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# Analysis and design of Miniaturization of ice cream vending machine

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## Abstract

**With the maturity of automatic control and mobile payment technology and the growth of per capita GDP, people's pursuit of the improvement of quality of life, Chinese vending machine market into a rapid growth period, fresh food products vending machine quickly into the market. The development of ice cream vending machine is relatively slow due to the high requirement of refrigeration temperature, and the existing products cannot meet the new market demand. Due to the rising rent of the space, effectively reducing the initial investment and operating costs is the core of market competition. Ice cream vending machines will tend to be small, intelligent and energy-saving development. According to the design requirements, a series of miniaturized ice cream vending machines are designed and experimentally studied in this paper.**

## Keywords

**Ice cream vending machine; Automatic control; Miniaturization; Intelligent; Energy saving.**

## 1. Introduction

The rapid development of the vending machine market, the vending machine put forward new requirements.With the diversification of sales products, especially the increasing pursuit of people's quality of life, fresh food products (including freshly ground coffee, fresh cut fruit and ice cream, etc.) are put into the market of automatic selling. Automatic vending machines need to provide a more stable storage environment of high and low temperature than beverage vending machines.

In order to match the stable delivery demand of special products or packages, rapid and stable intelligent control is needed. In addition, the delivery method with a sense of science and technology and visualization will be an important selling point in the rapid development period.The core of market competition is to control the initial investment cost and operation cost, which are mainly production cost, delivery cost, operation energy consumption and maintenance cost of automated cargo aircraft. In order to meet the above market demand, the development trend of ice cream vending machines can be summarized as miniaturization, Intelligent and energy saving.The ice cream vending machine needs a reasonable design of the structure and automatic shipment action, and organic combination with the refrigeration system, to provide fast and high-quality purchase experience;Refrigeration system is the main source of energy consumption of vending machines, energy saving is mainly to reduce the energy consumption of refrigeration system;The existing ice cream vending machine is mainly vertical vending machine, the space utilization is unreasonable, the large volume leads to high cost, the high space utilization of small vending machine will not only reduce the operating cost, but also help to reduce the heat load of the refrigeration system and the electricity load required by the air supply, so that the energy consumption of the vending machine is reduced.Therefore,

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miniaturized, intelligent and energy-saving ice cream vending machines conform to the market demand, is the future development trend.

## 2. History and development status quo

### 2.1. History and development status of vending machines

There are no restrictions on the opening hours of vending machines, known in Japan as "microstores."Its history can be traced back to 215 BC, when a "holy water vending machine" appeared in a temple in ancient Greece.In the later Jin period of China, someone invented a device to sell writing brushes by throwing copper coins.The oldest surviving vending machine in the world is one that sold cigarettes in an English tavern in 1615, followed by postcard vending machines in the early 1780s.

In 1993, China introduced vending machines from countries such as Japan and South Korea, mainly in Guangdong and Shanghai.At that time, only coins could be used to purchase goods, mainly due to the recognition technology of banknotes, from coins to paper money to electronic money;Along with the development of currency recognition technology, China's first self-developed vending machine was born in Beijing in 1995.In 1999, domestic vending machines began to be put into the market in bulk, but because of the high cost of vending machines, people's consumption concept and business environment has not changed, the overall development of the industry is slow;As of 2017, with the rapid development of China's domestic economy in recent years, the actual number of vending machines in public areas is about 200,000 units, with an annual growth rate of more than 25%, mainly distributed in the eastern developed areas such as Beijing, Shanghai and Guangzhou.Meanwhile, China's rapid development in mobile payments and artificial intelligence has given a big boost to the vending machine market.From 2003 to September 2017, a total of 91 vending machine related enterprises were established.Domestic manufacturers and operators responsible for hardware development, manufacturing and production, the market is gradually moving away from the mass purchase of vending machines from Japan.

### 2.2. Development status of vending machines with refrigeration system

The research and development of ice cream vending machines are mainly made by the relevant manufacturers of the vending machines. Through the research on the patents of vending machines with refrigeration systems, we can find that the existing products are much the same, and the main differences are in the energy utilization method, delivery method and refrigeration unit.There are more than 200 patents related to vending machines with refrigeration systems in China, but few of them mention the specific performance of refrigeration systems.

The domestic vending machine with refrigeration system is mainly vertical, all use a single stage refrigeration system, with the setting of the insulation layer can reach the freezing temperature storage environment requirements.Refrigeration system mostly adopts single stage steam compression system, below freezing temperature mainly adopts air cooling, refrigeration unit is mainly arranged in the lower part of the vertical box, evaporator is mainly arranged in the upper part of the storage room or the back wall;Shipment mechanical structure and cold room separation is the mainstream, the main use of mechanical arm to complete the shipment action, and part of the spring shipment, that is, the shipment structure is placed in the storage room, but the study did not involve the compact structure design of miniaturization.For tubs of ice cream, the falling delivery method can not meet the requirements of stable delivery;In order to meet the demand of compact structure, the delivery device needs to be placed in the low-temperature storage room, and the stable delivery mode that matches the shelf needs to be designed.

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In addition, a small number of patents began to pay attention to the energy efficiency of the system. For example, in 2015, He Yijian from Zhejiang University adopted the storage mode of multiple separated variable temperature Spaces and the control mode based on big data to achieve the effect of energy saving of the system. However, the expression of energy efficiency and temperature in the patent was vague, and there was no mention of the insulation layer of refrigeration system and the influence on mechanical parts at low temperature.

## 3. Miniaturized design

### 3.1. Design the structure, refrigeration system and control system of the ice cream vending machine according to the miniaturized market demand.

A design scheme of miniaturized ice cream vending machine is proposed, which realizes the compact design matching with the refrigeration system by using two modules of long-range multi-layer shelf and short-range multi-degree of freedom manipulator.The size of the machine meets the requirements of wall hanging. The thickness is only 380mm and the volume is 0.38m $^3$, which is 1/5 of the volume of the common ice cream vending machine.The design work of the system is carried out from four aspects: the whole machine structure, the automatic action, the control system and the refrigeration system. The design and calculation of the refrigeration system provide the theoretical support for the feasibility of the refrigeration method, and also provide the parameters for the selection of the components of the refrigeration system.

### 3.2. The experimental system of ice cream vending machine was built by ourselves to realize the automation of shipment action.

According to the design scheme, the experiment system of the ice cream vending machine is set up, and the error of the measurement system is checked.Realize the automatic control of the design and shipment action, middle ice cream purchase waiting time is 35s, upper and lower for 53s;The main reason for the long waiting time is that there are many movement steps and long distance uniform movement takes a large proportion of time.According to the proximity to the middle layer can reduce the movement time in the Z-axis direction, the placement of ice cream on multi-layer shelves should be arranged from the middle to the top according to the sales volume, so as to reduce the expectation of waiting time for purchase.By comparing the movement time ratio and the running step ratio of the same kind of motor, the response delay of action conversion in the control system is calculated and analyzed as 0.2s.In order to achieve stable delivery motion, an optimization scheme of integrating delivery lines, reducing the number of motion and non-uniform control of long range motion was proposed.

### 3.3. Debug the refrigeration system to determine the optimal refrigerant charging amount

The temperature field in the storage room was analyzed through the whole machine experiment, and the optimal arrangement of evaporator was proposed, which preliminarily solved the problems existing in the matching of various systems.

Through the measurement and analysis of the temperature of the evaporator inlet and outlet and the temperature of the storage room, the optimal refrigerant charging amount of the system is determined to be about 135g.The temperature field in the storage room was analyzed through the whole machine experiment, and the best scheme was put forward that the evaporator and the fan were arranged above the rear side wall of the shelf. The storage temperature of all the ice cream could reach about -21℃.The replenishment simulation experiment monitored the temperature change process of replenishment and reheating. In order to ensure the storage temperature is stable below -18℃, the replenishment time should be controlled within 1min;In the simulation experiment of shipment action,it was found that

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the influence of low temperature on the sensitivity of photoelectric sensor. By increasing the sensitivity, the origin of shelf positioning was moved to the right by 10mm to achieve the same positioning effect as at room temperature.

## 4. The foundation, problems and solutions for the implementation of the project

The school has all kinds of laboratories, with all kinds of related development devices, are open to students.The university has actively formulated various policies to encourage students to carry out scientific and technological innovation. The university has set up a school-level organization and coordination organization for college students' scientific and technological innovation projects, and formulated feasible management methods and supporting policies to provide supporting conditions.The students participating in the project are equipped with senior and intermediate instructors, who are responsible for guiding the students to carry out scientific and technological innovation projects;The university's Internet of Things laboratory,various development devices and key laboratories are provided free of charge to students participating in the project;The school shall provide no less than 1:1 supporting funds for the project.The school gives the tutor corresponding workload subsidy and so on.All these provide convenient conditions for the project research, and provide strong support of human, material and financial resources for the smooth implementation of the project.The instructors of this project are all front-line scientific research teachers with reasonable knowledge structure and solid theoretical foundation.The research direction carried out by the instructor team is closely related to the project, which ensures the feasibility of the project.

The main problems and solutions of the automatic movement of the manipulator at low temperature are summarized in the following table.In addition, the service life of the circuit will be affected by the carrier freezing effect when the electrical components are operating at low temperature.

| The main problem | The Solution |
|---|---|
| Assembly problems caused by thermal expansion and cold contraction of metal materials | Re-fix at low temperature and adjust pressure Angle |
| The cold brittleness of metals | Not mentioned |
| Condensation and frost of moving parts | Add manipulator and buffer to reduce hot and wet air entry |
| Low temperature viscosity of lubricating oil and metal rust | Low temperature lubrication grease is used |
| Low temperature motor operation | Low temperature servo motor (normal operation at -30℃) |
| Motion detection device | Photoelectric sensing system is adopted, which is not easy to be interfered by working environment |

## 5. Points of Innovation

1) Put forward the design scheme of miniaturized ice cream vending machine to meet the market demand.The structure of long-range multi-layer shelf and short-range multi-degree-of-

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freedom manipulator is designed, which is organically matched with the refrigeration system to reduce the volume of the whole machine by 5 times.

2) The feasibility of the design scheme of miniaturized ice cream vending machine is preliminarily proved through experiments.The matching mode between the shipping mode and the evaporator layout is optimized. The long range shelf and the horizontal and vertical small size design mode are conducive to the energy-saving of the air cooling system, which provides a new idea for the miniaturization and energy-saving design of the ice cream vending machine.

## 6. Prospect of Development

The miniaturization of the ice cream machine can not only reduce the cost, but also reduce the heat load of the refrigeration system and the power consumption required for air supply.The shipping structure of miniaturized design will be placed in low temperature environment, not only to achieve compact structure, but also to organically combine with the refrigeration system, and meet the product needs of convenient operation and maintenance.

In this paper, a series of design and experimental studies have been carried out on the miniaturized ice cream vending machine. However, due to the limitation of experimental conditions and time, there is a large space for optimization of the operation design and the performance of the refrigeration system. The main research work of this topic can be further carried out from the following aspects:

1) Further optimize the design of shipping action, effectively reduce the customer's waiting time for purchase, further integrate the path of shipping action, explore ways to reduce the number of actions and improve the control method of the main time-consuming action speed;

2) Further optimize the evaporator design of miniaturized equipment, design the high efficiency heat exchanger for freezing temperature applications, meet the requirements of small volume and not easy to be affected by frost, and achieve the design goals of efficient heat transfer and convenient defrosting;

3) Carry out the quantitative analysis of the matching between the evaporator and the storage room structure, and carry out the quantitative analysis of the matching between different air supply volumes and different structure sizes, providing a favorable reference for the miniaturization design of the ice cream vending machine.

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