Design of Refrigerating and Quick Freezing Equipment Based on Liquid Nitrogen Technology

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Abstract. With the improvement of people's living standards, it pays more attention to nutrition and quality of food demand. Diversification of consumption patterns, resulting in food preservation has higher requirements. With the extension of the highway, road transport is also developed. Fresh food as an important daily food category, with proper refrigeration technology, suitable industrial refrigeration products, reducing the degree of corruption of fresh food, it is not only related to food safety, but also reducing the waste of resources and reduce the loss of business, this is one of the important measures, in order to ensure that the company's economic. Based on the fresh frozen food refrigeration technology application status will be the rapid development of fresh food refrigeration technology, this paper designs Refrigerating and Quick Freezing Equipment Based on Liquid Nitrogen Technology, including visual design, structure design, safety design, control model design, PID algorithm design.

1. Introduction

Quick-frozen food is a kind of fast-frozen food. It means that the food can be stored in the environment below -18℃ and then transported and traded at -30℃ for 30 minutes. Through quick freezing, the colour, aroma, taste and nutritional value of food can be preserved. Fast-frozen food has a history of nearly 90 years so far. With the promulgation of the Regulations on the Manufacture of Frozen Food, it marks that the fast-frozen food is on the right track. Since then, the quick-frozen food has gradually been favoured by consumers, and industrial production has been realized. The development of quick-frozen food has ushered in new opportunities [1-2].

In ancient times, people knew that cooling prevented food from decaying, and people began to use ice to refrigerate food. In order to transport food, ensure food safety and non-decay, people use ice and food loading together, reduce the temperature in the box, prevent food deterioration. In order to keep the temperature in the carriage at low temperature, people will turn the material made of the carriage into heat insulation material, which is lighter; this is the ancient people's quick-frozen food. There was no foam in ancient times, but there were some kinds of thermal insulation materials such as cork, wood and so on. In contemporary society, the development of science and technology mainly uses chemicals as insulation materials, such as polystyrene foam and polyurethane foam [3].

With the higher pursuit of food freshness, the technology of food preservation has been further developed. Foods need to be frozen to quick-frozen in order to keep their nutrients intact and to keep their colours bright. Quick-frozen food will crystallize the internal components of food, and when food is eaten, thawing food is to crystallize into the juice of food, so that food changes back to the appearance before freezing, food will have a very delicious taste and rich nutrition [4].
Food in long-term transport or storage, affected by high temperature, high humidity and other factors, easy to decay and deterioration. In particular, some nutrient-rich foods such as fruits, vegetables, meat, milk, eggs and cheese, more susceptible to bacteria, mold growth and reproduction, thus accelerating decay. In order to improve the safety of food storage and transportation, food refrigerating equipment and refrigerated transport trucks are widely used. Because the low temperatures produced by refrigeration equipment can slow the growth of most microorganisms that cause food spoilage, food can be stored for a long time without spoilage or decay [5].

2. Existing equipment for quick freezing of food

Quick freezing equipment and general freezing equipment are two types of freezing equipment in China. Quick freezing equipment is quick freezing equipment, and general freezing equipment is slow freezing equipment. At the same time, according to the cryogenic rings do not understand the classification, usually divided into air freezing and liquid freezing two kinds.

Global quick-freezing equipment can be roughly divided into eight categories, of which liquid nitrogen quick-freezing equipment and jet mixing quick-freezing equipment are two types of emergence abroad, the remaining strong blast type quick-freezing equipment, fluidized bed type quick-freezing equipment, tunnel type freezing equipment, spiral type quick-freezing equipment, contact type freezing equipment and direct freezing equipment of the six categories of domestic countries. There are all outside. Among them, the strong blast type quick freezing equipment, the fluidized bed type quick freezing equipment, the tunnel type quick freezing equipment, and the spiral type quick freezing equipment are four kinds of air forced circulation refrigeration. Contact quick freezing is refrigerated by plate heat exchange, and direct freezing equipment is refrigerated by liquid. The following eight types of refrigeration equipment are described below.

Strong blast quick-freezing equipment: This quick-freezing strong blast quick-freezing equipment is high cost, energy consumption is very large, has not adapted to the pace of society. The principle is to freeze food and materials by driving the cold air through a strong blast. The freezing speed of the device is 2-4 times faster than that of the normal freezing. Because of the principle of cold air, the freezing speed is not uniform, even the winter amount is not uniform, the equipment as shown in Figure 1.

![Figure 1. Strong blast quick-freezing equipment](image1)

Fluidized bed quick freezing equipment: This equipment is only suitable for granular quick freezing. The principle is also the use of cold air, through the blower to make cold air flow from the bottom to the top, so that the internal objects to achieve the cooling effect. Although it overcomes the disadvantage of uneven freezing speed and accelerates the freezing speed, the type of quick-frozen food is very obvious. As shown in Figure 2.

Tunnel freezing equipment: This tunnel freezing equipment freezes quickly, but it consumes a lot of energy, costs a lot, and its structure is complicated. The principle of this equipment is to refrigerate food through the tunnel; the tunnel is equipped with air cooler and fan. Refrigerate the food through the tunnel. As shown in Figure 3.
Spiral quick-freezing equipment: This spiral quick-freezing equipment is characterized by small area, large production capacity, but in the process of quick-freezing transportation, may produce clogging conveyor pipe, and the internal structure is complex, disassembly is not easy, smooth operation of more uncertain factors. Its principle is basically similar to that of tunnel freezer, but it transforms the tunnel into a spiral tube.

Contact quick-freezing equipment, also known as plate quick-freezing equipment: this contact quick-freezing equipment is characterized by the equipment can operate at room temperature, low energy consumption, but cannot be continuously produced, the nature of food has certain limitations. The principle is: by evaporating the refrigerant, the food placed between the plates will be frozen quickly.

Direct freezing equipment: the direct freezing equipment is characterized by environmental protection, harmlessness. Its principle is: the food and refrigerant directly contact, is the internal heat of food and refrigerant heat exchange, quickly reduce the temperature of food.

Liquid nitrogen quick-freezing equipment: This liquid nitrogen quick-freezing equipment is characterized by the shortest freezing time, the fastest freezing, but the transport and storage of liquid nitrogen requires a large cost. The principle is that liquid nitrogen at -60 C is directly in contact with food and then exchanged with heat. There are three ways to contact liquid nitrogen with food: evaporation, spraying and liquid invasion.

Jet mixer: This device guarantees freshness, taste, colour, and nutrition. The principle of this equipment is: through the spiral jet pump to stir refrigerating liquid, so that liquid recirculation flows, to ensure that the temperature in -30 ~ -50%. This will make quick-frozen food.

3. Development and application of Liquid nitrogen

With the further improvement and development of liquid nitrogen freezing technology, it has been widely used in fish, shrimp, crab, chicken, duck, meat (cattle, sheep, etc.), fruit (bayberry, litchi, etc.), vegetables, and various prefabricated foods (steak, raw fish, meatballs, fried shrimp, meat pie, hamburger, pizza, egg products, soup). In the freezing process. In 1981, liquid nitrogen quick-frozen food accounted for 10% of frozen food in the United Kingdom, with liquid nitrogen exceeding 100kt. 1/3 for liquid nitrogen production in Western Europe is used for food quick freezing and refrigerated transport. Japan's liquid nitrogen quick-frozen food accounts for about 40 to 50% of frozen food. At present, hundreds of food processing enterprises in the United States adopt liquid nitrogen quick-freezing; only one fast-freezing steak factory uses 700 tons of liquid nitrogen every day. In the early 1970s, liquid nitrogen quick-frozen food production lines were developed in Beijing and Shanghai.
the 1980s, various kinds of quick-frozen packages (including liquid nitrogen quick-frozen) were introduced from Japan, Sweden, France, the United States and Denmark, and liquid nitrogen quick-frozen fresh aquatic products such as silver carp, lake crab and shrimp were successfully used. Due to the high price of liquid nitrogen and the need of 0.8-1 kg liquid nitrogen per kilogram of quick-frozen food, the use of liquid nitrogen in 250 sets of quick-frozen packages manufactured by China in 1991 was very few, resulting in a very low proportion of liquid nitrogen fast-frozen food in frozen food in China, which was not widely popularized.

In recent years, with the deepening of reform and opening-up, major foreign multinational gas companies have competed to establish joint ventures in China, bringing advanced air separation equipment, technology and management, resulting in a substantial increase in the production of cryogenic liquids in China, a continuous expansion of the supply area and scope, and a substantial reduction in the price of liquid nitrogen (the price of liquid nitrogen is 2 yuan/kg left). Right, reduced to less than 1 yuan/kg), greatly promoted the application of liquid nitrogen [6-7].

Its social and economic benefits are as follows:

(1) Liquid nitrogen is nontoxic and inert to food ingredients. Furthermore, it can minimize oxidation changes during freezing and packaging because it replaces air from food.

(2) Liquid nitrogen can be in close contact with all parts of food with irregular shape, so that the heat transfer resistance can be minimized.

(3) The dry food consumption of frozen food is small. The dry consumption rate of frozen food is between 3% and 6%, while that of frozen food with liquid nitrogen is between 0.6% and 1%. Therefore, it is suitable for freezing some foods with high moisture content, such as bayberry, tomato and crab meat.

(4) Small footprint, low initial investment and high efficiency.

(5) The quality of frozen food is high. Because of the direct contact between liquid nitrogen and food, the freezing speed is very fast, and the temperature can be reduced by 7-15 K per minute. The ice crystals in food are small and even, and the quality of food is high after thawing.

(6) The combination of the liquid nitrogen technology and the freight vehicle equipment can make the newly produced food keep fresh quickly, which is more conducive to the consumers to eat the original food. The liquidity is greatly enhanced after the combination of the liquid nitrogen technology and the freight vehicle equipment, which can rapidly cooperate with the agricultural and products enterprises and the agricultural products processing enterprises.

4. Design of Quick Refrigerating Equipment Using Liquid Nitrogen Technology

4.1 Visual design
The visual design of quick frozen products is mainly reflected in the colour aspect. Environmental protection, green and pollution-free is the national policy, but also we must protect the earth on which we live. The main performance of quick freezing is speed, to complete the quick freezing of food, so the use of streamlined lines and strong sharp symbols to express. Colour can use blue to express the feeling of freezing, can also use white or black, patterns can be added with ice and snow and other cold related. Quick-frozen products have some dynamic objects, moving objects, can use bright colours, attract people's attention, so can use blue contrast colour orange, yellow and other brighter colours [8].

4.2 Structure design
The structural design of quick-frozen products needs to consider the aesthetic design of the shape. The structure of the refrigerated car should conform to ergonomics, give people the feeling of common things in life, will not appear abrupt, there will never be difficult to integrate the feeling of life. It accords with the operation of commonly used transport vehicles, and is easy to operate, so that people can happily accept this refrigerator car.
4.3 Safety design
Safety design of quick-frozen products refers to the possibility of damage of quick-frozen equipment stored in the open air or in secret places of people. Leakage of chemical gases or liquids used to preserve food such as heat preservation will cause unnecessary property losses and endanger the safety of people nearby. Completeness design is In order to ensure the safety of products, eliminate these risks. So in product design, safety is a crucial link. The safety of the structure is to ensure the normal operation of the product, if there are problems and timely repair, timely reinforcement. Colour safety, as the name suggests, is to let people see that the colour of this product will not be misled [9].

4.4 Control model design
For many problems existing in original air compressor supply control, in order to meet the production line system automatically control requirements, the author introduces the design of liquid nitrogen freezing control system based on frequency control PID, as shown in Figure 4.

![Figure 4. Closed Loop Control System](attachment:figure4.png)

The system provides two modes, namely manual and automatic, with on-site real-time control, can display the status and fault alarm functions.

4.5 PID Algorithm design
PID is proportional-integral-derivative control algorithm in closed-loop control system. In regulator, PID control algorithm [10] for the simulation expression is:

\[
Y(t) = K_c e(t) + K_i \frac{1}{T_i} \int_0^t e(t) dt + K_d \frac{dd(t)}{dt} + M_{initial}
\]

Where: Y(t) is the output of the loop control algorithm; KC is the loop gain; TI is the integral time constant; TD is the derivative time constant; e(t) is the error; M_initial is the initial value of loop control algorithm output.

PID operation of the integral action can eliminate the static error of the system, improve accuracy, enhance the ability to adapt to changes in system parameters; and derivative action can overcome inertia lag, improve system stability and anti-jamming capability, can improve the system dynamic response speed. Therefore, PID controls pressure slow process with good results.

5. Conclusions
Fresh food has become a material demand for people's pursuit of quality of life. Liquid nitrogen refrigeration technology has great development prospects and space with its advantages of high efficiency, quick freezing, energy saving, environmental protection and light volume.

At the same time, designers have more space to study the quick-freezing equipment, including the shape, color, safety, emotional and so on. As long as continuous exploration, continuous research and continuous design will promote the development of this industry.

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