on the surface of the food and convert it into an electrical signal. The signal amplifier links the single-chip microcomputer to run the program, triggers the feedback mechanism, and realizes the voice prompt, so as to convert the pH value signal into a sound

signal. In the process, an image acquisition module and an AI image recognition and analysis module are added to synchronize with the single-chip microcomputer to run the program. In addition, a display screen is set at the end to synchronously transmit the signal to the display screen or link to the mobile phone app, thereby expanding the application scope of the device to ordinary people who pay attention to food safety and expect to obtain a portable characterization device.

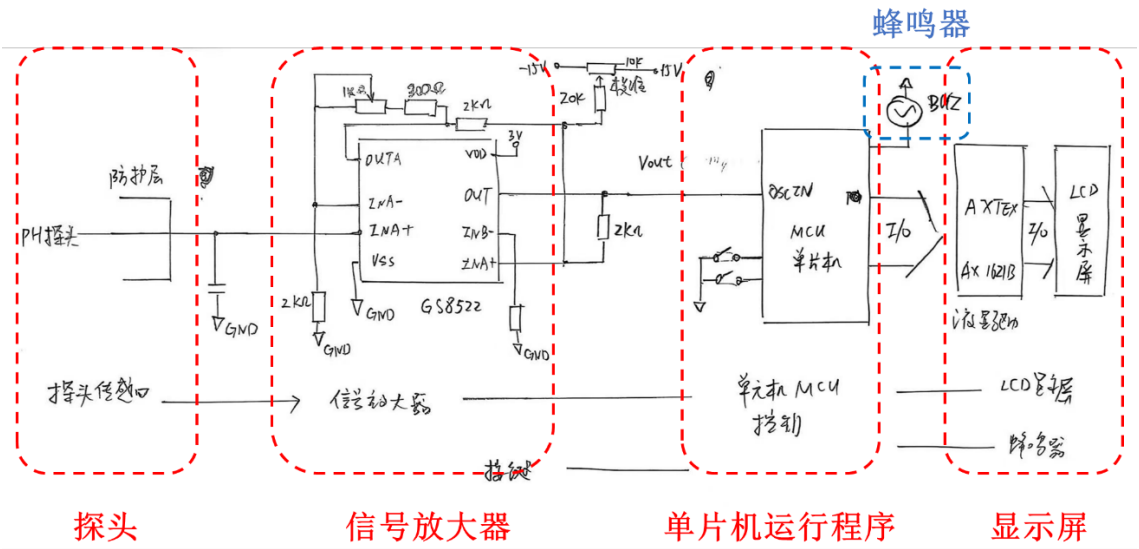

Figure 7 Circuit Diagram of the Food Safety Perception Device for the Blind

5. Conclusion and Discussion

5.1 Project Innovation Points

This project proposes a technical solution to the practical problem. The implementation of the project reflects technical innovation and social effects. The innovation points of the project are mainly reflected in three aspects: detection technology, user design and social benefits. Firstly, in terms of detection technology, this tool combines pH value detection with image recognition, and adopts a multi-dimensional analysis method to achieve accurate judgment of food spoilage. During the process of food spoilage, the pH value changes significantly due to microbial metabolic activities. Compared with traditional sensory judgment, using pH value as a spoilage indicator has high objectivity and scientific basis. This method is applicable to a variety of food types, such as fruits, meat and seafood.

Aiming at the needs of visually impaired people, the user design of the device fully reflects humanization. The device provides feedback through sound and vibration, ensuring that visually impaired users can intuitively understand the detection results. In addition, the operation method of the device is extremely simple, and only one-hand operation is required to complete startup and mode switching. In this way, the pH detection data can be quickly and accurately transmitted to the user, simplifying the operation process and greatly facilitating the use of the target group. The overall design of the tool is small and lightweight, easy to carry, and waterproof materials are used to improve durability. At the same time, the probe design combines detachable and easy-to-clean features to ensure the safety and practicality of the device in long-term use.

This scheme also achieves a breakthrough in portability and cost control. By selecting low-power pH sensors and high-efficiency AI chips, the device can operate for a long time while reducing manufacturing costs. Compared with traditional laboratory-level chemical detection, the built-in multi-modal system and AI algorithm of the device show significant advantages in portability and cost control, making the device more suitable for daily home use or personal carrying.

5.2 Social Benefits of the Project

The design of the food safety perception device for the blind has significant social benefits. It can help the blind group more conveniently and accurately perceive the safety information such as the freshness and shelf life of food, thereby effectively avoiding eating spoiled or expired food, ensuring their physical health, and reducing the risk of diseases caused by food safety problems. It also improves the independence of visually impaired people and reduces food waste. This not only improves the quality of life and independent living ability of the blind, enhances their confidence in participating in social life, but also reduces the social medical burden. At the same time, the popularization of this device also helps to increase social attention to the special needs of the blind, promote the further development of barrier-free facilities and technologies, promote the progress of social civilization, and create a better atmosphere of inclusiveness and care for vulnerable groups.

In addition, the scalability of the device also provides more possibilities for the future. For example, by updating the AI algorithm to adapt to more food types, or linking with smart phones to provide detection reports, it has greater potential for long-term optimization.

5.3 Limitations and Development Trends

Due to time constraints, the design of the research team still has certain limitations. For example, the selection of food samples is currently mainly limited to types such as fruits, and the setting of pH change thresholds is not yet perfect. The research team will continue to carry out experimental research on this system, expand the sample size of food, and control other variables such as humidity and temperature during spoilage to obtain more accurate pH value changes. In addition, the research team has designed the product circuit diagram, but the product has not yet been materialized. In the follow-up, we will continue to improve the product design, realize the product launch and use, and continue to follow up the use feedback of the visually impaired group for further improvement.

The future development trend of the food safety perception device for the blind shows characteristics in many aspects. Firstly, with the continuous progress of artificial intelligence technology, the device will become more intelligent and can more accurately identify various information of food. For example, through AI voice recognition technology, visually impaired users can interact with the device more naturally and obtain detailed information about food. Secondly, the application of the Internet of Things will enable the device to have remote monitoring and control functions, realizing the in-depth integration of smart home and food safety perception. In addition, the form of the device will also be more diversified, such as wearable devices, which are convenient for the blind to use anytime and anywhere. At the same time, with the continuous progress of the concept of barrier-free environment construction, the government and society pay more attention to the blind group, and relevant support policies are constantly introduced, which will provide strong support for the market promotion and technological innovation of the food safety perception device for the blind. Finally, from the perspective of market demand, the market for intelligent visual aids for the blind in China has great potential, and the penetration rate will surge in recent years, which will also promote the rapid development of related products such as the food safety perception device for the blind.

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