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TECHNOLOGICAL FEATURES OF COMBINING CONDENSED CANNED MILK WITH SUGAR AND FRUIT-BERRY SYRUPS DURING PROCESSING

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Abstract: *A mathematical model of combining milk and plant products was built on the basis of dependency of mass fraction of solids condensed canned milk (CCM).with sugar and FBS of mass fraction of solids milk-sugar mixture and the temperature of intensified lactose crystallization. Taking into consideration the rheological characteristics and constructive-technological parameters, the degree of homogeneity consistency and duration of formation of condensed milk with sugar and fruit-berry* syrup *"cranberry-blueberry" were studied.*

Keywords: *condensed canned milk with sugar, milk-sugar base, fruit-berry syrup, mathematical model, homogeneity, duration.*

1. Introduction

Dairy industry in Ukraine is characterized by a monotonous assortment; finished products are unbalanced with high content of calories. Such development is contrary to the newest industry food concepts, does not meet the needs of the modern consumer [1, 2].

Today, scientists and researchers are searching new ways and methods of the changing nature of food while preserving the fresh and natural raw materials; ensuring rational, balanced products according to the physiological needs of the human body.

A.G. Galstyan, L. V. Golubeva, K. K. Polyansky, I. A. Radayeva, L. V. Chekulayeva, and others [1] at different times were engaged in development and improvement of technologies and structure of CCM.

After detailed literature analysis, the authors recommended to review two possible ways of dynamic development of dairy industry: creating new types of specialized canned milk; improving and developing of technologies of canned milk with wider assortment and with new combinations of new components and adding of taste aromatic substances. At the same time, the proposed development of the industry using new raw material is more efficient because it does not limit the needs of people of all categories and a wide audience of consumers.

It was identified that usage of non-traditional raw materials of plant origin in CCM, such as fruit-berry syrup (FBS), will allow to create products of combined carbohydrate composition with reduced glycemic, with improved and stable quality characteristics during storage [3, 4, 5].

It also will help producers to diversify taste range of products, expand the sphere of using CCM (in the confectionery industry - as fillers in catering organizations – as filler like "topping").

But the production of condensed canned milk with sugar and fruit-berry fillings has several features which are affected by different physico-chemical properties of two environments: milk-sugar base (MSB) and FBS ("cranberry-blueberry", "rosehips-hawthorn", "rosehips-ehinatseya-mint").

Therefore, further in the work experimental study of combining operations, the parameters of which primarily depends on the mass fraction of solids milk and plant base's; temperature crystallization of lactose; quality and duration of cooling milk and sugar environment; structural and technological conditions combination MSB with FBS is presented.

2. Material and methods

According to classical technology milk-sugar mixture is concentrated to a mass fraction of solids 71...72%, due to the fact that during the cooling product thickens at 0,088% with a decrease of 1 ° C, ie on the 3-3.5% overall [1].

Thickening of MSB in the production of CCM with sugar and FBS cannot be made on the same principle as the mass fraction of FBS solids in accordance with experimental results are 67...70%. With this purpose influence of mass fraction of solids milk-sugar mixture and fruit-berry syrup on the mass fraction of solids in products was determined.

Milk-sugar mixture was thickened to the state of dry matter content of 70...76%, and after cooling (20 °C) to its composition contributed 15% of fruit-berry syrup with solids mass fraction not less than 69%. Table 1 shows the results of the experiment.

Table 1
Dependence the mass fraction of solids CCM with sugar and FBS of mass fraction of solids milk-sugar mixture

No.	Mass fraction solids of milk-sugar mixture, %	Mass fraction solids of cooled milk-sugar mixture, %	Mass fraction solids of CCM with sugar and FBS, %
1	70	73	69
2	71	74	70
3	72	76	72
4	73	77	73
5	74	78	74
6	75	79	74
7	76	80	76

Analysis of the data shows that the adding of FBS to the milk-sugar mixture that thickens to 70...72% of solids as required by classical technology of CCM, leads to appearing of defects of "liquid consistency" and production of finished product with irregular quality characteristics.

Thickening of milk-sugar base to the mass fraction of solids over 75% resulted in loss of fluidity of final products that is explained by the increase of protein content in the mixture.

As it is known, under these conditions, particles of casein-calcium-phosphate complex are converged, due to which there appear conditions for coagulation of protein [1] and as a result, an abrupt increase in viscosity, which is unacceptable.

Consequently, to obtain CCM with sugar and FBS with standard indicators milk-sugar mixture it is recommended thickening for mass fraction of solids 74 - 75%.

At the next stage of work conditions to adequately process the lactose crystallization during cooling were specified. Since in CCM with sugar and FBS lactose concentration decreased to 22.1 - 22.6% comparing with the classical CCM with sugar need to establish intensified crystallization temperature of lactose appeared.

In condensed milk with sugar lactose is crystallized according to the kinetic molecular theory in two stages: at the first stage emergence of centers of crystallization happens, at the second - increase of crystals quantity appears [1, 2].

Therefore, in a heterogeneous formation mechanism of germs seed is needed for basic surface crystallization. In the role of seed in industrial conditions refined crystalline lactose is used, content of which is 0.02% of the weight of the product [3].

According to the schedule of the Hudson (Fig.1) temperature of intensified crystallization of lactose in the investigated samples of condensed canned milk with sugar and selected fruit-berry syrups was determined. For investigated samples of milk-sugar base condensed milk with sugar and various FBS "lactose number" was calculated (formula 1). Received values were compared with lactose number of classic sweetened condensed milk.

$$L_{l.n} = (100L_{pr}) / (L_{pr} + W_{pr}) \quad (1)$$

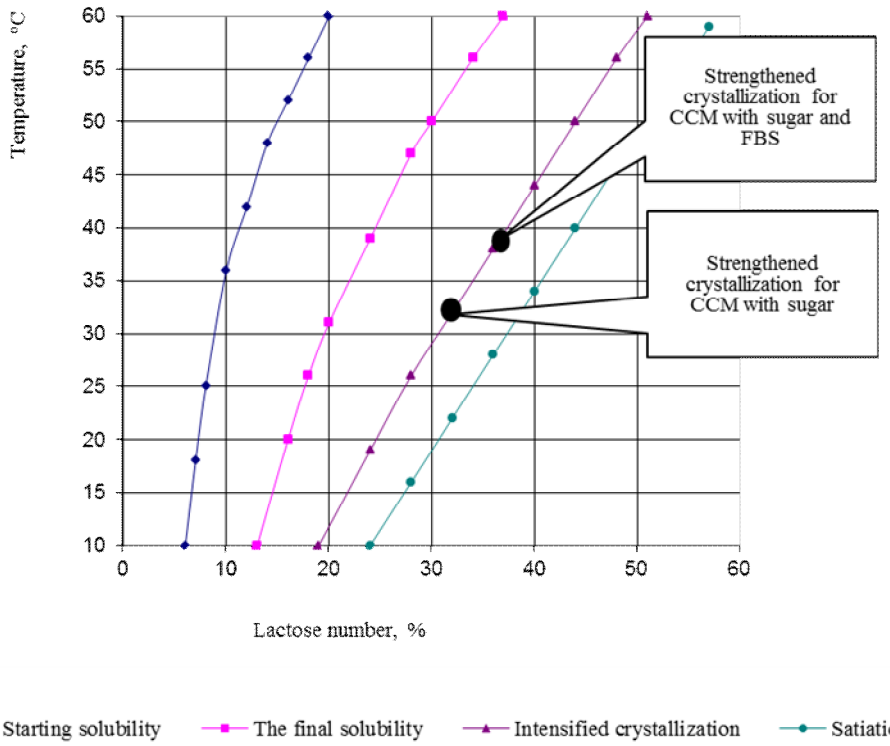


Fig.1. Temperature of lactose intensified crystallization in CCM with sugar and FBS on schedule of the Hudson

It was established "lactose number" for model samples:
- Condensed milk with sugar:

$$L_{l.n} = (100 \cdot 12.3) / (12.5 + 26) = 33.4\%$$

- Condensed milk with sugar and FBS "cranberry-blueberry":

$$L_{l.n} = (100 \cdot 12.3) / (8.59 + 22.5) \approx 39.5\%$$

- Condensed milk with sugar and FBS "rosehips-hawthorn ":

$$L_{l.n} = (100 \cdot 12.3) / (8.6 + 23) \approx 38.9\%$$

- Condensed milk with sugar and FBS "rosehips-echinacea-mint":

$$L_{l.n} = (100 \cdot 12.3) / (8.64 + 23) \approx 38.8\%$$

Via graph it was determined that intensified temperature of lactose crystallization for condensed canned milk with sugar and fruit-berry syrups should be 37...38 °C. while in the classic technology the temperature is 30...34 °C [6].
It was established that the adding of the seed at temperature treatment of 37...38 °C will allow a complete crystallization of lactose that will prevent the appearing of large crystals with size bigger than 15 microns.

3. Results and discussion

In order to ensure adequate crystal formation in the CCM with sugar and FBS further it was necessary to investigate the process of combining MSB cooled to a temperature of 20...22 °C with fruit-berry syrup. For this purpose based on software complex FlowVision. the mathematical model of combining milk and herbal products was constructed.
Since used higher FBS have similar rheological and physic-chemical characteristics. further studies performed on the example of CCM with sugar and FBS "cranberry blueberry." A mathematical model based on the dependencies described below [7. 8. 9]:
- Navier-Stokes equation:

$$\frac{\partial V}{\partial t} + \nabla(V \otimes V) = -\frac{\nabla P}{\rho} + \frac{1}{\rho}\nabla(\mu + \mu_t)$$

$$\left[\nabla V + (\nabla V)^T\right] + (1 - \frac{\rho_{hyd}}{\rho})g \qquad (2)$$

- Flow continuity equations

$$\nabla \mathbf{V} = 0; \qquad (3)$$

where V - the vector of relative velocity. *m/s*; t - time. s; P - relative pressure. *Pa*; ρ - density. kg/m^3; μ. μt - respectively dynamic and turbulent viscosity. *Pa·s*; ρ_{hyd} - hydrostatic density. *kg/m^3*; g - Vector force of gravity. *m / s^2*.
The model of raw materials movements is based on usage of k - ε turbulence model of the first circuit. within use of which for locking system it is required to get the formula for the coefficient of eddy viscosity μ_t.
Today for achieving of this goal the so-called two-parameter model is used most frequently. They are called two parameters since μ_t of these models is defined via two parameters. which are solved via additional differential equations in partial derivatives.
The equation for the turbulent viscosity has the form:

$$\mu_\tau = C_\mu \rho \frac{\kappa^2}{\varepsilon} \qquad (4)$$

Model also includes equations for the turbulent energy k and dissipation rate of turbulent energy ε:

$$\frac{d(\rho \mathrm{k})}{dt} + \nabla(\rho V \mathrm{k}) = \nabla\left[\left[\mu + \frac{\mu_\tau}{\sigma_k}\right]\nabla \mathrm{k}\right] + \mu_\tau G - \rho\varepsilon \qquad (5)$$

$$\frac{d(\rho\varepsilon)}{dt} + \nabla(\rho V \varepsilon) = \nabla\left[\left[\mu + \frac{\mu_\tau}{\sigma_\varepsilon}\right]\nabla\varepsilon\right] + \mu_\tau G - \rho\varepsilon + \qquad (6)$$

$$C_1 \frac{\varepsilon}{k}\mu_\tau G - C_2 \rho \frac{\varepsilon^2}{k}$$

where below mentioned expression is indicated by G:

$$G = D_{ij}\frac{dV_i}{dx_j};\ D_{ij} = S_{ij} - \frac{2}{3}\left[\nabla V + \frac{\rho\kappa}{\mu_\tau}\right]\delta_{ij};$$

$$S_{ij} = \frac{dV_i}{dx_j} + \frac{dV_j}{dx_i}$$

Where the value of the parameter is: σ_k=1; σ_ε=1.3; C_μ=0.09; C_1=1.44; C_2=1.92.

Transferring mixing components is solved via equation of convection - diffusion transfer:

$$\frac{dC}{d\tau} + \nabla(VC) = \frac{1}{\rho}\nabla\left[\left[\frac{\mu}{S_C} + \frac{\mu_\tau}{S_{C_\tau}}\right]\nabla C\right] \quad (7)$$

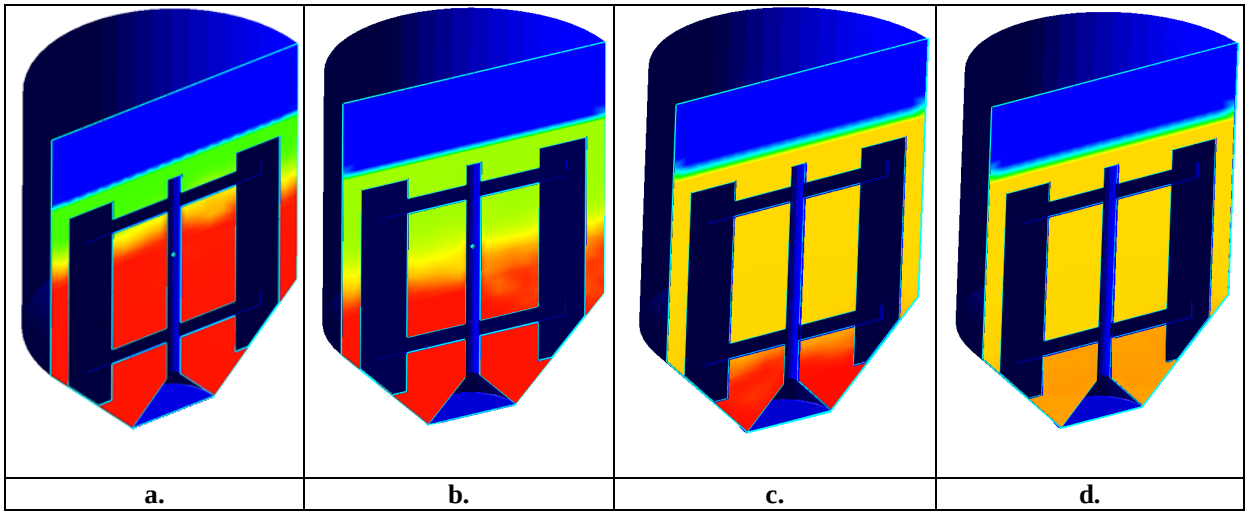
where C - concentration of the substance; Sc - Schmidt number.

The equation of transfer of filling function F has the form:

$$\frac{\partial F}{\partial t} + V\nabla F = 0. \quad (8)$$

Via usage of developed mathematical model combining of two environments "condensed milk-sugar base – fruit-berry syrup" comprehensive experimental and theoretical studies were done. As limiting (output) of data in real production conditions rheological properties were selected (density. viscosity. mass fraction of solids) and were chosen construction-technological parameters (volume. shape and design of the vacuum mold. the speed scraping like rotary body).

The results are presented in the form of field distribution uniformity consistency of milk- plant environment in a vacuum crystallizer Fig. 2.



a.	b.	c.	d.

Fig. 2. Change of homogeneity of milk-plant consistency of protection in time: a) 10 seconds; b) 150 seconds; a) 300 seconds; d) 700 seconds.

On figure 2 gradient filling of process combining milk-sugar base with fruit-berry syrup "cranberry-blueberry" is shown which allows to state the following: scraper agitator speed of 16 rev / min. provides a combination of two environments for 11.7 min to form a uniform consistency virtually all volume of vacuum crystallizer. Heterogeneity consistency was observed in a conical piece of equipment to which does not get scraper agitator. For leveling consistency

for the whole mass authors the process of creating CCM with sugar and FBS in time was studied. Analysis of Fig. 3 showed that the combination of milk-sugar and plant basis to form the final product in an amount of 99.17% lasts for 17 minutes. At the same time in classic technology for CCM with sugar and fillers (coffee. cocoa. chicory) a similar process lasts 20 minutes. 0.83% of the total weight accounted for inhomogeneous systems that are not available for mixing through the adhesive properties of CCM and designed features of vacuum crystallizer.

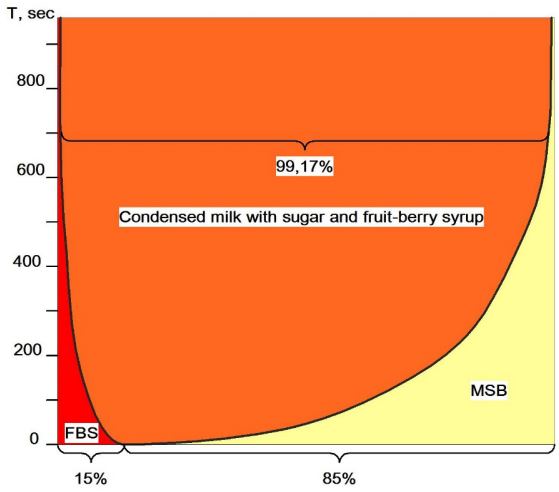


Fig. 3. The duration of the formation condensed milk with sugar and fruit-berry syrup "cranberry-blueberry" in a vacuum crystallizer

4. Conclusion

Summarizing the above mentioned information we can conclude that the adding of fruit-berry syrups to condensed canned milk promotes expansion of the range; increase biological value of products for vitamins and minerals; to savings of raw milk by 30%.

Correctly done processes of cooling and combining of MSB and FBS with simultaneous reduction of process time for 17 % ensures energy conservation for dairy industry enterprises.

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