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EFFECT OF PRE-TREATMENT ON QUALITATIVE INDICES OF WHITE ROOTS

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Abstract. In the work, various technological methods are presented of preliminary processing of celery and parsnip roots to prevent their darkening during cooking in restaurants. These methods are: immersing in a citric acid solution (c = 0.05%, 0.1%, 0.15%), in solution NaCl (c = 0.5%, 1%, 2%), and microwave processing in various modes. The activity of peroxidase, polyphenol oxidase, and ascorbate oxidase enzymes of root crops in the varietal section is also determined. Fresh white roots were selected as research objects: celery of the varieties Yablucnyy and Diamant, and parsnip of the varieties Student and Kruhlyy. It was revealed that polyphenol oxidase shows the highest activity. In order to inactivate the above-stated oxidoreductase, different methods of treating white roots were compared, too. The lowest oxidative enzymes activity was characteristic of the roots of the Diamant varieties and the parsnip roots of the Student variety, which were selected for further work. Studies have been carried out on changes in the mass fraction of L-ascorbic acid during steam blasting and microwave processing in different modes. It is proved that the treatment of white roots with ultra high frequency irradiation at 650 W for 1 minute is optimal. Such treatment allowes preventing the darkening of the raw material after its peeling due to the action of oxidation-reducing enzymes. It also allows preserving L-ascorbic acid by 64.6% and 65.0% in the roots of celery and parsnip, respectively. The distribution of polyphenol oxidase activity in the celery and parsnip root crop is analyzed. The results of the work can be used in preparation of dishes with the use of white roots in restaurants in order to improve technological techniques during processing of raw materials into finished products, improve its quality, and preserve L-ascorbic acid, as well as expand the range of culinary products based on spicy aromatic raw materials.

Keywords: pre-treatment, celery and parsnip roots, darkening of root crops, enzyme activity, peroxidase, polyphenol oxidase, ascorbate oxidase, L-ascorbic acid, blanching, microwave processing.

ВПЛИВ ПОПЕРЕДНЬОЇ ОБРОБКИ НА ЯКІСНІ ПОКАЗНИКИ БІЛИХ КОРЕНІВ

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Анотація. У роботі наведені різні технологічні прийоми попередньої обробки коріння селери і пастернаку з метою попередження їх потемніння при приготуванні страв у закладах ресторанного господарства. Визначена активність ферментів пероксидази, поліфенолоксидази та аскорбатоксидази коренеплодів у сортовому розрізі. З метою інактивації оксидоредуктаз було проведено порівняння різних способів обробки білих коренів. Встановлено, що оптимальною є НВЧ-обробка при 650 Вт протягом 1 хвилини, яка дозволила попередити потемніння сировини після її очищення і зберегти L-аскорбінову кислоту на 64,6% та 65,0% у коріннях селери та пастернаку відповідно. Результати роботи можуть бути використані при приготуванні страв у закладах ресторанного господарства з метою удосконалення технологічних прийомів при переробці сировини у готовий продукт, покращення показників якості та збереження L-аскорбінової кислоти, а також розширення асортименту кулінарних виробів на основі пряно-ароматичної сировини.

Ключові слова: попередня обробка, коріння селери і пастернаку, потемніння коренеплодів, активність ферментів, пероксидаза, поліфенолоксидаза, аскорбатоксидаза, L-аскорбінова кислота, бланшування, НВЧ-обробка.

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Introduction. Formulation of the problem

The main purpose of processing plant raw materials is cooking food with long-lasting nutrition value and taste. The formation of the quality of ready-to-serve food is influenced by such factors as the quality of primary raw material, its purpose, the peculiarities of chemical composition, the preprocessing method and the technology of cooking, the storage conditions, as well as the species and botanic variety [1].

Among the various kinds of plant raw materials, of special interest are root crops grown in all regions of Ukraine. Their processing into a finished product makes it possible to provide the human body with useful substances for a year. Especially valuable are white root vegetables because they contain dietary fibers, sugars, polyphenol compounds, β-carotene, minerals that strengthen blood vessels and improve blood pressure [2].

Certain types of root crops, before grinding, require different ways of processing: blanching with water, or with steam, or in water solutions of salts and acids. The correct preliminary processing is very important, as well as selecting the correct technological parameters to achieve the positive qualities of the finished product. As a result of heat treatment, the enzymes are inactivated, nutritional value increases, organoleptic product indicators improve. There is also some change in structural and mechanical properties (tissues softening, increasing or decreasing in volume and weight, cells permeability decreasing) [3,4].

While chopping, the color of pulp of white root vegetables changes significantly, which affects not only the organoleptic properties of the finished product, but also its nutritional and biological value.

That is why in this paper, it is important to investigate what factors affect the quality indicators of white roots, namely the color, flavor, and structure, and to find the way and the preprocessing mode to prevent darkening and preserve L-ascorbic acid that plays an important role in regulation of redox processes and provides immune protection for the human body [5].

Analysis of recent research and publications

It is known that the cause of fruit and vegetable darkening is oxidation of polyphenols contained in raw materials, in the presence of oxygen in the air due to the effect of oxidative enzymes, mainly polyphenol oxidase [6].

During storage of peeled root crops, melanins can form as a result of oxidation of chlorogenic acid, another substance of phenolic nature. In addition, the quinones formed from chlorogenic acid can connect with amino acids and proteins and form darker connections than products of oxidation of this acid [7].

Also condensed tannins present in celery and parsnip contain catechins in their structure – derivatives of flavones and anthocyanins which, when oxidized, form dark-colored products – flobbaphene.

During cleaning and cutting of celery and parsnip roots, cells are damaged, tonoplast ruptures, cellular juice mixes up with cytoplasm causing polyphenols to undergo irreversible fermented oxidation until dark-colored products are formed.

The rate of darkening is usually associated with polyphenol oxidase activity in the products: the higher it is, the faster the root crop flesh darkens [8].

Besides, vegetables with white pulp contain unequal number of tyrosine. This, in turn, is connected with the varietal features of root crops. We can assume that the accumulation of tyrosine affects the rate of vegetable darkening.

To ensure that the peeled root crops do not darken during storage in the open air, it is necessary either to exclude the contact of the products with oxygen or to inactivate the oxidative enzymes.

A feature of processing white roots is the fact that, when carrying out mechanical operations (cleaning, cutting, chopping), the raw materials darken, which significantly affects not only the organoleptic properties of the finished products, but also their food and biological value. Such changes result from the action of oxidoreductases – the latter become more active because of the presence of oxygen in the air [9,10].

Traditionally, when cooking first and second courses, such method of preprocessing white roots is used as blanching with water or steam. It affects not only the flavor of the final product, but also reduces its biological value [11].

To avoid the loss of nutritional and biological value and improve the organoleptic properties of food obtained from white roots, such enzymes as peroxidase, polyphenol oxidase, and ascorbate oxidase are of particular interest.

When the natural properties of vegetable raw materials change, peroxidase oxidizes polyphenols and some aromatic amines, catalyzes the reaction of the oxidation of o-diphenol and polyphenols, with the formation of intermediate semiquinones and o-quinones that form dark-colored products during condensation. Thus, the functioning of this enzyme leads to undesirable darkening of the finished product [12]. Peroxidase, as an oxidizer, uses peroxide oxygen. It catalyzes the reaction:

$$ROOH + AH_2 \rightarrow H_2O + ROH + A,$$

where ROOH can be hydrogen peroxide HOOH or organic peroxides, i. e. it is highly specific in relation to the hydrogen acceptor, and non at all specific in relation to the hydrogen donor. Numerous phenols, aminophenols, diamines, indophenols, ascorbate, and some amino acids can be oxidized. Thus, peroxydase is relatively specific.

The mechanism of peroxidase action can be described as follows:

$$Per\ (OH) + H_2O_2 \leftrightarrow Per\ (OOH) + H_2O;$$
$$Per\ (OOH) + AH_2 \leftrightarrow Per\ (OH) + H_2O + A.$$

Peroxidase with hydrogen peroxide forms an intermediate complex compound.

This enzyme is relatively resistant to heat: processing of raw materials at 85°C for 30 minutes inactivates peroxidase only by 50%.

Due to the fact that peroxidase is resistant to the action of high temperatures, its inactivation presents certain difficulties.

To increase the keeping capacity of food, it is necessary to remove or inhibit the action of peroxidase while inactivating polyphenol oxidase.

Polyphenol oxidase, involving the oxygen in the air or the oxygen located in the intercellular space, oxidizes mono-, di-, and polyphenols, tannins, catechins, phenolic acids, and aromatic alcohols into quinons that interact with amines, free amino acids, proteins, or with each other by polymerization and polycondensation. As a result, dark-colored substances are formed [11,12].

An enzyme is a protein that contains copper. When copper is removed, the enzyme is inactivated, but it is reactivated when copper is added. The activity optimum is not pronounced, it is within the range of pH level from 5 to 7 [13].

Thermal processing (blanching) is the traditional method of enzyme inactivation in food production. The desired time and heat treatment temperature depend on active acidity: with a decrease in it, there is a decrease in the enzymic activity. Polyphenol oxidase is irreversibly inactivated at a pH level below 3.

Ascorbate oxidase catalyzes oxidation of ascorbic acid into a dehydrogenform, which has no vitamin activity and thus, is responsible for the destruction of vitamin C, but at the same time, it positively affects the coloring and aroma of herbal products binding the oxygen. The optimum pH level of the enzyme is 5.6 [12].

In the food industry, special attention is paid to physical methods of influence on raw material, which can accelerate heat exchange processes, ensure microbiological safety, as well as improve and increase the nutritional value of the raw material. A physical method to achieve this is heating in the electromagnetic field [14–16].

Microwave processing is used in restaurants for the following technological processes: heating food and cooking it till ready, drying, defrosting, boiling, baking, decontamination, extraction. Besides, it can be a stimulating factor to intensify technological processes and improve the food value of the raw material, semi-finished, and finished products [17–21].

Microwave heating is successfully used to process raw material with active enzymes (for example, malt products, grains, seeds of plants), thus regulating and achieving the required parameters of enzyme activity. Depending on the processing modes, it is possible to increase the activity of enzymes or to cause their inactivation [22].

Dielectric properties of foodstuffs and of various materials depend mainly on their nature, humidity, temperature, and the frequency of field fluctuations. Complex interaction between the quantity of heat released and the depth of penetration of the microwave field makes it necessary to select certain processing modes and a certain thickness of the product to avoid the overheating of its external and internal layer [23].

The **purpose** of the work is studying the influence of different types of preliminary processing on the white root quality and determining the modes of processing root crops into semifinished products.

The main **objectives** of the research:

1. investigating the activity of oxidative enzymes in the roots of white varieties;
2. scientifically justifying the need and method of pretreatment of white roots to prevent darkening;
3. determining the optimum heat treatment for the maximum preservation of L-ascorbic acid in the roots of celery and parsnip;
4. expanding the range of food in catering industry.

Research Materials and Methods

White root vegetables grown in the Odessa region (the 2014–2016 harvest): the celery of the varieties Yabluchnyy and Diamant, and the parsnip Kruhlyy and Student were used in the work. The scheme of conducting the experiments, see Fig. 1.

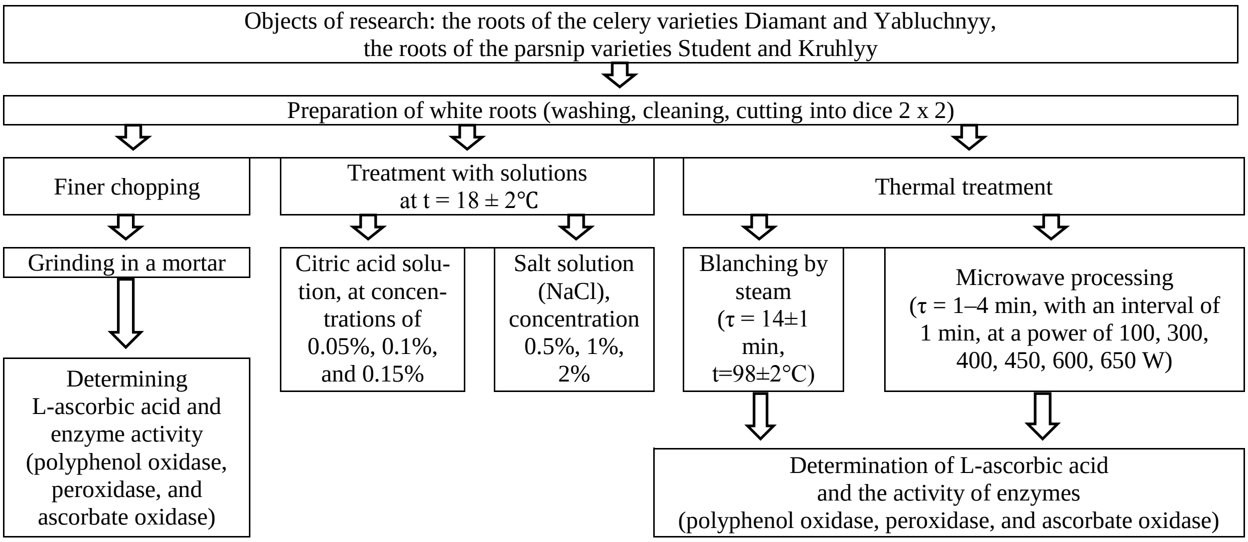

Fig. 1. Scheme of the experiments

The activity of polyphenol oxidase was determined by the titrimetric method [24,25]. The method is based on titrating an aqueous suspension with potassium iodate and determining the amount of oxidized ascorbic acid.

The activity of peroxidase and ascorbate oxidase was determined by the fluorometric method [25]. The activity of the enzyme was determined by the decrease in optical density, taking into account that the degree of oxidation of NADP·H2 (nicotinamide adenine dinucleotide phosphate) or NAD·H2 (nicotinamide adenine dinucleotide) is proportional to the amount of the enzyme.

L-ascorbic acid was determined by the Tylmans method based on extracting it from a raw material sample by means of a hydrochloric acid solution, followed by titrating it with the solution of 2.6 dichlorophenolindophenol [26, 27].

The color of the roots of celery and parsnip was being recorded after the preparation (washing, cleaning, cutting) for 1–3 minutes at room temperature, then all changes after the treatment were noted.

Results of the research and their discussion

Since the main factor in the darkening of white roots is the action of redox enzymes, it is advisable to analyze the change in their activity in the raw material before processing.

The results of the observations of the activity of peroxidase, polyphenol oxidase, and ascorbate oxidase of celery roots in the varietal section, depending on time, are shown in Fig. 2–4.

Fig. 2 shows that the activity of peroxidase was increased by the action of oxygen in the air and was, after 20 seconds, for the Diamant 0.029 E/g cm/sec, for the Yabluchnyy 0.053 E/g cm/sec, and in 360 seconds, it was 0.180 E/g cm/sec and 0.276 E/g cm/sec, respectively. Compared to the peroxidase activity of the two varieties of celery root, the activity of peroxidase in the Diamant is lower than in the Yabluchnyy by 34.8%.

The data shown in Fig. 3 indicate that the difference in the activity of polyphenol oxidase in the selected celery root varieties is insignificant. Over time, the activity of the enzyme increased. After 20 seconds, the activity of the varieties Yabluchnyy and Diamant differed by 0.02 E/g cm/sec, after 240 seconds, it was the same, at the end of the experiment, it was 0.16 E/g.c.m./sec. In this case, in the root of the celery variety Yabluchnyy, the activity of polyphenol oxidase is higher by 5%.

In Fig.ca 4, we can see that the activity of ascorbate oxidase was approximately 0.57 E/g.c.m./sec for two varieties of celery root. Over time, the activity of the enzyme was reduced. After 360 seconds, the activity of the celery variety Yabluchnyy is 9.4% higher than that of the Diamant variety.

The observation of the changes in the activity of the oxidative enzymes of parsnip root of the Kruhlyy and Student varieties is shown in Fig. 5–7.

These studies showed that the peroxidase activity of roots of the parsnip variety Kruhlyy is higher than that of Student. At the beginning of the experiment, the difference in the enzyme activity was insignificant, after 200 seconds, it increased, and after 360 seconds, it was 16.7%.

From the data shown in Fig. 6, it can be seen that the initial activity of polyphenol oxidase in the roots of the two varieties of parsnip was approximately 0.04 E/g.c.m./sec. The difference in the enzyme activity in the varietal section is insignificant, and at the end of the study (360 s), it reached almost the same value. The biggest difference in the enzyme activity was observed after 160 s: in the parsnip root of the Kruhlyy variety, it is 20% higher than in the Student variety.

Fig. 7 shows that the activity of ascorbate oxidase in the two varieties of parsnip decreases with time and is hardly different: at the beginning of the experiment, it is about 0.63 E/g cm/sec, and at the end, 0.32 E/g cm/sec. After 20 and 40 seconds, the enzyme activity of the variety was slightly higher, but in the middle of the experiment (80–240 s) it exceeded the activity of ascorbate oxidase of the Student variety. The highest activity of peroxidase is found in the parsnip root of the Kruhlyy variety (47.6 units/g), the lowest is in the celery root of the Diamant variety (3.596 units/g). When comparing the two celery varieties, it was found that the activity of peroxidase for the Yabluchnyy variety was 1.6 times higher than that for Diamant. For the parsnip varieties, this difference was insignificant.

It should be noted that the activity of polyphenol oxidase and ascorbate oxidase is also higher in the roots of parsnip. And in the varietal section for the two types of roots, there was a slight difference.

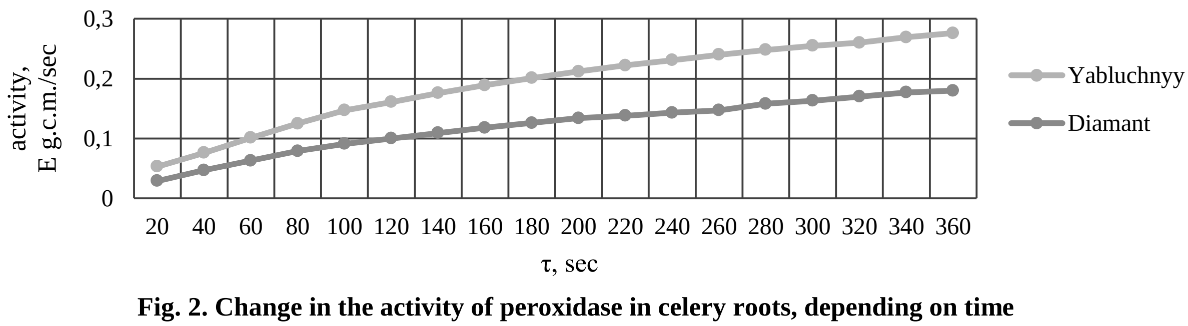

Fig. 2. Change in the activity of peroxidase in celery roots, depending on time

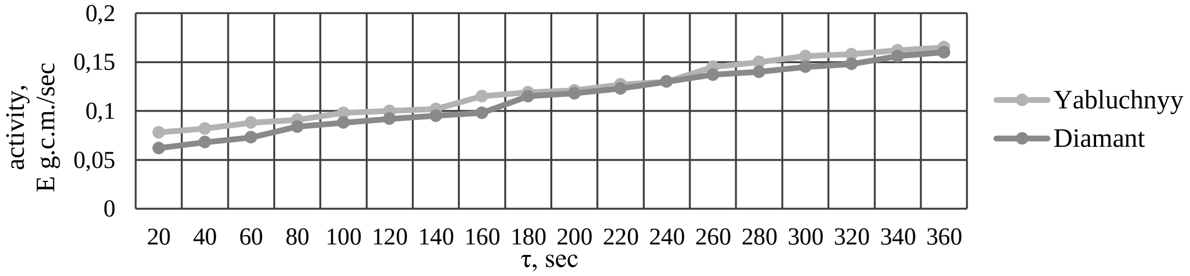

Fig. 3. Change in the activity of polyphenol oxidase in celery roots, depending on the time.

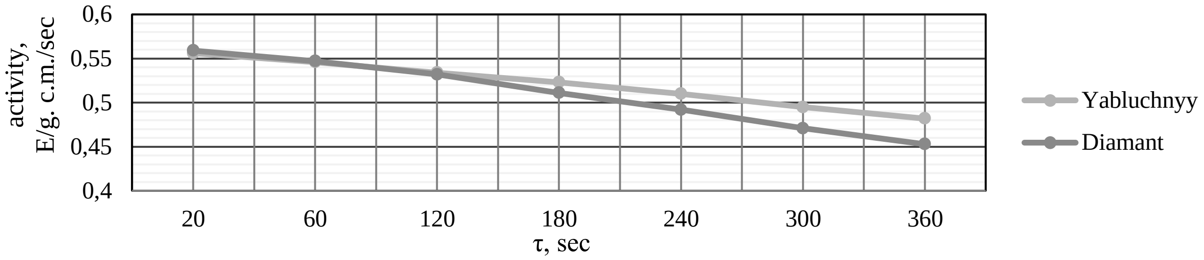

Fig. 4. Change in the activity of ascorbate oxidase in celery roots, depending on the time.

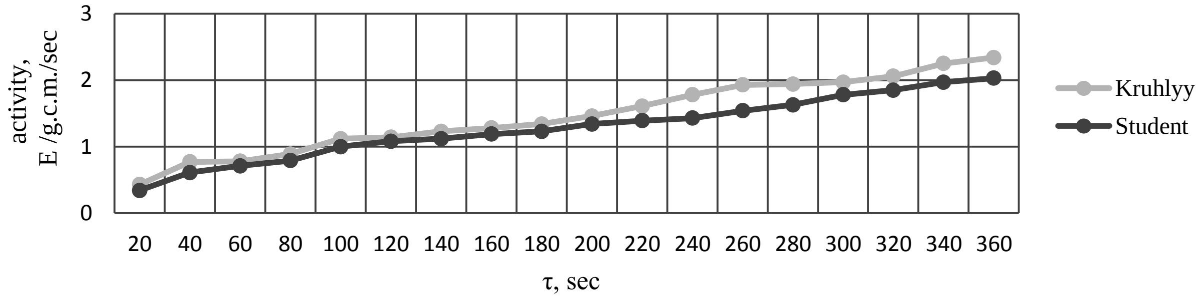

Fig. 5. The change in the activity of peroxidase in parsnip roots, depending on time.

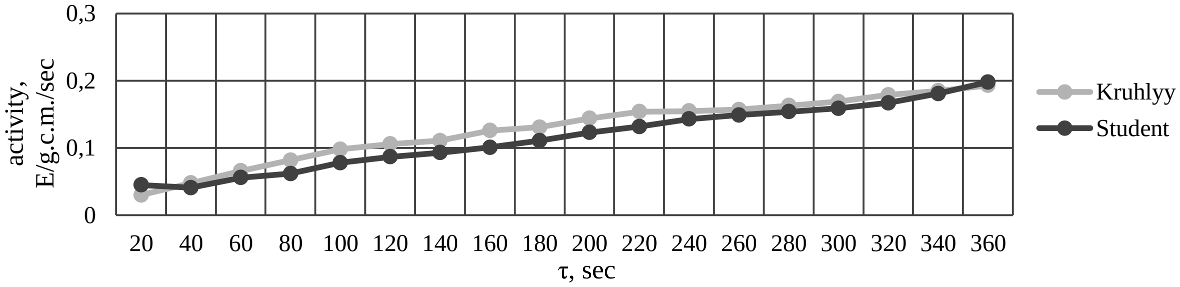

Fig. 6. Change in the activity of polyphenol oxidase in parsnip roots, depending on time.

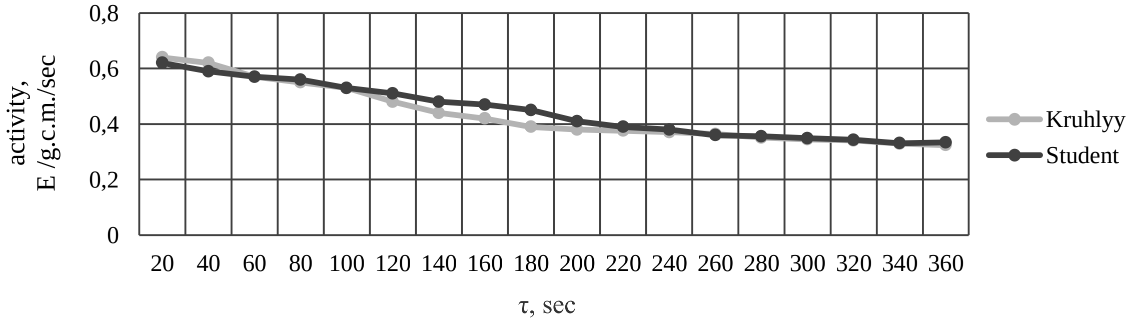

Fig. 7. Change in the activity of ascorbate oxidase in parsnip roots, depending on time.

Thus, the data obtained indicate that the activity of enzymes of one type of raw material depends on the variety characteristics. According to the results of the research, Diamant celery roots and Student parsnip roots were selected for further work, due to their lower activity of oxidative enzymes.

Since the preliminary processing of raw materials affects the quality of the dishes, the next step was to determine the change in the color of the white roots when treated in different solutions (citric acid and NaCl, at different concentrations), steam blanched, and processed in a microwave.

The results of the observation of the change in the color of celery and parsnip roots, when treated with citric acid solutions of various concentrations, are given in Table 1.

The data in Table 1 indicate that when the celery root is treated with a 0.05% solution of citric acid for 15 minutes, there is no change in color. In the root of the parsnip at the same concentration of the solution, there is a change of color after 5 minutes, and when processed with a 0.1% solution for 10 minutes, the color remains unchanged.

Changes in the color of celery and parsnip roots treated with salt solutions are given in Table 2. Based on the results of the observations, for celery roots it is enough to be treated with 1% salt solution for 10 minutes to prevent darkening due to oxidation-reducing enzymes. It is advisable to use a 2% solution of salt to treat parsnip root crops for 5 minutes. It should be noted that this treatment can result in changes in the organoleptic qualities of the finished products of white roots, especially desserts.

The results of the observation of changes in the color of celery and parsnip roots during heat treatment are given in Table 3. From Table 3, it is evident that after 3 and 5 min of blanching by steam, the pulp of celery and parsnip roots becomes yellow as the oxidizing enzymes are still active so this treatment should last at least 10 minutes for the roots of celery, and for parsnip roots, 15 min.

Yellowing is associated with the content of such polyphenolic compounds as flavonoids, and the non-carbohydrate component is aglycone. When root crops are treated with heat, the hydrolysis of these glycosides takes place, with the excretion of aglycon which is yellow in its free state. The oxy-derivative flavone in the presence of iron salts gives a green color which then becomes dark yellow or brown when iron-phenol compounds are formed [7].

Besides, blanching of peeled root crops inactivates enzymes only in the surface layer with a thickness of 2–5 mm. At the same time, the layer is softened, which facilitates the access of oxygen to the bottom layer, so during a short storage period of blanched root crops, a dark ring is formed between the cooked layer and the raw pulp as a result of active enzymes. That is why it is not desirable to use blanching to prevent darkening.

As restaurants are using microwave processing more and more often nowadays, we have investigated its impact on the quality indices and activity of white roots enzymes.

The results of microwave processing of celery and parsnip roots in different modes are given in Table 4.

Table 1 – Changes of the color of white roots when treated with citric acid(n = 3, p ≥ 0.95)

Observation time, min	**Concentration of citric acid,%**					
	0.05	0.1	0.15	0.05	0.1	0.15
	Celery roots of the Diamant variety			Parsnip roots of the Student variety		
5	yellow hue	no changes	no changes	grayish-yellow hue	grayish-yellow hue	no changes
10	yellow hue	no changes	no changes	grayish-yellow hue	no changes	no changes
15	no changes	no changes	no changes	no changes	no changes	no changes

Table 2 – Changes of the color of white roots when treated with salt solutions (n = 3, p ≥ 0.95)

Observation time, min	**Salt concentration,%**					
	0.5	1	2	0.5	1	2
	Celery roots of the Diamant variety			Parsnip roots of the Student variety		
5	yellow hue	yellow hue	no changes	grayish-yellow hue	grayish-yellow hue	no changes
10	yellow hue	no changes	no changes	grayish-yellow hue	darkens	no changes
15	no changes	no changes	no changes	Darkens after 3 min	no changes	no changes

Table 3 – Changes in the color of white roots during heat treatment (n = 3, p ≥ 0.95)

Observation time, min	**Blanching by steam**	
	Celery roots of the Diamant variety	Parsnip roots of the Student variety
3	yellow hue	yellow hue
5	dark yellow hue	dark yellow hue
10	no changes, juice is exuded	dark yellow hue
15	no changes, juice is exuded	no changes

Table 4 – Change in the color of white roots during microwave processing (n = 3, p ≥ 0.95)

Capacity, W	Processing time, min							
	1	2	3	4	1	2	3	4
	Celery roots of the Diamant variety				Parsnip roots of the Student variety			
100	darkens at once, hard	darkens at once, hard	darkens at once	darkened, dehydrated	darkens at once, hard	darkens at once, hard	darkens at once	at once darkens, dehydrated
300	darkens	darkens	edges dried, smell unusual for celery	edges dried, smell unusual for celery	darkens	darkens	edges dried, smell unusual for parsnip	edges dried, smell unusual for parsnip
400	darkens	darkens	edges dried, smell unusual for celery	edges dried, smell unusual for celery	darkens	darkens	edges dried, smell unusual for parsnip	edges dried, smell unusual for parsnip
450	darkens	darkens	edges dried, smell unusual for celery	edges brown, smell unusual for celery	darkens	edges dried	edges dried, smell unusual for parsnip	edges brown, smell unusual for parsnip
600	edges darken slightly	edges darken slightly	edges brown, smell unusual for celery, loses shape (dehydrated)	edges brown, smell unusual for celery, loses shape (dehydrated)	edges darken slightly	edges darken slightly	edges brown, smell unusual for parsnip	brown color, odor, loses shape
650	pulp white, moist, flavor retained	pulp white, slightly yellowish, moist, flavor retained	edges brown, smell unusual for celery	edges brown, smell unusual for celery, loses shape (dehydrated)	pulp white, moist, flavor retained	edges brown, smell unusual for parsnip	brown color, smell unusual for parsnip, loses shape	brown color, smell unusual for parsnip, loses shape

The studies presented in Table 4 indicate that to preserve the color and aroma of celery and parsnip roots, the treatment with a 650 W microwave jet for 1 min was the best. With longer processing, depending on the power, the raw material dehydrates and changes its color and aroma. This method was chosen as the main one, as it allowed preserving the color and aroma of the primary raw materials as well as reducing the length of the technological cycle, which is important in restaurant industry [12].

In the initial stages of root crops processing for first and second course dishes and desserts, they use heat treatment as a rule, during which, vitamin C is destroyed. The loss of this useful substance depends on the way in which this technological operation is carried out.

Table 5 shows the results of the studies that show changes in the content of ascorbic acid and in the activity of oxidoreductase in celery and parsnip roots, with different methods of heat treatment. Treatment of root crops by microwave jets was carried out at a power of 650 W for 1 to 4 min, measurements were carried out at intervals of 1 min.

Table 5 – Changes in the activity of white root enzymes (units /g) and the content of L-ascorbic acid (mg / 100 g), depending on the pre-treatment methods (n = 3, p ≥ 0.95)

Name of the indicator	Fresh raw materials	Steam processing	Microwave processing, min			
			1	2	3	4
Celery roots of the Diamant variety						
Peroxidase	3.596	0.46	0.45	0.42	0.38	0.32
Polyphenol oxidase	2.231	0.31	0.29	–	–	–
Ascorbate Oxidase	0.504	0.196	0.183	0.054	0.051	0.045
L-ascorbic acid	5.14	3.22	3.49	3.32	3.12	3.03
Losses of ascorbic acid,%	–	37.4	32.1	35.4	39.3	41.1
Parsnip roots of the Student variety						
Peroxidase	44.20	30.5	27.8	23.8	22.4	21.0
Polyphenol oxidase	4.720	0.67	0.60	–	–	–
Ascorbate Oxidase	4.812	1.87	1.68	0.51	0.48	0.39
L-ascorbic acid	14.6	9.45	10.05	9.49	8.78	8.63
Losses of ascorbic acid,%	–	35.3	31.2	35.0	39.9	40.9

These studies showed that, when steam-blanching white roots, the loss of L-ascorbic acid is 37.4% of its original content in the roots of celery and 35.3% in the root of parsnip. The best treatment of white roots with microwave currents was for 1–2 min. when the activity of peroxidase and ascorbate oxidase decreased significantly as compared to its initial level, while at the second minute, polyphenol oxidase was inactivated. Since microwave processing for 1 min allowed L-ascorbic acid to be stored at 67.9% and 68.8% in the roots of celery and parsnip, respectively and also taking into account the organoleptic characteristics of the white roots as given in Table 4, this mode was more appropriate.

Conclusion

It is determined how various methods of pre-treatment affect the quality indices of white roots as well as how the activity of oxidizing enzymes varies in the roots of celery and parsnip. It has been established that the best method for pre-treatment of root crops is 650 W microwave processing for 1 minute, which allowed the content of L-ascorbic acid to be maintained at 67.9% in the roots of celery and 68.8% in parsnip roots, as well as to reduce the activity of peroxidase by 87.5% and 16.4%, polyphenol oxidase by 87.0% and 87.3%, ascorbate oxidase by 63.7% and 65.1%, respectively.

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