Вивчено динаміку заморожування пасерованної цибулі та визначено в ній кислотне і перекисне число, досліджено зміни анатомічної будови клітин. Предметом дослідження була використана свіжа і заморожена пасерована цибуля. Встановлено збільшення кислотного числа і зменшення перекисного числа. Отримані дані можуть бути використані для визначення раціональних режимів заморожування і розморожування пасерованної цибулі в складі заморожених овочевих сумішей для перших страв

Ключові слова: заморожування, люмінесцуючі речовини, пасерування, анатомічна будова, кислотне число, холодильне зберігання

Изучена динамика замораживания пассерованного лука и определено в нем кислотное и перекисное число, исследованы изменения анатомического строения клеток. В качестве предмета исследования был использован свежий и замороженный пассерованный лук. Установлено увеличение кислотного числа и уменьшение перекисного числа. Полученные данные могут быть использованы для определения рациональных режимов замораживания и размораживания пассерованного лука в составе замороженных овощных смесей для первых блюд

Ключевые слова: замораживание, люминесцирующие вещества, пассерование, анатомическое строение, кислотное число, холодильное хранение

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EFFECT OF SAUTÉING OF ONION ON ITS STORAGE AT LOW TEMPERATURES

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1. Introduction

One of the most dynamically developed segments of the market of frozen products is the market of frozen vegetable mixes for soups.

Providing human organism with nutrients contained in fresh vegetables during winter becomes possible due to the use of different ways of processing of vegetable raw materials. Frozen vegetable mixes do not contain preservatives because they are frozen immediately after harvesting, thus saving maximum vitamins. Existing methods of processing of vegetable raw materials have significant shortcomings that are connected with the loss of biologically active substances and deterioration of their functional and technological properties [1]. Low temperature canning of vegetable mixes is one of methods of processing, which is characterized by a number of such advantages as: chemical composition is close to the original raw material, long term of storage, easy to use at restaurant enterprises [2].

At present stage, evolutionary changes take place in the production of canned food, their consumer properties towards increasing their degree of readiness. Extending the range of frozen vegetable mixes for soups of high degree of readiness remains a relevant area of research today.

Given the fact that the technology of production of frozen vegetable mixes with high degree of readiness implies the application of thermal treatment, it is necessary to select such a method of canning, which would enable retaining maximum nutrients of chemical composition of the product, as well as its organoleptic properties [3].

Sautéing is one of the popular methods of thermal treatment. It is used with the aim of softening products. By increasing the temperature, a product undergoes physical and chemical processes that are related to each other, resulting in the removal part of moisture, a product absorbs oils, there is a change in density and increase in porosity of the product [4]. At sautéing, essential oils contained in the products are partly transformed into fat, in this case, during their consequent preparing, they are evaporated much slower than when cooking in water, which helps to improve their taste. Study of the effect of thermal pre-treatment on the change in anatomical structure of vegetable tissues before and after freezing is relevant.

2. Literature review and problem statement

Research into the influence of low temperatures on the change in chemical composition of food products and stabi-

lizing, applying various methods of pre-treatment, optimization of the methods of freezing and defrosting is of great interest for some scientists [5]. Their results prove feasibility of the process of freezing for the long term storage of products of plant origin with low acidity.

A study of onion, which underwent thermal treatment, in particular freezing, pasteurization and sterilization, revealed that the freezing and pasteurization is a better alternative to obtain a product with high antioxidant properties [6].

Of great interest to scientists are the studies related to frozen onion with different periods of internal storage at ambient temperature [7]. The shortcoming of the method of storage at ambient temperature is the increase in the content of flavonoids in comparison with the corresponding chemical composition of onion before freezing. It was found that the freezing of onion increases its storage life. Thus, freezing can be one of the methods to prevent losses when storing fresh onion, preserving its antioxidant capacity as frozen onion may be a useful natural antioxidant source.

Authors in their scientific papers explore the storage of onion at low temperature and under conditions of low humidity [8, 9]. Storing at low temperatures preserves the content of flavonoids in onion. Controlled periods of time and storage temperature may affect metabolic activity of fresh vegetables and even increase phytochemical synthesis. The freezing of onion is one of the progressive methods of increasing its period of storage.

Some scientists [10, 11] consider initial thermal treatment of food products, which consequently may lead to the loss of water-soluble and oxygen-unstable nutrients such as vitamin C and the group B vitamins. Cooling slows respiration of vegetables and allows increasing their storage period. Positive feature in these studies is the use of freezing for perishable vegetables, which may be consumed all year round and safely transported to consumers all over the world, not just to those located near the region of harvesting. As a result of thermal treatment, the breathing slows, thus the intake of nutrients stops, and moisture loss is reduced, as well as growth of microorganisms. The selection of the process of thermal treatment leads to change in color, texture, taste and nutrients.

Physical and chemical processes and physical effects that occur during the processing of raw materials may serve a theoretical basis for the development of sample preparation and the methodology of quality assessment [12].

Much attention is paid to the issues concerning the improvement of quality of food products at freezing. They explore and analyze the effect of thermal pre-treatment on the process of freezing and storing in the products of vitamins, pectins, ascorbic acid and other components of chemical composition of vegetables.

Analysis of scientific works [6–13] revealed insufficient attention paid to the study of processes of freezing-defrosting of food products after conducting thermal pre-treatment and change in anatomical structure and chemical composition in frozen onion. Thus, more detailed research into this area is expedient and extremely important.

3. Aims and objectives of the research

The aim of the work is the study of change in anatomical structure at freezing and defrosting of sautéed onion and determining its acid and peroxide number after refrigeration storage.

To achieve the set aim, the following tasks were to be solved:

– to conduct analysis of the Ukrainian market of frozen vegetable mixes for soups with high degree of readiness, to explore the processes that occur at freezing and defrosting, and their effect on consumer and functional and technological properties;

– to examine changes in anatomical structure of frozen onion depending on thermal pre-treatment;

– to study dynamics and speed of low-temperature freezing of sautéed onion;

– to determine acid and peroxide number after freezing at temperature of 20 °C, after storing for 30 days at temperature of –18 °C.

By solving the number of set tasks, obtained experimental data may be used to determine rational modes of freezing and defrosting of sautéed onion in the composition of frozen vegetable mixes for soups with the purpose of providing for their high quality.

4. Methodology and results of research into dynamics of freezing sautéed onion and determining its acid and peroxide number

The application of thermal pre-treatment of vegetable raw materials before freezing affects functional and technological properties of food products, which allows producing frozen vegetable semi-finished products with high degree of readiness.

The object of study was the onion of variety of German selectionists (Stuttgarter Riesen), grown in Ukraine, which underwent sautéing and low-temperature freezing. The selected variety of onion is characterized by high content of dry substances, contains large amount of vitamin C and is also suitable for processing and storage. There are four modes of sautéing for onion: transparency “0.6”, golden color “1.0”, redness “1.2”, and attaining a noticeable reddish-brown tint “1.9”.

To conduct cryoscopic studies, it is necessary to have equipment, which would enable determining cryoscopic temperature of the examined object. In our case, such equipment was the designed low-temperature calorimeter [14]. A studied sample of onion was exposed to freezing in the form of ground homogenous mass of 20 g, which was immersed in a calorimeter with a given medium temperature. The registration was carried out by the chromel-copel thermocouples with the junction diameter of 0.2 mm. A signal from the thermocouples was registered by digital potentiometer connected to the port of PC. Statistical processing and approximation of database was conducted using the software MathCAD 14 [15].

As a result of the research, we found that at the temperature of freezing –20 °C, the value of maximum speed of freezing practically does not change; this indicates that the rate of cooling is not limited by thermal physical properties of the sample. In the examined sample of sautéed onion, the temperature of crystallization of the frozen-out water is shifted in direct dependence on the temperature of freezing [16].

Before and after the low-temperature freezing, we determined acid and peroxide number in the studied samples of sauéed onion.

To study the acid and peroxide number, the onion was exposed to sautéing on the sunflower oil at temperature of

approximately 120 °C and during 8 minutes until reaching golden color [17].

After conducting the studies we marked increase in acid number during storage (from 0.317 to 0.467 mg/KOH). This is due to the fact that during defrosting the ice crystals destroy the walls of onion's tissue, and the moisture is released as a result. Moisture, in its turn, activates hydrolytic processes. In the examined product, along with fat, there is excess moisture, which passed, as a result of thermal treatment, from onion to the fatty phase, as well as the chemical compounds that accelerate the hydrolysis. As a result of this, autocatalytic hydrolysis of fat occurs, that is, the lipolysis, accompanied by accumulation of free fatty acids.

The stability of fat during storage is affected by various components of the chemical composition of onion, moisture, ions of metals, nitrogenous compounds and temperature. The most common type of spoiling fats is considered to be oxidative rancidity or auto-oxidation. The start of auto-oxidation is the formation of free radicals. Their availability and accumulation in fats is the beginning of formation of hydroperoxides. This indicates the process of auto-oxidation that does not change taste and smell of the products at this stage of oxidation. Formation and catalysis of hydroperoxides occur in fats continuously. As a result of further transformations, fat accumulates radicals that enter the reaction and form secondary oxidation products, including aldehydes.

Based on the obtained results, we also observed reduction of peroxide number (from 0.034 to 0.012 mmol/kg $^1/_2$O).

The reaction of oxidation is slowed down by inhibitors or antioxidants. Antioxidants, in turn, possess natural synergistic properties. It is known that the composition of napiform onion includes sugars (maltose, glucose, saccharose, fructose – 3–14 %), vitamins A, B, C (6–11 mg/100 g), organic compounds (citric, malic, thiocianic, phytic acids), phosphates, essential oils (18–155 mg/100 g), glycosides, flavonoids (quercetin, epireozid), mineral salts (potassium, iron, cobalt, manganese, selenium, zinc, sulfur), etc. [18, 19].

During thermal treatment of onion, namely sautéing, vitamin C, citric acid and phosphates act as antioxidants. They are, as the result of sautéing of onion, pass into fatty phase; after defrosting, free moisture was released that led to the inhibition of oxidative processes in fat. This explains the reduction of peroxide number in the studied samples after defrosting.

5. Methodology and results of study of the change in anatomical structure of frozen onion depending on thermal pre-treatment

After the low-temperature freezing and defrosting of sautéed onion, we analyzed changes in its anatomical structure.

Light and luminescent microscopy is widely used in the studies of food products. Luminescent images of the elements of microstructure of a product may carry information about the form, dimensions and composition of components of a food product, as well as about chemical processes that occur. The resulting information may be used to assess quality.

The study of microstructure of the sample's tissue was carried out using the light microscope Celestron, a digital camera, the device of UV-radiation Prolux 370 with a wavelength of 250–300 nm. Sections of the examined sample were placed onto a glass slide and the images were taken in ultraviolet light.

We used received micrographs to conduct analyses: identification of substances that are included in chemical composition, determining of cells forms, tissue, distribution of luminescent objects on the area of the sample's section, determining diameter of the cells. Micrograph of the sample of fresh onion is shown in Fig. 1.

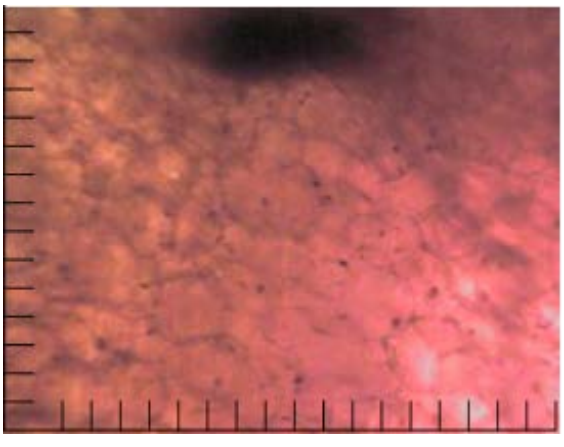

Fig. 1. Micrograph of fresh onion in cross section (wavelength 250—300 nm)

On the received micrograph (Fig. 1) of fresh onion in cross section, well distinguishable are the peculiarities of its structure. The cells are densely placed to each other and have rounded shape. Inside the cell is the cytoplasm, which is colored with iodine. The cell walls are visible and their boundaries that are formed by thick colorless shells that provide sustainable form of cell. Transporting the water with dissolved mineral and organic substances is performed thanks to the structure of cell membranes. The vacuole that contains the reserve of nutrients includes also solutions of mineral salts and organic acids, products of metabolism of substances of cell of the plant, pigments, etc.

To identify mineral substances, we carried out additional experiment on determining certain components of quality chemical composition of onion [20]. Fig. 2 presents the micrograph of onion under ultraviolet radiation.

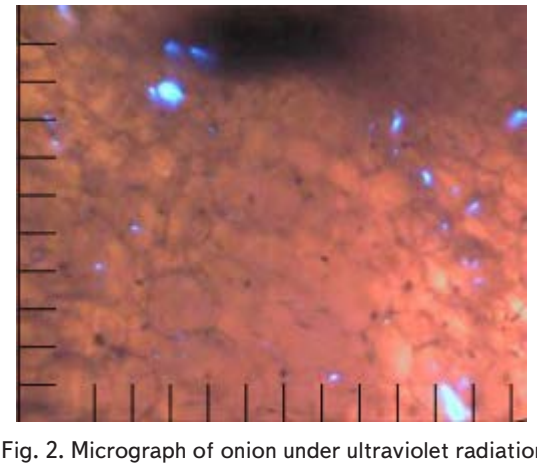

Fig. 2. Micrograph of onion under ultraviolet radiation

Under the influence of ultraviolet radiation, the substances that are part of cellular juice of onion, namely minerals such as calcium, potassium, magnesium, iron and phosphorus manifest the capacity to display fluorescence. In the micrograph, under ultraviolet lighting of a histological

cut of onion's plant tissue, one identifies bright formations of rounded form that have the color from light blue to violet (Fig. 2). These formations are localized in the intercellular fluid and are spread across the surface.

Compared to fresh onion, the microscopy of sautéed onion (Fig. 3) demonstrates significant changes to the cells. The cells changed their forms, acquired oblong form; the micrograph also displays small bubbles of oil.

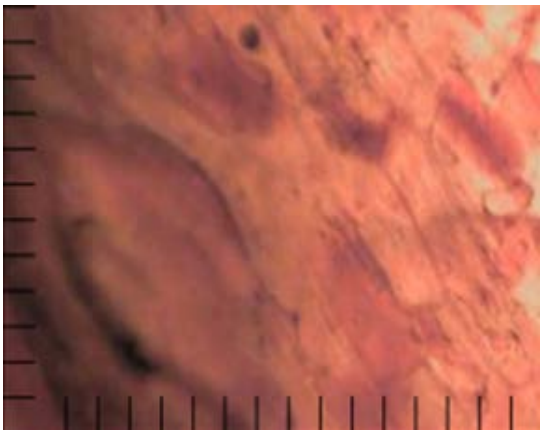

Fig. 3. Micrograph of sautéed onion in cross section (wavelength 250—300 nm)

Freezing leads to the formation of fine crystalline structure of ice in the volumes of the samples. Micrograph of frozen sautéed onion is in Fig. 4.

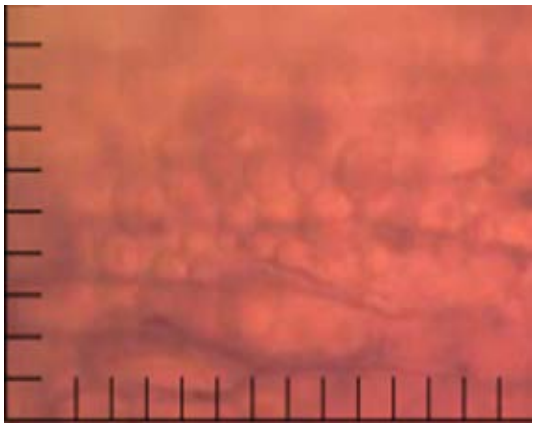

Fig. 4. Micrograph of sautéed and frozen onion in cross section (wavelength 250—300 nm)

Unlike fresh and sautéed onion, the frozen sautéed onion (Fig. 4) has clear cells with expressed elongated shape. They are densely located next to each other, with well the cell walls clearly visible.

6. Discussion of results of the conducted research into sautéed onion

It is proven that the use of thermal pre-treatment of onion before freezing affects its functional and technological properties, allowing producing frozen vegetable semi-finished products with high degree of readiness.

Duration of technological pre-treatment was determined experimentally for each mode of sautéing: sautéing duration to reaching transparency 0.6 should be 5 min.; mode 1.0 – 8 min.; mode 1.2 – 10 min., mode 1.9 – 15 min. For the given research we selected the mode of onion sautéing 1.0 – 8 minutes.

As a result of freezing at temperature of 20 °C, the value of maximum speed of freezing practically does not change; this indicates that the rate of cooling is not limited by thermal and physical properties of the sample. In the examined sample of sautéed onion, the temperature of crystallization of the frozen-out water shifts in direct dependence on the temperature of freezing. Maximum speed of freezing at temperature of –20 °C amounted to 0,021±0,002 °C/s, the point of crystallization was reached at –5.4 °C.

To study the acid and peroxide number, onions underwent sautéing according to the selected mode. We marked the increase in acid number during storage (from 0.317 to 0.467 mg/ KOH) and the reduction in peroxide number (from 0.034 to 0.012 mmol/kg 1/2O).

Before and after the low-temperature freezing and defrosting of sautéed onion, we analyzed changes in its anatomical structure. After taking the micrographs of fresh onion and sautéed onion before and after freezing in cross section (wavelength 250–300 nm), it was found that the cells in tissues changed their shape and structure: the cells do not have a clear-cut shape and orderliness, the breaks are visible at the contours of the walls of cells. After sautéing, onion luminescent formations change their shape due to deformation of cell membranes. Frozen sautéed onion has clear cells with expressed elongated shape and clearly visible densities of cellular structures. In the course of freezing, the plant cells are less prone to destructive action of ice crystals.

6. Conclusions

1. In the course of research we found that at temperature of freezing – 20 °C, the value of maximum speed of freezing practically does not change. This indicates that the rate of cooling is not limited by thermal and physical properties of the sample. In the examined sample of sautéed onion, temperature of crystallization of the frozen-out water shifts in direct dependence on the temperature of freezing.

2. We determined the increase in acid number (from 0.317 to 0.467 mg/KOH) in the process of storage, and the reduction in peroxide number (from 0.034 to 0.012 mmol/kg $^1/_2$O) in the examined samples of sautéed and frozen onion.

3. When exploring the structure of plant tissue of onion after technological pre-treatment (sautéing), it was found that cells in the tissues changed their shape and structure: the cells do not have a clear shape and orderliness, the breaks are visible at the contours of the walls of cells. After sautéing, onion luminescent formations change their shape due to deformation of cell membranes. These formations do not have specific shape and are not distributed evenly. Unlike fresh and sautéed onion, the frozen sautéed onion has clear cells with expressed elongated shape. Clearly visible are the densities of cellular structures. This demonstrates that in the process of freezing, the plant cells will be less susceptible to destructive action of crystals of ice.

4. The research results confirmed that adding sautéed onion to the frozen vegetable mixes is expedient and will not alter organoleptic properties of the product, will not accelerate the processes of oxidation of fats, but instead will help to preserve the integrity of form and delicate texture of onion in a soup prepared with such a mix.

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