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Original scientific paper

THE INFLUENCE OF PHYSICAL METHODS OF VEGETABLES PROCESSING ON THE QUALITY OF FROZEN PRODUCTS

Natalia S. Shishkina, Olga V. Karastoyanova, Lidya A. Borchenkova, Nadezhda V. Korovkina, Natalia I. Fedyanina*

All-Russian Scientific Research Institute of Technology of Preservation — Branch of the V.M. Gorbatov Federal Research Center for Food Systems of Russian Academy of Sciences, Vidnoe, Moscow Region, Russia

KEY WORDS:
microwave field, physical methods, vegetable semi-finished products, microbiological contamination, bound moisture, moisture holding capacity, loosely bound moisture, quality indicators

ABSTRACT
The indicators of quality and microbiological safety of frozen vegetable semi-finished products (for example, cut beet) processed in a microwave field for subsequent storage for 18 months at a temperature of minus 20±2 °C. Treatment with a microwave field was carried out under the following conditions: power 600 W and duration 5 min (180 kJ); power 1000 W and duration 4 min (240 kJ). It is established that treatment in the microwave field contributes to the preservation of consumer qualities of the product (total solids content, mass fraction of soluble solids, bound moisture content, microbiological effect) in the process of long-term low-temperature storage.

1. Introduction

Modern requirements to the optimization of the population nutrition system set the task of maximum preservation of the quality and composition of food products from plant raw materials rich in vitamins, minerals and biologically active substances for a long shelf life (12–24 months).

The blanching is a necessary step in the preparation of many types of vegetables for drying, frying and canning and freezing [1,2,3].

The blanching is a technological operation of short-term heat treatment of fruits, vegetables and mushrooms at a certain temperature in water or in aqueous solutions for inactivation of enzymes, changes in tissue structure [1].

In the process of heat treatment of plant raw materials by the blanching depending on the final method of preservation of products is provided:

- enzyme inactivation [4];
- coagulation of proteins;
- increase in the mass fraction of soluble pectin due to thermal hydrolysis of protopectin;
- reduction of microbial contamination;
- removal of air from the intercellular spaces of raw materials [5,6,7,8,9].

Blanching is subjected to potatoes, beets, carrots, the number of leafy vegetables (cauliflower cabbage, white cabbage, broccoli, spinach, sorrel), green peas, green beans, corn (grains, ears) and a number of fruits (apples) [10,11].

In the article [12], the authors point out the existence of a wide range of new modern blanching technologies with higher energy efficiency, less environmental impact and less loss of nutrients, including the treatment of hot air with high humidity, ohmic heating and infrared radiation and their combinations with hot air blanching, etc.

The variety of directional influence of physical methods of treatment consider, as part of the optimization of the technology of food production, including frozen vegetable foods, microwave processing instead of the step of blanching to increase the microbiological safety, preserve quality and extend shelf life.

Microwave field processing is characterized by volumetric heating of raw materials with a relatively high rate, bactericidal action, low energy consumption of processing and the absence of contact of the processed raw materials with the coolant [5,6,13].

In studies comparing the effects of asparagus treatment with microwave field and steam and hot water blanching [14], there was no significant difference in the texture and content of routine, higher antioxidant activity and better preservation of green color were also provided.

It is known that processing of microwave field leads to a 4–5 fold reduction of *Salmonella typhimurium* contamination of fresh jalapeño peppers and coriander foliage [15]; to softening the texture of slices of carrot, sweet potato [16]; to the maintenance of high organoleptic characteristics (aroma, taste, texture) and general indicators of quality of peas [17]; and the best preservation of the color, index, brightness and vitamin C in artichokes [18].

One of the important organoleptic characteristics is color. Therefore, for better preservation of coloring substances of dark-colored raw materials, including beets, the most appropriate is the use of microwave field treatment instead of blanching step in preparation for freezing.

Beet is a source of useful macro-and microelements, vitamins (F, C and group B, flavonoids), natural antioxidants, contains magnesium, iron, calcium, zinc, potassium and other vital substances to the human body, strengthens immunity, cleanses the body, effectively removes excess cholesterol, slags, toxins, heavy metals and other harmful substances [13].

Analysis of literature sources [19,20,21] showed that the optimum processing of fresh vegetables in the microwave field is in the range of capacities from 100 to 1800 W and duration from 1.5 to 5 minutes.

2. Materials and methods.

Standard and conventional physical and chemical research methods were used for the experiments.

As the test objects used semi-finished products of beet varieties, «Gaspadinya» and «Tenderness» after 1 and 18 months of storage at minus 20±2 °C after thawing. Semi-finished products [5] were cut beet cubes 10x10x10 mm in size, which were blanched in boiling water for 20 minutes (Option 1), as well as treated with a microwave field with a power of 600 W and a duration of 5 min (Option 2) and a power of 1000 W for 4 minutes (Option 3), followed by freezing them at minus 20±2 °C. Characteristics of microwave-installation:

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magnetron — OM75P, the operating frequency of the magnetron is 2450 MHz, output power 100 watts/1000 watts. Before freezing, the semi-finished products were packed in a polymer film RA/PE in a ratio 20:80, 80 microns thick, density 0.0143 g/cm^3, vapor permeability of H_2O 19 g/m^2/24 h, at 1 ATM and t=23 °C.

Microbiological parameters were determined by the residual concentration of mesophilic aerobic and facultative anaerobic microorganisms, fungi and yeasts, bacteria of *Enterobacteriaceae* family in 1 gram of the studied objects [22,23,24].

In the course of research the following physical and chemical parameters were determined: the mass fraction of soluble solids — by refractometric method [25]; the total dry matter content — by thermogravimetric method [26]; the mass fraction of bound moisture characterizing the moisture holding capacity of the products was determined by the press method of Grau and Hamma with subsequent determination of loosely bound moisture by weight method [27, 28].

Mass fraction of bound moisture X,% was calculated by the formula:

$$X = \left[\frac{m - m_1}{m}\right] \times 100 \qquad (1)$$

where

m is the total mass of moisture in the object, g, determined by the standard thermogravimetric method;

m1 — mass of loosely bound moisture released after pressing, g, determined by weight method.

All studies were conducted in 3 — fold repetition.

3. Results and discussion

As a result of the research, experimental data on the determination of the mass fraction of loosely bound and bound moisture in thawed samples of frozen beet (Table. 1), as well as data on the measurement of the mass fraction of total solids and soluble solids (Table. 2).

Table 1

Mass fraction of loosely bound and bound moisture in thawed samples of semi-finished beet after 18 months of storage

Beet variety	Treatment option	Mass fraction of loosely bound moisture, %	Mass fraction of bound moisture, %
Gaspadinya	Option 1	54.0±0.28	42.5±0.35
	Option 2	67.5±0.31	60.31±0.28
	Option 3	68.0±0.27	56.54±0.24
Tenderness	Option 1	51.0±0.33	34.93±0.38
	Option 2	67.0±0.25	57.28±0.27
	Option 3	67.75±0.18	58.86±0.22

Table 2

Mass fraction of total and soluble solids in thawed samples of semi-finished beet after 18 months of storage

Beet variety	Treatment option	Mass fraction of total solids, %	Mass fraction of soluble solids, Brics
Gaspadinya	Source	17.5±0.5	16.5±0.37
Tenderness		13.5±0.5	13.3±0.4
Gaspadinya	Option 1	20.3±0.18	21.1±0.41
	Option 2	24.36±0.26	23.1±0.44
	Option 3	22.75±0.15	21.8±0.4
Tenderness	Option 1	18.11±0.21	19.8±0.34
	Option 2	24.7±0.25	19.53±0.32
	Option 3	22.84±0.18	21.3±0.35

The values of the mass fraction of soluble solids in the studied samples of semi-finished frozen beets, depending on the method of blanching and shelf life are shown in Figure 1.

The results of the study of the concentration of microorganisms on the surface of the samples after treatment with a microwave field (options 2 and 3) and blanching (option 1) are presented in Table. 3.

Table 3

Concentration of microorganisms on the surface of thawed semi-finished beet

Beet variety	Treatment option	The number of QMAFAnM, CFU in 1 g of product	Number of fungi, CFU in 1 g of product	Amount of yeast, CFU in 1 g of product
Gaspadinya	Source*	$2.0 \cdot 10^3$	$2.0 \cdot 10^2$	Less 1
Tenderness		$1.5 \cdot 10^3$	$3.0 \cdot 10^2$	Less 1
1 month storage				
Gaspadinya	Option 1	$1.0 \cdot 10^2$	Less 1	Less 1
	Option 2	Less 1	Less 1	Less 1
	Option 3	Less 1	Less 1	Less 1
Tenderness	Option 1	$1.0 \cdot 10^2$	Less 1	Less 1
	Option 2	Less 1	Less 1	Less 1
	Option 3	Less 1	Less 1	Less 1
18 months storage				
Gaspadinya	Option 1	$2.8 \cdot 10^2$**	Less 1	Less 1
	Option 2	$2.2 \cdot 10^1$	Less 1	Less 1
	Option 3	$3.0 \cdot 10^1$	Less 1	Less 1
Tenderness	Option 1	$8.4 \cdot 10^2$	Less 1	Less 1
	Option 2	$6.0 \cdot 10^1$	Less 1	Less 1
	Option 3	$5.0 \cdot 10^1$	Less 1	Less 1

* Source — the cubes of beets to heat treatment.

** In accordance with TR CU021/2011 On food safety, the permissible level of the number of mesophilic aerobic and facultative anaerobic microorganisms (QMAFAnM) is not more than $1 \cdot 10^4$ CFU/g (cm^3)

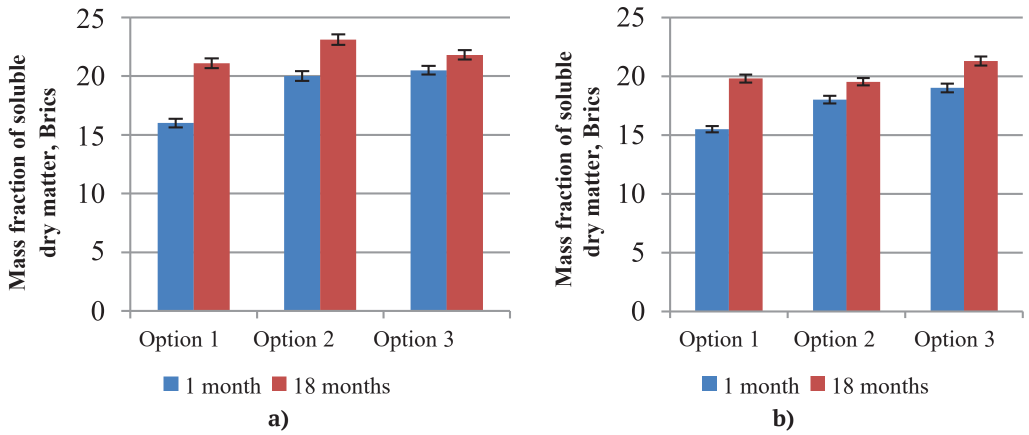

Figure 1. The change of the mass fraction of soluble solids in the samples of semi-frozen beet; a) the sort of «Gaspadinya», b) the sort of «Tenderness»

The results obtained for the measurement of the mass fraction of total solids and bound moisture (Table. 2) show an increase in the mass fraction of total solids by 13–36%.

Mass fraction of bound moisture (Table. 1) in beet samples after treatment with microwave field (options 2 and 3) higher by 33–68% compared with samples blanched in boiling water (option 1). Since the value of bound moisture characterizes the degree of change in the structure of the product by the ability of its tissues to retain moisture during defrosting, the increase in the mass fraction of bound moisture during defrosting of frozen semi-finished products treated with a microwave field indicates their higher water-holding capacity. Thawed semi-finished products with higher values of bound moisture are characterized by a higher degree of preservation of the quality of the original products during long-term storage. The decrease in water retention capacity in samples blanched in boiling water indicates a higher degree of washout of beet tissue components in the blanching process.

The obtained experimental data also showed differences in the change in the mass fraction of soluble solids in the samples under study during storage (Fig. 1). From the data obtained, it is clear that the use of microwave processing contributes to the preservation of a higher content of soluble solids in the raw material within the measurement error in comparison with samples blanched in boiling water.

In a closed storage system in the absence of metabolic processes takes place the following material balance:

$$\omega_1\gamma_1 = \omega_2\gamma_2, \qquad (2)$$

where

ω_1 is the mass fraction of soluble solids after 1 month of storage, BRICs;
ω_2 — mass fraction of soluble solids after 18 months of storage, BRICs;
γ_1 — mass fraction of moisture after 1 month of storage, %;
γ_2 — mass fraction of moisture after 18 months of storage, %;

Therefore, the relative residual moisture loss after 18 months of storage relative to the mass fraction of soluble solids after 1 month of storage can be determined as follows:

$$\frac{\gamma_2}{\gamma_1} = \frac{\omega_1}{\omega_2} \Rightarrow \dot{\gamma} = \left[1 - \frac{\gamma_2}{\gamma_1}\right] \cdot 100\% = \left[1 - \frac{\omega_1}{\omega_2}\right] \cdot 100\%, \qquad (3)$$

where

γ is the relative moisture loss, %;
100 — conversion factor in %.

The results of determining the relative moisture loss for the studied beet samples are shown in Fig. 2.

From Fig. 2 it follows that the optimum treatment for the selected varieties is different and is:

- for the sorts of « Tenderness» power of 600 W and a duration of 5 min.;
- for variety «Gaspadinya» power 1000 W and a duration of 4 min.

This conclusion is in good agreement with the results of measurements of the mass fraction of bound moisture, showing the advantages of treatment in the microwave field, compared with blanching in boiling water.

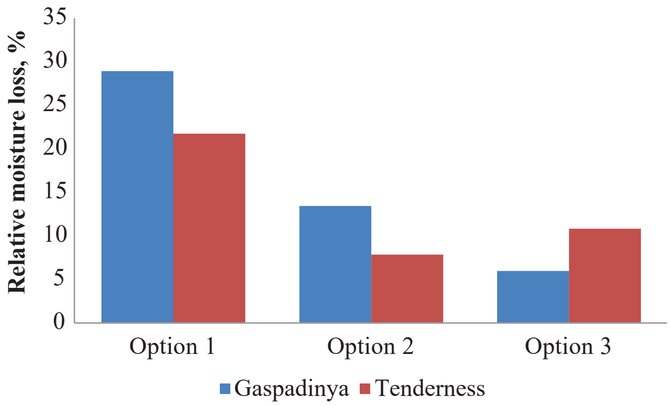

Figure 2. Change of moisture loss in samples of semi-finished frozen beets

Analysis of the results obtained by measuring the concentration of microorganisms on the surface of thawed semi-finished beet (Table. 2) shows noticeable bactericidal effect both after microwave treatment and after blanching. At the same time, in terms of QMAFAnM in samples treated in a microwave field, it was possible to achieve a stable decrease in microbiological contamination by 2 orders of magnitude, compared with the initial samples, and by 1–1.5 orders of magnitude compared with samples blanched in boiling water. The results suggest the validity of the use of microwave field to achieve a bactericidal effect and ensure the storage capacity of frozen semi-finished beet.

When comparing organoleptic quality indicators (color and density of tissues) of thawed semi-finished beet products after 18 months of low-temperature storage, samples treated in a microwave field retained higher values of these indicators compared to samples blanched in boiling water.

4. Conclusion

The obtained results demonstrated the effectiveness of application of microwave field for processing of semi-finished products of beet varieties, «Tenderness» and «Gaspadinya» before freezing and storing. The reduction of microbiological contamination of semi-finished products, the level of which is preserved in the process of low-temperature storage, is achieved. An increase in water-holding capacity was achieved, which provided a better texture of tissues of thawed beet samples treated in a microwave field after long-term low-temperature storage.

Processing of vegetable raw materials and vegetable semi-finished products by this physical method can be considered as an alternative to the blanching process in boiling water.

To determine the optimal conditions for the use of the microwave field as a technological mode of processing vegetables, ensuring the preservation of quality and nutritional value in the process of long-term low-temperature storage, it is necessary to conduct further comprehensive studies.

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AUTHOR INFORMATION

Natalia S. Shishkina — candidate of biological sciences, academician of the International Academy of Refrigeration, leading researcher, Laboratory of canning technology, All-Russian Scientific Research Institute of Technology of Preservation — Branch of the V.M. Gorbatov Federal Research Center for Food Systems of RAS, 142703, Moscow region, Vidnoye, School str, 78, Tel.: +7–495–668–70–31, e-mail: vnikopholod@yandex.ru

Olga V. Karastoyanova — senior researcher, Laboratory of canning technology, All-Russian Scientific Research Institute of Technology of Preservation — Branch of the V.M. Gorbatov Federal Research Center for Food Systems of RAS, 142703, Moscow region, Vidnoye, School str, 78, Tel.: +7–495–668–70–31, e-mail: vnikopholod@yandex.ru

Lidya A. Borchenkova — senior researcher, Laboratory of processes and equipment canning production, All-Russian Scientific Research Institute of Technology of Preservation — Branch of the V.M. Gorbatov Federal Research Center for Food Systems of RAS, 142703, Moscow region, Vidnoye, School str, 78, Tel.: +7–495–668–70–31, e-mail: borchenkova@rambler.ru

Nadezhda V. Korovkina — junior researcher, Laboratory of canning technology, All-Russian Scientific Research Institute of Technology of Preservation — Branch of the V.M. Gorbatov Federal Research Center for Food Systems of RAS, 142703, Moscow region, Vidnoye, School str, 78, Tel.: +7–495–668–70–31, e-mail:, e-mail: vnikopholod@yandex.ru

Natalia I. Fedyanina — graduate student, senior researcher, Laboratory of canning technology, All-Russian Scientific Research Institute of Technology of Preservation — Branch of the V.M. Gorbatov Federal Research Center for Food Systems of RAS, 142703, Moscow region, Vidnoye, School str, 78, Tel.: +7–495–668–70–31, e-mail: vnikopholod@yandex.ru
* corresponding author

Authors are equally relevant to the writing of the manuscript, and equally responsible for plagiarism

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