Запропоновано та розроблено метод глибокої переробки каротинвмісних овочів – альтернативний кріогенній обробці. Метод заснований на комплексній дії на сировину паротермічної обробки та дрібнодисперсного подрібнення з використанням нового покоління обладнання, яке застосовується на підприємствах ресторанного бізнесу. Новий метод дозволяє більш повно використати біологічний потенціал сировини (у 2…3 рази більше) і отримати харчові продукти в нанoформі

Ключові слова: глибока переробка, каротиновмісні овочі, паротермічна обробка, дрібнодисперсне подрібнення, пароконвекційна піч, продукти у нанoформі

Предложен и разработан метод глубокой переработки каротинсодержащих овощей – альтернативный криогенной обработке. Метод основан на комплексном воздействии на сырье паротермической обработки и мелкодисперсного измельчения с использованием нового поколения оборудования, применяемого на предприятиях ресторанного бизнеса. Новый метод позволяет более полно использовать биологический потенциал (в 2…3 раза больше) и получить пищевые продукты в наноформе

Ключевые слова: глубокая переработка, каротинсодержащие овощи, паротермическая обработка, мелкодисперсное измельчение, пароконвекционная печь, продукты в наноформе

UDC 621.59: 613.229:547.455.65
DOI: 10.15587/1729-4061.2016.76232

DEEP PROCESSING OF CAROTENE-CONTAINING VEGETABLES AND OBTAINING NANOFOOD WITH THE USE OF EQUIPMENT OF NEW GENERATION

R. Pavlyuk
Doctor of Technical Sciences, Professor,
The State Prize laureate of Ukraine,
Honored figure of Science and Technology in Ukraine*
E-mail: ktppom@ukr.net
V. Pogarskaya
Doctor of Technical Sciences, Professor,
The State Prize laureate of Ukraine*
E-mail: viktoria.pogarskaya@ukr.net
L. Radchenko
PhD, Professor, Director
Kharkiv Trade-Economic Colledge of
Kyiv National University of Trade and Economics
Klochkivskaya str., 202, Kharkiv, Ukraine, 61045
E-mail: kharkiv@htek.com.ua
R. Tauber
Doctor of Pedagogical Sciences, Professor, Rector
Academy of Hospitality and Catering in the Poznan
Nieszawska str., 19, Poznan, Poland, 61-022
E-mail: wshigua@i.ua
N. Timofeeva*
E-mail: kdp2010@yandex.ua
*Department of Technology Processing of
Fruits, Vegetables and Milk
Kharkiv State University of Food Technology and Trade
Klochkivska str., 333, Kharkiv, Ukraine, 61051

1. Introduction

Today a global problem in international practice in a large number of countries is the shortage of vitamins, carotene, mineral substances, proteins and other biologically active substances (BAS) in the food diet. The need of the Ukrainian population in them is satisfied by 50 % [1–3]. There is also imbalance of the food diet: shortage of milk, fish, meat, fruits and berries, i.e., those products that provide for health improvement of the population of Ukraine. It is also known that 50 % of the Earth's population is starving. In this regard, there are many programs in many countries of the world, according to which industrial manufacturing of many synthetic foodstuffs (in particular, milk, meat, vegetables, flour, cereals, etc.) are created and implemented already [4]. They are almost indistinguishable from natural products in the physical appearance and taste but they are harmful to the human body that practically does not assimilate them. This is because humans do not have enzymes that could facilitate their absorption, and they are difficult to dispose of while being deposited in the form of allergens, which leads to various pathological shifts in the human body and different diseases [4]. In addition, deterioration of ecological situation and the reduction of immunity in the population of the entire Earth are observed [5–7].

With regard to it, functional health improving foods (especially from fruits and vegetables), which are aimed at strengthening health, enjoy growing popularity in many countries of the world. Today this problem is given a lot of attention in the works of scientists. This is one of the most important and relevant scientific areas that is rapidly developing in international practice. Particularly relevant and promising direction of obtaining health improving food products is the use of carotene-containing vegetables (par-

ticularly, carrots, pumpkin, tomatoes, sweet Bulgarian pepper, etc.) for their manufacturing. They are largely different from other vegetable raw materials in high content of biologically active substances, in particular, carotenoids, L-ascorbic acid, phenolic compounds with P-vitamin and antioxidant activity (rutin, catechins, coumaric acids, etc.), polyphenolic tannins that have immunomodulating antioxidant detoxic and antitumor effect [5, 8–10]. These vegetables are very popular among the population of different countries of the world (especially in Japan, USA, Germany and others). It is known that unsaturated conjugated carotenoid compounds possess antitumor, antiradiation effect and significantly increase protective forces of the human body, especially in combination with ascorbic acid and phenolic compounds, which are contained in large amounts in carrots and pumpkin, and is the source of carotene, traditional for Ukraine [8, 9, 11].

According to the latest scientific research data, which were obtained in international practice in the field of molecular biology by outstanding scientists-vitaminologists Klaus Oberbeil (Germany), Martin Prince, John Frizoli (USA) and others, it was found that consumption of natural carotenoids in foods with their high content is reliable protection of the human body from cancer and other diseases [12]. Carotenes also protect cells of the human body from pathogens and quench free oxidative radicals, which try to oxidize, i. e., to burn unprotected parts of the cells. It is also shown that, along with vitamin A, carotenes in our immune system fight viruses, bacteria and other pathogens, support youth and health of our bodies, prevent aging, improve visual acuity, make skin smooth and elastic.

The Nobel Award winner George Whipple (USA) discovered rejuvenating detoxic effect on the human body from regular consumption by people of plant foods, high in carotene. The author compares the impact of such carotenoid products on the human body to the functioning of the liver that is a filtering organ of the body [12]. According to the author, there is only one possibility in order to be healthy – regular consumption of the food, enriched with carotene.

It is known that carrot and pumpkin are very popular among the population of Ukraine. They use them both in the individual and mass catering of the population, as well as in restaurants, supermarkets and at large enterprises in the manufacturing of various canned foods (juices, purees, sauces, side dishes, toppings, frozen mixtures, etc.). Traditional ways of their processing lead to significant losses of carotenoids and other BAS (from 20 to 80 %) [5, 6, 11].

The difficulties in processing and consumption of carotene-containing vegetables, according to the authors, are linked to the fact that considerable part of the carotene molecules (for example, in carrot) are tightly packed in plant fibers-nanocomplexes or nano associates of heteropolysaccharides and protein and are difficult to extract to the soluble phase while processing the raw materials, as well as in human stomach. Data analysis of periodic scientific and technical literature on processing carotene-containing vegetables and production of food products made of them is mainly devoted to organoleptic, physical-chemical and rheological characteristics of the obtained products. As for carotenoids of raw materials and their transformation, the information on this sibject is very limited and it is contradictory in nature [8, 9, 11]. It is known that the most efficient equipment in the technology of food manufacturing from carotene-containing raw materials is the use of modern equipment – steam convection furnaces and various crushers. But we have not found deep fundamental studies in this direction [3, 4, 6].

2. Literature review and problem statement

It is known that the thermal treatment of vegetables is one of the main technological methods used in the production of culinary products when processing fruits and vegetables to different types of foods and semi-finished foods, including in steam convection furnaces. Thermal treatment is conducted with the purpose of inactivation of oxidative enzymes, reduction in the amount of vegetative and spore forms of microorganisms, increasing cell permeability, improving the texture of the product, softening the tissue of vegetable raw materials, reducing its volume, providing product with specific organoleptic properties and taste.

In the process of thermal treatment, changes in structural and mechanical, physical-chemical, biochemical, chemical, microbiological and organoleptic properties of raw materials occur, as well as changes in nutritional and biological value [1, 2].

Traditional ways of thermal treatment of vegetable raw materials are blanching, cooking, roasting, warming up and sautéing. At the processing and canning enterprises, as well as in restaurant business, different types of devices are used for this purpose: blanchers, cooking boilers, vacuum units, etc.

It is also known that when using traditional equipment during thermal treatment of fruits and vegetables, a significant amount of vitamins and other biologically active substances is lost (from 20 to 80 %) [3, 4]. Traditional thermal culinary treatment is accompanied by a significant loss in the mass of semi-finished and finished products [13]. One of the advanced ways of solving this problem is thermal treatment of vegetables in a combi steamer, in the same working chamber of which, when using steam and circulating air, there is a capacity to apply different methods of thermal treatment to raw materials [13].

Analysis of periodical literature over the past 10 years has shown that it is relevant to search for technological methods and to design a new generation of equipment that makes it possible to preserve biological potential of food raw materials [6, 7]. At present, at public catering enterprises, particularly, in restaurant business, a new generation of modern thermal equipment is gaining traction and is widely used – steam convection ovens that provide for the possibility of combining three processes in a single device – cooking, frying and steam cooking. The known benefits of thermal treatment in steam convection furnaces are that due to the design features of the unit, adjusting the intensity of steam supply and the steam flow temperature, as well as pressure in the middle of the chamber, the product is evenly heated and the process of boiling occurs at temperature of 70 °C. This provides high quality of the product and significant reduction in the time of making the product [14–16].

It was found by analyzing the data of scientific literature over the last 10 years that the works of the majority of scientists are devoted to the study of influence of the modes of steam and thermal treatment in steam convection furnaces on the quality of various foods (baked goods, culinary products made of fish, meat, fruits and vegetables, etc.), which are made at the enterprises of restaurant business [14–16]. The quality is understood by the authors as the texture of products, their organoleptic indicators, thermal-physical characteristics and heat transfer characteristics [13, 15–17].

The authors point out that combi steamers are the universal thermal equipment with high degree of automation and capacities to program technological processes [18]. This enables to stabilize quality and provide for its harmlessness. It was found that in the course of thermal treatment of food (of vegetable and animal origin) in a convection vaporizer, unlike traditional methods, the products do not lose their weight, products' volume is not reduced and the fibers do not become denser. Thermal treatment of products in a convection vaporizer allows obtaining juicy products, with delicate texture, such products in the human body are better exposed to the action of enzymes and digested [18, 19].

Thus, the conducted analysis of literature data concerning the effect of steam thermal treatment in steam convection furnaces on the products quality revealed that in the scientific literature there is no data about comprehensive influence of thermal treatment in combi steamer, as well as finely dispersed grinding of carotene-containing vegetables (carrot and pumpkin) on preservation and extraction of carotene and other biologically active substances from hidden (bound) form to free state and the fuller use of biological potential of raw materials.

It is known that one of the promising methods of deep processing of vegetable raw materials is cryogenic grinding and finely dispersed grinding without using cold. In the food industry, these processes have hardly been studied [20].

In this regard, the task of this work included the search for and development of the method of deep processing of raw materials without using low temperatures, alternative to cryogenic treatment, which allows maximal preservation and using biological potential, inherent to raw materials [3, 5–7]. As an alternative to cryogenic, it was proposed to use comprehensive action of steam thermal treatment and finely dispersed grinding on the raw materials in the method of deep processing, using a new generation of highly efficient modern equipment – a steam convection furnace (Italy) and an activator-homogenizer-crusher-cutter (France). This equipment is widely used in international practice and is already applied in Ukraine in elite restaurants, culinary shops in supermarkets, canteens of sanatoria-profilaktoria, meal making shops for schoolchildren and others. According to manufacturers and technologists, the indicated types of equipment is a new word in technology and techniques for obtaining high quality food [7, 8]. However, we did not find in the scientific literature any data on the impact of technological treatment using the specified types of modern equipment on the quality of raw materials by the content of BAS at their processing and obtaining products of high quality. No mechanisms of the processes that occur in food raw materials were revealed [16, 18, 19].

In this regard, it is promising to study the impact of processes of deep processing of carotene-containing vegetables on the preservation and transformation of carotenoids and other biologically active substances during steam thermal treatment and finely dispersed grinding. In particular, it is of interest to study the influence of steam thermal and finely dispersed treatment of carotene-containing raw materials (CCR) on preservation and transformation of carotenoids and other BAS on the enzyme, biochemical, physical and chemical processes that occur in the course of treatment of raw materials in modern devices in restaurant business. The obtained semi-finished products made of CCR may be used in making various types of culinary products, soups and other meals, desserts, nanodrinks, nanoicecream, sorbets, muffins, sponge cakes, cakes, creams, etc. for health improving diet.

3. The purpose and objectives of the study

The aim of the work is to study the influence of deep processing of carotene-containing vegetables using steam thermal treatment and finely dispersed grinding on the preservation and extraction of carotenoids and other biologically active substances using a new generation of equipment and obtaining products in the nanodimensional form.

To achieve the set goal, the following tasks are to be solved:

– to study the effect of steam thermal treatment in a steam convection furnace on the activity of oxidative enzymes (peroxidase, polyphenol oxidase) in the carotene-containing raw material;

– to explore the effect of steam thermal treatment in a steam convection furnace on biologically active substances (in particular, β-carotene, L-ascorbic acid) of carotene-containing vegetables compared to traditional blanching;

– to examine the impact of steam thermal treatment and finely dispersed grinding on the quality of carotene-containing vegetables in the content of BAS in the course of obtaining finely dispersed puree in nanodimensional form from them;

– to compare the quality of nanostructured puree from carotene-containing vegetables (carrot, pumpkin) by the content of BAS obtained by using steam thermal treatment and mechanodestruction to the quality of puree obtained by cryogenic technology and the analogues.

4. Materials and methods of research

4. 1. The studied materials and equipment used in the experiments

The research was conducted at the Department of Technology of Processing Fruits, Vegetables and Milk HDUHT (Kharkiv, Ukraine), in the laboratory "Innovative cryo- and nanotechnologies of plant supplements and health products", using the steam convection furnace UNOX SPA series XVC (Italy), which has 70 programs that differ in the modes of technological treatment (temperature, intensity and amount of steam supply, availability of circulation or airflow (Fig. 1).

Fig. 1. Steam convection furnace UNOX SPA series XVC (Italy)

We used carotene-containing raw materials – pumpkin and carrot – as the objects of study. Comparison of the effect of different kinds of steam thermal treatment in the steam convection furnace UNOX SPA series XVC (Italy) and traditional way of thermal treatment of raw materials – blanching – on the carotene-containing raw materials (carrot, pumpkin) were conducted by fermentative activity of oxidative enzymes, by mass

fraction of L-ascorbic acid and by the β-carotene content. The experiment was carried out by the method described in [21].

4. 2. Methods for determining indicators of the studied samples

To perform the set tasks, we used generally accepted standard research methods, in particular, the colorimetric Muri method for determining β-carotene [22, 23], the method of visual and potentiometric titration for determining L-ascorbic acid [24], the colorimetric Folin-Denis method for determining the total amount of low molecular phenolic compounds [25], colorimetric method for determining the sum of flavonol glycosides [25], as well as the method of D. M. Mikhlin and Z. S. Bronovitska for determining fermentative activity [26]. All the techniques of determining the indicators of the studied samples can be found in [21].

5. Results of research into the influence of deep processing of carotene-containing vegetable raw materials using steam thermal treatment and finely dispersed grinding and discussion of them

Kharkiv State University of Food and Trade (Kharkiv, Ukraine) in collaboration with Kharkiv Trade and Economy College of Kiev National Trade and Economy University, municipal enterprise «Dytyachy kombinat» (Kharkiv, Ukraine) and the Academy of Hotel Management and Restaurant Business in Poznan (Poland) proposed and designed the method of deep processing of vegetable raw materials without using low temperatures, alternative to cryogenic treatment, which makes it possible to maximally preserve and use biological potential, inherent to the raw materials. In this paper, we propose to apply the comprehensive action of steam thermal treatment and finely dispersed grinding on the raw materials using highly efficient modern equipment of new generation – a steam convection furnace (Italy) and an activator-homogenizer-crusher (France) [12].

It was found that the steam thermal treatment of carotene-containing vegetables with the use of steam convection furnace and traditional thermal treatment using the blanching method by immersion in hot boiling water proceed differently.

It was revealed that, compared to the traditional method of heat treatment in the processing of carotene-containing vegetables in a combi steamer, the fermentative processes occur with less intensity. The quantitative values of maximum activity of polyphenol oxidase are 2...4,5 times lower, peroxidase – by 1,5 ...1,6 times (Fig. 2).

Heating the product contributes to activation of oxidative enzymes, much more at blanching. It was found that during blanching, in 10 minutes of steam thermal treatment, the polyphenol oxidase enzyme activity is significantly increased. The increase amounts to: in carrot – by 9 times, in pumpkin – by 5,5 times. In this case, the activity of the peroxidase enzyme increases less: in carrot – by 5,8 times, in pumpkin – by 2 times (Fig. 2).

The activity of oxidative enzymes at steam thermal treatment in a combi steamer grows less: polyphenol oxidase – by 2,7 times (carrot) and by 2,0 times (pumpkin), peroxidase – by 1,5 times (carrot) and by 1.6 times (pumpkin). We determined the enzymatic activity optimum for both types of oxidative enzymes at thermal treatment of carrot and pumpkin depending on the duration and type of thermal treatment that was used. It was demonstrated that the maximum activity of oxidative enzymes occurs after thermal treatment of carotene-containing vegetables for 10 minutes (Fig. 2) and does not depend on the type of thermal treatment (blanching or treatment in a combi steamer).

During thermal treatment of pumpkin, the difference in the activity of enzymes during different types of thermal treatment is significantly less than in carrot. It was demonstrated that the complete inactivation of oxidative enzymes in the treatment of CCV in a combi steamer happens by 30 % faster than at blanching.

Thus, in comparison with blanching, during thermal treatment of carotene-containing vegetables in a combi steamer, activation of oxidative enzymes occurs much less. In this regard, it was assumed that the destruction of BAS during thermal treatment of carrot and pumpkin in a combi steamer compared to blanching would be considerably less as well.

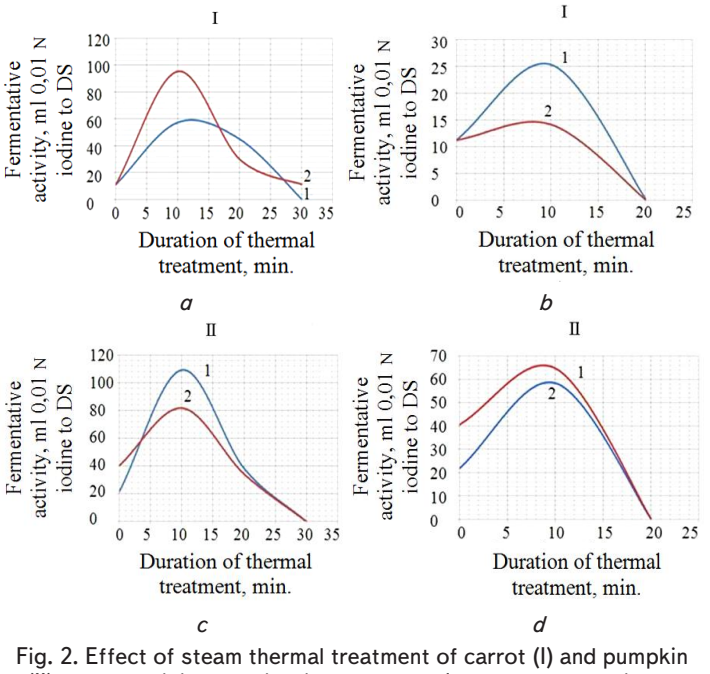

Fig. 2. Effect of steam thermal treatment of carrot (I) and pumpkin (II) on the activity of oxidative enzymes: 1 – polyphenol oxidase (dark blue marker); 2 – peroxydase (red marker), where *a, b* are the steam thermal treatment using blanching; *c, d* are the steam thermal treatment in a combi steamer

The main objective of the work when applying steam thermal treatment during obtaining the finished products and semi-finished products from carotene-containing vegetables was to reduce the losses and to maximally preserve carotenoids (by the content of β-carotene), L-ascorbic acid and other labile BAS, as well as maximally remove or extract their hidden, bound to biopolymers (proteins, polysaccharides), forms, with the purpose of the fuller use and revealing biopotential of vegetable raw materials and plant cell, compared to traditional types of thermal treatment. It should be noted that traditional methods of thermal treatment and other methods of technological processing of vegetable raw materials that are used in international practice lead to significant losses of the listed BAS. Depending on the type of technological treatment, kind of raw material and BAS, the loss amounts to 15 to 100 %. According to the literature data, at present there are no reliable methods of technologi-

cal treatment of raw materials that allow preserving BAS or eliminating or minimizing the loss. The exceptions are freezing and freeze-drying, which are characterized by minimal loss of BAS.

During thermal treatment of carotene-containing vegetables (carrot, pumpkin) in a combi steamer (under the above mentioned modes), not only the preservation of β-carotene occurs in 10 minutes' time, but also increase in its mass fraction by 2... 2.3 times compared to fresh raw material that occurs due to the release from the hidden state (forms bound with biopolymers) to free form, which is registered by the chemical methods of the research (Fig. 3).

The same patterns apply to blanching. It was also found that the loss of vitamin C during thermal treatment of carotene-containing vegetables in a combi steamer is much smaller than at blanching. Thus, after 20 minutes of thermal treatment in the combi steamer, the mass fraction of L-ascorbic acid remained by 65...80 % while after blanching by 40...50 % (Fig. 2).

Thus, it was found that during thermal treatment of CCV in a combi steamer, the oxidation and destruction of L-ascorbic acid occurs less intensively than during blanching.

It was also revealed that after steam thermal treatment and finely dispersed grinding of carotene-containing vegetables when making puree, a significant increase in the extraction of L-ascorbic acid and β-carotene occurs, which for pumpkin is 2 and 3 times larger, respectively, for carrot – 1,7 and 2,5 times larger, respectively, compared to the original raw material (Fig. 3).

Such data were obtained after a rather long thermal treatment of raw materials, which is 60 minutes for carrot that has dense, solid structure, and 35–40 minutes for pumpkin. The mechanism of the specified process was discovered that is associated with mechanodestruction and mechanocracking of the nanocomplexes of biopolymer-carotenoid and release of the hidden bound forms of carotene and L-ascorbic acid from nano associates and nanocomplexes with proteins, polysaccharides, tannic substances, etc.

It was found that the comprehensive application of steam thermal treatment to vegetable raw materials in a combi steamer with finely dispersed grinding makes it possible to obtain puree, the quality of which is close to that of the puree obtained with the use of cryogenic treatment of the product (Fig. 4, 5 and Table 1).

For example, the mass fraction of β-carotene per 100 g of fresh pumpkin is 8,H5 mg, in the finely dispersed puree – 26,5 mg, in the cryopuree – 32,2 mg per 100 g. The mass fraction of β-carotene per 100 g of fresh carrot and the finely dispersed puree made of it is 9,2 mg and 24,6 mg, respectively, in the cryopuree – 28,8 mg per 100 g. As for L-ascorbic acid, it is 8,5 mg per 100 g of fresh carrot and in the finely dispersed puree made of it – 15,0 mg per 100 g; in the cryopuree – 29,7 mg per 100 g; in fresh pumpkin – 9,8 mg per 100 g, in the finely dispersed puree – 16,5 mg per 100 g, in the cryopuree – 19,6 mg per 100 g.

Thus, it was found that after the steam thermal treatment and finely dispersed grinding of carotene-containing vegetables when making puree, a significant increase in the extraction of L-ascorbic acid and -carotene occurs, which is 2 and 3 times larger for pumpkin, respectively, and for carrot – 1,7 and 2,5 times larger, respectively.

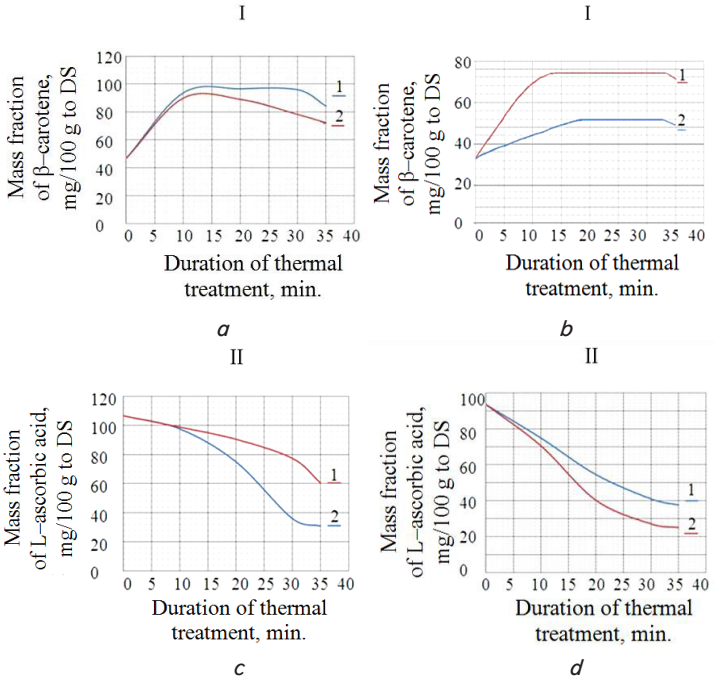

Fig. 3. Effect of duration of steam thermal treatment of carrot (*a, c*) and pumpkin (*b, d*) in a combi steamer – 1 (red marker) and blanching under normal conditions at t=105 °C – 2 (red marker) on the content of β-carotene (I) and L-ascorbic acid (II)

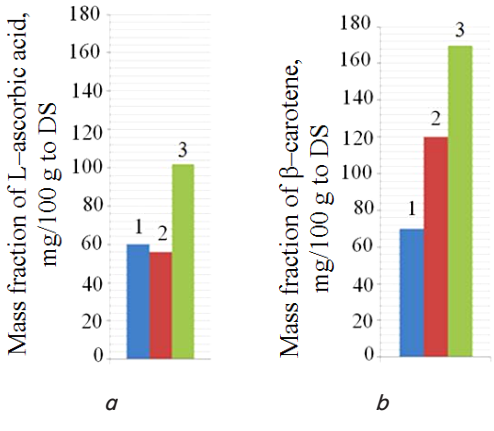

Fig. 4. Effect of steam thermal treatment of carrot (I) and finely dispersed grinding of carrot on the content of L-ascorbic acid (*a*) and β-carotene (*b*) compared with fresh raw materials: 1 – fresh carrot (dark blue marker); 2 – carrot after steam thermal treatment (red marker); 3 – finely dispersed puree of carrot (green marker)

The described results of the research enabled comprehensive treatment of vegetable raw materials using a new generation of equipment for steam thermal treatment and finely dispersed grinding, which is used in restaurant business, as well as to consider the method of deep processing of vegetable raw materials, which makes it possible to achieve a high degree of preservation and extraction of BAS of the fresh (original) raw materials in the production of finely dispersed supplements in the form of puree from carotene-containing vegetables.

The quality of the obtained puree from carotene-containing vegetables by the content of BAS is 1,7...3 times higher than the quality of the original raw materials and is close to the quality of the puree, obtained using the cryo-

genic treatment of the product and significantly exceeds the quality of the purees – analogues, obtained using traditional methods of thermal treatment of raw materials and grinding, accompanied by the loss of BAS compared to the fresh raw material by 20...80 %.

Table 1

Comparative characteristic of the content of carotene and other BAS in fresh, steam thermally treated, frozen carotene-containing vegetables and in the nanostructured puree made of them (≥3)

Product	Mass fraction (mg per 100 g)			
	β-carotene	L-ascorbic acid	Phenolic compounds (by chlorogenic acid)	Flavonol glycosides (by rutine)
Fresh carrot	9,5±0,3	8,2±0,2	146±1,5	50,2±1,8
Carrot frozen in pieces	18,6±1,0	17,2±0,8	240,2±2,0	117,2±2,4
Nanostructured cryopuree made of carrot	28,8±2,5	29,7±1,5	262,6±2,8	105,8±2,8
Carrot, steam thermally treated in a combi steamer	19,4±1,8	7,0±0,3	120,4±1,4	40,2±0,9
Finely dispersed puree from carrot, thermally treated	24,6±2,0	15,2±0,9	200,6±3,2	85,4±2,4
Fresh pumpkin	8,5±0,3	9,8±0,2	128,4±1,8	45,4±1,2
Pumpkin frozen in pieces	17,2±1,2	14,6±0,7	178,5±2,1	75,4±2,6
Nanostructured cryopuree made of pumpkin	32,2±2,6	19,7±1,0	210,6±2,8	98,6±1,8
Pumpkin, steam thermally treated in a combi steamer	20,0±3,4	8,2±0,2	95,8±2,0	39,2±0,5
Finely dispersed puree from pumpkin, thermally treated	26,5±4,2	16,5±1,8	210,6±3,5	78,8±1,6

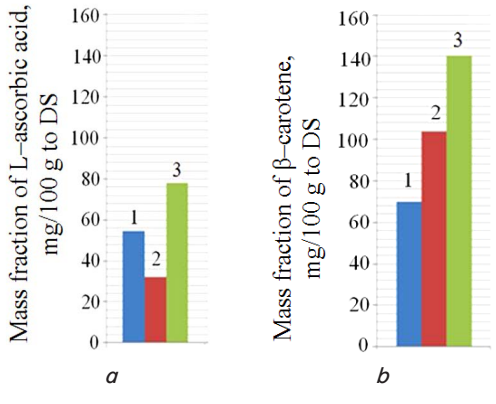

Fig. 5. Effect of steam thermal treatment of pumpkin (I) and finely dispersed grinding on the content of L-ascorbic acid (*a*) and β-carotene (*b*) compared with fresh raw materials: 1 – fresh pumpkin (dark blue marker); 2 – pumpkin after steam thermal treatment (red marker); 3 – finely dispersed puree of pumpkin (green marker)

All this allows us to stress high efficiency of applying the new generation of equipment for steam thermal treatment and finely dispersed grinding of carotene-containing vegetables. Verification under manufacturing conditions of KP "KDH", NVF "HPK", "KRIAS PLUS" (Kharkiv, Ukraine) of the conducted research and production of experimental samples of nanoproducts from carotene-containing vegetables confirm the practicability of applying deep processing of CCV at obtaining nanoproducts using the new generation of equipment in restaurant business and trade enterprises. Thus, the above-described method of deep processing of vegetable raw materials makes it possible to more fully uncover biological potential of CCR, which may be useful not only in food industry, but also when obtaining natural carotenoid pharmaceutical preparations (for immunization of the population) and others.

Development and continuation of research into this direction is to study the influence of deep processing of vegetable raw materials on the indigestable components of food – prebiotics, in particular cellulose, protein, pectic substances, exploring their assimilation by living organisms – by the method of biotesting and others.

7. Conclusions

1. It was found that in the process of deep (steam convection) processing of carotene-containing vegetables (carrot and pumpkin) with the use of modern steam convection equipment, the fermentative processes proceed with less intensity than at traditional method of thermal treatment – blanching by immersion in boiling water. The quantitative indicator of the maximum fermentative activity during treating the carotene-containing vegetables in a combi steamer, compared with blanching, is 2–4,5 times less for polyphenol oxidase, by 3 times for peroxidase. It was demonstrated that the complete inactivation of oxidative enzymes during thermal treatment of carotene-containing vegetables in a combi steamer occurs earlier than during blanching and takes place in 20 minutes, which is 10–15 minutes faster than at blanching. The complete inactivation of oxidative enzymes at blanching of carotene-containing vegetables occurs in 30–35 minutes.

2. It was demonstrated that, compared with fresh raw materials, during thermal treatment of carotene-containing vegetables (carrot, pumpkin) in a combi steamer (in the above mentioned modes), not only the preservation of β-carotene is achieved in 10 minutes, but also the increase in its mass fraction by 2...2,3 times that occurs due to the release from the hidden state (forms, associated with biopolymers) to free form, which is registered by the chemical methods of research. It was found that the loss of vitamin C during thermal treatment of carotene-containing vegetables in a combi steamer is much lower than during blanching. Thus, after 20 minutes of thermal treatment in the combi steamer, the mass fraction of L-ascorbic acid remained by 65...80 %, while after blanching – by 40...50 %.

3. It was demonstrated that after the steam thermal treatment and finely dispersed grinding of carotene-containing vegetables when making puree, a significant increase in the extraction of L-ascorbic acid and β-carotene occurs in comparison to the original raw materials, which is 2 and 3 times larger for pumpkin, respectively, and for carrot – 1,7 and 2,5 times, respectively.

4. It was found that the comprehensive application of steam thermal treatment of vegetable raw materials in a combi steamer with finely dispersed grinding makes it possible to obtain puree, the quality of which is close to the quality of the puree, obtained using the cryogenic product treatment (in particular, the content of β-carotene is 2,5...3 times during steam thermal treatment and is 2,8...3,5 times during cryogenic treatment).

References

1. FAO/WHO/UNU. Global Strategy on Diet, Physical Activity and Health [Text]. – Resolution WHA.55.23 accepted session of World Health Assembly (WHA), World Health Organization, Geneva, 2013.
2. FAO/WHO/UNU. Dietary protein quality evalution in human nutrition. Report of an FAO Expert Consultation [Text] // Food and agriculture organization of the united nations Rome. – 2013. – Vol. 92–57.
3. Pavljuk, R. Ju. Krio- i mehanohimija v pishhevyh tehnologijah [Text] / R. Ju. Pavljuk, V. V. Pogarskaja, V. A. Pavljuk, L. A. Radchenko, O. A. Jur'eva, N. F. Maksimova. – Kharkiv: Finart, 2014. – 260 p.
4. Reznikov, O. H. Pro- and antioxidant systems and pathological processes in humans [Text] / O. H. Reznikov, O. M. Polumbryk, Y. H. Balion, M. O. Polumbryk // Visnik NAM of Ukraine. – 2014. – Vol. 10. – P. 17–27.
5. Pogarskaya, V., Pavlyuk, R. (). Activation of the hydrophilic properties of herbal raw materials carotenoids [Text] / V. Pogarskaya, R. Pavlyuk. – Kharkiv: Finart, 2013. – 345 p.
6. Goni I. Bioaccessibility of beta-carotene, lutein, and lycopene from fruits and vegetables [Text] / I. Goni, J. Serrano, F. Saura-Calixto // Agric Food Chem. – 2006. – Vol. 54, Issue 15. – P. 5382–5387. doi: 10.1021/jf0609835
7. Bernstein, P. S. Identification and quantitation of carotenoids and their metabolites in the tissues of the human eye [Text] / P. S. Bernstein, F. Khachik, L. S. Carvalho, G. J. Muir, D.-Y. Zhao, N. B. Katz // Experimental Eye Research. – 2001. – Vol. 72, Issue 3. – P. 215–223. doi: 10.1006/exer.2000.0954
8. Dherani, M. Blood levels of vitamin C, carotenoids and retinol are inversely associated with cataract in a North Indian population [Text] / M. Dherani, G. V. S. Murthy, S. K. Gupta, I. S. Young, G. Maraini, M. Camparini et. al. // Investigative Opthalmology & Visual Science. – 2008. – Vol. 49, Issue 8. – P. 3328–3335. doi: 10.1167/iovs.07-1202
9. Stahl, W. Lycopene: a biologically important carotenoid for humans? [Text] / W. Stahl, H. Sies // Archives of Biochemistry and Biophysics. – 1996. – Vol. 336, Issue 1. – P. 1–9. doi: 10.1006/abbi.1996.0525
10. Frese, R. N. Electric field effects on red chlorophylls, -carotenes and P700 in cyanobacterial photosystem I complexes [Text] / R. N. Frese, M. A. Palacios, A. I. Azzizi, I. H. M. van Stokkum, J. Kruip, M. R gner et. al. // Biochimica et Biophysica Acta (BBA) - Bioenergetics. – 2002. – Vol. 1554, Issue 3. – P. 180–191. doi: 10.1016/s0005-2728(02)00242-6
11. Rakhimberdieva, M. G. Carotenoid-induced quenching of the phycobilisome fluorescence in photosystem II-deficient mutant of Synechocistis sp. [Text] / M. G. Rakhimberdieva, I. N. Stadnichuk, I. V. Elanskaya, N. V. Karapetyan // FEBS Letters. – 2004. – Vol. 574, Issue 1-3. – P. 85–88. doi: 10.1016/j.febslet.2004.07.087
12. Oberbayl, K. Vitamins healer [Text] / K. Oberbayl. – Minsk: Paradoks, 1998. – 424 p.
13. Lisichenok, O. V. Effect of heat treatment methods on the nutritional value of fish culinary products [Text] / O. V. Lisichenok et. al. // Bulletin of Novosibirsk State Agrarian University. – 2014. – Vol. 4, Issue 33. – P. 100–104.
14. Ivanov, A. The results of experimental studies of heat transfer in the machine Steam convection [Text] / A. Ivanov, I. Kirik, A. V. Kirik // Innovative technologies in the production and processing of agricultural products. – 2011. – Part 2. – P. 47–49.
15. Kirik, A. Investigation of heat exchange processes in machine Steam convection [Text] / A. Kirik // Engineering and technology of food production. – 2010. – Part 1. – P. 8–9.
16. Kirik, M. Steam convection apparatus for catering [Text] / M. Kirik et. al. – Innovative technologies in the food industry, 2009. – P. 394–401.
17. Kutkina, M. Combi-Steamer: Know and be able to: recommendations for heat treatment of different types of culinary products [Text] / M. Kutkina, E. Fedinishina // Power and society. – 2007. – Vol. 10. – P. 10–12.
18. Kotova, V. Study of the heat treatment of fish using combined heat [Text] / V. Kotova, V. Ryabov, I. Dolmatova // Innovative technologies in agricultural production, food processing industry, 2013. – P. 63–65.
19. Kutkina, M. Development of individual vegetable semis technology high availability [Text] / M. Kutkina, S. Eliseev // Proceedings of the universities. Food technology. – 2014. – Vol. 2/3. – P. 66–69.
20. Pavlyuk, R. Cryo- and Mechanochemistry in food technology [Text] / R. Pavlyuk, V. Pogarskaya, V. Pavlyuk, L. Radchenko et. al. – Kharkiv: Fact, 2015. – 255 p.
21. Pavlyuk, R. The new method of processing of carotene-containing vegetables for the production of nanoproducts using combi-steamers and fine-dispersed comminution [Text] / R. Pavlyuk, V. Pogarska, L. Radchenko, R. D. Tauber, N. Timofeyeva, T. Kotuyk // Eureka: Life Sciences. – 2016. – Vol. 3 (4). – P. 44–49. doi: 10.21303/2504-5695.2016.00146
22. GOST 13496.17 – 95. Mezhgosudarstvennyy standard. Stern. Method of determination of carotin [Text]. – Moscow: Standartinform, 2011. – 5 p.
23. DSTU 4305:2004. Fruit, vegetables and products of their processing. Method of determination of carotin [Text]. – Kyiv: Derzhspozhivstandart, 2005. – 18 p.
24. GOST 24556-89. Mezhgosudarstvennyy standard. Products of processing of fruit and vegetables. Method of determination of vitamin C [Text]. – Moscow: IPK publishing house of standards, 2003. – 12 p.

25. DSTU 4373:2005. National standard of Ukraine. Fruit, vegetables and products of their processing. Methods of determination of polifenoliv [Text]. – (). Kyiv: Derzhspozhivstandart, 2006. – 10 p.
26. Makaseeva, O. N. Enzymes. Ch. 2. Vitamins and enzymes. Methodical pointing to laboratory practical work. (Determination of activity of o-difenoloksidazy (polifenoloksidazy) and peroksidazy on Mikhlinu and Bronevickoy) [Text] / O. N. Makaseeva, L. M. Tkachenko. – Mogilevskiy state technological institute, 2001. – P. 25–27.

Методом гальваностатичної кулонометрії визначено загальну антиоксидантну ємність мармеладу желейно-фруктового та маршмелоу з рослинними добавками з яблук, айви, винограду, гарбуза, моркви, шипшини, обліпихи, суданської троянди, чорноплідної горобини, отриманих за кріогенними технологіями. На підставі розрахунків, які базуються на адитивній схемі, показано, що функціональні властивості виробів обумовлені антиоксидантними властивостями введених добавок

Ключові слова: антиоксидант, кулонометрія, рослинна добавка, кріогенна технологія, кріопаста, кріопорошок, мармелад, маршмелоу

Методом гальваностатической кулонометрии определена общая антиоксидантная емкость мармелада желейно-фруктового и маршмелоу с растительными добавками из яблок, айвы, винограда, тыквы, моркови, шиповника, облепихи, суданской розы, черноплодной рябины, полученных по криогенным технологиям. На основании расчетов по аддитивной схеме показано, что функциональные свойства изделий определяются антиоксидантными свойствами введенных добавок

Ключевые слова: антиоксидант, кулонометрия, растительная добавка, криогенная технология, криопаста, криопорошок, мармелад, маршмеллоу

UDC 664.858
DOI: 10.15587/1729-4061.2016.73546

DETERMINATION OF TOTAL ANTIOXIDANT CAPACITY IN MARMALADE AND MARSHMALLOW

S. Gubsky
PhD, Associate Professor**
E-mail: s.gubsky@hduht.edu.ua
M. Artamonova
PhD, Associate Professor*
E-mail: artamonova_maya@hduht.edu.ua
N. Shmatchenko
Postgraduate Student*
E-mail: shmatchenko_nat@hduht.edu.ua
I. Piliugina
Senior Lecture**
E-mail: inna.piliugina@ukr.net
E. Aksenova
PhD, Associate Professor**
E-mail: aksenova@hduht.edu.ua
*Department of technology of bread, confectionary, pasta and food concentrates***
Department of chemistry, microbiology and hygiene of food*
***Kharkiv State University Food Technology and Trade
Klochkovska str., 333, Kharkiv, Ukraine, 61051

1. Introduction

According to the results of recent research in the field of medicine, one of the main reasons for the change of pathological conditions in a human body that cause many diseases and lead to premature aging is an excessive level of free oxygen radicals [1–3]. Their constant high content in intercellular and intracellular biological fluids creates conditions for the development of oxidative stress, which from the biochemical point of view is expressed in oxidation of vessel walls, proteins, DNA, lipids [4].

Harmful effects of free radicals can be reduced by regular consumption of natural foods such as fruits, vegetables, herbs and the like. Another source of antioxidants is functional foods, made with the addition of natural additives. Natural additives beneficial effects on human health are due to the presence of natural phenols and polyphenols, which are able to break off the chain free radical oxidation reactions [5, 6]. Phenolic compounds combine several classes of chemical compounds, among which a special place belongs to flavonoids – the most important natural antioxidants. Synthesis of these structures in living organisms is impossible. In this regard, the creation of functional foods with various plant additives as a preventive means in population antioxidant protection programs is an urgent task.

2. Literature review and problem statement

Confectionery, including fruit jelly and marshmallow, are in high demand among the population, especially children, due to a pleasant taste and bright color. However, they