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EVALUATION OF TECHNOLOGICAL PROPERTIES AND SAFETY INDICATORS OF POULTRY PRODUCTS MADE USING NATURAL MARINADES

The object of research is the technology and quality parameters of marinated semi-finished poultry meat products using marinades based on cherry juice of the Chernokorka variety (Cherry tree Chernokorka) and Josta berries (Josta). The problem solved in the research is the lack of an exhaustive definition of the influence of natural marinades on the complex of indicators of natural semi-finished poultry meat products. The key evaluation parameters were: color, pH, moisture retention capacity, marinade absorption, losses during heat treatment, sensory indicators, safety indicators of finished products. The process of passive marinating (soaking) was carried out for 12 hours. For this, chicken breasts were soaked in marinade solutions No. 1 (josta berry juice: purified water: sea salt – 60:37:3) and No. 2 (cherry berry juice: purified water: sea salt – 60:37:3). As a control, samples were marinated in marinades of the company Spice Land LLC (Ukraine).

It was found that the juice of josta berries differs from cherry juice in a higher content of total phenolic compounds (327.16 versus 201.31 mg/100 ml) and a higher titrated acidity (3.5%). The antioxidant activity of josta juice is at a high level: juice polyphenols inhibit 97.41 ± 1.57% of the DPPH free radical. An increase in moisture content was determined in products marinated with cherry juice (76.21%) and josta juice (77.16%). The use of cherry and josta juice in marinades accelerates their diffusion into muscle tissue. The highest sorption capacity was found in samples treated with marinade with josta juice (1.43%), which is 1.5 times higher than the control. The use of berry juices in marinades reduces thermal losses by 2.17–2.68%.

It has been proven that the use of cherry and josta juice as bases for marinades in the technology of semi-finished poultry meat products improves the taste and aroma profile of finished products, inhibits oxidative processes in marinated semi-finished poultry meat products, and ensures their microbiological safety during storage.

Keywords: *marinated meat semi-finished products, cherry juice, josta juice, marinade absorption, antioxidant activity.*

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1. Introduction

With the growing consumer demand for healthy and natural foods, researchers are increasingly focusing on incorporating natural ingredients and additives into the meat marinating process, replacing synthetic components. The use of marinades as an effective preservative is the oldest and most common practice in the meat industry. Marinades enhance flavor, retain moisture, improve texture, inhibit bacterial growth, and increase the yield of final products. According to the classical definition, marinades are seasoned or flavored mixtures of ingredients used to improve the color, texture, flavor, and tenderness of meat and meat products.

Scientific studies have demonstrated the important role of marinade ingredients, such as polyphenols, in exerting various beneficial actions, including antibacterial and anti-allergic effects.

The use of physical methods to accelerate pork marinating by laser perforation, high pressure, and ultrasound has been shown to be promising [1–3]. It has been established [4] that the use of buttermilk and whey for marinating chicken breast has a positive effect on the organoleptic characteristics and tenderness of finished products.

It has been proven that herbs and spices added to marinades significantly improve meat quality and have a health effect by controlling or minimizing lipid oxidation [5] and extending the shelf life [6] of finished products. It has been established [7] that marinades based on beer, oregano, parsley, mustard, salt, pepper, garlic, olive oil, vinegar, and fresh onion act as antioxidants during the marinating process.

It has been proven [8] that marinating chicken meat with apple juice and a mixture of apple and lemon juices resulted in a decrease in pH, increased tenderness of raw and fried products, and improved microbiological quality.

Most studies prove that the most effective way to improve the sensory quality and safety of game meat and its products is possible through the use of acidic biological marinades. Acidic marinades change the surface, but do not penetrate deeply. They add flavor and can help browning. They do not leave any residue on the meat. Therefore, biological marinades can be used in the meat industry, as they are inexpensive and can reduce health risks.

In [9], it was reported that the use of marinades with a high content of organic acids can significantly improve the structural, mechanical and taste qualities of finished game meat products. For marinating game birds with a richer taste, such as ducks, geese and grouse, a greater effect is obtained from sweeter marinades [10], which helps to balance the taste of their dark meat.

To obtain the best results from marinating, it is necessary to take into account that a certain fruit or vegetable will give the meat a unique taste (from neutral to sweeter or sour). It is known that fruit enzymes can have both positive and negative effects on the quality of products. Lipase catalyzes the breakdown of fats, and proteases break down proteins into free amino acids [11]. Therefore, when choosing a marinade base, one should consider not only the taste properties, but above all the structural and technological properties of the meat that will be marinated.

The effectiveness of the marinating process, even for the same type of meat, can depend on several factors, such as the type of marinade, the marinating method, the holding time and temperature.

The technological process of marinating is constantly being improved through the strategy of chemical and mechanical processing methods, the selection of innovative ingredients for marinade formulations to achieve the desired characteristics of products and extend their shelf life.

Currently, the technique of marinating meat varies significantly from passive absorption of marinade (simple immersion in marinade), to the use of modern marinating methods, such as vacuum mixing, injection, massaging, ultrasonic marinating, etc. [12, 13].

Marinating meat products by immersion is the cheapest method and does not require special equipment. At the same time, some researchers point to its low efficiency compared to the latest physical methods – hydrodynamic and high pressure [14], ultrasound with the addition of papain [15], pulsed electric field [16].

However, exquisite craft pickled meat products, which can be found not only in specialized stores, but also on restaurant menus, are made by soaking in a liquid marinade mixture of various ingredients. This method of marinating is ideal for meat that requires additional tenderness and juiciness (steaks, chicken breasts, game meat). At the same time, bioactive components contained in large quantities in berry and fruit marinade bases, with prolonged soaking, break down proteins more intensively, making the meat juicy and aromatic [17]. In addition, due to the gradual passive movement of marinade components into the meat by osmosis, the taste and softness of the meat and its ability to retain moisture are improved.

An innovative component of the marinade base can be the juice of josta berries. This berry shrub produces sweet and sour fruits that have a pleasant nutmeg flavor and are filled with various phytochemicals, most of which are phenolic molecules. Josta is characterized by its overall antioxidant power, as it inherited from black currant an extremely high concentration of vitamin C, which works as an "amplifier" for phenols. The berries are rich in minerals, vitamin C, provitamin A, and B vitamins. The berries are useful for diabetics due to their high fructose content of 15% [18]. A powerful antioxidant found in the berries is rutin, which is soluble in water. Nutritional value of 100 g of Josta berries: water – 80 g, proteins – 0.7 g, fats – 0.2 g, carbohydrates – 9.1 g. Josta is a hybrid of black currant (Johannisbeere) and gooseberry (Stachelbeere). It was established [19] that in terms of titrated acidity (1.74%), pectin content (0.75%), and flavonoid content (317.6 mg/100 g); it is closest to blackcurrant berries, which are known for their high antioxidant properties [20].

Cherry tree Chernokorka berries were used to obtain cherry juice. According to [21], the fruits are rich in phenolic compounds, such as anthocyanins and flavonoids, which have numerous biologically active properties. Due to their phenolic composition and sensory characteristics, they are highly valued for fresh consumption or as industrial products and as components of marinades for meat [22].

However, the issues of dosage and technological parameters for the use of marinades based on cherry and josta juice remain unresolved. Therefore, *the object of this research* was the technology and quality parameters of marinated semi-finished poultry meat products using marinades based on cherry juice of the Chernokorka variety (Cherry tree Chernokorka) and Josta berries (Josta).

The aim of this research is to determine the functional and technological properties and safety indicators of chicken meat products made using cherry and josta berry juice as natural marinade bases for pickling.

To achieve the aim, the following objectives were solved:

1) to determine the technological indicators of natural cherry and josta berry juices used as a basis for natural marinades;

2) to determine the technological indicators of finished semi-finished poultry meat products made using natural marinades;

3) to conduct an organoleptic assessment of experimental semi-finished poultry meat products;

4) to determine the effect of marinades on the safety indicators of finished semi-finished products during storage to predict stability and further use in the production of meat products.

2. Materials and Methods

2.1. Research hypothesis

The complex effect of natural marinades based on cherry juice and josta berry juice on the technological, organoleptic, and microbiological characteristics of the final product, as well as on the dynamics of oxidative processes during storage of the finished product, was investigated. Josta is a hybrid obtained by crossing black currant and common gooseberry (Fig. 1).

The hypothesis of research was that the use of marinades based on cherry and josta berry juice will allow for targeted management of the quality of marinated semi-finished poultry meat products. It was postulated that cherry and josta berry juice will act as a functional component, softening the texture of the meat and improving organoleptic characteristics. And the antioxidant substances of the berries will ensure the chemical and microbiological stability of the resulting products during storage.

Fig. 1. Josta – a hybrid obtained by crossing blackcurrant and common gooseberry

2.2. Materials

The raw material for the research was poultry meat (chicken breast fillets), purchased in the "farm products" department of the "Sam Market" retail store. In order to exclude possible differences in the parameters of the raw material, the meat was from one production batch. Meat samples (breast muscles) were divided into three groups: marinade based on cherry juice (No. 1); marinade based on josta berry juice (No. 2); marinades from Spice Land LLC (control). Before marinating, the samples were stored in containers at a temperature of 2–4°C.

2.2.1. Preparation of marinades

Marinades based on cherry and josta berry juice, collected during the mass harvest period, at full maturity, were prepared in laboratory conditions. In order to disinfect pathogenic microflora, the squeezed juice was pasteurized at a temperature of 80°C for 10 minutes. The recipes of the developed marinades are given in Table 1.

Table 1

Recipes of marinades, %

Ingredients	Marinade samples		
	Control	1	2
Cherry juice	–	60	–
Josta juice	–	–	60
Purified water	50	37	37
Sea salt, food grade No. 1	–	3	3
Marinade (Spice Land LLC, Ukraine)	50	–	–

Marinade solutions were prepared in the following ratio: cherry juice: purified water: sea salt, food grade No. 1 – 60:37:3 (recipe No. 1); josta berries: purified water: sea salt, food grade No. 1 – 60:37:3 (recipe No. 2). To prepare the control marinade solution (recipe No. 3), the dry base was diluted with water in a ratio of 1:1. For use, the marinade was cooled to 4°C.

2.2.2. Poultry meat marinating technology

Marination was carried out by immersion for 12 hours, in a ratio of 1:1 (meat: marinade). The semi-finished product was stored in vacuum bags (based on PET/PE film, thickness 80–100 μm) at a temperature of 0–4°C and a relative humidity of 75–78% for 15 days.

2.3. Determination of physicochemical parameters of marinades

The marinade absorption was calculated using the following equation (1). Before weighing, the product was left to drain for 10 minutes at room temperature and then frozen in airtight bags at approximately –18°C

$$P = \frac{(B_B - B_0)}{B_0} \cdot 100, \quad (1)$$

where P – the marinade absorption index by the product, %; B_m – the mass of the marinated product, g; B_0 – the initial mass of the product before marinating, g.

When determining the titrated acidity of juices and marinades, 25 cm^3 of liquid was taken into a 250 cm^3 volumetric flask and made up to the mark with distilled water. After thorough mixing of the contents of the flask, 50 cm^3 of liquid was taken, 3–5 drops of 1% alcoholic solution of phenolphthalein were added and titrated with 0.1 M potassium hydroxide solution until a pink color appeared. The content of organic acids was calculated by the formula

$$K = \frac{V_c C M V_0}{m V_1}, \quad (2)$$

where V_c – the amount of 0.1 alkali used for titration; C – the molar concentration of the titrated alkali, mol/dm^3; M – the molar mass g/mol, which is equal to: malic acid – 0.067; citric acid – 0.064; acetic – 0.060; milk – 0.0090; wine – 0.0075; V_0 – volume to which the sample was brought, cm^3; m – mass of the sample, g; V_1 – volume of the filtrate taken for titration.

The total content of phenols in fruit juices and marinades was estimated by the Folin-Ciocalteu method [23]. 1 cm^3 of the test sample was mixed with 10 cm^3 of distilled water and 4 cm^3 of Folin-Ciocalteu reagent, 6 cm^3 of sodium carbonate (20%) was added and the final mixture was brought to a volume of 50 cm^3 with distilled water. In the control sample, 1 cm^3 of distilled water was added instead of marinades. To construct a calibration graph, 1, 2, 3, 5, 10 of the stock solution of gallic acid with a mass concentration of 5 mg/cm^3 were added to five volumetric flasks. The volume was brought to 100 cm^3 with distilled water. Then, 1 cm^3 of working solutions were taken from each flask for measurements and prepared as with the test samples. After 2 hours, the optical density was measured at a wavelength of 765 nm on a Spekol-11 spectrophotocolorimeter (Germany). The results were expressed in mg gallic acid equivalents (GAE) mg/cm^3.

The antioxidant activity of fruit juices was measured using the DPPH (2.2-diphenyl-1-picrylhydrazyl) method [23]. Samples (50 μl) were mixed with 3 ml of a 0.004% (v/v) methanolic solution of DPPH. After incubation in the dark for 30 minutes, the optical density was measured at a wavelength of 517 nm using a Spekol–11 spectrophotocolorimeter (Germany). The ability of the sample to absorb the DPPH radical was calculated as follows: DPPH absorption activity (%) = = [1 – (sample absorbance/control absorbance)] × 100.

2.4. Determination of technological parameters of marinated semi-finished poultry meat products

2.4.1. pH measurement

Meat samples (5 g) were ground on FSH-2A/JJ-2 homogenizer and homogenized with 50 ml of distilled water for 3 minutes. The pH of fruit juices, marinades and meat homogenates was determined using a pH-150 MI pH meter (Labimpex LTD, Ukraine). The device was calibrated before each measurement session using standard buffer solutions with pH 4.00, pH 7.00 and pH 10.00. The pH determination limits are from 0 to 14 units, at a temperature in the range of 0–60°C; step – 0.01 pH units, 0.1°C; error – ±0.02 pH, ±0.4°C.

2.4.2. Determination of moisture content

Moisture content was determined by drying to constant mass at a temperature of 100–105°C [24]. To determine the moisture content in the prepared samples, the following instruments were used: analytical balance (VLT-500-M (Poland); drying oven WS-100 (Germany); aluminum laboratory boxes; desiccator without a tap 2-180.

2.4.3. Cooking losses

The samples were placed on trays lined with aluminum foil and cooked for 20 minutes in a convection oven (Hurakan HKN-XFT333M, China) at a temperature of 150°C. During cooking, the internal temperature of the meat was maintained at 75°C. Temperature control of raw material samples was carried out using a digital thermometer DT-34 with a scale division value of 0.1°C. Weight losses during cooking were calculated as the difference in weight before and after cooking.

2.5. Study of the dynamics of lipid peroxidation of marinated semi-finished products in the process storage

2.5.1. Determination of peroxide value

The procedure for determining the peroxide value is carried out in accordance with the requirements of DSTU 4570:2006. The method is based on the reaction of the oxidation products of oils and fats (peroxides and hydroperoxides) with potassium iodide in a solution of acetic acid and chloroform and subsequent quantitative determination of the released iodine with a solution of sodium thiosulfate by the titrimetric method [25].

Depending on the value of the peroxide value, the degree of freshness of the fat in the finished product was determined by the formula

$$X_1 = \frac{\left[\left(V - V_1\right) \cdot K \cdot 0.00127 \cdot 100\right]}{m}, \quad (3)$$

where 0.00127 – the amount of iodine equal to 1 ml of 0.01 n sodium thiosulfate solution, g; K – the conversion factor exactly to 0.001 n sodium thiosulfate solution; V_1, V_2 – the volume of 0.01 n sodium thiosulfate solution used to titrate the experimental and control solution, respectively, ml; m_0 – mass of the test product sample, g.

2.5.2. Determination of acid number

The acid number (mg KOH) is determined by the formula [25]

$$X = \frac{VK \cdot 5.61}{m}, \tag{4}$$

where V – volume of potassium or sodium hydroxide solution with molar concentration of 0.1 mol/dm^3, used for titration, cm; K – correction to the alkali solution for conversion to an exact (0.1 mol/dm^3) solution; 5.61 – number of ml of potassium hydroxide contained in 1 cm^3 (0.1 mol/dm^3) of the solution; m – mass of the fat sample, g.

2.6. Determination of microbiological indicators

Microbiological indicators of semi-finished products were determined by QMAFAnM according to the method [26], BGKP – according to the method [27].

2.7. Sensory analysis

The test and control samples of chicken meat were analyzed by sensory evaluation method, which was carried out by a trained group of 11 tasters. The evaluation was carried out on the first day after marinating. Samples cooked in a convection oven (Hurakan HKN-XFT333M, China) were analyzed for color, texture, taste and overall acceptability. The scores were given on a 9-point scale, where 9 corresponded to an extremely desirable result and 1 to an extremely undesirable result, according to the method [28]. For sensory evaluation, chicken breast fillet samples heat-treated under identical conditions and cooking method were cut into pieces of the same thickness (2.0–2.5 cm) across the muscle fibers. Each piece was served in a glass container marked with a random three-digit code. To neutralize the taste and cleanse the taste buds, the experts were offered to drink still water between tastings of different samples.

Since individual organoleptic characteristics have unequal impact on the overall perception of the product by the consumer, it is possible to apply the method of calculating the weighted average score. The analysis took into account the weighting coefficients (K_w): for taste – 0.4; for aroma, tenderness and juiciness – 0.2 each. The weighted average score is calculated by the formula

$$P(average) = \sum(B_i \cdot K_w),$$

where B_i – the score for the indicator; K_w – the weighting coefficient.

2.8. Statistical analysis

The results of experimental studies were subjected to statistical processing, implemented using standard Microsoft Office software packages.

3. Results and Discussions

3.1. Results of research on technological indicators of cherry and josta juices as bases for marinades

To develop marinade recipes for semi-finished poultry meat products, cherry and josta juices were selected as marinade bases, in which technological indicators were studied. The results of the research are presented in Table 2.

Based on the comparative analysis, it was found that the juice of josta berries differs from cherry juice in a higher content of total phenolic compounds (327.16 versus 201.31 mg/100 ml) and a higher titrated acidity (3.5%). The antioxidant activity of josta juice was at a high level: juice polyphenols inhibit 97.41 ± 1.57% of the DPPH free radical. This is consistent with the data [29, 30], which confirm the high content of flavonoids such as quercetin, myricetin, kaempferol, which in synergy with vitamin C determine the high antioxidant activity of josta juice. Both juices are highly acidic. Thus, the pH of cherry juice is 3.5, and josta juice is even more acidic with an index of 3.2. This makes them excellent components for marinades, as they combine natural acids and antioxidants that can simultaneously tenderize meat and improve its quality [31].

Table 2

Technological characteristics of marinade bases

Indicators	Cherry juice	Josta juice
Total phenol content, mg/cm^3	201.31 ± 4.77	327.16 ± 9.27
Antioxidant activity, % inhibition	97.83 ± 1.31	97.41 ± 1.57
pH (juice)	3.5 ± 0.11	3.2 ± 0.03
Titrated acidity, %	2.51	3.53
Taste perception	Sour-tart	Spicy-sour
pH (marinade)	3.83 ± 0.16	3.57 ± 0.09

The pH values of cherry and josta juice-based marinades are 3.83 and 3.57, respectively. According to available data [32, 33], in such an environment, the number of free electrical charges on protein molecules increases, which begin to actively attract and hold water molecules. The study [34] reported that organic acids (citric, malic) in marinades can play a crucial role in tenderizing marinated meat. They contribute to the degradation and dissolution of connective tissues, which leads to a decrease in the diameter and thickness of muscle fibers. Such changes lead to swelling of meat fibers and increased proteolysis by cathepsins (the optimal pH for this activity is in the range of 3.5–5.0). There is also an increased conversion of collagen to gelatin at low pH during heat treatment.

This process weakens electrostatic interactions between myofibrillar protein chains and connective tissues, while increasing proteolysis mediated by cathepsins [35]. Marinades containing proteolytic enzymes or characterized by low pH can be used as tenderizers in the technology of marinated semi-finished products, including those made from tough meats, such as wild boar.

According to studies [36–38], the use of marinades contributes to the retention of meat juice during heat treatment, ensuring a tender consistency and juiciness of the product, which has a positive effect on its digestibility. It is known that the use of marinades based on pineapple juice and cherry plum juice [39] for marinating pork improves the moisture-binding properties of meat products, increases moisture and reduces protein losses.

However, the use of chemical tenderizers only improves the properties of meat to a limited extent, and their excess can worsen the flavor profile (the appearance of bitterness or metallic aftertaste [40]), which contradicts the concept of naturalness of food products.

3.2. Determination of technological indicators of finished semi-finished poultry meat products made using natural marinades

After preparing marinades according to the given recipes (Table 1) for the further production of marinated products (chicken breast fillets), the technological indicators of marinated semi-finished products were investigated. The results are presented in Table 3.

The analysis of Table 3 showed that the highest acidity is characteristic of sample No. 2 (marinade based on josta berry juice), and the lowest acidity is characteristic of the marinade of the control sample. As a result of the action of marinades, the acidity of the finished product also shifts to the acidic side. In the sample with josta, the pH is 4.64, which contributes to better protein breakdown and improved product consistency compared to the control.

Table 3

Technological indicators of marinated semi-finished products, ($M \pm m$), $n = 3$

Controlled parameters	Samples*		
	1	2	Control
Moisture content, %	76.21 ± 0.11	77.16 ± 0.17	73.11 ± 0.19
Marinade absorption, %	1.27 ± 0.03	1.43 ± 0.01	0.96 ± 0.03
pH	5.23 ± 0.17	4.64 ± 0.11	5.73 ± 0.11
Cooking losses, %	18.24 ± 0.37	17.73 ± 0.19	20.41 ± 0.11

Note:* – sample 1 – semi-finished products marinated in marinade according to recipe 1 (with cherry juice); sample 2 – semi-finished products marinated in marinade according to recipe 2 (with josta juice)

The use of berry juices has a positive effect on the ability of meat to retain moisture. Experimental data indicate an increase in moisture content in samples with cherry juice (76.21%) and josta juice (77.16%) compared to the control (73.11%). It is possible to attribute this effect to a decrease in pH and an increase in the ionic strength of the medium, which stimulates the swelling of myofibrillar proteins and increases their extractability. The results obtained are consistent with the data of other researchers who, during the marinating of turkey breast [41] and chicken breasts [42], drumsticks and thighs [43] with fruit and berry mixtures, recorded an increase in the mass of the raw material, which is directly due to the improvement of its ability to retain moisture.

A decrease in the moisture content of turkey breast as a result of marinating in fruit juices has been established [41]. The cause of this phenomenon is considered to be osmotic dehydration of meat [44]. Since the concentration of sugars in juices is higher than in meat tissue, under the influence of osmotic pressure, moisture is redistributed, which leads to its partial leaching into the marinade.

The results of the studies show that a concentration of fruit juice of 60% accelerates the diffusion of the marinade into muscle tissue. The highest sorption capacity was found in samples treated with a marinade with josta juice, where the absorption rate was 1.43%, which is 1.5 times higher than the similar value in the control sample (0.96%).

The use of berry juices in the composition of marinades allowed to significantly reduce thermal losses. In the control sample, losses are 20.41%. In the sample with cherry juice, they decreased to 18.24%. The best result was shown by the marinade with josta juice – only 17.73%.

Thus, the marinade based on josta berry juice turned out to be the most technological, since it provides maximum moisture retention and the least mass loss during cooking. It should also be noted that marinating chicken breast fillets using cherry and josta juices is more effective than the traditional (control) method in all technological parameters.

The main goal of the meat marinating process is to form consumer properties (taste, color, consistency) and prevent microbiological spoilage during the regulated shelf life. This is achieved through complex biochemical and mass exchange processes, such as changing the state of proteins, accumulation and redistribution of salting substances, changing the water-binding capacity, changing the qualitative and quantitative state of microflora, etc.

3.3. Organoleptic evaluation of experimental semi-finished poultry meat products

The results of the organoleptic evaluation are given taking into account the weight coefficients (Fig. 2).

A comparative analysis showed that the control is significantly inferior to the experimental samples in all indicators. Its weighted average score was 6.82 points. The lowest scores on the tenderness scale (6.51) indicate that without the use of berry additives, the product structure remains insufficiently elastic. Technologically, this is explained by the presence of organic acids and enzymes in the juices, which act as natural softeners of the structure, providing a more tender consistency of the product.

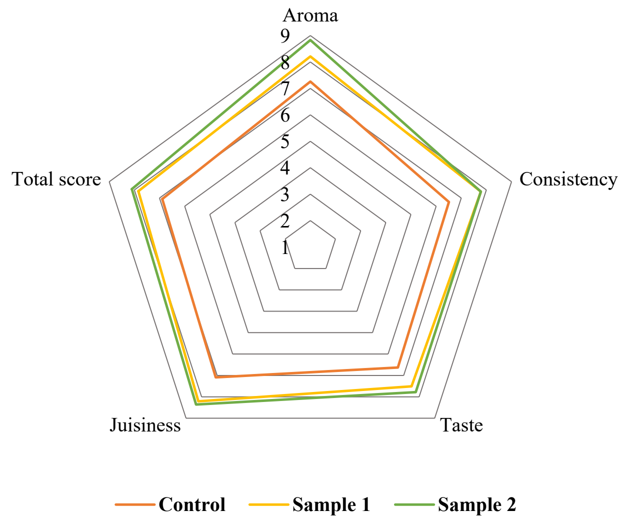

Fig. 2. Organoleptic characteristics of marinated semi-finished products

The results of the organoleptic assessment of sample 1 (with cherry juice) demonstrated positive dynamics of quality growth. Due to the high content of organic acids in cherry juice, the juiciness indicator increased to 8.21 points. This allowed to obtain a final weighted average score of 7.84, which corresponds to the quality level "very good".

Sample 2 (with josta juice) received the highest comprehensive score – 8.10 points. In particular, the aromatic profile was 8.83 points, which indicates the creation of a unique bouquet, which is characteristic of the anthocyanin complex of josta. And the taste profile with a score of 7.78 points, with the highest weighting coefficient (0.4) confirms the harmony of the marinade recipe composition. This is explained by the high concentration of pectin substances and vitamin C, which give the marinade based on josta juice the properties of a technological structure corrector, ensuring maximum tenderness and juiciness of the finished product. The results obtained are consistent with studies that have shown that the use of marinades based on coffee [45], apple and blackcurrant juices [46], fruit and berry vinegars from chokeberry, grape and hawthorn [33] has a positive effect on the organoleptic indicators of meat raw materials due to the action of natural acids during the pickling process.

Thus, according to the results of organoleptic analysis using a weighted evaluation matrix, the most promising for mass production during pickling of poultry meat was identified as a marinade with josta juice, which can be an attractive alternative to common marinades.

3.4. Determination of the influence of marinades on the safety indicators of finished semi-finished products during storage

In order to improve the technological map, the influence of the developed marinades on the intensity of lipid oxidation of marinated chicken breast fillet was investigated. The test samples were stored in vacuum packaging for 15 days at a temperature of 0–(+4)°C.

The results of the study of the dynamics of oxidative processes in pickled semi-finished products during storage are given in Table 4.

Lipid oxidation is considered the main process responsible for deterioration of quality during storage, mainly due to its negative impact on taste, color, texture and nutritional value [47–49]. As can be seen from Table 4, the acid number of the experimental samples throughout the storage period was slightly lower compared to the control. Thus, already on the 5th day of storage, the acid number of the control sample was higher by 16.83–26.15% compared to the experimental semi-finished products. A similar trend was observed when studying the peroxide number of marinated semi-finished products. At the end of storage, the peroxide number of sample 1 was 0.046% J_2, sample 2 – 0.030% J_2, which is 2.8–3.3 times lower than in the control. It was found that the marinade based on josta juice contributes to a more intensive inhibition of oxidative processes in marinated semi-finished products from poultry meat.

The results of the study of microbiological safety indicators of marinated semi-finished products are given in Table 5.

It has been established that such components of marinades as organic acids [50] or essential oils of spicy herbs [51] are able to reduce the level of contamination with food pathogens both immediately after processing and during the storage period. The effectiveness of deactivation of microorganisms by acidic fruit marinades is determined by the concentration of organic acids, pH value and temperature regime of the process. However, it is worth noting that individual marinade formulations may have a minimal effect on the microbial load of poultry meat during storage.

According to the research results of the conducted studies, a high inhibitory activity of marinades based on cherry and josta juices was established regarding the mesophilic microflora of semi-finished chicken fillet products. It was experimentally proven that the introduction of berry juices into the composition of marinades significantly slows down the growth dynamics of QMAFAnM. While in the control sample on the 10th day of storage, an excess of the maximum permissible level (5×10^6 CFU/g) was observed in accordance with regulatory requirements. Samples treated with experimental marinades maintained microbiological stability throughout the entire exposure period of 15 days. The highest bactericidal and bacteriostatic effect was recorded in marinades with josta juice. This is due to the phenomenon of synergism between the high concentration of ascorbic acid, a complex of organic acids and phenolic compounds that inhibit the metabolic activity of foreign microflora. On the 15th day, the number of CFU in this sample was several orders of magnitude lower than the control. The absence of Salmonella bacteria in 25 g of the product for 15 days indicates high hygienic quality and safety of the raw materials and confirms the antiseptic properties of the studied marinade components. The obtained data allow classifying cherry and josta juices as effective biopreservatives. Their use ensures the extension of the shelf life of meat semi-finished products by at least 50% compared to traditional storage methods under similar temperature conditions.

Table 4

Dynamics of acid and peroxide numbers of pickled semi-finished products during storage, ($M \pm m$), $n = 3$

Samples	Shelf life, days			
	1	5	10	15
Acid value, mg KOH				
Control	1.281 ± 0.03	1.312 ± 0.01	1.396 ± 0.03	1.631 ± 0.08
Sample 1	1.063 ± 0.07	1.123 ± 0.03	1.128 ± 0.03	1.280 ± 0.07
Sample 2	1.044 ± 0.07	1.040 ± 0.03	1.113 ± 0.0	1.110 ± 0.09
Peroxide value, % J_2				
Control	0.014 ± 0.01	0.021 ± 0.01	0.076 ± 0.00	0.098 ± 0.01
Sample 1	0.013 ± 0.00	0.018 ± 0.01	0.024 ± 0.00	0.046 ± 0.00
Sample 2	0.013 ± 0.00	0.018 ± 0.01	0.022 ± 0.00	0.030 ± 0.00

Table 5

Microbiological indicators of marinated semi–finished products

Sample	Indicator	Shelf life, days			
		1	5	10	15
Control	QMAFAnM, CFU/g	1.2×10^2	4.5×10^4	8.0×10^6	$>10^8$ (spoilage)
Sample 1	QMAFAnM, CFU/g	1.2×10^2	1.5×10^3	2.1×10^4	5.0×10^5
Sample 2	QMAFAnM, CFU/g	0.8×10^2	1.2×10^3	1.8×10^4	3.5×10^5
All samples	Salmonella, in 25 g	Not detected	Not detected	Not detected	Not detected

3.5. Limitations and directions of research development

A limitation of this research is that it is suitable for a certain type of meat, namely chicken, which has a fairly tender consistency and muscle fiber structure. Other types of meat containing more connective tissue, such as beef or pork and/or game meat, such as wild boar, are not covered by this research. In addition, before proposing final technological solutions, a specialized study of the structural and mechanical properties of marinated meat semi-finished products from meat of different animal species is necessary.

Further research should focus on studying the structural and mechanical properties of raw materials and the mechanisms of biochemical processes that cause changes in the quality of traditional types of meat during marinating, and their subsequent impact on the consumer properties of the manufactured semi-finished products. It is also considered promising to determine the impact of the developed marinades on semi-finished products from other types of meat, including game.

4. Conclusions

1. As a research result of the technological indicators of natural juices of cherries and josta berries, it was found that the juice of josta berries differs from cherry juice in a higher content of total phenolic compounds (327.16 versus 201.31 mg/100 ml) and a higher titrated acidity (3.5%). The antioxidant activity of cherries and josta juices is high: the degree of inhibition of the free radical DPPH is 97.41–97.83%. Marinades based on cherries and josta juices had a low pH (3.57–3.83), which allows them to be used as tenderizers in the technology of marinated semi-finished products from poultry meat.

2. It was found that in samples of marinated semi-finished products with cherry juice and josta juice, the moisture content increases compared to the control to 76.21 and 77.16%, respectively, which is 4.24–5.54 higher. This effect is associated with a decrease in the pH level of the experimental samples by 9.56–23.49% and an increase in the ionic strength of the medium, which stimulates the swelling of myofibrillar proteins and increases their extractability. The highest sorption capacity was found in samples treated with marinade with josta juice, where the absorption rate was 1.43%, which is 1.5 times higher than the control. The use of berry juices in the composition of marinades reduces losses during heat treatment of semi-finished products by 11.9–15.11%.

3. According to the results of organoleptic analysis, the most promising for mass production during marinating of poultry meat was identified as marinade with josta juice, which can be an attractive alternative to common marinades. Semi-finished products marinated with marinade with josta juice received the highest comprehensive score – 8, 10 points.

4. The high antioxidant activity of marinades based on cherry and josta juice was confirmed when used in the technology of marinated semi-finished poultry meat products. The high inhibitory activity of marinades based on cherry and josta juices against the mesophilic microflora of semi-finished chicken fillet products was established. The samples retain microbiological stability throughout the entire storage period.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, including financial, personal, authorship, or other conflicts that could affect the research and its results presented in this article.

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Data availability

The manuscript has no linked data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in creating the submitted work.

Authors' contributions

Vasyl Tischenko: Conceptualization, Methodology, Writing – original draft; ***Svitlana Huba:*** Methodology, Investigation; ***Nataliia Bozhko:*** Formal analysis, Writing – review and editing, Visualization, Writing – original draft.

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