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## PROBATION OF THE IMPROVED UNINTERRUPTED PASTEURIZATION SET “TUBE IN TUBE”

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### Abstract

There have been conducted probation studies of an improved uninterrupted pasteurization set “tube in tube” that allowed to provide modern market needs of consumers in getting high-quality food products that must undergo pasteurization stages at technological production. Heat delivery by FFREHRT is used in the set for providing heat flow distribution evenness. There has been established the optimal working space of processed raw materials by studying a temperature drop in the middle of the raw material flow and at the apparatus surface. At the width of the linear ring size of the working environment as 9.5 mm and the flow speed as

0.4 m/s there is provided the least temperature drop value as 0.7 °C. At decreasing the air gap width, the temperature drop value increases and at 5.5 mm is equal to 2 °C that favors the effectiveness decrease of the pasteurization process.

According to results of comparative indices of the main composition and obtained quality of pasteurized cow milk, just the experimental sample, obtained at the probation of the offered apparatus is advantageous, comparing with a traditional. It is explained by the decrease of milk temperature processing at the expanse of double pasteurization by FFREHRT, comparing with the traditional pasteurization method.

The conducted studies prove the effectiveness of constructive-technological solutions for realization of pasteurization in the set “tube in tube”: the use of two-side heating by FFREHRT that due to its technical parameters is able to take any geometric form of the working chamber and at that provides the necessary evenness of heat flow distribution. We must also note the improvement of exploitation parameters of the offered set, namely facilitation of the automatic control of temperature regulation and the absence of the steam coat and correspondent armature as in the traditional apparatus that decreases metal consumption essentially.

The obtained results are urgent for using the presented invention for pasteurization of different food raw materials (milk, juice, low-alcohol beverages and so on). The use of the improved pasteurizer allows to decrease resource consumption and to improve the quality of obtained products.

**Keywords:** pasteurization, milk, heat-mass exchanging processing, pasteurizer “tube in tube”, IR-radiation, electric heating, temperature distribution.

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## 1. Introduction

Development tendencies of farm enterprises and food industry of many European Union countries needs innovatively-grounded technical re-equipment of pasteurization sections for providing maximal preservation of initial properties of processed raw materials [1, 2]. Pasteurization of food raw materials (milk, low-alcohol beverages and so on) eliminates and prevents the development of an essential amount of undesirable microflora, thus at pasteurizing milk during 15...20 s at temperature 73...77 °C all pathogenic and undesirable microorganisms are eliminated with further cooling to 4...6 °C and storing no more 3 days [3, 4], providing consumption cooperation with high-quality food products of the natural origin with a substantiated value and storage term.

The aim of the work is to conduct probation studies of the improved uninterrupted pasteurization set “tube in tube” for determining a possibility of satisfying modern market needs of consumers in getting high-quality pasteurized food products. It conditions a need in improving the existing technological equipment, especially for conducting the effective uninterrupted pasteurization, based on implementing modern resource-effective engineer-technological solutions.

The resource effectiveness is provided by implementing modern heat-generating elements with effective parameters of energy and metal consumption that allow to repeat diverse geometric constructions of working surfaces of apparatuses and to provide the evenness of heat flows distribution. Just that is why for improving the uninterrupted pasteurization set, it was offered to use the flexible film resistive electric heater of the radiation type (FFREHRT) with IR-radiation diapason 1.5...5 mcm at working surface temperature 15...110 °C, repeatedly used effectively in the heat-mass exchanging equipment, as IR-radiator [5, 6]. At the same time the use of IR-radiation at pasteurization processes gives a possibility to intensify the technological process, to increase the quality of ready products, but only under conditions of correspondence of spectral characteristics of milk and radiator. This in its turn conditions the expedience of determining obtained quality indices of heat-mass exchanging processing for confirming the effectiveness of offered innovative solutions at improving the set “tube in tube”. The offered innovative construction-technological solutions allow to make high-quality food products at the expanse of the effective pasteurization process with maximal preservation of natural properties.

## 2. Problem review

A special feature of pasteurization process realization is one time short-term passage (5...40 s) of food raw materials under conditions of their heating within 63...98 °C that conditions a necessity of the substantiated selection of a resource-effective IR-radiator [7, 8]. It is substantiated by the technical-technological imperfection of pasteurization sets of uninterrupted effect, presented

at the market. Main defects may be considered as an essential energy and resource consumption, one-side heating of the working surface, use of auxiliary heat carriers and technical equipment for their working capacity [9]. All these factors result in uneven distribution of the heat flow, essential heat losses from the equipment to the external environment and unfortunately inevitable quality decrease of obtained products at the expense of their overheating and loss of initial properties, so the consumer's demand decrease, because their price doesn't correspond to their quality.

For solving these defects, at improving and technically re-equipping pasteurization sets "tube in tube", it is necessary not only to take into account calculating physical models, but also to implement modern resource-effective heat-generating devices [10, 11]. Their main peculiarity is guaranteeing of the distinctly stabilized even temperature influence under conditions of the increased surface of heat exchange at the synchronous decrease of metal and energy consumption of the pasteurization set in whole, conditioning the expedience of their improvement.

### 3. Materials and methods

The studies of the improved uninterrupted pasteurization set "tube in tube" were conducted on the base of the scientific-educational center "New biotechnologies and equipment for food products with high healthy properties" at Kharkiv state university of food and trade (Ukraine). The improved apparatus is designed for realizing heat-mass exchanging processes (pasteurization, cooling, heating) of food raw materials (milk raw materials, vine, juices, beer and so on) in the direct flow at thermal processing diapason 15...110 °C. The improved construction was probated under conditions of milk pasteurization, accepted by SSU 3662-97. «Unskimmed cow milk» (**Fig. 1**) [12].



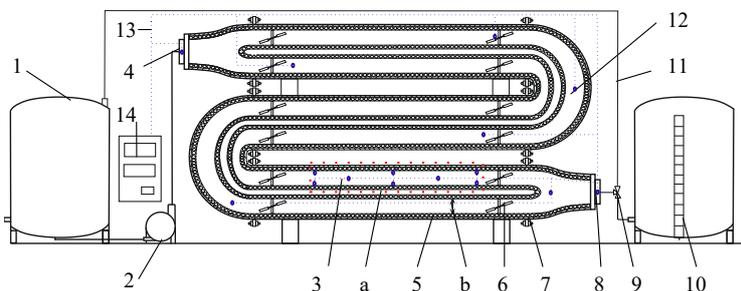
**Fig. 1.** Sample of the raw material – cow milk before pasteurization, acidity 16–17 T, temperature  $5 \pm 2$  °C (SSU 3662-97)

The studies of milk pasteurization with using an experimental model sample of the uninterrupted set "tube in tube" were conducted according to the scheme of the section stand, presented on **Fig. 2**.

Unskimmed cow milk is delivered from previous storage chamber 1 by pump-supplier 2 with delivery speed regulation to uninterrupted pasteurization set "tube in tube" 3. The set has entrance and exit sleeves of the raw material 4, 8, and pasteurization is realized at the expense of IR-radiation from flexible film resistive electric heater of the radiant type 5, placed at the internal and external surface of apparatus 3. FFREHRT provided the spectral length of IR-spectrum within 1.75...2.5 mcm that corresponds to effective properties of radiation absorption for milk (1.8...2 mcm). The improved set also has mixers-distributors 6 for mixing the volume of the raw material flow. The studies of milk pasteurization were conducted under conditions of the raw material flow width within 0.03...0.4 m/s with using standard calculating and experimental methods.

The temperature distribution by the working perimeter of the improved set "tube in tube" was realized using thermocouples 12, connected with operation block 14 by commutation nets 13, allowing to measure temperature by TRM in real time, a measuring error didn't exceed 0.5 °C. The additional determination of the raw material flow speed and volume of its pasteurization was realized under conditions of comparing raw material losses from previous storage chamber 1 and measuring cistern 10 for a certain period of time. Namely the duration of heating and pasteurization

of drinking milk at temperature 73...77 °C and keeping 15...20 s, is 27.5 s, comparing with the traditional processing in the basic set with only external heating as 50 s.



**Fig. 2.** The scheme of the stand section of milk pasteurization with using an experimental model sample of the uninterrupted set “tube in tube”: 1 – chamber of previous storage of unskimmed cow milk; 2 – pump for milk delivery; 3 – set “tube in tube”; 4, 8 – entrance and exit sleeves of the raw material; 5 – flexible film resistive electric heater of the radiant type (FFREHRT); 6 – mixer-distributor of the milk flow; 7 – bolt flange fixers; 9 – three-running valve; 10 – cistern-measurer of the pasteurized raw material; 11 – net of the pipeline for returning the non-pasteurized raw material; 12 – thermocouples; 13 – net of technical maintenance of thermocouples (communication); 14 – operation block; a – section of studying the temperature drop; b – linear ring size (diameter) of the intertube space

Milk that didn’t correspond to the pasteurization temperature regime (lower 80 °C) was returned to previous storage chamber 1 by the three-running valve by the pipeline net for repeated pasteurization. The main condition for the high-quality process of cow milk pasteurization is the observance of SSU 2661:2010 «Drinking cow milk» requirements [13]

The influence of pasteurization on the obtained quality and correspondence to SSU 2661:2010 was assessed by estimating organoleptic and physical-chemical parameters of milk experimental samples before and after the improved set “tube in tube” by the conventional methods.

#### 4. Experimental procedures

At the probation of the improved uninterrupted pasteurization set, the comparative indices of the main composition and obtained quality of pasteurized cow milk were obtained (**Table 1**).

**Table 1**

The comparative indices of the main composition and obtained quality of pasteurized cow milk by the traditional and improved methods

Parameter	Unskimmed cow milk (SSU 3662-97)	Milk pasteurization by the traditional method	Milk pasteurization in the improved set “tube in tube”
		SSU 2661:2010	
Fat content, %	3.2	3.2	3.2
General outlook		Homogenous liquid without a taste	
Color		From white to light yellow	
Taste and smell	Pure, inherent to natural unskimmed milk	Pure with expressed pasteurization	Pure with light expressed pasteurization
Density, g/cm <sup>3</sup>		1,027	
Total protein, %		2.8	
Storage term, hour	25	38	38
Generalized number of bacteria in 1 g	4.3·10 <sup>5</sup>	2.5·10 <sup>5</sup>	1.8·10 <sup>5</sup>
Residual microflora of pasteurized milk, %	–	0.08	0,0345
Pasteurization effectiveness, %	–	99.9	99.98

The chemical composition of pasteurized milk was also studied; the results are presented in **Table 2**.

**Table 2**

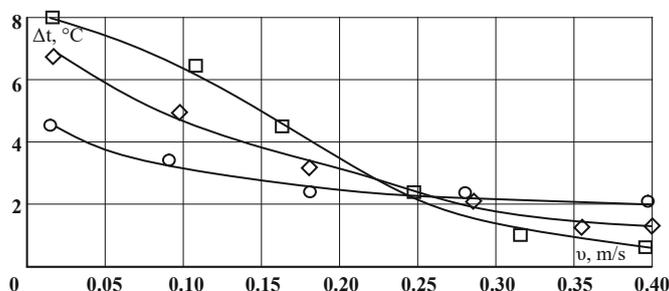
The indices of the pasteurized milk chemical composition

Method of milk processing	Characteristic of milk quality									
	Unskimmed cow milk (SSU 3662-97)					Pasteurized milk SSU 2661:2010				
	Albumin, globulin, %	Vitamin				Albumin, globulin, %	Vitamin			
	A, mg/l	E, mg/l	B <sub>6</sub> , mg/l	C, mg/l	A, mg/l	E, mg/l	B <sub>6</sub> , mg/l	C, mg/l		
Milk pasteurization by the traditional method	0.54	0,152	1.8	0.76	14.5	0.31	0.14	1.04	0.5	12.0
Milk pasteurization in the improved set “tube in tube”	0.54	0,152	1.8	0.76	14.5	0.53	0.16	1.58	0.76	14.2

The analysis of the obtained indices of the main composition, obtained quality and chemical composition of pasteurized cow milk (**Tables 1, 2**) confirm the effectiveness of using the improved set “tube in tube”, offered for probation. Thus, the index of vitamin C in pasteurized milk at the improved method is 1.18 times more, comparing with the traditional one. The analysis of the obtained results (**Tables 1, 2**) confirms maximal preservation of natural properties of the initial raw material, so the competitiveness of obtained products.

### 5. Results

Under conditions of the two-side influence of IR-radiation from FFREHRT in the set “tube in tube” an unalienable component is determination of its optimal parameters, especially the linear ring size (diameter) of the intertube space (**Fig. 2, pos. b**) depending on the change of the raw material speed flow (**Fig. 3**).



**Fig. 3.** Dependence of the temperature drop at milk pasteurization in the set “tube in tube” at linear ring size (diameter) of the intertube space of the working environment:  
 ○ – 5.5 mm; ◇ – 7.5 mm; □ – 9.5 mm

The mean temperature indices of milk at the temperature drop research section were determined (**Fig. 2, pos. a**) under conditions of placing the thermocouples at the internal and external surfaces of the pasteurization set and in the middle of the ring space. The temperature drop, at air gap width 9.5 mm was established as 0.7 °C, and at width 5.5 mm – 2 °C, respectively.

### 6. Discussion of the probation results of the improved uninterrupted pasteurization set “tube in tube”

The conducted probation of the improved uninterrupted pasteurization set “tube in tube” confirms the effectiveness of previously offered constructive-technological solutions. The use of heat delivery by FFREHRT provides the evenness of heat flow distribution that is proved experimentally. The optimal working space of the processed raw material is established by studying the

temperature drop within the raw material flow and on the apparatus surface. At the width of the linear ring space of the intertube working environment as 9.5 mm and flow speed as 0.4 m/s, the least value of the temperature drop in the raw material as 0.7 °C is provided. At decreasing the linear space width, the temperature drop index increases and at value 5.5 mm is equal to 2 °C that favors the decrease of the pasteurization process effectiveness.

According to results of comparative indices of the main composition and the obtained quality of pasteurized cow milk, just the experimental sample, obtained at probation of the offered apparatus is advantageous, comparing with a traditional. It is explained by the decrease of milk temperature processing at the expense of double pasteurization by FFREhRT, comparing with the traditional pasteurization method (50 s).

The conducted studies prove the effectiveness of constructive-technological solutions for realization of pasteurization in the set “tube in tube”: the use of two-side heating by FFREHRT that due to its technical parameters is able to take any geometric form of the working chamber and at that provides the necessary evenness of heat flow distribution. We must also note the improvement of exploitation parameters of the offered set, namely facilitation of the automatic control of temperature regulation and the absence of the steam coat and correspondent armature as in the traditional apparatus that decreases metal consumption essentially.

The obtained results are urgent for using the presented invention for pasteurization of different food raw materials (milk, juice, low-alcohol beverages and so on) that allows to conduct the effective thermal processing and to eliminate the essential amount of microflora, undesirable for the human organism.

The improved pasteurization method is characterized by the increase of heat consumption for heating the apparatus that is 1372.8 kJ, comparing with ones in the basic pasteurizer – 8448 kJ at the synchronous increase of quality indices of obtained products, confirming the prospect of implementing obtained pasteurized products at the Ukrainian market and abroad under conditions of introducing modern marketing solutions and increasing the economic efficiency of such implementation in particular.

## 7. Conclusions

The influence of the raw material flow speed depending on the diameter change of the working pasteurization space on the evenness of thermal flow distribution under conditions of its two-side heating by FFREHRT has been confirmed. It has been established, that at the flow speed up to 0.4 m/s the heating evenness is 0.7 °C at the width of the linear ring space of the pasteurized environment as 9.5 mm, and at width 5.5 mm – 2 °C respectively.

The analysis of the obtained experimental-comparative data testifies to the high-quality pasteurization processing in the improved uninterrupted set “tube in tube”, explained by two-side processing (Tables 1, 2), comparing with the traditional pasteurization way. Milk pasteurization in the improved set “tube in tube” eliminates 99.98 % of microorganisms, comparing with properties of unskimmed milk by SSU 3662-97. The storage term of pasteurized milk is 38 hours at temperature 2...3 °C.

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## PROSPECTS OF USING SPINACH IN PRODUCTION TECHNOLOGY OF CHAPATTI OF WHOLEGRAIN FLOUR

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### Abstract

It is urgent to enrich floury products with vegetable magnesium sources. One of such plants is garden spinach – one-year plant, a representative of *Spinacia* genus. For this aim, there were studied functional-technological properties of wholegrain flour for substantiating preparation in the chapatti technology.

Research results demonstrated that barley flour had the most water-absorbing capacity – 400 %, this parameter was almost twice less in rice and wheat flour. The most fat-retaining capacity was inherent to barley flour – 87 %, whereas in the control (highest sort wheat flour) this index was 25 %.