The effect of protein products from sesame seeds on the oxidative stability of emulsion products

Natalia Bugaets1,*, Sergey Usatikov1,2, Igor Tereshchenko1, Natalia Shamkova1 and Olga Bugaets3

1Kuban State Technological University, 2, Moskovskaya St., Krasnodar, 350072, Russian Federation
2Kuban State University, 149, Stavropolskaya St., Krasnodar, 350040, Russian Federation
3Kuban State Agrarian University, 13, Kalinina St., Krasnodar, 350044, Russian Federation

*E-mail: kubanochka23@yandex.ru

Abstract. Lipid oxidation is one of the leading indicators that determine the storage duration of emulsion fatty products. To protect fat and oil products from oxidative spoilage, antioxidants are widely used, the mechanism of action of which is to terminate the reaction molecular chains. As a result of the studies carried out, it was found that physical modification of protein products from sesame seeds (full-fat flour, protein concentrate), used in the production of mayonnaise as a structurant and stabilizer, by treatment with electromagnetic fields of extremely low frequencies, makes it possible to increase the resistance of the finished product to oxidation.

1. Introduction
The consumption of emulsion products, including mayonnaise, is growing progressively. The multicomponent composition of mayonnaise allows you to widely vary the recipe composition, use ingredients that increase the biological value of the finished product. The recipe components of mayonnaise not only create a pleasant taste and aroma, but also increase the energy, nutritional and physiological value of the product [1, 2].

A new direction in the creation of fatty products based on vegetable raw materials is the introduction of additives into the formulation that are beneficial to human health. Relevant is the development of recipes and the organization of production of mayonnaise for functional, therapeutic and prophylactic and specialized purposes [2, 3, 4].

The expansion of the range of mayonnaise is associated with the ease of varying the flavor profile of the product, the introduction of various additives into the formulations that have certain functional and/or physiological properties, and the possibility of replacing traditional ingredients (for example, the emulsifying ingredient of the emulsion with berry, pectin-containing raw materials, etc.) [5].

Each of the ingredients included in the mayonnaise or sauce recipe has a certain effect on the characteristics of the final product. Mayonnaise should have pleasant organoleptic characteristics, acceptable to consumers, high oxidation stability and colloidal stability, providing a long shelf life [5, 6].
The development of new formulations of mayonnaise requires not only the selection of the correct combination of ingredients, but also the stabilization of antioxidant and microbiological processes. Antioxidants, due to interaction with atmospheric oxygen, interrupting the oxidation reaction or destroying the already formed peroxide, make it possible to keep fresh food during the entire shelf life [7].

The storage duration is determined when the peroxide number of the fat phase of the mayonnaise sauce reaches or exceeds the critical value – 10.0 meq (mmol) of active oxygen / kg of product [5, 8].

A new vector for the development of formulations is being determined: antioxidants used in mayonnaise are aimed not only at preventing oxidative processes occurring in a food product, but also inside the body using this product. The greatest contribution to the antioxidant activity is made by phenolic compounds, organic acids, tannins, some vitamins [7].

The technology of functional mayonnaise has been developed on the basis of an emulsifier-stabilizer composition consisting of chitosan and protein concentrate, which makes it possible to exclude egg yolk from the mayonnaise formulation [9]. In order to optimize the technical and functional properties (water and fat-retaining, fat-emulsifying ability), sesame seed proteins were modified by treatment with extremely low frequency electromagnetic fields (ELF EMF) [10].

The aim of the research is to assess the effect of ELF EMF treatment on the antioxidant properties of protein products from sesame seeds.

2. Materials and methods

Objects of research – protein products from sesame seeds - full-fat flour (FFF), which is crushed sesame seeds with a protein content of up to 20 % and an oil content of 59 %, and protein concentrate (PC) – finely ground skin seeds with a protein content of up to 70 % and lipids – up to 29 %.

The processing of protein products from sesame seeds with EMP ELF was carried out on an experimental setup in the Department of Storage and Integrated Processing of Agricultural Raw Materials of the Krasnodar Research Institute for Storage and Processing of Agricultural Products [11].

Evaluation of the effect of physical methods on protein products from sesame seeds was carried out by determining the antioxidant capacity of additives. The antioxidant activity of protein products from sesame seeds was determined by the indicator of oxidative spoilage - the peroxide number (p.p.) of the fat phase isolated from the emulsion product. The change in the peroxide value was controlled depending on the protein product (full-fat flour, protein concentrate) introduced into the emulsion. The research was carried out in the laboratory of the Center for Collective Use "Research Center for Food and Chemical Technologies" of the Kuban State Technological University [12].

The experiment to assess the effect of ELF EMF processing parameters on the properties of FFF and PC was carried out according to a three-level three-factor complete plan.

\[ P(\omega, T, I) = a_0 + a_1 \frac{T}{I_{\max}} + a_2 \frac{\omega}{\omega_{\max}} \frac{I}{I_{\max}} + b_1 \left( \frac{T}{I_{\max}} \right)^2 + b_2 \frac{\omega}{\omega_{\max}} \frac{T}{I_{\max}} + b_3 \left( \frac{\omega}{\omega_{\max}} \frac{I}{I_{\max}} \right)^2 \] (1)

where \(a_0, a_1, a_2, b_1, b_2, b_3\) – regression coefficients;

\(\omega\) – factor 1, frequency, Hz;

\(T\) – factor 2, processing time, min;

\(I\) – factor 3, amperage, A.

Each of the listed factors has three levels of variation.

1) Frequency variation levels \(\omega: \omega_0 = \text{level } -1 = 0 \text{ Hz}; \omega_{av} = \text{level } 0 = 20 \text{ Hz}; \omega_{max} = \text{level } +1 = 40 \text{ Hz}.

2) Variation levels of treatment duration, \(T\): \(T_0 = \text{level } -1 = 0 \text{ min}; \ T_{av} = \text{level } 0 = 15 \text{ min}; \ T_{max} = \text{level } 1 = 30 \text{ min}.

3) Levels of varying the current strength, \(I\): \(I_0 = \text{level } -1 = 0 \text{ A}; \ I_{av} = \text{level } 0 = 15 \text{ A}; \ I_{max} = \text{level } 1 = 30 \text{ A}.

2
The obtained experimental data were calculated using the mathematical tools MathCAD and Statistica.

3. Results and discussion
To determine the effective processing parameters of ELF EMF, the antioxidant properties of PC (table 1) and FFF (table 2) were determined.

Table 1. Effect of ELF EMF Treatment on PC Antioxidant Properties.

| n/a no. | Oc (%) | T (min) | ω (Hz) | I (A) | T/Tmax | ω/ωmax | I/Imax | x = I/ωlmax | x = T/Tlmax | P    |
|---------|--------|---------|-------|-------|--------|---------|--------|-------------|-------------|------|
| 1       | 28.96  | 0       | 0     | 0     | 0      | 0       | 0      | 0           | 0           | 0.29 |
| 2       | 28.96  | 15      | 20    | 15    | 0.5    | 0.5     | 0.5    | 0.25        | 0.125       | 0.157|
| 3       | 28.96  | 15      | 20    | 30    | 0.5    | 0.5     | 1      | 0.5         | 0.25        | 0.229|
| 4       | 28.96  | 30      | 20    | 15    | 1      | 0.5     | 0.5    | 0.25        | 0.25        | 0.074|
| 5       | 28.96  | 30      | 20    | 30    | 1      | 0.5     | 1      | 0.5         | 0.5         | 0.227|
| 6       | 28.96  | 15      | 40    | 15    | 0.5    | 1       | 0.5    | 0.5         | 0.25        | 0.215|
| 7       | 28.96  | 15      | 40    | 30    | 0.5    | 1       | 1      | 1           | 0.5         | 0.277|
| 8       | 28.96  | 30      | 40    | 15    | 1      | 1       | 0.5    | 0.5         | 0.5         | 0.152|
| 9       | 28.96  | 30      | 40    | 30    | 1      | 1       | 1      | 1           | 0.5         | 0.207|
| 10      | 28.96  | 15      | 20    | 0     | 0.5    | 0.5     | 0      | 0           | 0           | 0.29 |
| 11      | 28.96  | 30      | 0     | 15    | 0      | 1       | 0.5    | 0           | 0           | 0.29 |
| 12      | 28.96  | 0       | 40    | 30    | 1      | 0       | 1      | 0           | 0           | 0.29 |
| 13      | 28.96  | 0       | 20    | 15    | 0.5    | 0      | 0.5    | 0           | 0           | 0.29 |
| 14      | 28.96  | 15      | 0     | 30    | 0      | 0.5    | 1      | 0           | 0.5         | 0.29 |
| 15      | 28.96  | 30      | 40    | 0     | 1      | 1      | 0      | 0           | 0           | 0.29 |
| 16      | 28.96  | 0       | 40    | 30    | 1      | 0      | 1      | 0           | 0           | 0.29 |
| 17      | 28.96  | 15      | 20    | 15    | 0.5    | 0.5    | 0.5    | 0.25        | 0.125       | 0.315|
| 18      | 28.96  | 15      | 20    | 30    | 0.5    | 0.5    | 1      | 0.5         | 0.5         | 0.459|
| 19      | 28.96  | 30      | 20    | 15    | 1      | 0.5    | 0.5    | 0.25        | 0.25        | 0.148|
| 20      | 28.96  | 30      | 20    | 30    | 1      | 0.5    | 1      | 0.5         | 0.5         | 0.453|
| 21      | 28.96  | 15      | 40    | 15    | 0.5    | 1      | 0.5    | 0.5         | 0.25        | 0.431|
| 22      | 28.96  | 15      | 40    | 30    | 0.5    | 1      | 1      | 1           | 0.5         | 0.553|
| 23      | 28.96  | 30      | 40    | 15    | 1      | 1      | 0.5    | 0.5         | 0.5         | 0.304|
| 24      | 28.96  | 30      | 40    | 30    | 1      | 1      | 1      | 1           | 1           | 0.413|
| 25      | 28.96  | 15      | 20    | 0     | 0.5    | 0.5    | 0      | 0           | 0           | 0.57 |
| 26      | 28.96  | 30      | 0     | 15    | 0      | 1      | 0.5    | 0           | 0.5         | 0.57 |
| 27      | 28.96  | 0       | 40    | 30    | 1      | 0      | 1      | 0           | 0           | 0.57 |
| 28      | 28.96  | 0       | 20    | 15    | 0.5    | 0      | 0.5    | 0           | 0           | 0.57 |
| 29      | 28.96  | 15      | 0     | 30    | 0      | 0.5    | 1      | 0.5         | 0           | 0.57 |
| 30      | 28.96  | 30      | 40    | 0     | 1      | 1      | 0      | 0           | 0           | 0.57 |

Table 2. The effect of ELF EMF treatment on the antioxidant properties of FFF.

| n/a no. | Oc (%) | T (min) | ω (Hz) | I (A) | T/Tmax | ω/ωmax | I/Imax | x = I/ωlmax | x = T/Tlmax | P    |
|---------|--------|---------|-------|-------|--------|---------|--------|-------------|-------------|------|
| 1       | 59.5   | 0       | 0     | 0     | 0      | 0       | 0      | 0           | 0           | 0.34 |
| 2       | 59.5   | 15      | 20    | 15    | 0.5    | 0.5     | 0.5    | 0.25        | 0.125       | 0.84 |
| 3       | 59.5   | 15      | 20    | 30    | 0.5    | 0.5     | 1      | 0.5         | 0.25        | 0.44 |
| 4       | 59.5   | 30      | 20    | 15    | 1      | 0.5    | 0.5    | 0.25        | 0.25        | 0.15 |
| 5       | 59.5   | 30      | 20    | 30    | 1      | 0.5    | 1      | 0.5         | 0.5         | 0.22 |
| 6       | 59.5   | 15      | 40    | 15    | 0.5    | 1      | 0.5    | 0.5         | 0.25        | 0.16 |
| 7       | 59.5   | 15      | 40    | 30    | 0.5    | 1      | 1      | 1           | 0.5         | 0.21 |
| 8       | 59.5   | 30      | 40    | 15    | 1      | 1      | 0.5    | 0.5         | 0.5         | 0.34 |
| 9       | 59.5   | 30      | 40    | 30    | 1      | 1      | 1      | 1           | 1           | 0.27 |
| 10      | 59.5   | 15      | 20    | 0     | 0.5    | 0.5    | 0      | 0           | 0           | 0.34 |
| 11      | 59.5   | 30      | 0     | 15    | 0      | 1      | 0.5    | 0           | 0.5         | 0.34 |
A regression analysis of the experimental data (table 1, 2) was carried out using the Statistica v.12 package to obtain the dependences of the antioxidant (P) properties of PC and FFF on the processing parameters of ELF EMF (ω, Hz, I, A, T, min).

Regression models of the dependences of the antioxidant (P) properties of PC (2) and FFF (3) on the processing parameters of ELF EMF (ω, Hz, I, A, T, min):

\[
P(\text{PC}) = 0.4525 - 0.1453 \cdot X + 0.3142Y + 0.0906X^2 - 0.2676 \cdot X \cdot Y + 0.4933Y^2 \tag{2}
\]

\[
P(\text{FFF}) = 0.5551 + 0.4465 X + 0.0612 Y - 0.5779(X)^2 + 0.1817XY - 0.423(Y)^2 \tag{3}
\]

where \(X = \frac{T}{T_{\text{max}}}, \quad Y = \frac{I}{I_{\text{max}}}, \quad \omega = \frac{\omega_{\text{max}}}{\omega_{\text{max}}} \).

The graphs of the regression models PC and FFF are shown in Figure 1.

**Figure 1.** Graphs of regression models of the dependences of the antioxidant (P) properties of PC and LFM on the processing parameters of ELF EMF (ω, Hz, I, A, T, min).
The processing parameters of ELF EMF were determined, at which $P \to 0$:
- for PC minimum $P = 0.01$ is achieved at $T = T_{max}$, $\omega = 0.6$, $I = 0.6$ or $T = 30$ min, $\omega = 20$ Hz, $I = 15$ A;
- for FFF minimum $P = 0.1$ is achieved at $T = T_{max}$, $\omega = 0.6$, $I = 15$ A or $T = 30$ min, $\omega = 20$ Hz, $I = 10$ A.

4. Conclusion
Mass production of mayonnaise without the use of antioxidants is impossible. Antioxidants allow not only to preserve the freshness of the product and extend the shelf life, but also to impart functional properties to the product.

Sesame seed products (sesame oil, full-fat flour, protein concentrate) are sources of phytosterols, natural antioxidants that include beta-sitosterol, campesterol, stigmasterol, and delta-5-avenasterol. A feature of sesame seeds is the content of lignans - sesamin, sesamolin, episesamin, sesaminol and sesamol, which have an antioxidant effect [13].

Physical modification has been found to increase the antioxidant properties of protein products from sesame seeds.

References
[1] Sarmalayev A A, Abuova A B, Baibatyr T A and Zhazykbaeva G M 2016 Bulletin of Almaty technological university 2 94-8
[2] Starovoytova K V and Tereshchuk L V 2018 Food Processing: Techniques and Technology 1(48) 91-8 doi: 10.21603/2074-9414-2018-1-91-98.
[3] Gaipova Sh, Salijanova Sh and Ruzibaev A 2019 Universum: technical sciences 9(66)
[4] Sobirova M, Suvanova F and Shirinboyev M 2021 Universum: technical sciences 4-3(85) 51-4 doi: 10.32743/UniTech.2021.85.4-3.51-54
[5] Davydova U Yu and Velichko N A 2017 Bulletin of KSAU 6(129) 85-90
[6] Pokrovsky N V and Tikhoikina I M 2016 Education and science without borders: basic and applied research 2 64-8
[7] Zhmurina N D, Illarionov E F and Skorobogatov V V 2017 Scientific notes Orel state university of economics and trade 5(23) 66-70
[8] Rakhimova E I, Sirotkin A S and Valiullova A A 2019 Technology and merchandising of the innovative foodstuff 2(55) 98-103
[9] Bukhtoyarov R YU, Bugayets N A and Bukhtoyarova Z T 2014 Food technology 2-3(338-339) 51-3
[10] Bugaets N A, Kaloeva A K, Tereshchenko I V, Usatikov S V 2019 Proceedings of the International Scientific Conference The fifth technological order: prospects for the development and modernization of the russian agro-industrial sector (TFTS-2019) (Omsk: State Agrarian University named after P.A. Stolypin) pp 366-70 doi: 10.2991/assehr.k.200113.204
[11] Pershakova T V, Kupin G A, Mikhailyuta L V, Yatsushko E S, Gorlov S M and Prichko T G 2020 International Journal of Emerging Trends in Engineering Research 3(8) 705-9
[12] Center for the collective use of scientific equipment «Food and Chemical Technology Research Center» Retrieved from: https://fct.kubstu.ru/
[13] Panina E V and Isaev E A 2018 Technologies and commodity science of agricultural products 2(11) 145-52