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STUDY OF OLEOGEL BASED ON COMPONENTS *HELIANTHUS ANNUUS L.* AND *ROSMARINUS OFFICINALIS L.* AS FRYING OIL

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KEY WORDS:
Helianthus annuus L., Rosmarinus officinalis L., frying oil, high oleic sunflower oil, oleogel, sunflower wax, rosemary extract

ABSTRACT

The aim of this study was to study the oxidation resistance and functional properties of oleogels based on high oleic oil and wax from *Helianthus annuus L.* with the addition of a natural complex antioxidant — an extract from *Rosmarinus officinalis L.* and lecithin from *Helianthus annuus L.* — when used as a frying medium for French-fries. High oleic sunflower oil was structured into an oleogel with sunflower wax at a dosage of 5%. Studies were carried out to determine the possibility of replacing the synthetic antioxidant tert-butylhydroquinone at a dosage of 200 mg/kg with a natural antioxidant based on rosemary extract and sunflower lecithin in an oleogel with a defoamer. It was determined that the introduction of sunflower wax increased the induction period of high-oleic sunflower oil by 1.6 times, and the additional introduction of defoamer and antioxidants increased this figure by 1.8–2 times. The rate of accumulation of oxidation products in oil, which is characterized by the level of total polar materials, decreased when wax and antioxidants were added. The degree of thermal oxidation most quickly reached the limit value in oil without additives; in oleogels, it significantly decreased. The introduction of sunflower wax into oil contributed to a noticeable decrease in the absorption of oil by potatoes: fried in oleogel, it absorbed 34–38% less oil than fried in oil without additives. The addition of 0.07% rosemary extract with sunflower lecithin to the oleogel increased the operating time of frying oil by at least 2 times, approximately the same as that of the oleogel with tert-butylhydroquinone. This makes it possible to replace the synthetic antioxidant in deep-frying oleogel with natural rosemary extract with sunflower lecithin. The developed oleogel is a frying oil that has a longer service life and allows you to get fried products with a lower amount of fat.

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ИССЛЕДОВАНИЕ ОЛЕОГЕЛЯ НА ОСНОВЕ КОМПОНЕНТОВ *HELIANTHUS ANNUUS L.* И *ROSMARINUS OFFICINALIS L.* В КАЧЕСТВЕ ФРИТЮРНОГО ЖИРА

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КЛЮЧЕВЫЕ СЛОВА:
Helianthus annuus L., Rosmarinus officinalis L., фритюрный жир, высокоолеиновое подсолнечное масло, олеогель, подсолнечный воск, экстракт розмарина

АННОТАЦИЯ

Целью настоящего исследования являлось изучение устойчивости к окислению и функциональных свойств олеогелей на основе высокоолеинового масла и воска из *Helianthus annuus L.* с вводом натурального комплексного антиокислителя — экстракта из *Rosmarinus officinalis L.* и лецитина из *Helianthus annuus L.* — при использовании их в качестве жарочной среды для картофеля-фри. Высокоолеиновое подсолнечное масло было структурировано в олеогель подсолнечным воском в дозировке 5%. Проводили исследования по определению возможности замены синтетического антиокислителя трет-бутилгидрохинона в дозировке 200 мг/кг на натуральный антиокислитель на основе экстракта розмарина и подсолнечного лецитина в олеогеле с пеногасителем. Было определено, что внесение подсолнечного воска увеличило индукционный период высокоолеинового подсолнечного масла в 1.6 раза, а дополнительный ввод пеногасителя и антиокислителей увеличил данный показатель уже в 1.8–2 раза. Скорость накопления продуктов окисления в масле, характеризующаяся уровнем общих полярных веществ, при внесении воска и антиокислителей снижалась. Степень термического окисления быстрее всех достигла предельного значения в масле без добавок, в олеогелях она заметно снижалась. Введение в масло подсолнечного воска способствовало заметному снижению впитываемости масла картофелем: обжаренный в олеогеле, он впитывал на 34–38% меньше масла, чем обжаренный в масле без добавок. Внесение в олеогель 0.07% экстракта розмарина с подсолнечным лецитином увеличивало время эксплуатации фритюрного жира не менее чем в 2 раза,

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примерно также, как и у олеогеля с трет-бутилгидрохиноном. Это дает возможность произвести замену синтетического антиокислителя в олеогеле для фритюра на натуральный экстракт розмарина с подсолнечным лецитином. Разработанный олеогель является фритюрным жиром, имеющим более длительный срок эксплуатации и позволяющим получать обжаренные продукты с более низким количеством жира.

1. Introduction

Development of landmark technologies as solution to the issue of safety and quality of food is of immediate interest and contributes to the sixth wave of innovation in the agro-industrial complex [1]. For example, oleogels constitute a specific continuous form of organogels consisting of liquid at ambient temperature oils and fats — oil and fat products obtained in a new manner by oil modification (oleogel formation). Oleogel is a solid dispersed system, the dispersion medium of which is liquid edible oil, while the dispersed phase is represented by low- and high-molecular weight compounds forming a continuous homogeneous structure [2]. Compared to other classic ways of fat modification (hydrogenation, interesterification and fractionation), oleogel formation allows obtaining analogues of solid at ambient temperature fats — confectionary, baking, frying fats, margarine without or with reduced content of trans and saturated fatty acids. For the purpose of replacement of tropic oils, their fractions, hydrogenated fats and other fatty acids with high content of saturated and trans fats, oleogels were studied as frying fats. Oleogels were studied when deep frying potatoes [3–5], chicken [6], and in the technology of instant noodles [7–9]. Any liquid at ambient temperature oils and fats may be used as the base of oleogel, but the most oxidation-resistant due to reduced content of PUFAs appear the best choice for deep frying: high oleic sunflower oil, rape seed oil, soya bean oil and palm super olein. Being a domestic raw material, high oleic sunflower oil is of immediate interest.

Different organic substances were studied as gelling agents in oleogels [2]. Various waxes can be distinguished due to their market availability [4,7,13,14,18,19,23,28,29]. However, carnauba wax (E903) [6,8,9,16,17], bee wax (901) [5,10,12,15,21,27], candelilla wax (E 902) [21], and rice bran wax (E908) [25], used in such studies, have restrictions in the application and/or acceptable content in products. Sunflower wax was also studied in oleogels [3,11,16,17,21,22,24,26,27,30], though it is not a food additive (does not have E index), but is contained in traditional food items such as sunflower seeds, unrefined sunflower oil. As compared to the most waxes used, the sunflower wax almost does not contain any free fatty alcohol, acids, or hydrocarbons, and 95% of it is wax ester. Today, the use of sunflower wax in food is not restricted by Russian or international laws. However, of course appropriate hygienic studies are required to assess the risks of its use in food. Besides, the sunflower wax is a secondary product of treatment of the sunflower oil refinery waste, which makes it a cost effective domestic raw material to be used in the manufacturing of oleogels. According to the researchers, advantages of using waxes in oleogels include reduced oil absorption by the deep fried product [3–5,8].

Traditional antioxidants for frying oils are synthetic tert-butylhydroquinone (E 319), butylated hydroxyanisole (E320), butylated hydroxytoluene (E321), gallates (E310, E311, E312). Their content in frying oils is restricted by safety requirements CU TR029/2012[1]. The following natural organic compounds were studied as alternative to synthetic antioxidants in frying oils: tocochromanols (tocopherols, tocotrienols), phytosterols, phenolic acids and their esters (gallic, caffeic, rosmarinic, ferulic, gamma oryzanol), lignans (sesamin, sesamol, sesamolin, sesaminol, sesamolinol), carotenoids (beta-carotene), terpenoids (squalene, carnosic acid, carnosol), phospholipids (phosphatidylcholine), polyphenols (catechins, gallates), flavonoids (quercetine), phenolamides (capsaicine), diarylheptanoids (curcumin) [31–34]. Among natural antioxidants, maximum antioxidant activity and thermal resistance was demonstrated by phenolic compounds contained in the extracts of the following plants: olive leaves, hazel leaves, oregano, thyme, grape seeds, rosemary, sage, green tea, green coffee, bamboo, coriander, etc. [32,34]. Presently, rosemary extracts prevail in the markets.

Phospholipids play a special role among natural antioxidants. Depending on the medium they can demonstrate pro- or antioxidant properties [35]. Prooxidant effect was observed in unrefined oil due to the surface activity of phospholipids, and in products with low humidity. At the same time, phospholipids together with tocopherols and flavonoids demonstrate a synergistic effect and enhance the antioxidant activity due to their regeneration [36–37]. The effect of phospholipids towards tocopherols is determined by a substituted aminogroup in their structure [38]. Due to lecithin availability in the market, incl. domestic sunflower lecithin, it is of interest as a synergist to the antioxidant for frying oils.

Based on the literature analysis and market demands, manufacturing of frying oils out of domestic raw materials with reduced content of saturated fats and clean label seems relevant for the food industry. However, the literature does not contain any data on such manufacturing.

The purpose of this article is to study the effect of rosemary plant extract and sunflower lecithin as compared to synthetic antioxidant tert-butylhydroquinone within oleogels based on high oleic sunflower oil and sunflower wax on the quality indicators in the deep frying technology.

The following tasks were to be solved to achieve the objective:

1. Obtaining of oleogel based on high oleic sunflower oil and sunflower wax.
2. Obtaining of a complex antioxidant based on rosemary extract and sunflower lecithin.
3. Study of the effect of rosemary extract, sunflower lecithin and sunflower wax on the properties of oleogel based on high oleic frying oil in the technology of French-fried potatoes.

It was suggested that rosemary extract and sunflower lecithin can replace the traditional synthetic antioxidant tert-butylhydroquinone in oleogel for frying without loss of its properties during the deep frying of potatoes. It was also supposed that the oil absorption by potatoes would be lower when frying them in oleogel based on high oleic sunflower oil due to sunflower wax.

2. Materials and methods

The following materials were used as study objects: refined and deodorised high oleic sunflower oil (HOSFO) (Rusagro Group, Russia); refined and deodorised sunflower oil (Laguna, Russia); refined and deodorised palm oil (Efko Group, Russia); sunflower wax (SFW) (Koster Keunen Holland B.V., Netherlands); sunflower lecithin (SFL) (Lasenor, Russia); rosemary extract (RE) (20% carnosol and carnosic acid) (Synthite, India), polydimethyl siloxane (PDMS) (Dew, USA), synthetic antioxidant Grindox 443 (30% tert-butylhydroquinone (TBHQ)) (DuPont, USA).

The following physicochemical and organoleptic methods of analysis were used in Aquanova RUS and Rusagro Group laboratories:

[1] CU TR 029/2012 Customs Union Technical Regulation “On safety requirements for food additives, flavouring agents and processing supplements”, adopted by the Decree No. 5 of July 20, 2012 of the Council of the Eurasian Economic Commission. (In Russian)

- in oil: peroxide value (PV) — according to GOST ISO 3960–2020[2], acid value (AV) — according to GOST 31933–2012[3], total polar materials (TPM) by device FOM 320, thermal oxidation (TO) by spectrophotometric method, colour, taste and odour organoleptically — according to GOST R 54607.3–2014[4], induction period (IP) by device Rancimat — according to GOST 31758–2012[5], and by device Oxitest — according to GOST 34815–2021[6], dynamic viscosity (DV) — by rheometer Haake Viscotester iQ equipped with Peltier temperature module, using the cylinder in cylinder measuring system CC25 DIN/Ti — 02200715, fatty acid content (FAC) — according to GOST 30418–96[7], GOST 31663–2012[8];
- in deep fried potatoes: fat weight ratio by gravimetric method with extraction using chloroform and spirit mix — according to GOST 8756.21–89[9], colour, taste, odour and texture — according to GOST 33314–2015[10].

The oleogel was obtained at the laboratory of Saratov Fat-Processing Plant (Rusagro Group) by mixing HOSFO heated to 85 °C with SFW in a dose of 1, 3 and 5% until its complete meltdown and further cooling in water bath with ice to 52–55 °C at a speed of 5–7 °C/min. while agitation in IKA RW 20 D at the rate of 700 rpm. Cooling to ambient temperature was performed in static condition. The cool samples were put into a fridge for 24 h. Oil binding capacity of the SFW in oleogels at ambient temperature, and organoleptic characteristics at consumer testing of French — fries were evaluated. Oil binding capacity of the SFW was evaluated as described below. One mL of melted oleogel was added to pre-weighed empty tubes and left for 2 days at ambient temperature for crystallisation completion. The tubes were centrifugated at 3000 rpm for 30 min. at ambient temperature. Then the tubes were turned upside down and left for a night on filter paper for drainage of separated oil. The tubes were weighed to calculate the quantity of the separated oil.

The complex antioxidant was obtained at Aquanova RUS laboratory by mixing RE with SFL in a dose of 5–10% and sunflower oil, so that the content of the extract's active substances in the mixture (carnosol and carnosic acid) was 6.75% (determined in the previous studies when antioxidants were obtained). The antioxidant activity of the complex antioxidant was evaluated by its dilution in melted palm oil in a dose of 0.07% (determined in the previous studies of the authors) and IP assessment in the samples of oil with antioxidant in Rancimat (sample weight: 4 g, temperature: 120 °C) [34].

The following samples of frying oil were made at Rusagro Group laboratory:

1. Absolute control — HOSFO without additives;
2. Control — oleogel: HOSFO with SFW without other additives;
3. Oleogel + PDMS + TBHQ: oleogel with PDMS 0.001% and synthetic antioxidant Grindox 443 in a standard dose of 0.066% (200 mg/kg TBHQ according to CU TR 029/2012[11]);
4. Oleogel + PDMS + Rosemary extract AR 2506 0.05%: oleogel with PDMS 0.001% and complex antioxidant based on RE and SFL in optimum ratio (Rosemary Extract AR 2506) in a dose of 0.05%;
5. Oleogel + PDMS + Rosemary Extract AR 2506 0.07%: oleogel with PDMS 0.001% and complex antioxidant based on RE and SFL in optimum ratio (Rosemary Extract AR 2506) in a dose of 0.07%.

PDMS was used as a standard antifoamer for frying oils in the maximum allowable dose of 0.001% according to CU TR 029/2012[11].

The effect of RE, SFL and SFW on the characteristics of HOSFO-based oleogel for frying oils in the technology of French-fried potatoes was studied at Aquanova RUS laboratory by deep frying of potatoes using 5 samples of frying oil presented by Rusagro Group. Potatoes pre-sliced into matchsticks of equal size were frozen at −18 °C, and then defrosted before frying. Potatoes were fried in a semi-professional deep fryer with the volume of 4 L with a metal basket. Frying parameters: required quantity of fresh frying oil: 3 kg, frying temperature: 170–175 °C, portion of potatoes: 100 g, frying time per portion: 8 min. Frying process: the oil was heated to 180 °C, 2 portions of potatoes were fried one after the other, then 2 h of idle heating, then again 2 portions of potatoes were fried, etc. up to the end of the work day (total 4 frying cycles at 10 a. m., 12 a. m., 2 p. m., 4 p. m.), after that the deep fryer was switched off and closed with the lid, the oil was not filtered. The next day the same oil was heated to 180 °C, and frying cycles were repeated. PV and IP were determined in the fresh oil using Oxitest (sample weight: 10 g, temperature: 90 °C). While frying, the following oil quality parameters were determined by taking samples (10 mL) from the deep fryer at the beginning of the test; AV, TO, taste, colour and odour were determined after the first and the last idle heating during a day. TPM were determined directly in the deep fryer at the beginning of the test and after the further 2 h idle heating. At the end of the workday, after the oil sample cooled down to the ambient temperature, the following parameters were additionally determined: IP using Rancimat (sample weight: 4 g, temperature: 120 °C), DV. Based on the results, the objective index of rejection of any frying oil according to organoleptic parameters obtained in the international study [39] was calculated — degradation level of frying oil DEGLEV:

$$DEGLEV = 117 - 8 \cdot AV - 3 \cdot TPM \; [\%]. \quad (1)$$

When this index fell below 50%, the frying oil had unacceptable organoleptic parameters restricting its further use, therefore frying was stopped.

The fresh sample and the sample of oil from each batch upon completion of frying were forwarded for FAC determination (to Rusagro Group laboratory). Mass content of oil in the samples of fried potatoes was determined at the beginning and at the end of frying.

The total time of use of the frying oil for a given batch was recorded when one of the target indicators of frying oil quality reached threshold values according to GOST R 54607.3–2014[12]: AV — over 0.6 mg KOH/g, TPM — over 20%, TO — over 1% or less than 2 points based on organoleptic parameters.

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[2] GOST ISO 3960–2020 Animal and vegetable fats and oils. Determination of peroxide value. Iodometric (visual) endpoint determination. — M.: Standartinform, 2021. — 18 p. (In Russian)

[3] GOST 31933–2012 as amended by Amendment 1. Vegetable oils. Methods for determination of acid value. — M.: Standartinform, 2019. — 14 p. Amendment No. 1 was introduced by the database author in the text IUS No. 10, 2020. (In Russian)

[4] GOST R 54607.3–2014 Public catering services. Methods of laboratory quality control of products catering. Part 3. Methods of control of manufacturing processes of products of public catering. — M.: Standartinform, 2020. — 15 p. (In Russian)

[5] GOST 31758–2012 Animal and vegetable fats and oils. Determination of oxidative stability (accelerated oxidation test). — M.: Standartinform, 2019. — 16 p. (In Russian)

[6] GOST 34815–2021 Foods. Accelerated oxidation test using the oxidation test reactor. — M.: Standartinform, 2022. — 12 p. (In Russian)

[7] GOST 30418–96 Vegetable oils. Method for determination of fatty acid content. — Minsk: MGSSMS, 1996. — 116 p. (In Russian)

[8] GOST 31663–2012 Vegetable oils and animal fats. Determination of methyl esters of fatty acids by gas chromatography method. — M.: Standartinform, 2013. — 8 p. (In Russian)

[9] GOST 8756.21–89 Products of fruits and vegetables processing. Methods for determination of fat. — M.: Standartinform, 2010. — 68 p. (In Russian)

[10] GOST 33314–2015 Quick-frozen potatoes. General specifications. — M.: Standartinform, 2016. — 9 p. (In Russian)

[11] CU TR 029/2012 Customs Union Technical Regulation "On safety requirements for food additives, flavouring agents and processing supplements", adopted by the Decree No. 5 of July 20, 2012 of the Council of the Eurasian Economic Commission. (In Russian)

[12] GOST R 54607.3–2014 Public catering services. Methods of laboratory quality control of products catering. Part 3. Methods of control of manufacturing processes of products of public catering. — M.: Standartinform, 2020. — 15 p. (In Russian)

Statistical processing of data was performed according to the standard methods of mathematical statics using software Statistica 10.0. The confidence level was determined based on 3 parallel measurements according to Student's t-test. The difference between the average values was considered significant at confidential probability $p \leqslant 0.05$. The measurement results are given as average values ± standard deviation (n = 3).

3. Results and discussion

3.1. Obtaining of oleogel based on HOSFO and SFW

Different doses of SFW (1, 3 and 5%) were used to determine the minimum content necessary for oleogel formation. Content of 1% resulted in a weak oleogel web, which ran down the inclined surface. Minimum quantity of SFW for oleogel formation: 3%. Oil binding capacity test was performed using 3% and 5% oleogels. Neither sample of oleogel demonstrated oil separation. Oleogels with 3% and 5% SFW content were used in 2 cycles of frying potatoes. When evaluating organoleptic parameters, all the testers noted less oily surface of potato matchsticks fried in the 5% oleogel, their taste seemed less oily, they were drier. The odour of ready products was similar.

Based on the results of this stage of study, it was determined, that 5% is optimum content of SFW in the HOSFO-based oleogel for deep frying.

3.2. Obtaining of complex antioxidant based on RE and SFL

The results of IP determination in the antioxidants based on RE and SFL are given in Table 1.

Table 1. **IP of complex antioxidants based on RE and SFL in palm oil**

Таблица 1. **Индукционный период комплексных антиокислителей на основе ЭР и ПЛ в пальмовом масле**

Sample	IP, h (Rancimat, 120 °C)
Palm oil, control	17.50 ± 0.70
Palm oil + 0.07% RE	20.80* ± 0.83
Palm oil + 0.07% RE with 5% SFL	20.34* ± 0.81
Palm oil + 0.07% RE with 10% SFL	22.58 ± 0.90

The values marked with <*> have no significant difference (p > 0.05)

Based on the results of this stage of study, it was determined that maximum antioxidant activity is demonstrated by RE with 10% SFL, obtained by Rosemary Extract AR 2506 (Aquanova RUS). Doses of Rosemary Extract AR 2506 in oleogels for the next stage of study: 0.07 and 0.05% (to evaluate the possibility of dose reduction).

3.3. Results of study of RE, SFL and SFW impact on the characteristics of HOSFO-based oleogel for deep frying in the technology of French-fried potatoes

PV in all the samples of frying oil was below 1 mEq of active oxygen per kg, which shows freshness and low oxidation of raw materials: HOSFO, SFW, SFL.

The results of study are given in the diagrams and charts, Figures 1–10.

Figure 1 shows that SFW added to HOSFO increases IP (Oxitest) of fresh frying oil by 1.6 times, adding of antioxidants increases this value by 1.8–2 times.

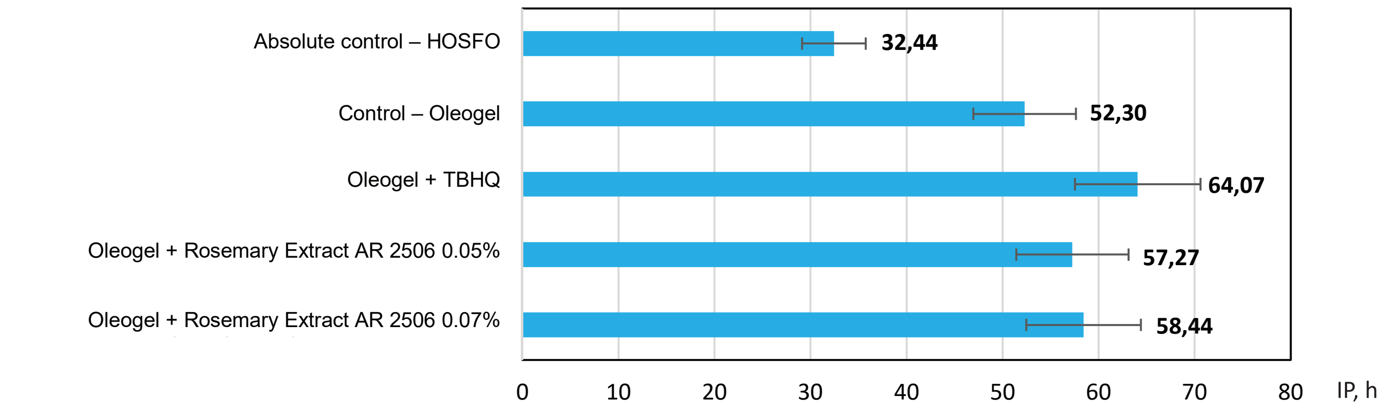

Figure 1. **IP of fresh frying oil determined with Oxitest (at 90 °C)**

Рисунок 1. **Индукционный период свежих фритюрных жиров на приборе Окситест (при 90 °C)**

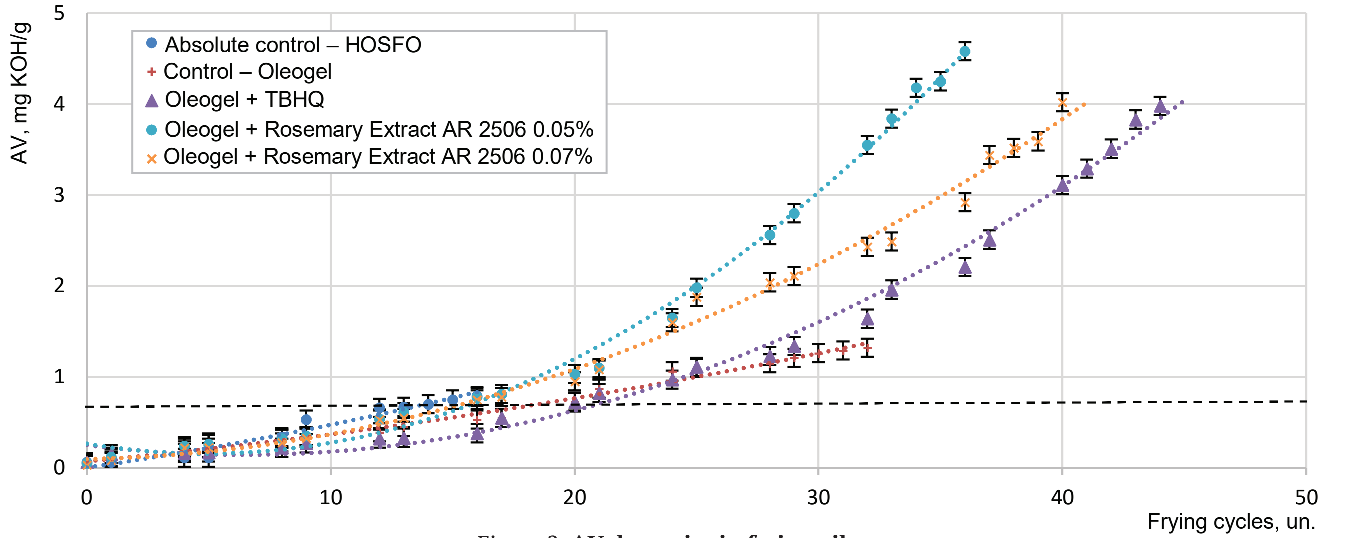

Figure 2. **AV dynamics in frying oil**

Рисунок 2. **Изменение кислотного числа фритюрного жира**

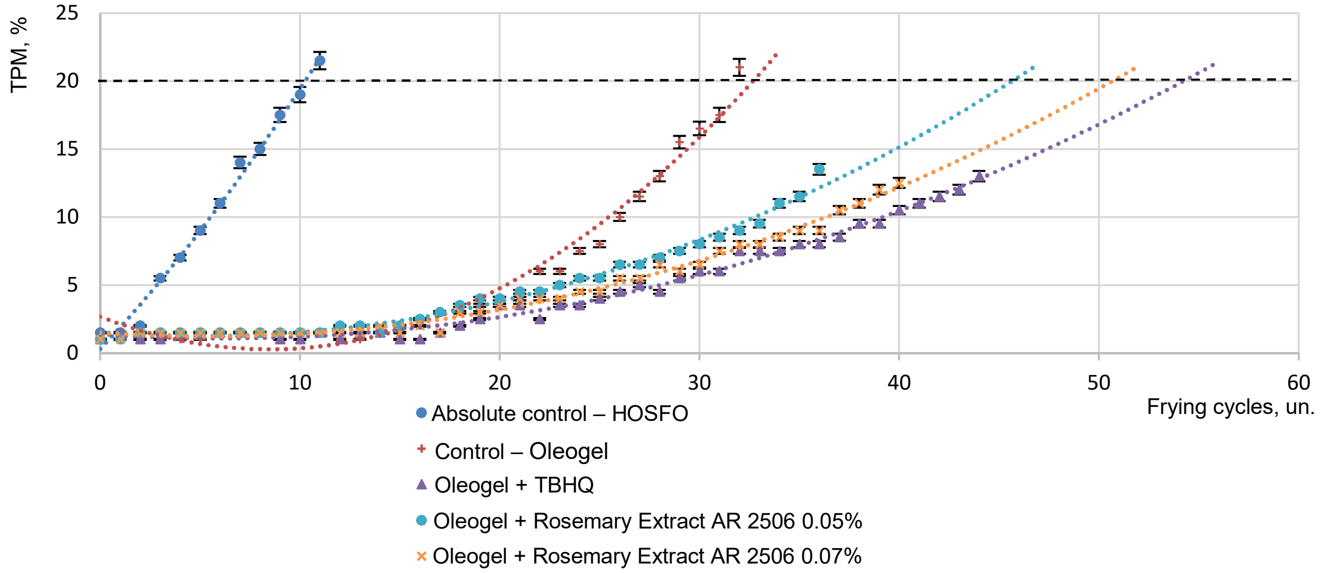

Figure 3. **TPM dynamics in frying oil**

Рисунок 3. **Изменение общих полярных веществ фритюрного жира**

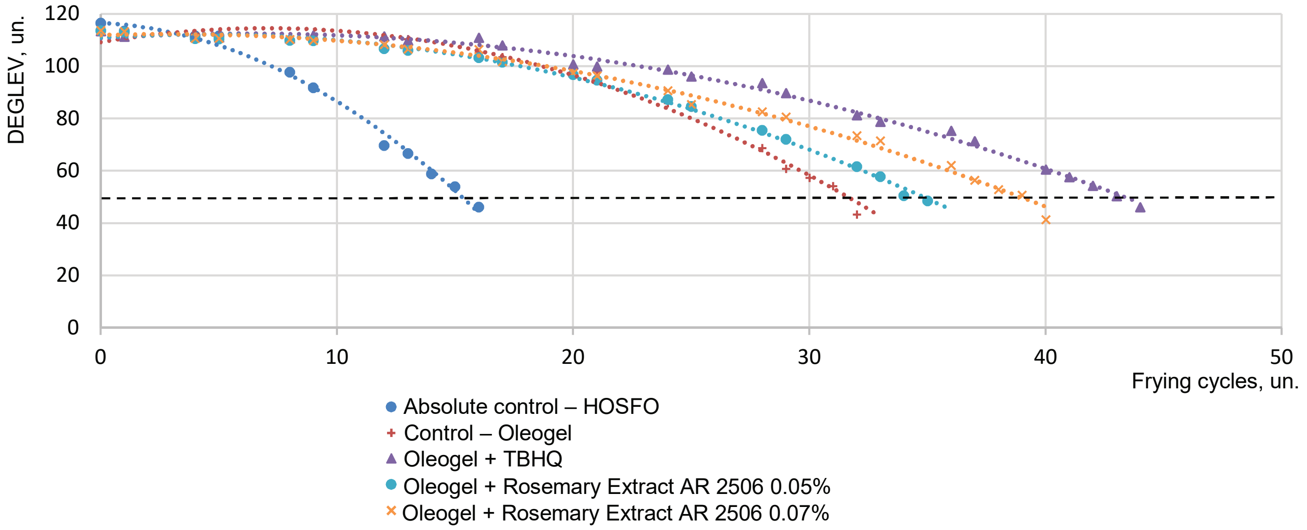

Figure 4. **DEGLEV dynamics in frying oil**

Рисунок 4. **Изменение DEGLEV фритюрного жира**

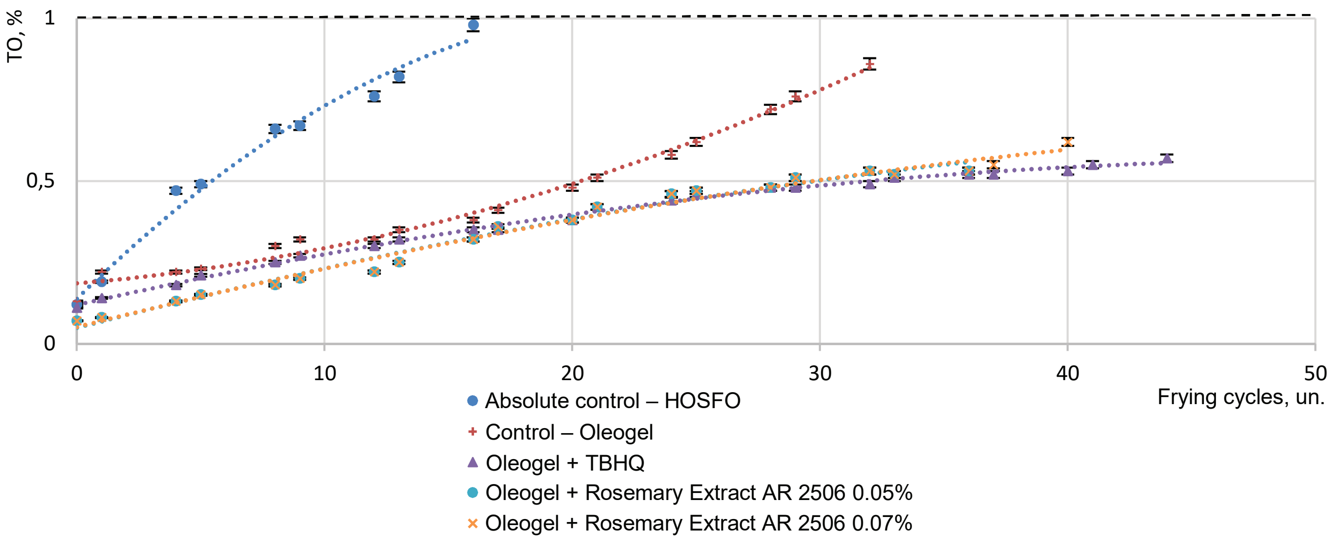

Figure 5. **TO dynamics in frying oil**

Рисунок 5. **Изменение степени термического окисления фритюрного жира**

Based on Figure 4, the actual number of potatoes frying cycles is shown in Table 2.

Table 2. **Actual number of potatoes frying cycles**
Таблица 2. **Фактическое количество проведённых жарок картофеля**

Frying oil	Number of frying cycles, un.
Absolute control — HOSFO	16
Control — Oleogel	32
Oleogel + TBHQ	44
Oleogel + Rosemary Extract AR 2506 0.05%	36
Oleogel + Rosemary Extract AR 2506 0.07%	40

The actual number of frying cycles given in Table 2 was determined on the basis of reduction of the frying oil degradation level DEGLEV below 50%. According to the formula (1), DEGLEV depends on the AV and TPM, the data given in Figures 2–4 shows that maximum growth rate of AV and TPM, and, consequently, maximum falling rate of DEGLEV are recorded in absolute control — HOSFO. Accumulation rate of oxidation products, characterised by TPM level, is much lower in oleogel without antioxidants, than in absolute control due to added SFW, while antioxidants added to oleogel decreased the rate even more. TPM content in the absolute control — HOSFO — reached the threshold of 20% after 10 frying cycles, in the control — oleogel — only after 32 frying cycles, while in the samples with antioxidants after 45–54 frying cycles depending on their type and dose (Figure 3). Analysis of the AV growth in Figure 2 shows, that the quickest achievement of the threshold of 0.6 mg KOH/g was observed in the absolute control — HOSFO (after 12 frying cycles), in the control (oleogel) and samples with antioxidants — after 14–19 frying cycles. As AV characterises the fat splitting, but not oxidation, there is no correlation between adding antioxidants and the value growth rate. As compared to AV, the TPM content dynamics shows that minimum rate of the value growth was observed in the oleogel sample with TBHQ, and the closest result was obtained in the sample with Rosemary Extract AR 2506 0.07%, which demonstrates the antioxidant activity of these antioxidants in frying oil and its longer period of use. TO accumulation rate (Figure 5) shows the same trend as TPM: the quickest achievement of the threshold of 1% was observed in the absolute control — HOSFO (after 19 frying cycles), in the control — oleogel — after — 36 frying cycles, while the rest 3 samples with antioxidants did not reach the threshold at all up to the end of the test.

Evaluation of changes in organoleptic parameters of frying oil, given in Figure 6, shows that their quickest fall to the threshold of 2 points was observed in the absolute control — HOSFO (after 14 frying cycles), samples in the order of reduction in the parameter falling ratio: Oleogel + TBHQ (after 27 frying cycles), Oleogel + Rosemary Extract AR 2506 0.05% (after 29 frying

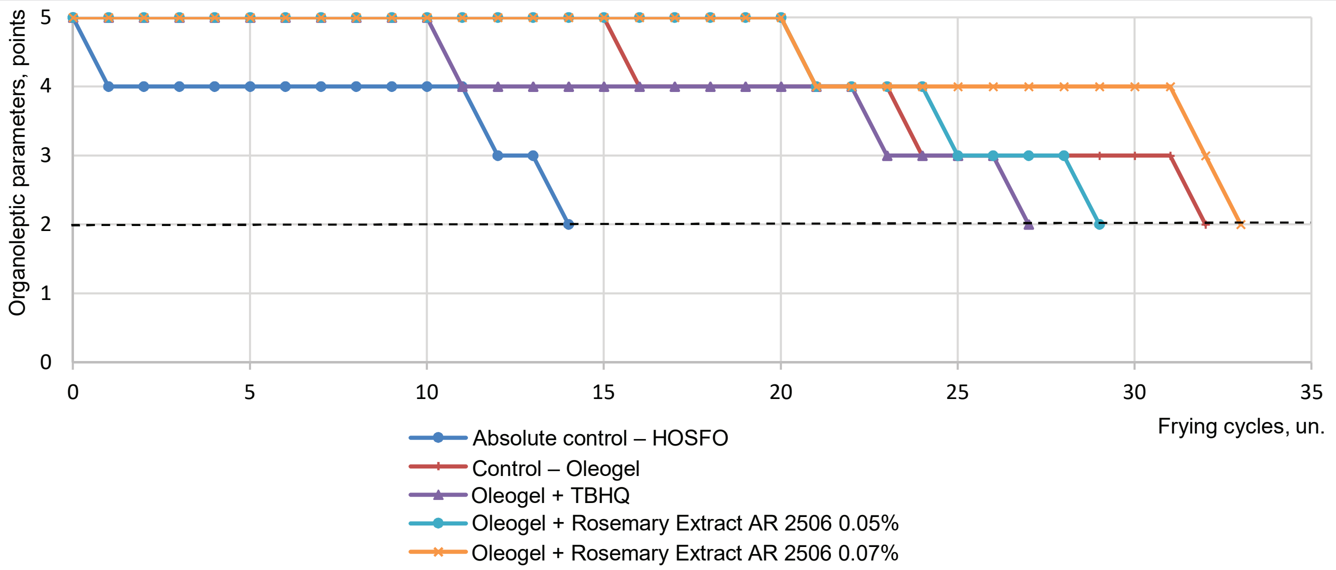

Figure 6. **Dynamics of organoleptic parameters of frying oil**
Рисунок 6. **Изменение органолептических показателей фритюрного жира**

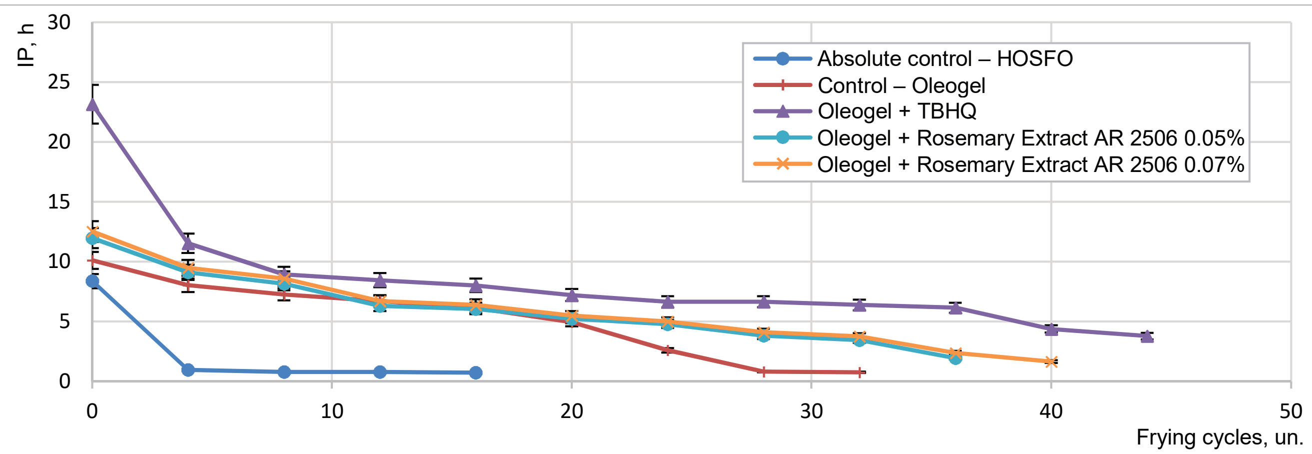

Figure 7. **IP dynamic in frying oil determined with Rancimat (at 120 °C)**
Рисунок 7. **Изменение индукционного периода фритюрного жира на приборе Ранцимат (при 120 °C)**

cycles), Control — Oleogel (after 32 frying cycles), Oleogel + Rosemary Extract AR 2506 0.07% (after 33 frying cycles). SFW added to HOSFO increased the period of use of the frying oil approximately by 2 times (control — oleogel — as compared to absolute control — HOSFO), which correlates to DEGLEV (Table 2, Figure 4) and confirms its objectivity for evaluation of the period of use of frying oils.

Based on physicochemical (AV, TPM, TO) and organoleptic parameters of frying fat, standardised under GOST R 54607.3–2014[13], the quickest achievement of thresholds was observed in the absolute control — HOSFO, which demonstrates practicability of use of the studied additives for extension of the period of its use.

According to the previous studies of the authors, good correlation to the period of use of the frying oil is demonstrated by IP obtained using Oxitest at 90 °C [34]. It is confirmed by the current study, as IP of oleogels with all types of antioxidants increased the indicator by 1.8–2 times as compared to the absolute control — HOSFO, while the period of use increases similarly.

Added SFW reduced the falling ratio of frying oil IP (using Rancimat at 120 °C) (Figure 7). Maximum IP in fresh oils was observed in the sample of oleogel with TBHQ (23.15 h), other samples in descending order: Oleogel + Rosemary Extract AR 2506 0.05% (11.97 h) and 0.07% (12.52 h), Oleogel — Control (10.12 h), Absolute control — HOSFO (8.38 h). Such distribution correlates to IP obtained using Oxitest (Figure 1). The sharpest drop in IP after 4 frying cycles was observed in the absolute control — HOSFO, and in the sample with TBHQ. However, at the end of frying, maximum value was observed in the sample with TBHQ (3.78 h after 44 frying cycles), minimum value — in the absolute control — HOSFO (0.73 h after 16 frying cycles). Positive effect of all types of antioxidants on the reduction of IP falling ratio is observed: Rosemary Extract AR 2506 and TBHQ cause softer fall in IP during frying as compared to the absolute and ordinary control. The data obtained by the authors in the previous study also demonstrates the possibility of replacement of synthetic TBHQ with rosemary extract in the frying oil with retention of its regulated parameters [34].

Statistically significant difference of IP, TPM and TO (Figures 1,3,5,7) from the absolute control — HOSFO — was observed in the samples of all oleogels ($p \leqslant 0.05$), while added antioxidants significantly improved TPM and TO in oleogels ($p \leqslant 0.05$).

Added antioxidants reduced the frying oil DV growth rate during frying (statistically significant difference of DV after the last frying cycle as compared to the absolute control — HOSFO — was observed in all the samples with antioxidants, $p \leqslant 0.05$) (Figure 8). Viscosity of oleogels with antioxidants at the end of frying increased by 17–21% depending on the oil sample and temperature of measurement, while viscosity in the absolute control — HOSFO — increased by 32–44%. This effect may be associated with the impact of waxes and antioxidants on the decrease in formation of polymer compounds in the frying oil.

Added antioxidants hampered degradation of the most exposed polyunsaturated fatty acids of the frying oil during frying. For example, the content of linoleic acid ($C_{18:2}$) contained in the oil in the statistically significant amount (10.2–10.3%) decreased approximately by 18% in the samples of oil with antioxidants, while it decreased by 32–33% in oil without such additives (absolute control and control) (statistically significant difference in $C_{18:2}$ content after the last frying cycle as compared to

[13] GOST R 54607.3–2014 Public catering services. Methods of laboratoryquality control of products catering. Part 3. Methods of control of manufacturing processes of products of public catering. — M.: Standartinform, 2020. — 15 p. (In Russian)

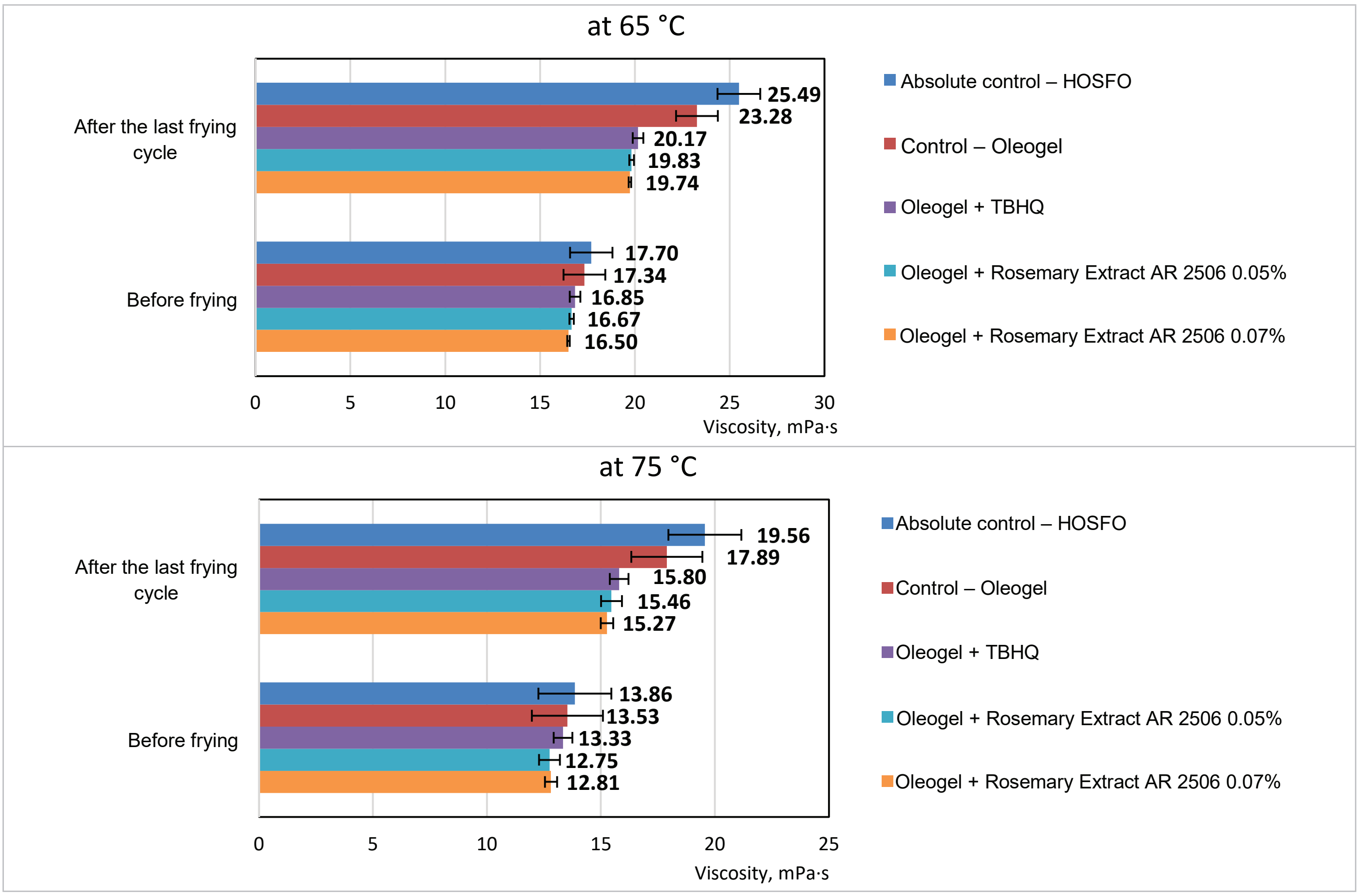

Figure 8. **DV dynamics in frying oil**
Рисунок 8. **Изменение динамической вязкости фритюрного жира**

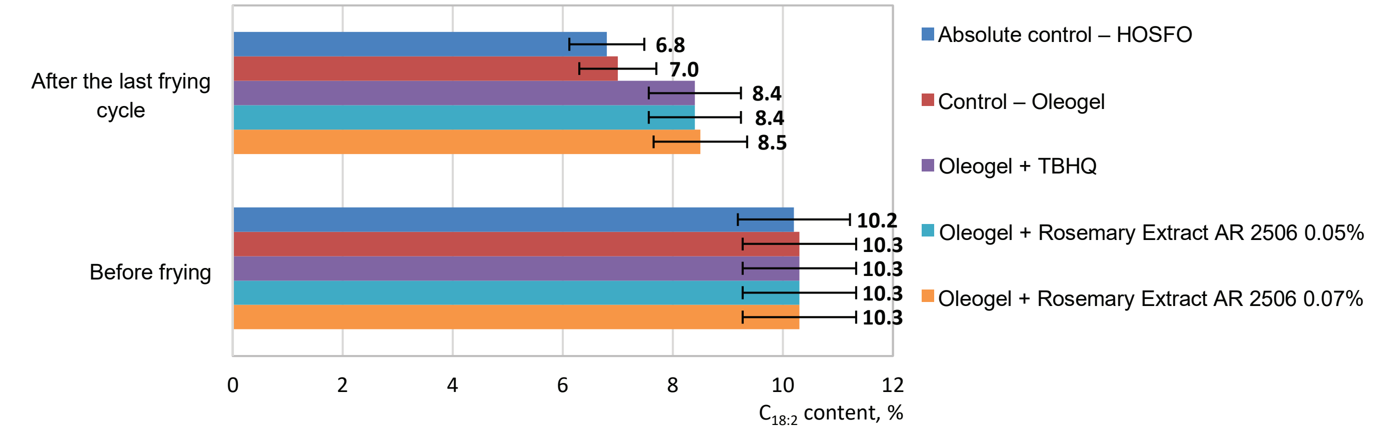

Figure 9. **Change in the content of linoleic acid ($C_{18:2}$) in frying oil**
Рисунок 9. **Изменение содержания линолевой кислоты ($C_{18:2}$) фритюрного жира**

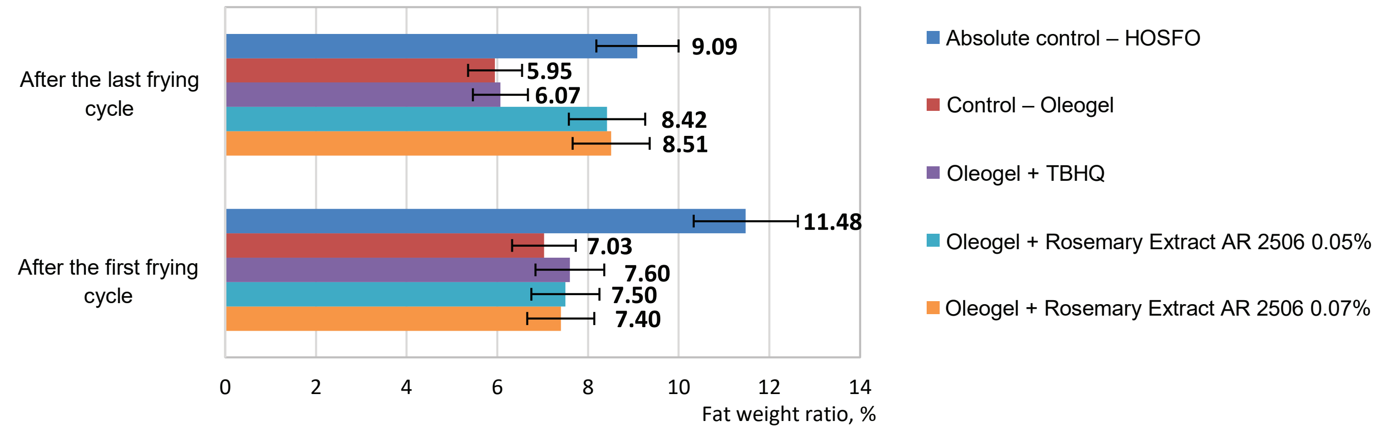

Figure 10. **Change in the fat weight ratio in French-fries**
Рисунок 10. **Изменение массовой доли жира в картофеле-фри**

the absolute control — HOSFO — was observed in all the samples of oleogel, $p \leqslant 0.05$) (Figure 9). There was no significant difference in the content of saturated (palmitic and stearic acids) and monounsaturated fatty acids (oleic acid) due to their high resistance to oxidation, and in the content of linoleic acid and trans fats due to their low concentration in the initial oil (up to 1%) between the oil samples during frying. Added waxes did not have a significant impact on the FAC dynamics in fresh oil and in the oil after frying.

Added SFW decreased absorption of oil by deep fried potatoes at the beginning of frying by 34–39% (statistically significant difference in fat weight ratio in deep fried potatoes after the last frying cycle as compared to the absolute control — HOSFO — was observed in all the samples of oleogel, $p \leqslant 0.05$) (Figure 10). At the end of frying the trend remained. The potato samples fried in oleogels with added SFW contained less oil than those fried in the absolute control. The obtained data correlates to the data [3], where absorption of oil by deep fried potatoes fried in oleogel based on sunflower oil with 3–8% of bee wax decreased in average by 20%.

4. Conclusion

As a result of the study, oleogel based on high oleic sunflower oil, antifoamer, components of *Rosmarinus officinalis L.* and *Helianthus annuus L.* (sunflower wax, sunflower lecithin and rosemary extract) was obtained. Positive effect of complex antioxidant based on rosemary extract and sunflower lecithin on the quality indicators of oleogels in the technology of French-fries was studied: lower growth in the degree of thermal oxidation, decrease in total polar substances and dynamic viscosity of frying oil during the use.

Added Rosemary Extract AR 2506 0.07% in oleogel increased the period of use of high oleic sunflower oil at least by 2 times, which is very close to the indicators of oleogel sample with tert-butylhydroquinone in a dose of 200 mg/kg. It means that the synthetic antioxidant in frying oil (oleogel) may be replaced with natural rosemary extract with sunflower lecithin. The idea of decreased absorption of oil by potatoes while frying in oleogel due to added sunflower wax was confirmed. Correlation between the period of use of oleogel-based frying oil until the thresholds of regulated quality indicators are reached and the induction period were found.

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