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# Optimization of oleogel production formulation based on sesame oil and its effect on physicochemical and quality properties of mayonnaise

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## ABSTRACT

The purpose of this study was to investigate the production of mayonnaise containing oleogel prepared based on sesame oil and organogelators of ethyl cellulose and carnauba wax and to evaluate its physicochemical and organoleptic properties. In this research, the optimization of oleogel production was done based on the hardness and oil migration rate, and the treatment containing 7.41 grams of carnauba wax and 4.41 grams of ethyl cellulose was selected as the optimal treatment. Then 5 types of mayonnaise samples were prepared and physicochemical and sensory tests were performed on them on days 1, 30 and 60. During the storage period, the amount of replaced oleogel had an inverse relationship with peroxide index, thiobarbituric acid and the amount of released oil and a direct relationship with the emulsion stability of the samples. Also, the results showed that the storage time has no significant effect on the color characteristics of the samples; But with increasing amount of oleogel, the *L component of the samples decreases, but the *a and *b components of the samples increase. In the organoleptic evaluation, at the end of the shelf life, all the treatments were in the optimal and moderate range. Therefore, the results showed that mayonnaise with desirable physicochemical and sensory properties can be prepared using oleogels based on sesame oil and organogels of ethylcellulose and carnoba wax.

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## 1- Introduction

The main sources of dietary lipids are meat, dairy products, fish, oil and fats in the form of fats and oils for frying, butter, margarine, vegetable creams and special fats (shortenings), processed products such as bread, cakes, biscuits, chocolate, There are ice cream and mayonnaise, and it creates playability[1], aroma and mouthfeel[2] Desirable as well as semi-solid and good rheological properties are found in these materials[1]. Among its disadvantages, we can mention the saturation and also the presence of abundant trans fatty acids in these lipids. Since there is a positive correlation between the amount of saturated fat and trans fatty acids with an increase in bad cholesterol and also with diseases such as cardiovascular diseases, type 2 diabetes, obesity followed by fatty liver, joint wear and tear, sleep apnea (stopping breathing during sleep). ) and gallstones caused by cholesterol [2]; Therefore, in order to reduce these problems caused by consuming a lot of oil containing saturated and trans fatty acids, as well as to use oils in a wider range of products, it is necessary to use new technologies to produce fat-based structures such as oleogel production [3]. One of the new methods that has recently received attention with the aim of reducing trans and saturated fatty acids is organic gelatinization, in which oleogels with quasi-solid properties are formed due to the freezing of organic liquid in a reversible thermal network. In other words, oleogels are quasi-solid systems based on the gelation of organic solutions by organic gelling agents, which are compounds with low molecular weight or macromolecules dissolved in the oil phase that are able to create a three-dimensional network [4]. Reducing the mobility and migration of fat, replacing saturated and trans fatty acids, the stability of emulsions and the ability to control the release of nutrients in solutions are the main advantages of using edible gels in food products. [5] Carnauba wax, which is also called Brazilian wax or palm wax. It is also known that they are obtained from vegetable waxes derived from the leaves of the Brazilian palm tree [6]. This wax has higher branched methyl groups and a greater amount of double and triple bonds of carbon atoms. [7] Therefore, this wax has a very high ability to bind to oil. Carnauba wax also simply has the ability to form a solid crystalline network and trap a very large volume of liquid oil, and for this reason, it increases the oxidative stability of vegetable oil with high unsaturation.[8] Sima Naji Tabasi et al. (2019) in investigating the properties of oleogel prepared by emulsion molding method stabilized with solid particles of basil gum complex and soy protein isolate as a fat substitute in cream showed that the presence of basil gum along with protein causes the formation of oleogel. It became more stable and has higher mechanical strength. The produced oleogel was used to produce cream with reduced fat (5, 10 and 15%). The highest overall acceptance rate in the sample was achieved with a 5% fat reduction, which was not significantly different from the control cream [9]. On the other hand, the structure of ethyl cellulose polymer, which is known as an organogelator, is semi-crystalline. This semi-crystalline structure and the hydrophobic nature of ethyl cellulose have enabled its use in liquid edible oils to form gels. The substitution degree of 2.5-3 is necessary for the dissolution of ethyl cellulose in non-polar compounds such as vegetable oils. [10] Bemer et al. (2016)

1 -Spreadability

2 - Mouth feel

investigated the production of oleogel by rice bran wax and ethyl cellulose and its application in raw cheeses. The results indicated that samples containing oleogel showed a 25% reduction in fat compared to commercial raw cheese samples. On the other hand, the improvement of the fatty acid profile in the sample was observed through the replacement of unsaturated fats in the tested products [11]. The fatty acid composition of sesame oil includes oleic and linoleic acids (about 43%), palmitic acid (about 9%) and stearic acid (about 4%). Increased vitamin activity due to increased gamma tocopherol[3] Blood plasma leads to the prevention of cancer and heart disease. The high content of unsaturated fat in sesame oil is known to reduce blood cholesterol. Bioactive compounds in sesame oil such as lignan, sesamin, sesamulin and sesamol have high antioxidant activity and are also very stable. [12] Liu et al. Low methoxy pectin concluded that the produced treatments have less energy but higher water content than the control sample. Also, the obtained results showed that the samples produced based on low methoxy pectin have an acceptable sensory score [13]. Due to the presence of a high amount of unsaturated fat in sesame oil as well as the nutritional properties of this oil, therefore, in this research, an attempt is made to investigate the production of mayonnaise containing oleogel based on sesame oil and organogelators of ethyl cellulose and carnauba wax and to evaluate its properties. Its physicochemical and organoleptic properties should be discussed. It is worth mentioning that the present study is innovative from the point of view of the type of oil and gelators used in the production of oleogel and its use in mayonnaise.

## 2- Materials and methods:

**2-1** Materials

Sesame oil was obtained from a local market located in Tehran, carnauba wax and ethyl cellulose were obtained from Sigma company. Solvents (hexane, ethanol, acetic acid, etc.) were purchased from Dr. Majalli and chemicals such as potassium iodide, iodine trichloride, potassium hydroxide, potassium iodate and other chemicals used in this research were purchased from Merck.

2-2- Methods

2-2-1- Determining the characteristics of sesame oil:

In order to check the characteristics of the purchased sesame oil, humidity and manual index tests were performed according to standard methods with numbers 4291 and 4886, respectively [14]. The peroxide index was determined according to the AOCS Cd 8-53 method and the amount of free fatty acids was determined according to the AOCS Cd 3d-63 method [15].

2-2-2- optimalProduction of sesame oil oleogel:

Optimizing the production of sesame oil oleogels using the response surface method (RSM) was done with the variables of carnauba wax and ethyl cellulose. For this purpose, according to Table 1, first, the carnauba wax samples were slowly heated in a bain-marie to 80 degrees Celsius until they melted, and then they were completely mixed with sesame oil at a temperature of 40 degrees Celsius. Next, ethyl cellulose was added to the mixture and each sample was cooled to room temperature. Finally, the mixtures produced for

[3] -Gamma Tocopherol

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It was placed in the refrigerator for one night and then they were tested (firmness level and percentage of oil migration).RSM) and was calculated with a ratio of 1 to 10 (the central point of the variables of carnauba wax and ethyl cellulose: oil content).

2-2-2-1- Measurement of oil migration percentage:

After weighing the empty Eppendorf tubes (a), 15 ml of prepared oleogel samples were poured into these tubes and weighed after keeping overnight at 5 degrees Celsius (b). Then the tubes were centrifuged for 15 minutes at 9170 g, and then to remove the oily part, the tubes were turned upside down for 4 minutes and finally the tubes were weighed (c). Using the following formula, the percentage of oil migration was calculated [7].

$$100*Percentage\ of\ oil\ migration = \frac{[(b-a)*(c-a)]}{(b-a)}$$

2-2-2-2- Measuring the hardness of prepared oleogels:

The hardness of oleogels (with dimensions of 5 x 5 square centimeters) was measured by a histometer. For this purpose, a rod probe with a diameter of 14 mm and a speed of 30 mm/min touched the surface of the oleogel samples and penetrated to a depth of 1 cm of each sample and then removed. Finally, according to the stress-strain diagram, the maximum force required for the penetration of the probe was determined and reported as the hardness (Newton) of the oleogel.[17]

2-2-3- Preparation of mayonnaise based on optimal oleogel:

In order to prepare mayonnaise, ingredients with ratios of soybean oil (78%), egg yolk (7%), vinegar (2.2%), sugar (2%), water (9.8-9.75%) and salt (1%) were mixed together. At first, the dry additives were mixed separately in a container containing one third of the total amount of water and vinegar to get a uniform mixture. The resulting mixture was added to the egg yolk and mixed together for 5 minutes. Next, oil was slowly added to the resulting mixture under constant stirring conditions and an emulsion was formed. After the formation of emulsion and complete addition of oil, the resulting mixture was stirred for 5 minutes. After this step, the remaining amount of water and vinegar was slowly added to it and the mixing continued for another 5 minutes. In order to use the optimal oleogel in the structure of the sauce samples, in the amount of 25, 50, 75 and 100%, its oil was replaced by the optimal oleogel and different characteristics of the mayonnaise sauce during the storage period (day 1, day 30 and day 60) at the temperature of the refrigerator. was evaluated.

2-2-4- Tests performed on mayonnaise samples:

2-2-4-1 Measurement of peroxide index of samples:

At first, the oil needed to perform the peroxide test was extracted by the method of Blay and Dyer (1959) [18]. In the next step, to determine the peroxide index, 5 grams of the extracted oil was mixed with 30 milliliters of acetic acid-chloroform solution (with a ratio of 3 to 2) and after adding 0.5 milliliters of saturated potassium iodide solution, it was stirred and then It was placed in the dark for 1 minute. After the dark stage, 30 ml of distilled water was added to it and titrated with sodium thiosulfate one percent of normal. 1 ml of starch indicator was added immediately after the yellow color of the solution disappeared and titrated up to

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The blue color continued to fade. The peroxide index of the samples was determined using the following formula [19]:

$$PV= (V_2-IN_1) \times N \times 1000/M$$

$IN_2$: Titer volume in sample $V_1$: titer volume in control N: normality of sodium thiosulfate solution M: gram weight of sample: PV peroxide value

2-2-4-2 Measurement of thiobarbituric index of samples:

Thiobarbituric acid index was measured using Gravella et al.'s (2012) method [20]. When two molecules of thiobarbituric acid react with one molecule of malonaldehyde, a pink colored complex is formed. The reaction of different samples with thiobarbituric acid was measured using a spectrophotometer and their absorbance at 535 nm on the first day and the end of the 60th day of storage at ambient temperature. The TBA index was expressed as milligrams of malonaldehyde per kilogram of sample.

2-2-4-3 Measuring the amount of released oil:

After weighing the empty Eppendorf tubes (a), 15 ml of prepared oleogel samples were poured into these tubes and weighed after keeping overnight at 5 degrees Celsius (b). Then the tubes were centrifuged for 15 minutes at 9170 g, and then to remove the oily part, the tubes were turned upside down for 4 minutes and finally the tubes were weighed (c). Using the following formula, the percentage of oil migration was calculated.[20]

$$100 * Percentage\ of\ oil\ migration = \frac{[(b-a)*(c-a)]}{(b-a)}$$

2-2-4-4 Measuring the emulsion stability of the samples:

15 grams of each sample was poured into a centrifuge tube and then centrifuged at 5000 rpm for 30 minutes. The percentage of emulsion stability was calculated according to the following formula:[22]

100x (initial weight of each sample ÷ weight of precipitated part) = emulsion stability percentage

2-2-4-5 Evaluation of the color characteristics of the samples:

To measure the color parameters L* (transparency index), a* (redness index) and b* (yellowness index) the HunterLab device will be used.[16]

2-2-4-6 Evaluation of sensory characteristics of samples:

For sensory evaluation, indices such as (texture, color, aroma, taste, and overall acceptance) were used, and the overall score was obtained from the sum of the points given to the sensory indicators in evaluation levels 1 to 5; 1: very unfavorable; 2: unfavorable; 3: medium; 4: favorable and 5: very favorable.[23]

2-2-5- Statistical analysis:

At first, in order to optimize the oleogel formulation based on sesame oil, using the response surface method (RSM) and the central composite design ([4]CCD) with 6 central points, and was used by Design-Expert software. All the tests were done in 3 repetitions by SPSS software and based on factorial test in the form of completely randomized design and ANOVA analysis of variance and the significant difference of the means at the probability level of 5% ($P<0.05$)

[4]- Central Composite Designs

was done by Duncan's test. Figures and graphs were drawn using Excel software.

3. Results and Discussion:

3-1 The results of examining the properties of sesame oil:

Table 1 shows the results related to the characteristics of sesame oil. According to the results, the values of all the measured characteristics of sesame oil are within the standard range. In relation to the peroxide index, the obtained results were consistent with the findings of Valalavita et al. (2016)[24]. The peroxide index depends on various factors, including the type and degree of oil saturation, temperature and length of oil storage period, packaging conditions, and environmental pollution, including through light. Oxidative stability is one of the most important factors determining the quality and acceptance of the product by the consumer, as well as the duration of oil storage.[24]

Table 1 Characteristics of sesame oil

| Standard range | Calculated amount | Test |
|---|---|---|
| Maximum 0.1 | 0.09 | Moisture(%) |
| Maximum 5 | 2 | Peroxide value (milliequivalents of grams of peroxide per kilogram of sample) |
| Maximum 0.1 | 0.08 | free fatty acids(%) |
| 103-118 | 112 | Iodine value (grams per 100 grams of sample) |

2-3 Results of optimization of oleogel samples by answer level software:

3-2-1 The results related to the optimization of oleogel samples based on the amount of oil migration:

Figure 1 shows the effect of different proportions of carnauba wax and ethyl cellulose on the amount of oil migration of the produced oleogel samples. As can be seen; At low concentrations of ethyl cellulose, with a decrease in the amount of carnauba wax, no significant increase ($P<0.05$) in the amount of oil migration was observed; But in high concentrations of ethyl cellulose, with the decrease in the amount of carnauba wax, a significant increase ($P<0.05$) in the amount of oil was observed. On the other hand, the results showed that in high concentrations of carnauba wax with an increase in the amount of ethyl cellulose, there was no significant increase ($P<0.05$) in the rate of oil migration, but in low concentrations of carnauba wax with an increase in the amount of ethyl cellulose, the rate of oil migration was observed. There is a significant increase ($P<0.05$). The results showed that the lowest amount of oil migration occurs with the amount of 4.5 at the point with the amounts of ethyl cellulose 4.32 and carnauba 7.35 and the lowest.

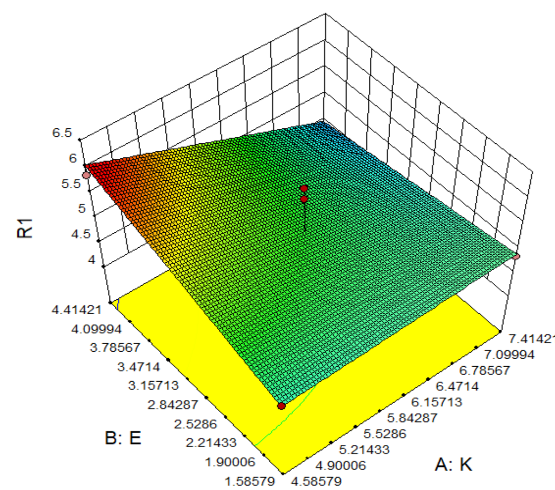


Fig1; Three-dimensional response surface diagram of the effect of different proportions of carnauba wax and ethyl cellulose on the degree of hardness

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**3-2-2 The results related to the optimization of oleogel samples based on the degree of stiffness:**

Figure 2 shows the effect of different proportions of carnauba wax and ethyl cellulose on the stiffness of the produced oleogel samples. The results showed that, in low concentrations of ethyl cellulose, with an increase in the amount of carnauba wax, there was no significant increase (P<0.05) in the hardness of the oleogel samples; But in high concentrations of ethyl cellulose, with increasing amount of carnauba wax, a significant increase (P<0.05) in the hardness of the samples was observed. On the other hand, the results showed that in low amounts of carnauba wax with an increase in the amount of ethyl cellulose, there was no significant decrease (P<0.05) in the hardness of the samples, but in high amounts of carnauba wax with an increase in the amount of ethyl cellulose, a significant increase was observed. There was a difference (P<0.05) in the hardness of the samples. The results showed that the highest level of stiffness with the value of 1.34 occurs at the point with the values of 4.36 ethyl cellulose and 7.37 carnauba.

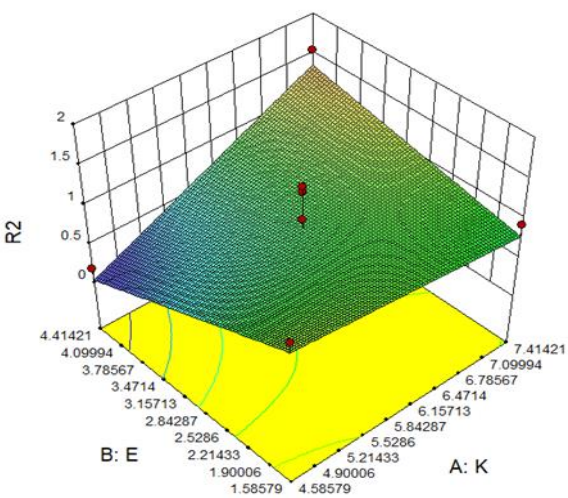


Fig2; Three-dimensional response surface diagram of the effect of different proportions of carnauba wax and ethyl cellulose on oil migration rate

**3-2-3 Choosing the optimal treatment and validating the model:**

The optimal conditions suggested by the software were 7.41 grams of carnauba wax and 4.4 grams of ethyl cellulose, which corresponded to the oil migration rate of 4.47 and the stiffness rate of 1.36 and had a degree of desirability of 0.861. In the mentioned conditions, the oil migration rate and hardness tests were performed; And the values of 4.12 and 1.25 were obtained for these tests, respectively. The results showed that the proposed model has a good ability to investigate the effect of independent variables on oil migration rate and stiffness rate.

3-3 The results of tests performed on mayonnaise samples:

3-3-1 The results of the peroxide value of the samples:

The results related to the peroxide index of mayonnaise samples during the storage period are shown in Table 2. as you see; During the maintenance period, a significant upward trend (P<0.05) is observed in all treatments. But according to the national standard of 2015, after the storage period, the amount of peroxide number of all samples was within the permissible and usable limit (5 milliequivalent grams of peroxide per kilogram of sample). In this connection, the results of this research were consistent with the results of Shariati et al. (2017)[25]. By investigating the production of oleogel using a mixture of ethyl cellulose and polyglycerol polyricinoleate, these researchers concluded that during the storage period, an increasing trend in the amount of peroxide value of the samples is observed. On the other hand, in the comparison between different ratios of oleogel replacement, the results showed that increasing the amount of oleogel in the mayonnaise samples caused a significant increase (P<0.05) in the stability of the treatments. The oxidative stability of samples containing oleogel depends on the degree of unsaturation and antioxidant compounds in the oil.[21] The presence of higher antioxidant compounds such as sesamin, sesamulin and tocopherols in samples containing more oleogel is one of the reasons for this. The presence of more carnauba wax and ethyl cellulose is one of the other reasons for reducing the amount of peroxide in mayonnaise samples containing oleogel. Khayabani et al. (2016) reported greater stability of produced oleogels in the presence of higher amounts of carnouba-adipic acid, which was consistent with the results of this study [9].

Table 2: Changes in pv (meq/kg) in samples during storage.

| Day 60 | Day 30 | Day 1 | Treatment |
|---|---|---|---|
| Aa 0.22 ± 3.93 | Ab 0.013 ± 2.89 | 0.003 And ± 1.73 | T0 |
| Aa 0.007 ± 3.82 | Ab 0.1 ± 2.78 | 0.003 And ± 1.73 | T25 |
| Not 0.003 ± 3.12 | Bb 0.003 ± 2.28 | Bc 0.003 ± 1.32 | T50 |
| That 0.006 ± 2.58 | Cb 0.003 ± 1.84 | 0.007 Cc ± 1.16 | T75 |
| And 0.003 ± 1.89 | Db 0.007 ± 1.21 | Dc 0.003 ± 0.87 | T100 |

(Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters are indicate significant differences between each samples ($p < 0.05$)).

According to the obtained results, at the end of the storage period, only the sample containing 25% oleogel had the same peroxide number as the control sample; But other treatments had lower peroxide value than the control sample. From this point of view, the results of this research did not agree with the results of Ilmaz and Etlo (2014) [7]. By investigating the production of oleogel produced by sunflower wax and beeswax based on olive oil at different levels and its use in breakfast margarine, they concluded that the peroxide index of all samples was stable during the storage period. Among the reasons for its inconsistency with the current research, we can mention the difference in the compounds used to produce oleogel, as well as the difference in the type of oil used.

3-3-2 The results of the thiobarbituric acid index of the samples:

Peroxide index is an indicator of primary oxidation products and does not detect the formation of secondary oxidation products. For this reason, it is necessary to determine the index of thiobarbituric acid, which is an index of secondary oxidation products. The results related to the thiobarbituric acid index of the samples are given in Table 3. The results showed that the storage time and the amount of replaced oleogel have a significant effect ($P<0.05$) on the thiobarbituric index of mayonnaise samples. As seen in the table below; The highest amount of thiobarbituric index is in the sample without oleogel and the sample containing 25% oleogel and the lowest in the sample containing 100% oleogel. In relation to the effect of the percentage of oleogel in mayonnaise, in general, the results showed that by increasing the amount of replaced oleogel.

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A significant decrease (P<0.05) occurs in the thiobarbituric index of the samples; The lowest level of thiobarbituric index was observed in the sample containing 100% oleogel. In general, it can be stated that, due to the protective effect of oleogels, the samples containing higher percentage of oleogels have lower oxidation indices. Qaraei et al. (2017) investigated the use of oily gels produced from sesame oil in biscuits and concluded that the thiobarbituric index of samples containing oleogel is significantly lower than the sample containing oil; which was consistent with the results of this study. These researchers explained the reason for this, the protective role of gels against oxidation as well as antioxidants in sesame oil [26].

Table 3 : Changes in TBA(mg malon aldehid/ kg) in samples during storage.

| Day 60 | Day 30 | Day 1 | Treatment |
|---|---|---|---|
| Aa 0.0011 ± 0.041 | Ab 0.002 ± 0.024 | 0.001 And ± 0.013 | T0 |
| Aa 0.001 ± 0.04 | Ab 0.001 ± 0.023 | 0.001 And ± 0.012 | T25 |
| Not 0.0013 ± 0.035 | Bb 0.0011 ± 0.018 | Bc 0.001 ± 0.009 | T50 |
| Not 0.002 ± 0.033 | Bb 0.002 ± 0.016 | 0.0001 Bc ± 0.008 | T75 |
| That 0.001 ± 0.022 | Cb 0.001 ± 0.011 | Cc 0.0002 ± 0.005 | T100 |

(Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters are indicate significant differences between each samples (p < 0.05)).

On the other hand, the results showed that peroxide value and thiobarbituric acid index of mayonnaise samples were not similar to each other in all days; One of the reasons for this is that a number of antioxidant compounds prevent the initiation of the oxidation reaction and the formation of peroxide, but some others delay the decomposition of peroxides and the production of secondary products. Also, the results showed that in the early days of storage, the amount of thiobarbituric acid is low, but during the storage period, due to the increase in the production of primary oxidation products, and as a result of the decomposition of these products, the amount of thiobarbituric acid also increased significantly (P<0.05). Found. which was consistent with the results of Shariati et al. (2017) who conducted research on the effect of ethyl cellulose concentration on the oxidative stability of sesame oil oleogel. These researchers also reported an increase in thiobarbituric acid index over time. The lowest and highest amount of thiobarbituric acid index was observed in the samples of day 1 and day 60 of the storage period, respectively [25].

3-3-3 The results of the amount of released oil of the samples:

The rate of oil release is a very important indicator in evaluating the quality of oleogels. This index determines the binding capacity of oil in oleogels. The results related to the amount of oil release of the samples during the storage period are shown in Table 7-4. As seen in Table 4; During the storage period, an increasing trend was observed in all 5 samples, but this increase was not significant (P<0.05). On the other hand, the results showed that by increasing the amount of oleogel, the release rate of oil decreases significantly (P<0.05); Thus, the lowest rate of oil release was observed in the sample containing 100% oleogel and the highest rate of oil release was observed in the sample without oleogel. The reason for this can be the formation of an elastic interfacial layer by oleogels and as a result protection of oil droplets [27]. The reduction of oil leakage due to the increase in the amount of oleogels can be attributed to the increase in the intermolecular network in carnauba wax and ethyl cellulose and as a result, the improvement of oil trapping. From this point of view, the results of this research were similar to the results of Holly et al. (2020) who investigated the use of oleogel based on sunflower wax in mayonnaise [28]. These researchers also reported a decrease in oil release due to increasing oleogel concentration. Among other reasons for less oil leakage in oleogels with higher concentrations, we can mention the high hydrophobic properties of carnauba wax to prevent oil release.

Table 4 : Changes in the amount of oil loss (%) in samples during storage.

| Day 60 | Day 30 | Day 1 | Treatment |
|---|---|---|---|
| Aa 2.1 ± 56.12 | Ab 1.13 ± 50.81 | 2.3 Ab ± 48.13 | T0 |
| Not 1.7 ± 36.82 | Not 3.1 ± 33.54 | 1.4 Not ± 30.23 | T25 |
| Not 1.3 ± 17.32 | Not 2.1 ± 15.28 | Not 1.2 ± 14.11 | T50 |
| That 0.9 ± 5.98 | That 0.6 ± 5.14 | 0.7 that ± 4.26 | T75 |
| And 0. 1 ± 0.33 | And 0.01 ± 0.22 | And 0.03 ± 0.21 | T100 |

(Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters are indicate significant differences between each samples ($p < 0.05$)).

### 3-3-4 Emulsion stability results of the samples:

Emulsion in which mixing phenomena[5]becoming raw[6] and lying down[7] If it does not happen, it is known as a stable emulsion. Table 5 shows the results related to the emulsion stability of the samples. According to these results, in most of the samples, no significant decrease ($P<0.05$) was observed in the emulsion stability of the samples; Only in the samples containing 50 and 75% oleogel, a significant difference ($P<0.05$) was observed in the treatments on day 1 and 60 of the storage period. One of the reasons for this is keeping these samples at refrigerator temperature. Because an increase in temperature can cause the destruction of molecular structures, increase in freedom, increase in mobility of molecules and decrease in viscosity, and as a result, decrease in emulsion stability [29]. In relation to the amount of oleogel used, a significant decrease in the stability of the emulsion was observed by increasing the concentration of oleogel in different storage days. In this connection, the results of this research were consistent with the results of O'Sullivan et al. (2016) and Zimanska et al. (2020); These researchers stated that oleogels based on ethyl cellulose are sensitive to shear force; And they came to the conclusion that centrifugal force is the main factor in the destruction of the polymer network structure and the increase in the instability of the emulsion [30, 31].

Table 5 : Changes in stability of emulsions (%) in samples during storage.

| Day 60 | Day 30 | Day 1 | Treatment |
|---|---|---|---|
| Aa 0.1 ± 99.9 | Aa 0.02 ± 100.00 | 0.00 Aa ± 100.00 | T0 |
| Aa 0.2 ± 99.8 | Not 0.1 ± 99.73 | 0.1 ABa ± 99.81 | T25 |
| Bb 0.2 ± 99.2 | Cab 0.1 ± 99.41 | Not 0.2 ± 99.6 | T50 |
| BCb 0.21 ± 98.8 | Ghost 0.1 ± 99.1 | 0.1 That ± 99.2 | T75 |
| That 0.1 ± 98.7 | And 0.1 ± 98.9 | That 0.2 ± 99.1 | T100 |

(Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters are indicate significant differences between each samples ($p < 0.05$)).

### 3-3-5 Results of the color characteristics of the samples:

In this benchmark test*L, brightness and transparency (its range is from zero (pure black) to 100 (pure white)), index*a, the degree of greenness and redness (its range is pure green (-120) to pure red (120+)) and index*b shows the degree of closeness to blue and yellow (its range is from pure blue (-120) to pure yellow (120+). The results related to the color characteristics of mayonnaise samples during the storage period are given in Table 6. According to the table

5 -Coalescence

6 - Creaming

7 -Flocculation

6; The storage time has no significant effect (P<0.05) on the color characteristics of the samples. In relation to the amount of replaced oleogel, the results showed that with the increase in the amount of oleogel, the transparency of the samples decreased. In this research, by increasing the amount of oleogel, the texture of mayonnaise is more cohesive and compact, and as a result, the color component*L, which indicates the amount of light reflection and brightness, decreased. Also, the results showed that by increasing the amount of oleogel, the component*a (the degree of redness of mayonnaise samples kept at refrigerator temperature) increases significantly (P<0.05), so that the highest and lowest redness of the best quality belonged to the sample containing 100 and 0% oleogel. On the other hand, the results related to the component*b, which shows the yellowness of the mayonnaise samples, showed that due to the increase in the amount of oleogel in the mayonnaise samples, the yellowness has increased significantly (P<0.05). The reason for this can be attributed to the color of carnouba wax used in the production of oleogels in mayonnaise samples. From this point of view, the results of this research were similar to the results of Moqtadaei et al. (2015) who investigated the use of sesame oil oleogel produced based on ethyl cellulose and beeswax in hamburger formulation. These researchers also reported an increase in the amount of yellowness due to the increase in the amount of oleogel in the hamburger formulation[32].

Table 6 : Changes in Color in samples during storage.

| Day 60 | Day 30 | Day 1 | Treatment | Component |
|---|---|---|---|---|
| 0.1 $^{Aa}$ ± 78.2 | 0.3 $^{Aa}$ ± 78.23 | 0.1 $^{Aa}$ ± 78.21 | T0 | *L |
| 0.1 $^{Not}$ ± 76.3 | 0.2 $^{Not}$ ± 76.29 | 0.2 $^{Not}$ ± 76.32 | T25 | |
| $^{That}$ 0.3 ± 72.24 | $^{That}$ 0.1 ± 72.23 | $^{That}$ 0.2 ± 72.25 | T50 | |
| 0.1 $^{And}$ ± 69.77 | 0.2 $^{And}$ ± 69.78 | 0.1 $^{And}$ ± 69.75 | T75 | |
| $^{Yes}$ 0.1 ± 65.72 | $^{Yes}$ 0.2 ± 65.71 | $^{Yes}$ 0.3 ± 65.69 | T100 | |
| 0.01 $^{Yes}$ ± -1.22 | 0.01 $^{Yes}$ ± -1.22 | 0.01 $^{Yes}$ ± -1.22 | T0 | *a |
| 0.02 $^{And}$ ± -0.82 | 0.02 $^{And}$ ± -0.82 | 0.02 $^{And}$ ± -0.82 | T25 | |
| $^{That}$ 0.02 ± -0.13 | $^{That}$ 0.02 ± -0.13 | $^{That}$ 0.02 ± -0.13 | T50 | |
| 0.01 $^{Not}$ ± 0.32 | 0.01 $^{Not}$ ± 0.32 | 0.01 $^{Not}$ ± 0.32 | T75 | |
| $^{Aa}$ 0.01 ± 0.81 | $^{Aa}$ 0.01 ± 0.81 | $^{Aa}$ 0.01 ± 0.81 | T100 | |
| 0.1 $^{Yes}$ ± 11.68 | 0.1 $^{Yes}$ ± 11.68 | 0.1 $^{Yes}$ ± 11.69 | T0 | *b |
| 0.01 $^{And}$ ± 13.05 | 0.01 $^{And}$ ± 13.06 | 0.01 $^{And}$ ± 13.05 | T25 | |
| $^{That}$ 0.02 ± 15.84 | $^{That}$ 0.02 ± 15.83 | $^{That}$ 0.02 ± 15.85 | T50 | |
| 0.02 $^{Not}$ ± 16.32 | 0.02 $^{Not}$ ± 16.31 | 0.02 $^{Not}$ ± 16.32 | T75 | |
| $^{Aa}$ 0.01 ± 17.22 | $^{Aa}$ 0.01 ± 17.21 | $^{Aa}$ 0.01 ± 17.21 | T100 | |

(Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters are indicate significant differences between each samples (p < 0.05)).

3-3-6 Sensory evaluation results of the samples:

One of the most important quality factors of food products is the color and appearance of these products, which has a direct relationship with the high quality of the product and its marketability. The results related to the color and appearance of mayonnaise samples during the storage period are given in Figure 3. The results showed that the factors of time and amount of oleogel replaced during the storage period have a significant effect (P<0.05) on all treatments. As seen in Figure 3, the control sample has the highest score on the first day, and the sample containing 75% replaced oleogel and the sample containing 100% replaced oleogel on the 60th day have the lowest score. In relation to the effect of time, a significant decrease (P<0.05) was observed in the appearance characteristic score of all treatments during the time. Also, the results showed that on the same days, there is an inverse relationship between the amount of oleogel replaced and the score related to the color and appearance of the samples. It should be noted that at the end of the maintenance period, all treatments were in the optimal and average range in terms of scores. In Figure 4, the results related to the taste characteristics during the storage period are given. The results indicated that the taste score in all samples had a significant decrease (P<0.05) during the storage period; As such, the highest score related to taste was observed in treatments on the 1st day of the storage period. Among the reasons for this, we can mention the increase in the production of lipase and protease enzymes by cold-loving bacteria during the storage period and as a result, the increase in the breakdown of fat and protein [33]. Oxidation changes over time are also considered to be another reason for the loss of taste. On the other hand, the results showed that the amount of replaced oleogel has no significant effect (P<0.05) on the taste of the samples.

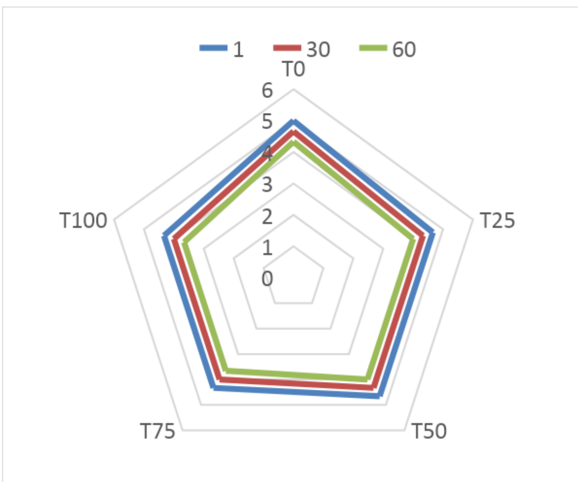


Fig 3: Changes in colour and appearance in samples during storage
(Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters are indicate significant differences between each samples (p < 0.05)).

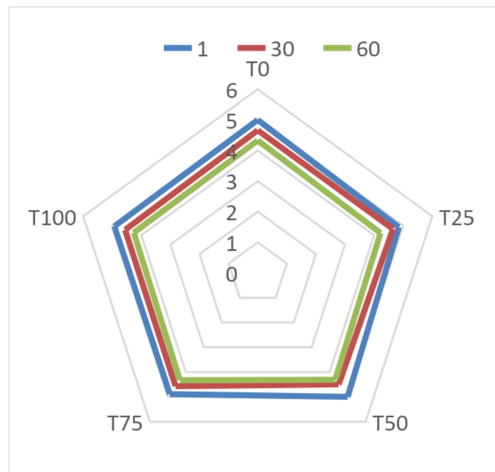


Fig 4 : Changes in taste in samples during storage
(Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters are indicate significant differences between each samples (p < 0.05)).

The results related to the effect of time on the sensory characteristics of aroma and texture of mayonnaise samples are shown in Figures 5 and 6, respectively. The results showed that the variables of time and amount of oleogel, during the storage period, have a significant effect (P<0.05) on the aroma. They are the texture of the treatments. In this regard, the control sample on day 1 had the highest score and the 75% and 100% oleogel samples on day 60 had the lowest score related to the sensory characteristics of aroma and texture. On the other hand, there was a significant decrease (P<0.05) in the aroma and texture scores of all treatments during the storage period. Also, the results showed that the increase in the amount of oleogel in the samples of the same day has a reciprocal relationship with the aroma and texture score of the mayonnaise samples. In these tests, at the end of the storage period, the results indicated that the aroma and texture scores were favorable and moderate.

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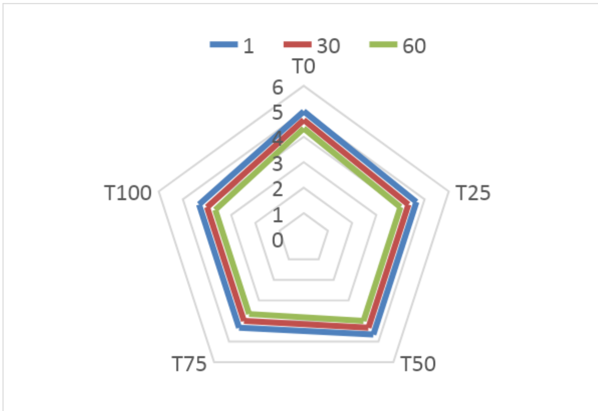


Fig 5: Changes in odor in samples during storage (Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters are indicate significant differences between each samples (p < 0.05)).

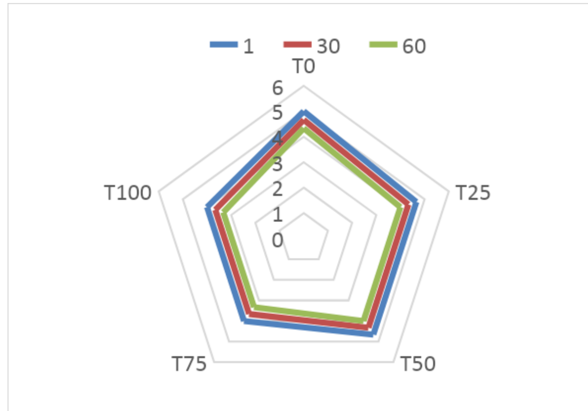


Fig 6 : Changes in texture in samples during storage (Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters are indicate significant differences between each samples (p < 0.05)).

The results related to the general acceptability of mayonnaise samples are shown in Figure 7. According to these results, the time factor has an inverse and significant relationship (P<0.05) with the overall acceptance of mayonnaise samples. On the other hand, the amount of replaced oleogel also had an indirect and significant relationship (P<0.05) on the overall acceptability of mayonnaise samples; In this way, with the increase in the amount of replaced oleogel, the overall acceptability score of the treatments decreased significantly (P<0.05). In terms of overall acceptability, as in the test related to the sensory characteristic of the texture, the 25% and 50% oleogel samples, as well as the 75% and 100% oleogel samples, did not have any significant differences (P<0.05) during the storage period. The control sample had the highest overall acceptability score on the first day, and the 75% and 100% oleogel samples had the lowest overall acceptance score on the 60th day.

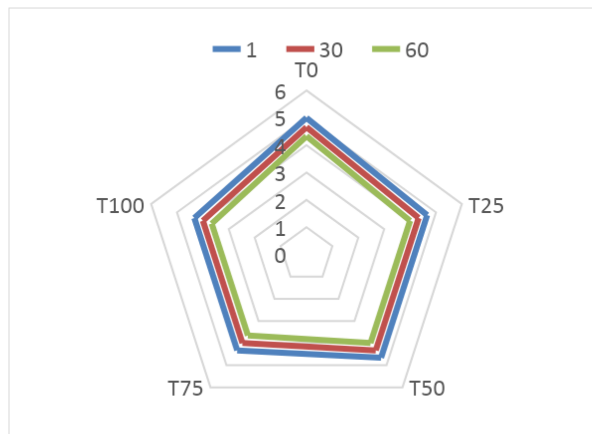


Fig 7: Changes in general acceptability in samples during storage. (Capital dissimilar letters indicate significant differences between the samples on the same day and small dissimilar letters indicate significant differences between in each of the samples (p < 0.05)).

Liu et al. (2007) investigated the textural and sensory properties of low-fat mayonnaise based on low-methoxy pectin and found that due to the reduction of fat, the samples had a firmer texture and received a lower score for color, appearance and overall acceptance. It was consistent with the results of this research; These researchers considered the higher moisture level in mayonnaise sauces produced based on pectin and the dilution of the color of the samples as the reason for the decrease in the scores related to color and appearance [13]. In another study, Moqtadaei et al. (2015) investigated the use of sesame oil oleogel produced by ethyl cellulose and beeswax in hamburger formulation. These researchers reported that ethyl cellulose oleogel has a positive effect, but beeswax oleogel has no effect on the texture of the product; Also, these researchers reported an improvement in overall acceptance by increasing the amount of sesame oil oleogel produced by ethyl cellulose and beeswax in the hamburger formulation [32].

## 4 - Conclusion:

In this research, an attempt was made to investigate the optimization of the oleogel formulation based on sesame oil and two types of organogelators, ethyl cellulose and carnauba wax, and its effect on physicochemical properties (peroxide index, thiobarbituric acid index, amount of released oil, emulsion stability, and color properties). and sensory (color and appearance, taste, texture, aroma and general acceptability) of mayonnaise was discussed. The results showed that in relation to the physicochemical properties during the storage period, the amount of replaced oleogel had an inverse relationship with peroxide index, thiobarbituric acid index and the amount of released oil and a direct relationship with the emulsion stability of mayonnaise samples. Regarding the color characteristics, the results showed that the storage time has no significant effect ($P<0.05$) on the color characteristics of the samples. In relation to the amount of replaced oleogel, the results showed that with increasing the amount of oleogel, the component $^{*}L$ samples less but component $^{*}a$ and $^{*}b$ The samples increase. In the organoleptic evaluation, mayonnaise samples containing more substituted oleogel scored lower sensory scores. However, at the end of the maintenance period, all treatments were in the optimal and moderate range. Therefore, the results indicated that it is possible to prepare mayonnaise sauce with desirable physicochemical and sensory properties by using oleogel based on sesame oil and organogelators of ethyl cellulose and carnauba wax.

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**مقاله علمی_پژوهشی**

# بهینه سازی فرمولاسیون تولید اولئوژل برپایه روغن کنجد و تاثیر آن بر خصوصیات فیزیکوشیمیایی و کیفی سس مایونز

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**چکیده**

هدف از مطالعه حاضر بررسی تولید سس مایونز حاوی اولئوژل تهیه شده بر پایه روغن کنجد و ارگانوژلاتورهای اتیل سلولز و موم کارنوبا و ارزیابی خصوصیات فیزیکوشیمیایی و ارگانولپتیکی آن بود. در این پژوهش، ابتدا بهینه سازی تولید اولئوژل، بر اساس میزان سفتی و میزان مهاجرت روغن، صورت پذیرفت و تیمار حاوی ۷/۴۱ گرم از موم کارنوبا و ۴/۴۱ گرم اتیل سلولز بعنوان تیمار بهینه انتخاب گردید. سپس ۵ نوع نمونه سس مایونز تهیه و آزمون‌های فیزیکوشیمیایی و حسی در روزهای ۱ ، ۳۰ و ۶۰، روی آن‌ها انجام شد. در طی دوره نگهداری، میزان اولئوژل جایگزین شده دارای یک رابطه عکس با اندیس پراکسید، تیوباربیتوریک اسید و میزان روغن آزاد شده و یک رابطه مستقیم با پایداری امولسیون نمونه‌ها بود. همچنین نتایج نشان داد که زمان نگهداری، تاثیر معنی داری روی خصوصیات رنگی نمونه‌ها ندارد؛ اما با افزایش میزان اولئوژل، مولفه $L^*$ نمونه‌ها کمتر اما مولفه $a^*$ و $b^*$ نمونه‌ها بیشتر می‌گردد. در ارزیابی ارگانولپتیکی، در انتهای دوره نگهداری همه تیمارها در محدوده مطلوب و متوسط قرار داشتند. بنابراین می‌توان با استفاده از اولئوژل بر پایه روغن کنجد و ارگانوژلاتورهای اتیل سلولز و موم کارنوبا، سس مایونزی با خواص فیزیکوشیمیایی و حسی مطلوب تهیه کرد.