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POULTRY FATS. SPECIFIC FEATURES OF THEIR COMPOSITION AND CHARACTERISTICS OXIDATION RESISTANCE

L. Tyshchenko, Candidate of Technical Sciences, Associate Professor
O. Shtonda, Candidate of Technical Sciences, Associate Professor
O. Pylypchuk, Candidate of Agricultural Sciences, Assistant
A. Menchynska, Candidate of Technical Sciences, Senior Lecturer
V. Shakhvorostova, Master
Department of technology of meat, fish and seafood
National University of Life and Environmental Sciences of Ukraine
st. Heroes of Oborona, 15, Kiev, Ukraine., 03041

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Correspondence:

L. Tyshchenko
E-mail: ltishchenko@ukr.net

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Abstract. The article studies the technological characteristics of poultry fat. The work considers the fatty acid composition of goose, duck, chicken, and turkey fats, and gives a comparative analysis of the differences in the content of saturated, monounsaturated, and polyunsaturated fatty acids in each fat described. The peroxide values, under different oxidation modes, are characterised for melted poultry fats, and for fats with popular spices (nutmeg, black pepper, fresh garlic, mustard powder) and their oily extracts added. The research included intentional spoilage of fat in a drying cabinet at t=102 °C and storage for 4 months at 4±2°C. The results of studying the peroxide value of poultry fats have allowed determining how their oxidation rate depends on the storage conditions, fatty acid composition, and the presence of natural antioxidants. It has been found that turkey and chicken fats are more oxidation-resistant, and goose and duck fats are less resistant (their induction periods being 8, 6, 4, and 4 hours, respectively). The research results have shown that the induction period of fats with natural antioxidants added significantly increases, compared to that of native fats. This indicates that natural antioxidants not only increase the nutritional and biological value, but are also a free radical trap for fatty acids. Thus, the peroxide values of fats kept for 4 months in a refrigerator do not change significantly and do not exceed 0.05 mmol (½ O)/kg, except for goose fat. Therefore, enriching fats with mixtures of spices and their oil extracts is an alternative way to preserve the fat quality and extend the shelf life of meat products. As they are safe and available, natural spices can be used as safe stabilisers of food fats and fat-containing products, according to the requirements of the Ministry of Health of Ukraine.

Keywords: poultry fat, fat spoilage, oxidation processes, intentional spoilage, peroxide value.

Introduction. Formulation of the problem

Fats are an integral part of any food and are always present in the human diet, as they are found in both animal and plant tissues. For many centuries, fats of animal origin have been used in the food industry. (Vegetable oils have also been used, but to a lesser extent.) They have a tremendous influence on the taste properties of the products. Poultry fats are high in oleic (C 18:1n9c), palmitic (C 16:0), stearic (C 18:0), and linoleic (C 18:2n6c) acids. Fats with a high oleic acid content are easily digestible. Linoleic acid is involved in the synthesis of arachidonic acid, and in the formation of phospholipids of cell membranes. However, while fatty foods or fats isolated from them are manufactured and stored, various transformations can occur caused by physical, chemical, and biological factors. It leads to changes in the chemical composition, to deterioration of the sensory characteristics and nutritional value of fats, and results in their spoilage. Regardless of the processing and storage modes and of the types of fats, the only changes taking place in them are hydrolysis and oxidation

Analysis of recent research and publications

There are no fats that are highly resistant to oxidation and fully meet the requirements of a balanced fatty acid composition [1,2]. So, measures are needed to prevent these changes and control the quality of lipids in order to preserve their consumption characteristics and biological value [1,3].

Passive and active methods are used to prevent destructive processes in lipids and protect fats from damage. Passive methods include preventing the factors that cause or catalyse deterioration processes. Active methods involve introducing various additives,

in particular, antioxidants (substances that interrupt oxidation of oils and are intended to prolong their shelf life) [1,2,4,5].

Health authorities regulate the use of antioxidants and other food additives. Ingredients that are part of fats and products based on them must be biologically active, safe, have standard rates of daily consumption, and act as antioxidants [1,3,6].

I. Tsykhanovska *et al.* investigated how the biologically active additive *Magnetite* effected on oxidation of unrefined and refined deodorised oils, melted animal fats, and shortenings during 90 days of storage at 20 °C, and how the physical and chemical structures of native fats and oils changed with the addition of 0.05 wt.% of *Magnetite*. It was found that addition of *Magnetite* increased the shelf life of fats and oils [7].

It was investigated how antioxidant additives (vitamins A, E, carotenoids and their complexes) inhibited the oxidation processes during storage of butter-like spreads. The results of the study indicated that antioxidant additives in spreads inhibited the process of accelerated oxidation at room temperature. It was found that the rational content of antioxidants was: 0.6% of β-carotene, 0.3% of vitamin E, and 0.11% of vitamin A, because the peroxide value of spreads with the lowest antioxidant content differed but slightly from that of the product with the highest content of antioxidants [8].

I. Pakhomova and A. Tkachenko investigated the oxidation and hydrolysis of shortening stored with the addition of non-traditional raw materials as natural antioxidants. It was found that powdered common knotgrass, barberry, basil, ginger, and rose hips used as dry additives in the amount 0.2% of the fat's weight effectively inhibited oxidation processes and retain its high quality during the storage. However, the common knotgrass had the best antioxidant properties [9].

In order to inhibit oxidative processes in meat products, a number of plant-based antioxidant preparations were proposed [10,11]. In particular, plants belonging to the Labiatae family (rosemary, oregano, sage, marjoram, etc.) are high in flavonoids, phenolic acids, rosmarinic and caffeic acids, carnosol and carnosic acid. Products of processing red grapes (skins, grape seeds, and their extracts) are known for their high concentration of gallic acid, catechins, anthocyanins [12].

Infusions of medicinal herbs [13] and essential oils with antioxidant properties are also used in the meat products technology. Sage is used to protect meat products against lipid oxidation [14]. The antioxidant properties of rosemary essential oils combined with sage were studied on a liver pâté sample stored at 4°C for 90 days. It was found that plant essential oils inhibited the oxidative spoilage of liver pâté better than a synthetic antioxidant [15]. A thyme and sage infusion slowed down the oxidative spoilage of meat [16].

St. Mary's thistle extract in the maximum permissible dose (40 mg/100 g of minced meat) slowed down the undesirable processes in the experimental sausages made of poultry meat. It was found that the peroxide value of the control samples exceeded 0.1% of iodine after 5 days of storage, whereas the values in the test samples reached a critical level only after 10 days [17,18].

Scientists studied the antioxidant properties of oily, ethanol-glycerol, and water-ethanol extracts of oak bark, sage leaves, and green tea. It was established that adding 1% of fat soluble antioxidant obtained from vegetable raw materials (oak bark, sage leaves, and green tea) and 0.05% of tocopherol increased the shelf life of shortening by 3.8 times [19,20].

Natural spices highly improve the taste of fat products. However, in scientific literature, the effect of spices on the extension of shelf life has not been considered before. That is why, the antioxidant properties of natural spices and their extracts in the production and storage of fat-containing products remain a topical problem to study.

The purpose was to study the oxidation processes in fresh melted poultry fats and in fats with natural antioxidants.

To achieve this purpose, the following **objectives** were set:

– to study the fatty acid composition of poultry fats;

– to determine the peroxide value of melted native poultry fats, of fats with spices, and of fats with sunflower oil infusion of spices;

– to determine the induction period of native fats and fats with antioxidants;

– to suggest ways to increase the shelf life and inhibit oxidation processes.

Research materials and methods

The experimental studies were carried out at the Meat, Fish, and Seafood Technology Department of the National University of Life and Environmental Sciences of Ukraine.

The object of the study was poultry fats (goose, chicken, duck, and turkey) obtained by traditional dry rendering. Some natural antioxidants were studied, too: a mixture of spices and a sunflower oil infusion of these spices. The spices in the mixture (nutmeg, black pepper, fresh garlic, and mustard powder, in the ratio 0.15:0.15:0.05:0.2) were taken in the amount prescribed in the recipe of cooked sausage: 0.55 g of spices/25 g of fat. A similar ratio of the spices (0.55 g of spices/100 ml of sunflower oil) was used in the infusion, which was then kept in a refrigerator at +(3–5)°C for 4 days. The amount of the extract added was 0.5 ml/20 g of melted fat.

The chemical and chromatographic methods were used to evaluate the quality of the poultry fats:

1. The peroxide value (the chemical indicator) was determined according to DSTU (State Standard) ISO

3960-2001 "Animal and plant fats and oils. Determination of the peroxide value."

2. The fatty acid composition of the poultry fats was determined chromatographically on a chromatograph *Kupol*-55 [21].

Results of the research and their discussion

The fatty acid composition of fats determines their nutritional and biological value, physical properties, and specific features of hardening, which, in turn, characterise the structural and mechanical parameters, consistency, digestibility, and shelf life.

The fatty acid composition of goose, chicken, duck, and turkey fats has been studied. It has been found that poultry fats have a high content of oleic (C 18:1n9c), palmitic (C 16:0), stearic (C 18:0), and linoleic (C 18:2n6c) acids (Table 1).

Table 1 – Fatty acid composition of poultry fats

No	Shorthand notation of fatty acids	Fatty acid composition, %			
		Goose	Chicken	Duck	Turkey
1	C 14:0	0.675	0.599	0.559	0.922
2	C 16:0	26.964	18.183	21.235	23.335
3	C 16:1	2.677	2.844	3.922	7.794
4	C 17:0	0.120	0.368	0.125	0.185
5	C 17:1	0.044	0.116	0.084	0.089
6	C 18:0	9.094	4.805	4.873	5.182
7	C 18:1н9т	0.383	0,074	0.279	0.231
8	C 18:1н9с	50.116	35.374	45.325	40.752
9	C 18:2н6т	0.208	0.027	0.286	0.183
10	C 18:2н6с	8.394	36.495	21.282	19.712
11	C 18:3н6	0.277	0.175	0.076	0.062
12	C 18:3н3	0.466	0.252	0.434	0.317
13	C 20:0	0.582	0.688	1.520	1.237
Total	–	100.00	100.00	100.00	100.00

According to our estimates, poultry fats differ in their fatty acid composition, namely:

- Goose fat contains 9.5% of polyunsaturated, 53.0% of monounsaturated, and 37.5% of saturated fatty acids;
- Chicken fat contains 37.0% of polyunsaturated, 38.2% of monounsaturated, and 24.8% of saturated fatty acids;
- Duck fat contains 22.1% of polyunsaturated, 49.5% of monounsaturated, and 28.4% of saturated fatty acids;
- Turkey fat contains 20.3% of polyunsaturated, 48.7% of monounsaturated, and 31.0% of saturated fatty acids.

Thus, the fatty acid composition of poultry fats is close to balanced, and has an effect on the processes of spoilage, because of a significant proportion of unsaturated fatty acids.

The research considered the forced oxidation of native poultry fats and fats with natural antioxidants heated to 102°C. Their induction periods have been determined, too (Tables 2-4). According to the experimental data (Table 2), raw poultry fats have the following induction periods: goose and duck 4 hours, chicken 6 hours, turkey 8 hours. Fresh fat does not contain peroxides. To extend the shelf life of the fats, spices (nutmeg, black pepper, fresh garlic, mustard powder) were used in the classical ratio taken from the recipes of cooked sausage (Table 3)

Table 2 – Peroxide values of fresh melted fats after forced deterioration at t = 102°C

Fat	Peroxide value, mmol (½ O)/kg								
	fresh	2 hours	4 hours	6 hours	8 hours	10 hours	12 hours	14 hours	16 hours
Goose	0.0198	0.030	0.183	0.246	0.403	0.424	0.498	0.530	0.602
Chicken	0.0073	0.025	0.062	0.118	0.149	0.260	0.316	0.361	0.443
Duck	0.0085	0.010	0.116	0.279	0.515	0.737	0.824	0.895	0.959
Turkey	0.0056	0.006	0.034	0.062	0.196	0.292	0.323	0.387	0.471

Table 3 – Peroxide values of fresh melted fats with spices after forced deterioration at t=102°C

Fat	Peroxide value, mmol (½ O)/kg							
	2 hours	4 hours	6 hours	8 hours	10 hours	12 hours	14 hours	16 hours
Goose	0.0339	0.0339	0.139	0.324	0.343	0.424	0.5937	0.6253
Chicken	0.00508	0.0143	0.0198	0.0254	0.0617	0.0798	0.1343	0.1702
Duck	0.0339	0.0559	0.054	0.175	0.243	0.259	0.3734	0.5144
Turkey	0.00635	0.0143	0.0163	0.0198	0.0254	0.0435	0.0762	0.1334

After the addition of spices, we can observe an increase in the induction period: in the goose fat – by 2 hours, in the chicken and turkey ones – by 8 hours, in the duck one – by 4 hours, compared with the induction period of the raw fat. This indicates that spices contain a significant amount of natural antioxidants, namely phenolic compounds, which are a free radical "trap" for fatty acids [22].

Also, a sunflower oil infusion of spices was used to extend the shelf life of the fats (Table 4). The amount of spices added to the oil had been determined in accordance with the recipes for sausage production. The infusion was kept in a refrigerator for 4 days.

Table 4 – Peroxide values of fresh melted fats with the sunflower oil infusion of spices after forced deterioration at t=102°C

Fat	Peroxide value, mmol (½ O)/kg							
	2 hours	4 hours	6 hours	8 hours	10 hours	12 hours	14 hours	16 hours
Goose	0.0540	0.093	0.098	0.1044	0.1492	0.181	0.2455	0.3443
Chicken	0.0085	0.0085	0.020	0.022	0.048	0.1003	0.175	0.2794
Duck	0.0222	0.0540	0.080	0.1016	0.1609	0.221	0.2975	0.3715
Turkey	0.0056	0.0064	0.0178	0.0178	0.0435	0.0762	0.1175	0.175

The research results have shown that a spice infusion, too, effectively inhibits oxidation. According to the data in Table 4, the induction periods of fats increased as follows: goose and duck by 4 hours, chicken and turkey by 6 hours. So, due to the infusion, the shelf life increases because vegetable oils have a significant tocopherol content, and sunflower oil is especially high in it (40–70 mg/100g) [23].

Thus, according to the results of experimental studies, a comparative characteristic of poultry fats has been performed.

The change in the peroxide value of goose fat (Fig. 1) is characterised by a linear increase, with the coefficient of determination R^2=0.96. The stability of the induction period is only 2 hours, which indicates the absence of natural antioxidants in the composition of fat. In the study of the fat sample with spices added, the induction period increases up to 4 hours, and the oxidation process is characterised by lower peroxide values. When the sunflower oil infusion of spices is added to the goose fat, the induction period of oxidation is extended up to 8 hours, and the subsequent increase in the peroxide values is characterised by values that are twice lower than the corresponding values of pure fat.

The dynamics of the peroxide value increase after forced deterioration of the chicken fat without the addition of antioxidants (Fig. 2) is characterised by a rapid linear growth, like it was with the goose fat. In the chicken fat samples with antioxidants added the peroxide values increase but slowly. The induction period is 10 hours till the peroxide value reaches 0.0617 mmol (½ O)/kg for the sample with spices added, and 0.048 mmol (½ O)/kg for the sample with sunflower oil infusion of spices added. Thus, the activity of natural antioxidants contained in the infusion is better.

According to Fig. 3, the turkey fat is characterised by the longest shelf life, compared to the other poultry fat samples tested. The peroxide values during forced deterioration of pure melted fat increase sharply, which is characteristic of pure fats. However, there is almost no change in the peroxide value of the turkey fat with antioxidants. The induction period of this fat with spices added is 12 hours, which is 2 hours longer than that of the sample with the spices-infused oil.

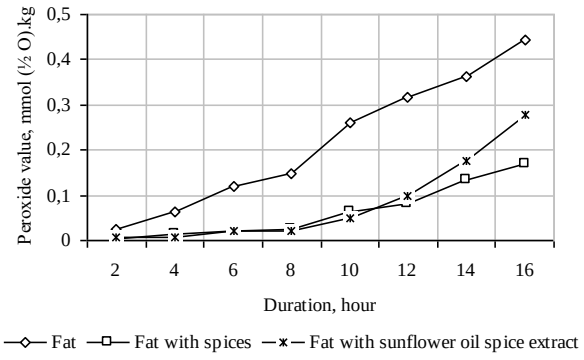

Fig. 1. Dynamics of the peroxide value increase in the goose fat

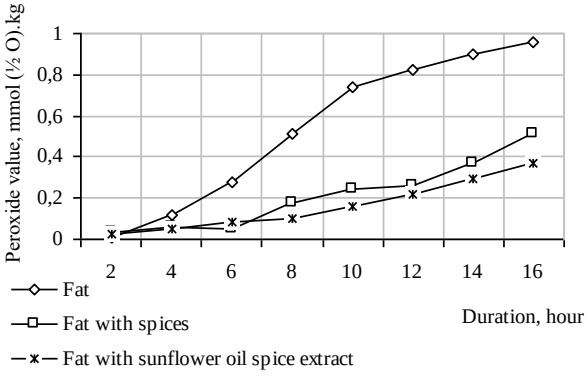

Fig. 2. Dynamics of the peroxide value increase in the chicken fat

Studying the duck fat peroxide value (Fig. 4) has allowed establishing that this sample is the least resistant to oxidation. The peroxide value of pure duck fat after forced deterioration was significantly higher, with sampling every 2 hours. The induction period of the samples with antioxidants added is only 6 hours, which is 4–6 hours less than that of the other samples tested.

The studies have shown that fats of waterfowl have a higher oxidation rate in comparison with those of land birds. Thus, in 4 months, the samples of pure fat of waterfowl reached peroxide values that exceeded the ones provided for by official regulations. The fats with spices added are characterised by significantly lower peroxide values.

The induction period of the fats with antioxidants increased: goose – 6.7 times, chicken – 2.6 times, duck – 4.6 times, turkey – 3.3 times. This indicates that natural spices have a high antioxidant effect and can prolong storage of fats significantly, without any loss in their freshness and quality.

The results of the studies confirm that spices and their fat extracts have high antioxidant activity. The latter is due to biologically active natural substances that inhibit oxidation of poultry fats and increase their induction period.

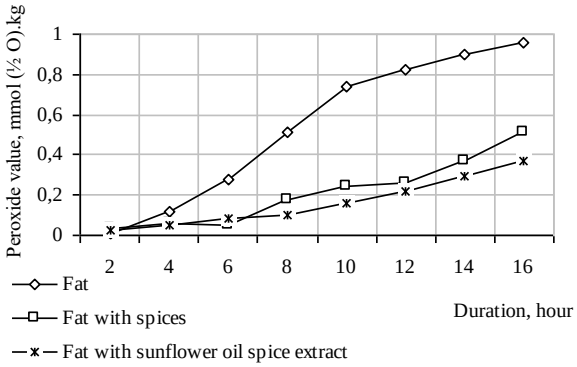

Fig. 3. Dynamics of the peroxide value increase in the turkey fat

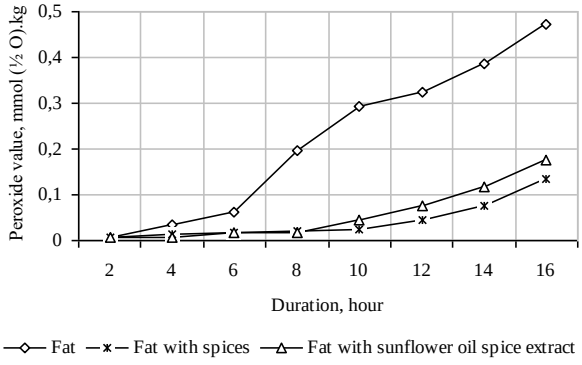

Fig. 4. Dynamics of the peroxide value increase in the duck fat

Native fats and fats with spices have also been examined for 4 months of storage in a refrigerator (Fig. 5).

Taking into account their non-toxicity and availability, natural spices can be used as the best and safest stabilisers of food fats and fat-containing products, according to the requirements of the Ministry of Health of Ukraine.

The results obtained are useful for processing and storing fat in the industry, and for the manufacture of food products containing fat materials. The study has also shown the prospect of using a combination of natural antioxidants to ensure long-term freshness of fats.

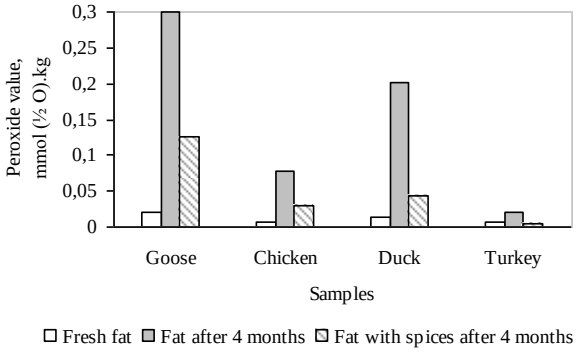

Fig. 5. Peroxide value of the poultry fats after 4 months' storage in a refrigerator

Conclusion

The fatty acid composition of poultry fats has been studied. The ratio of polyunsaturated, monounsaturated, and saturated fatty acids has been determined in each fat.

The results of studying the oxidation resistance have allowed establishing the induction periods of native fats and fats with antioxidants. Of the poultry fats, the turkey and chicken ones has appeared to be more resistant to oxidation than the goose and duck fats, with the induction periods 8, 6, 4, and 4 hours, respectively.

Comparative characterisation of the oxidation process at 102°C has been carried out for each fat with antioxidants individually. The increase in the peroxide values of the native fats was quite sharp, in comparison with the fats with spices and their oil extracts. It has been found that using spices prolongs the induction period of fat by at least two hours: that of the chicken and turkey fats by 8 hours, of the goose fat by 4 hours, of the duck fat by 2 hours. Using fat extracts, like using native spices, prolongs the induction period. For duck fat, the best antioxidant is an oily extract of spices.

The oxidation processes have been studied in poultry fats and fats with spices added, which are close to the prescribed terms and modes of meat storage. It has been found that after 4 months' storage in a refrigerator (at +4°C), fats with antioxidants inhibit oxidation and are characterised, by their peroxide values, as fresh, and not oxidised.

The study has proved the advantages of using combinations of natural antioxidants (nutmeg, black pepper, fresh garlic, mustard powder) that increase the induction period of the growth of the peroxide values of fats. This will allow predicting more exactly how long the shelf life of fat products will be.

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ПТАШИНІ ЖИРИ. ОСОБЛИВОСТІ СКЛАДУ ТА ХАРАКТЕРИСТИКИ СТІЙКОСТІ ДО ОКИСЛЕННЯ

Л.М. Тищенко, кандидат технічних наук, доцент, *E-mail:* ltishchenko@ukr.net
О.А. Штонда, кандидат технічних наук, доцент, *E-mail:*oasht@ukr.net
О.С. Пилипчук, кандидат технічних наук, асистент , *E-mail:*pilipchuk_os@ukr.net
А.А. Менчинська, кандидат технічних наук, старший викладач, *E-mail:* menchynska@ukr.net
В.М. Шахворостова, Master, *E-mail:* shakhvorostova1995@mail.ru
Кафедра технології м'ясних, рибних та морепродуктів
Національний університет біоресурсів і природокористування України, вул. Героїв Оборони, 15, Київ, Україна., 03041

Анотація. Статтю присвячено вивченню технологічних характеристик пташиних жирів. Наведено жирнокислотний склад гусячого, качиного, курячого та індичого жирів, порівняльний аналіз відмінностей вмісту насичених, мононенасичених та поліненасичених жирних кислот у їхньому складі. Представлено характеристики пероксидних чисел нативних топлених жирів, та жирів з додаванням традиційних широковживаних спецій (та їхніх олійних екстрактів мускатний горіх, чорний перець, свіжий часник, гірчичний порошок) за різних режимів окислення. Дослідження проводили за примусового псування в сушильній шафі при t=102℃, та при зберіганні протягом 4-х місяців за температури 4±2°С. За результатами дослідження пероксидного числа пташиних жирів встановлено початкові значення, що характеризували жири як свіжі і придатні до зберігання, та відмінності швидкості процесів окислення залежно від умов зберігання, жирнокислотного складу та наявності природних антиоксидантів. Встановлено, що пташині жири псуються в такій послідовності: 1 – гусячий, 2 – качиний, 3 – курячий, 4 – індичий, що залежить від різного співвідношення насичених та ненасичених жирних кислот та індивідуальної стійкості до псування. Результати досліджень показали, що індукційний період жирів з додаванням природних антиоксидантів значно збільшується в порівнянні з нативними жирами. Це свідчить про те, що природні антиоксиданти не тільки підвищують харчову та біологічну цінність, але й слугують вільнорадикальною пасткою для жирних кислот. Таким чином, пероксидні числа жирів, витриманих 4 місяці в умовах холодильника, не суттєво змінюються та не

перевищують 0,05 ммоль (½ О)/кг, за винятком гусячого. Отже, збагачення жирів сумішами спецій та їхніми олійними екстрактами є альтернативним шляхом для збереження якості жиру та подовження терміну зберігання м'ясних продуктів**.** Враховуючи їхню безпечність і доступність, спеції природного походження є безпечним варіантом за вимогами МОЗ України для стабілізації харчових жирів і продуктів, до складу яких вони входять.

Ключові слова: пташині жири, псування жирів, процеси окислення, примусове псування, пероксидне число

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