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Влияние обработки высоким давлением на срок годности готовых к употреблению салатов

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Аннотация. Введение. *Цель. Обосновать эффективность использования технологии обработки пищевых продуктов высоким давлением (High Pressure Processing (HPP)) подавление и уничтожение патогенных микроорганизмов.* ***Материалы и методы****. В ходе исследования воздействия технологий HPP для инактивации и уничтожения микроорганизмов в приготовленных овощных салатах, были проведены эксперименты по обработке высоким давлением с использованием системы «Пищевой гидростат, модель 600 МПа/30 л». Отбор образцов и оценка их качества осуществлялись в соответствии с установленными методами в Испытательном лабораторном центре (Федеральное бюджетное учреждение здравоохранения «Центр гигиены и эпидемиологии в Свердловской области»), а микробиологические исследования проводились в независимой лаборатории ООО «Кволити Мед».* ***Результаты и обсуждение.*** *При использовании сверхвысокого давления (High Pressure Processing (HPP) в процессе обработки, упакованные продукты помещаются в специальные контейнеры, полностью погруженные в воду, где они подвергаются равномерному сжатию со всех сторон. Процесс высокого гидростатического давления основан на применении давления до нескольких тысяч бар, что позволяет уничтожить патогенные микроорганизмы, сохраняя при этом питательные вещества и органолептические свойства продуктов. Этот метод действует на продукты равномерно и мгновенно по всему объему, независимо от их формы и размера, не имея ограничений. Проведенные исследования готовой продукции по завершении технологического процесса показали полное соответствие установленному стандарту для показателя КМАФАнМ (5×10^3 КОЕ/г). В процессе хранения обоих образцов обработанных HPP салатов отмечается увеличение общего уровня микробного загрязнения. Однако даже после 7-дневного хранения все исследованные образцы соответствовали установленным критериям для данного показателя (в значениях lg КОЕ/г не превышали $5x10^4$ КОЕ/см^3), в то время как уровень КМАФАнМ в образце салата без обработки высоким давлением превышал норматив в 10 раз после 7 дней.* ***Заключение.*** *Обработка высоким давлением является эффективным методом для продления срока хранения готовых к употреблению салатов. Она позволяет значительно снизить уровень патогенной микробиоты и сохранить физико-химические характеристики продуктов. Перспективы применения HPP открывают новые возможности для улучшения безопасности и качества готовых овощных салатов, что особенно актуально в условиях современного рынка питания.*

Ключевые слова: овощные салаты, готовая кулинарная продукция, высокое давление, срок годности

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Research article

The effect of high-pressure treatment on the shelf life of ready-to-eat salads

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Abstract. Introduction. *The aim. To substantiate the effectiveness of the use of High Pressure Processing (HPP) technology for food processing suppression and destruction of pathogenic microorganisms.* ***Materials and methods****. In the process of studying the impact of HPR technologies for the suppression and destruction of microorganisms in ready-made vegetable salads, high-pressure processing studies using the "Food Hydrostat, model 600MPa/30L" were conducted. Sampling and quality assessment were carried out in accordance with standard methods on the basis of a Testing laboratory Center (FBUZ Center for Hygiene and Epidemiology in the Sverdlovsk Region), microbiological indicators on the basis of an independent laboratory of Quality Med LLC.* ***Results and discussion.*** *When using high Pressure Processing (HPP) in the processing process, packaged products are placed in special containers completely immersed in water, where they are subjected to uniform compression from all sides. The process of high hydrostatic pressure is based on the application of pressure up to several thousand bar, which makes it possible to destroy pathogenic microorganisms, while preserving the nutrients and organoleptic properties of the products. This method acts on products uniformly and instantly throughout the entire volume, regardless of their shape and size, without restrictions. The conducted studies of finished products at the end of the technological process showed full compliance with the established standard for the KMAFAnM indicator (5×10^3 CFU/g). During the storage of both samples of HPR-treated salads, an increase in the overall level of microbial contamination is noted. However, even after 7 days of storage, all the studied samples met the established criteria for this indicator (in lg CFU/g values did not exceed $5x10^4$ CFU/cm^3), while the level of CMAFAnM in a salad sample without high-pressure treatment exceeded the standard 10 times after 7 days.* ***Conclusion.*** *High pressure treatment is an effective method for extending the shelf life of ready-to-eat salads. It allows you to significantly reduce the level of pathogenic microbiota and preserve the physico-chemical characteristics of products. The prospects for the use of HPR open up new opportunities to improve the safety and quality of ready-made vegetable salads, which is especially important in the conditions of the modern food market.*

Keywords: vegetable salads, ready-made culinary products, high pressure, shelf life

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Introduction. The use of the latest technological developments allows not only to solve the problems of hunger and access to essential nutrients, such as vitamins, but also to create new challenges for the human body, which it and its offspring may face both in the near future and in

the long term. In the modern world, where the pace of life is becoming increasingly fast, it is important to ensure the safety and security of food products. The development of technologies that allow extending the shelf life of finished culinary products, including salads, is an urgent task from the point of view of consumers, producers and the environment [2].

Ready-to-eat salads are becoming increasingly popular due to their convenience and variety. However, despite their high demand, they have a limited shelf life. Salads can lose their taste and safety in a short period of time, which necessitates the development of methods to extend their shelf life.

In today's world, it is important to use innovative approaches to extend the shelf life of food products, and one of the effective methods is the use of non-thermal physical preservation methods. These methods are based on the use of various physical processes that can reduce the activity of microorganisms and increase the shelf life of products, while significantly reducing the use of preservatives [3]. The development of new technologies for extending shelf life contributes to the development of the prepared food industry, allowing to expand the range of products and improve storage and transportation conditions.

One of the promising methods is high pressure processing (*HPP*) , which allows disinfecting products without the use of chemical preservatives. In this article, we will consider the effectiveness of *HPP* in relation to the natural microflora of ready-made salads and its effect on the physicochemical properties [4].

HPP is a method based on the effect of pressure up to 600 MPa on products. This method allows to destroy pathogenic microorganisms and slow down the growth of unwanted microflora without significant damage to the organoleptic properties of the product.

Advantages of *NRR* :

Preservation of vitamins and minerals – high blood pressure does not impair the content of nutrients;

Improved safety – reducing the number of pathogenic bacteria reduces the risk of foodborne infections;

Extending shelf life – by neutralizing microorganisms, the shelf life of the product can be increased [5,6].

The aim of the study is to substantiate the effectiveness of using *High Pressure Processing (HPP)* technology to suppress and destroy pathogenic microorganisms.

Materials and research methods. In the process of studying the impact of high-pressure technologies on reducing the number of microorganisms in ready-made salads, experiments were conducted using the "Food hydrostat, model 600MPa/30L" in the tolling center of RAS Technologies Group LLC together with the M.N. Mikheev Institute of Metal Physics of the Ural Branch of the Russian Academy of Sciences, strength laboratory.

The ready-to-eat salads were packed in innovative skin packaging to ensure freshness during storage and were subjected to high pressure treatment using HPP technology. This process involved pressure treatment of 3000 and 5500 MPa, lasting 300 seconds at a stable temperature of 21 ± 3°C. The HPR (High Pressure Reactor) equipment is equipped with a high-pressure vessel with a diameter of 200 mm and a length of 2000 mm, capable of providing pressure up to 6000 MPa. In addition, it interacts with a refrigeration system, allowing for precise control of the temperature of the cooling liquid used to create the required pressure in the process.

Objects of study:

Sample No. 3181 - Vitamin Salad; production date: 21.03.2024; shelf life: 18 hours; batch size: 10 pcs; packaging: skin packaging;

Sample No. 3185 - Vitamin Salad; production date: 21.03.2024; shelf life: 7 days; batch size: 10 pcs; packaging: skin packaging, unprocessed;

Sample No. 3186 - Vitamin Salad; production date: 21.03.2024; shelf life: 7 days; batch size: 10 pcs; packaging: skin packaging. Processed with *HPP* 3000 MPa, exposure 300 s .

Sample No. 3187 - Vitamin Salad; production date: 21.03.2024; shelf life: 7 days; batch size: 10 pcs; packaging: skin packaging. Processed with *HPP* 5500 MPa, exposure 300 s .

Sampling was carried out in accordance with GOST R 54607.1-2011 "Public catering services. Methods of laboratory control of public catering products. Part 1. Sampling and preparation for physical and chemical testing."

Research methods:

GOST 30538-97 "Food products. Methodology for determining toxic elements by the atomic emission method"

GOST 34151-2017 "Food products. Determination of vitamin C" using HPLC.

GOST R 54607.5-2015 "Public catering services. Methods of laboratory control of public catering products. Part 5. Methods for determination of fat" p. 7.3.

GOST R 54607.7-2016 "Public catering services. Methods of laboratory control of public catering products. Part 7. Determination of protein by the Kjeldahl method".

MU 122-5/72 "Methodological guidelines for laboratory quality control of public catering products." p. 7.4.5.

The studies were conducted at the Testing Laboratory Center (Federal Budgetary Institution of Health "Center for Hygiene and Epidemiology in the Sverdlovsk Region"), microbiological indicators were conducted at the independent laboratory of Quality Med LLC. The equipment used: Vitek MS mass spectrometer analyzer (BioMerieux, France).

Research results and their discussion. "When production products public nutrition, at manufacturing salads With enlarged term storage is regulated row sanitary and hygienic operations, V in particular, washing vegetables purified water. However, technology sinks raw materials used at production culinary products, Not provides achievement standardized microbiological indicators: contamination microorganisms remains high. IN That same time microflora recycled vegetable raw materials Very varied: Also possible bacteria, yeast, moldy mushrooms, pathogenic microorganisms" [7]. For provision hygienic purity prescription components salad products necessary improve technology their preparation, including through the use of physical methods of disinfection.

The Vitamin salad was immediately after production packed in skin packaging - a tray made of polymeric materials for Skin sealing, processed under high pressure and stored at a temperature of 0-4 ^{0}C for 7 days to conduct physical, chemical and microbiological indicators and for 10 days to conduct an organoleptic assessment.

When using ultra-high pressure in the processing process, the packaged products are placed in special containers completely immersed in water, where they are subjected to uniform compression from all sides. The high hydrostatic pressure process is based on the application of pressure up to several thousand bars, which allows to destroy harmful microorganisms, while preserving the nutrients and organoleptic properties of the products. This method acts on the products uniformly and instantly throughout the entire volume, regardless of their shape and size, without any restrictions. The results of the influence of *HPP* on the physicochemical properties of salads, including during storage, are presented in Table 1.

Table 1 – Changes in physical and chemical parameters of salads during storage

Name of the indicator	Unit of measurement	Sample No. 3181	Sample No. 3185	Sample No. 3186	Sample No. 3187
Squirrels	%	1.1±0.9	1.1±0.8	1.0±0.9	1.0±0.5
Fats	%	1.9±1.0	1.9±1.0	1.6±1.0	1.5 ± 1.0
Carbohydrates	g/100g	7.9	7.5	7.9	7.9
pH		5	8.5	5.5	5.5
Vitamin C	mr/l00r	12.4±2.0	4.4±1.0	12.4±2.9	12.0±1.5

An assessment of the effect of *HPP* on the physicochemical properties of salads showed that the treatment resulted in slight changes in pH, but these were most often within acceptable limits and did not affect the safety or taste of the product. During the storage of vegetable salads,

a gradual decrease in the vitamin C content was observed. The loss of this vitamin occurs mainly due to the activity of oxidative enzymes, whose partial renewal leads to an acceleration of the oxidation process. Violation of the integrity of plant tissue and the release of cell juice also contribute to this process. Nevertheless, the use of HPP technology made it possible to preserve the vitamin C content in vegetable salads, giving them freshness and useful properties. The processes occurring during the treatment of food systems with high pressure are consistent with the studies of other authors [7-9, 11].

The organoleptic evaluation of salads processed using *HPP technology* showed that the salads retained their crispy texture and pleasant taste. This is especially important for consumers who value freshness and quality of products. In general, the organoleptic evaluation showed that vegetable salads packed in skin packaging and processed using *HPP* retain high organoleptic characteristics for 7 days of storage.

The dynamics of microbiological indicators of vegetable salads during storage are presented in Table 2.

Table 2 – Dynamics of microbiological indicators during storage

Name of the indicator	Permissible level value*	Sample No. 3181	Sample No. 3185	Sample No. 3186	Sample No. 3187
KMAFANM	$5x10^4$ CFU/cm^3	$3x10^3$	$5x10^5$	$5x10^3$	$8x10^3$
BGKP	not allowed in 0.1 g	Not found	Discovered	Not found	
Salmonella spp.	not allowed in 25.0 g	Not found			
Listeria monocytogenes	not allowed in 25.0 g	Not found	Discovered	Not found	
Staphylococcus aureus	not allowed in 0.1 g	Not found			
Proteus spp.	not allowed in 0.1 g	Not found			
E.coli	not allowed in 1.0 g	Not found	Discovered	Not found	
Yeast	no more than 200 CFU/g	0	400	0	0
Molds	no more than 50 CFU/g	0	90	0	0

* According to TR CU 021/2011 "On the safety of food products"

HPP treatment has been shown to be effective in reducing pathogenic bacteria such as Salmonella, E. coli and Listeria monocytogenes. Even short-term exposure (1-3 minutes) at high pressure can reduce the number of these microorganisms by 99% or more.

HPP technology also affects lactic acid bacteria, molds and yeasts, which allows controlling the fermentation process and prevents product spoilage, which is consistent with the data of similar studies [10, 12-14]. Reducing their numbers helps extend the shelf life of vegetable salads.

During the studies conducted on the finished products after the technological process was completed, it was found that all samples met the established standard for the QMAFAnM indicator (5×10^3 CFU/g). During storage of the samples of salads processed with HPP, an increase in the total microbial contamination was observed. Despite this, even after 7 days of storage, all samples met the requirements for this indicator (lg CFU/g does not exceed 5×10^4 CFU/cm^3). However, in the case of a salad sample that was stored without high-pressure treatment, the QMAFAnM level exceeded the norm by 10 times after 7 days.

Conclusion. High-pressure processing is an effective method for extending the shelf life of ready-to-eat salads. It allows to significantly reduce the level of pathogenic microbiota and preserve the physicochemical characteristics of products [15, 16]. The prospects for the use of

HPP open up new opportunities for improving the safety and quality of ready-to-eat vegetable salads, which is especially important in the conditions of the modern food market.

The high pressure applied in the HPP process acts at the cellular level, destroying intracellular vacuoles, cell walls and the cytoplasmic membrane. This treatment method is uniformly distributed throughout the entire volume of the product without restrictions on size and shape, without compromising the structural integrity of the product, which prevents its deformation or rupture.

The experiments conducted confirm that further research in this area can lead to the optimization of production and storage technologies for ready-to-eat salads, which will increase consumer satisfaction and reduce food waste. The advantages of using HPP technology include extending the shelf life of products, preserving their natural taste and texture, and increasing sterility without changing the organic nature of the products. Due to the comprehensive compression under high pressure, this processing method becomes a reliable way to ensure the safety and quality of food products

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