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Concentration of cattle blood by moisture freezing

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Abstract. Prospects for the use and processing of cattle blood for food and pharmaceutical purposes were described in the article. The process of blood cyclic concentration by the method of moisture freezing was investigated. A crystallizer with a flowing liquid film was used in the experiments. Research showed that increasing of the refrigerant boiling point in the crystallizer evaporator causes a decrease in the specific amount of frozen from the blood ice. Increase in the amount of frozen ice contributes to an increase in the liquid flow rate that irrigates the crystallizer evaporator. Increase of the initial solids content causes a decrease in the frozen ice value. A decrease in the refrigerant boiling point in the crystallizer evaporator causes an increase in the solids content of the solution obtained by frozen ice melting. An increase in the blood flow irrigating the crystallizer evaporator causes a decrease in the solids content in the solution obtained by frozen ice melting. It characterizes the amount of loss of target substances that are removed with frozen ice. An increase in the initial content of dry substances in the blood causes an increase in the content of soluble substances in the frozen ice solution. Spectral analysis of the chemical composition of the concentrated blood showed its high quality, while preserving almost all proteins, bilirubin and lecithin.

1. Introduction

Nowadays agricultural and food industry are becoming more and more high-tech. They urgently require new methods of agricultural raw materials processing, the introduction of the most breakthrough and promising ways of products manufacturing. One of the real sources of raw materials for processing is the blood of slaughter animals, the value of which is extremely low even today. The valuable chemical composition and vast resources of food blood throughout the country require urgent rethinking of the existing and application of new approaches to its deep and integrated processing. This will maximize useful components extraction as well as reduce the environmental impact of its processed products recycling. The cattle blood contains a large complex of chemical substances in its composition. Due to the high content of various protein molecules in the blood and its thermal instability, the concentration process is very complex. Therefore, we propose to use a modern method of concentration by the moisture freezing. This will increase the resource potential, develop the production of new foods rich in protein and medicines for people suffering from iron deficiency.

2. Materials and methods

The crystallizer with a flowing liquid film shown in figure 1 was used to study the process of cattle blood concentration by moisture freezing.



The crystallizer with a flowing liquid film contains a refrigerating compressor-condensing unit 1 with a gasket-free hermetic compressor, a refrigeration unit panel 2 for controlling the suction pressure, refrigerant discharge and its boiling point.

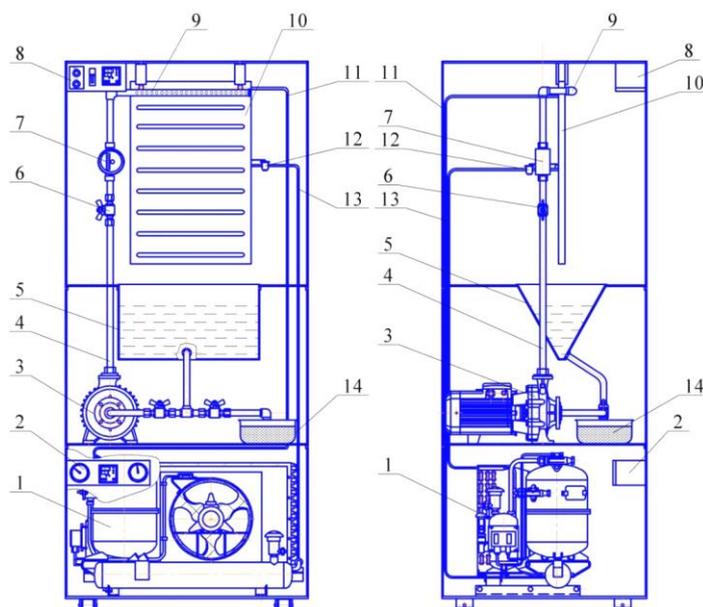


Figure 1. The crystallizer with a flowing liquid film:

1 – refrigeration unit; 2 - refrigeration unit panel; 3 - centrifugal pump; 4 - pressure pipeline; 5 - pressure tank; 6 - valve; 7 - liquid counter; 8 - management panel; 9 - blood spraying collector; 10 - evaporator; 11 - pipeline for refrigerant vapors outlet; 12 - throttling valve; 13 - liquid refrigerant supply pipeline; 14 - concentrated blood collecting container.

The source fluid from the pressure tank 5 is pumped by the pump 3 into the blood spraying collector 9 through the pressure pipeline 4. This ensures the source fluid spraying on the surface of the evaporator 10 with a developed surface, due to the wave-like ledges.

Flowing under the gravitational forces action blood loses some of amount of water due to its freezing on the evaporator 10 heat exchange surface, ensuring an increase in the concentration of soluble substances. When the required concentration of soluble substances in the solution is reached, the moisture freezing concentration process is stopped and the concentrated solution is poured into the container 14.

The frozen ice was placed in a pre-weighted flask, and the total weight of the flask with ice was determined on an analytical balance. To determine the amount of dry matter in a liquid trapped in ice, the frozen ice was melted, thermostatically controlled at a temperature of 293 K, and the dry matter content was determined with a refractometer.

The refrigerant supply system into the internal cavity of the evaporator 10 consists of a refrigeration unit 1 containing a piston hermetic compressor, a two-part air condenser, a receiver, a filter drier, a throttling valve 12, the sensitive cylinder of which is attached to the refrigerant suction pipe to the compressor, a pressure switch, and solenoid valves. “Freon 22” was used as a refrigerant in the refrigeration machine. The power of the refrigeration unit made it possible to obtain the boiling point of the refrigerant from 262 to 250 K by changing the compressor cooling capacity. The pressure in the suction and discharge piping of the compressor was controlled with pressure gauges placed on the panel 2.

The following technique was used for research.

The chiller was put into operation after an external inspection of the unit. The refrigerant supply valve to the evaporator was opened and the refrigerant boiling point was controlled.

After reaching of the evaporator required temperature, the pump 3 was turned on. It supplied blood from tank 5 to the evaporator 10 surface. The stopwatch was also turned on. The cattle blood flow was changed by regulating the flow area of the blood supply pipe, by the valve partially closing.

During the study, indications of the refrigerant boiling point in the evaporator, the compressor suction and discharge pressure, the flow rate and the duration of the freezing cycle were recorded. Measurements of voltage and current in the circuit of the electric motor of the unit were carried out simultaneously.

After the expiration of the freezing cycle time, taken to be 60 minutes, the electric motor pump was turned off and the operation of the refrigeration unit was switched to the “thawing” mode. At the same time, due to the switching of solenoid valves, the supply of hot refrigerant vapor to the evaporator was carried out, a layer of frozen ice partially melted and separated freely from the evaporator.

The unit capacity for frozen ice, the content of solids in the concentrated liquid and the solution obtained after frozen ice melting were determined after the freezing cycle.

3. Results and their discussion

The dependence in the specific amount of frozen ice per unit area of the crystallizer evaporator surface on the content of soluble substances in the initial blood and various operational parameters of the crystallizer was investigated in the work (Figures 2, 3).

It was found out that an increase in the refrigerant boiling point in the crystallizer evaporator provides a proportional reduction in the value of frozen ice specific amount which coincides with the physical picture of the process.

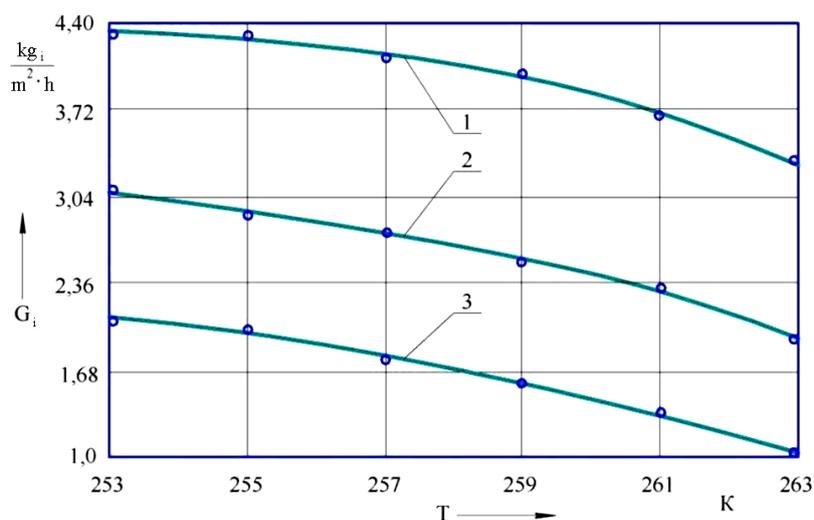


Figure 2. The dependence in the specific amount of frozen ice per unit area of the crystallizer evaporator surface G_i , $\text{kg}_i/(\text{m}^2 \cdot \text{h})$ on the refrigerant boiling point in the evaporator T , K and the initial solids content CB_h , % with the blood flow $Q=0.17 \cdot 10^{-3}$, m^3/s :
1 – 19.1%; 2 – 23.2 %; 3 – 27.8 %.

The increase in the frozen ice specific amount causes an increase in the liquid flow rate irrigating the crystallizer evaporator. This is due to the increased intensity of the heat exchange process at the interface between the liquid and solid phases due to an increase in the heat transfer coefficient.

The increase in the initial solids content causes a decrease in the frozen ice value. This is due to the increased nature of the bond between water molecules and the soluble substance during the dissolved blood components concentration. It is natural to assume that when a certain “critical” concentration of solutes in a liquid is reached, moisture freezing from it stops completely.

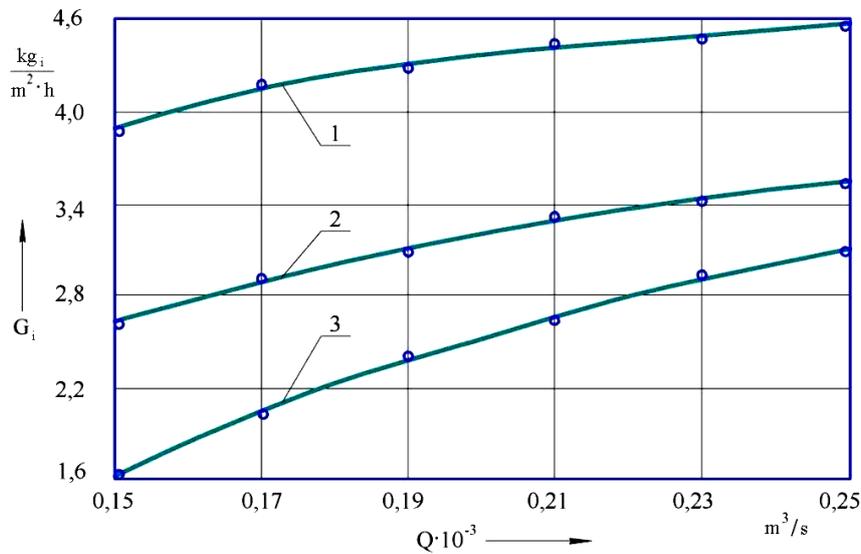


Figure 3. The dependence in the specific amount of frozen ice per unit area of the crystallizer evaporator surface G_i , $\text{kg}_i/(\text{m}^2 \cdot \text{h})$ on the blood flow $Q \cdot 10^{-3}$, m^3/s , and the initial solids content CB_h , % with the refrigerant boiling point of $T = 255 \text{ K}$ in the evaporator $Q = 0.17 \cdot 10^{-3}$, m^3/s :
 1 – 19.1%; 2 – 23.2 %; 3 – 27.8 %.

The dependence of the solids content in the solution obtained by frozen ice melting on the refrigerant boiling point in the crystallizer evaporator, the blood flow irrigating the evaporator surface and the solids content in the blood was studied (Figure 4, 5).

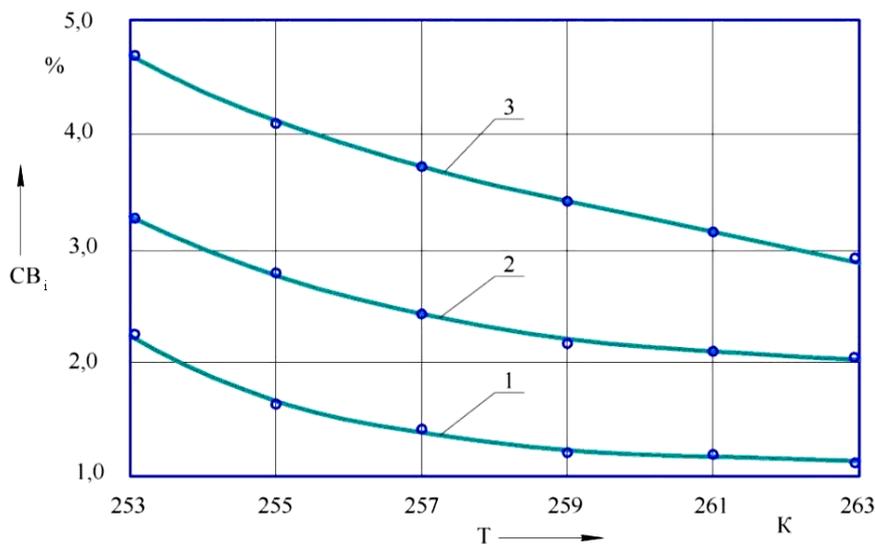


Figure 4. The dependence of the solids content in the solution obtained by frozen ice melting CB_h , % on the refrigerant boiling point in the evaporator T , K and the initial solids content CB_h , % with blood flow $Q = 0.17 \cdot 10^{-3} \text{ m}^3/\text{s}$: 1 – 19.1%; 2 – 23.2 %; 3 – 27.8 %.

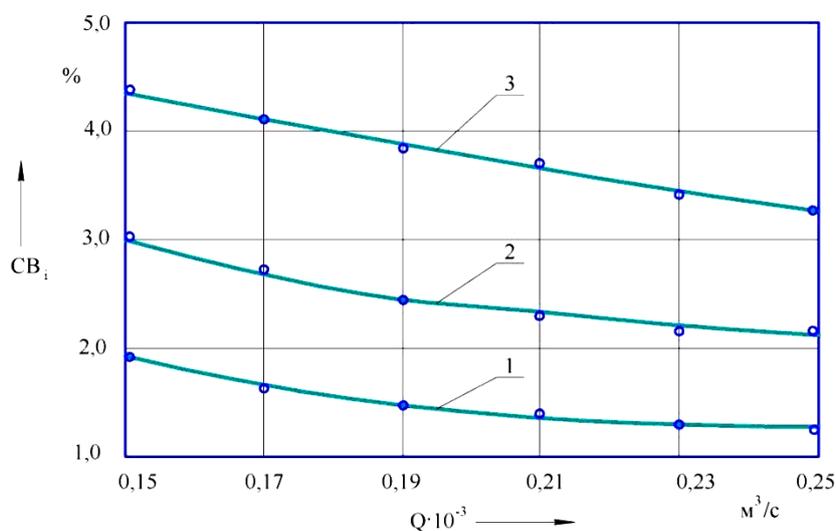


Figure 5. The dependence of the solids content in the solution obtained by frozen ice melting CB_i , % on the blood flow $Q \cdot 10^{-3}$, m^3/s , and the initial solids content of CB_i , % at the refrigerant boiling point in the evaporator $T = 255$ K:
1 – 19.1%; 2 – 23.2 %; 3 – 27.8 %.

The decrease in the refrigerant boiling point in the crystallizer evaporator causes an increase in the solids content in the solution obtained by frozen ice melting. It can be explained by the disparity between the mutual migration rates of water molecules and dissolved blood substances with a significant temperature difference.

An increase in blood flow irrigating the crystallizer evaporator causes a decrease in the content of solids in the solution obtained by frozen ice melting. This is due to the washing off intensification of more concentrated liquid layers from the surface of ice formation with a solution with a lower initial concentration. The results of studies of the solids content in the solution obtained by frozen ice melting, depending on the initial solids content in the blood, show that an increase in the initial solids content in the blood causes an increase in the soluble matter content in the frozen ice solution.

This is due to the capture of a significant amount of the solute in the cattle blood by water molecules due to molecular forces at the appropriate diffusion rates and the crystalline ice structure formation.

Spectral analysis of the chemical composition of the initial cattle blood and the blood concentrated by freezing showed that the concentrate contains a small amount of compounds responsible for the alkenes hydration and highlighted almost complete preservation of bilirubin and lecithin structure. The preservation of characteristic molecules responsible for the conformational transition of the primary structure of the hemoglobin protein to the secondary and tertiary with the formation of a pronounced β immunoglobular structure, the preservation of fatty acid phosphoxidases was also noted in the paper.

4. Conclusions

Summarizing the results obtained it should be noted that the efficiency of the process in the cyclic freezing unit depends on the refrigerant boiling point in the evaporator, the blood flow irrigating the surface of the evaporator and the initial blood concentration supplied into the unit during the cattle blood concentration.

The analysis of chemical changes in the blood structure concentrated by moisture freezing shows almost complete preservation of the chemical nature of biological blood complexes, which is very important for further processing for food and pharmacological purposes.

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