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# OPTIMIZATION OF CONDITIONS FOR OBTAINING ALGINATE/OLIVE OIL CAPSULES FOR APPLICATION IN DAIRY INDUSTRY

– Research paper –

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**Abstract**: Encapsulation is a process of incorporation of bioactive substances in a specific matrix. It results in increasing and/or maintaining of the biological agent concentration in the food matrix or the fermentation system. The encapsulation process is influenced by various factors. The aim of the present work was to investigate the influence of alginate type and concentration, homogenization rate and the oil phase amount in the preparation of capsules rich in olive oil. It has been found that emulsions obtained with medium viscosity alginate were characterized by better stability. To establish the joint influence of the factors was used screening design experiment, the optimization features selected being temperature, centrifugal and microscopic stability. The optimal levels of the factors were established and they we applied for capsule preparation. The obtained capsules showed maximum stability and possibility to be used in dairy product manufacture.

**Keywords:** emulsions stability; oil phase concentration; capsules; optimization; screening design of experiment

## INTRODUCTION

Encapsulation is the process of incorporation of bioactive substances in a matrix (carrier) in order to achieve certain effects. Capsules of solid, liquid or gaseous components coated with a continuous membrane are formed in microencapsulation. As a result of this process are prepared matrices, whose core contains a bioactive component, and the membrane protects it from the harmful effects of the environment. Capsules with spherical shape, the size depending on the technique used (varies between 100 and 2500 μm) are obtained as a result of the encapsulation process. Two types of capsules are prepared depending on the encapsulation system chosen – reservoir type capsules, wherein the active agent is separated from the capsule by a membrane; and matrix type capsules, in which the content is distributed uniformly in the nucleus, which allows obtaining very small particles (Rathore et al., 2013; Zuidam and Shimoni, 2010; Chan et al., 2009; Chan, 2011).

Oil encapsulation is necessary due to a many reasons like the conversion of the oil phase to solid state for easier transportation, handling or incorporation into a food matrix. Another reason is masking of the unpleasant oil taste and flavor, retention of the oil biological activity, controlled release in the human body. Oils of vegetable or animal origin which are used in food and pharmaceutical industries can be subjected to immobilization (Chan, 2011).

A number of authors explore the opportunities of developing healthy dairy products enriched with microcapsules containing polyunsaturated fatty acids, α-tocopherol, polyphenols, carotenoids and antioxidants (Burgain et al., 2011; Nazzaro et al., 2012). A technology for

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omega-3-fatty acid microencapsulation, ensuring conservation of the bioactive substances during processing has been developed (Augustin et al., 2005). The resulting microcapsules are applied in cheese production (Bermudez-Aguirre and Barbosa-Canovas, 2011). Another research team (Santos et al., 2011) applied essential oils incorporated in microcapsules in fresh cheese, cheese spreads and butter, which increases the biological value and the antioxidant activity of the finished products.

The encapsulation process is influenced and controlled by a number of factors: the oil type, the matrix material type, the encapsulation method, etc. (Kostov et al., 2016). Oil incorporation in the dairy (milk) matrix requires the preparation of capsules with high oil phase content. The reason is the requirement of obtaining a product with specific oil phase content, on one hand, and because the high oil phase content is important in order to reduce the amount of capsules used in the preparation of the food product, whilst retaining the biological activity, on the other hand (Chan, 2011).

The purpose of the present work was to model and optimize the conditions for obtaining capsules of Ca-alginate high in oil phase. Olive oil was selected as a model system because it is easily accessible and has high biological activity and typical flavor that can easily be identified in the finished product. All capsules were prepared and dripped in a gelling bath in a procedure similar to microorganism immobilization. The influence of the oil phase concentration on emulsion stability as well as the effect of the emulsification process parameters (alginate concentration, oil phase concentration and homogenization rate) on the stability of the emulsions and the obtained capsules were studied. The study was conducted using the methods of the screening design experiment.

## MATERIALS AND METHODS

### Model suspensions

*Alginate type and preparation of alginate solutions*

Alginic acid sodium salt from brown algae with low viscosity (4-12 cP) and medium viscosity (≥2000 cP), supplied by Sigma Aldrich was used in the present work. Solutions with a concentration of 0.5%, 1%, 2% and 3% (w/v) of the respective alginate were prepared. The alginate was soaked in the appropriate quantity of distilled water for 24 h until complete dissolution, then sterilized in a microwave (800 W for 5 min) to ensure the microbiological stability of the solution prepared.

*2% $CaCl_2$ solution*

*Market olive oil (extra virgin)*

### Obtaining model emulsions

*Selection of alginate for capsule preparation.*

The obtained alginate solutions (2.1.1) were used for the preparation of emulsions with oil phase content of 20%, 30%, 40%, 50% and 60% (v/v). The emulsions were homogenized for 5 min at 10000 rpm at a laboratory homogenizer IKAT18 digital ULTRA TURRAX.

*Optimization of the process parameters for preparation of capsules with high oil phase content.*

Condition optimization for obtaining capsules with oil phase content was performed by using a screening design experiment with three factors on 2 levels. The alginate solution concentration, the concentration of the oil phase in the emulsion and the homogenization rate were selected as independent variables. They are shown in Table 1.

Table 1. Levels of variation of the independent variables in emulsion optimization

| | Lower level | Center level | Upper level |
|---|---|---|---|
| Alginate solution concentration, %(w/v) | 1 | 1.5 | 2 |
| Homogenization rate, rpm | 10000 | 15000 | 20000 |
| Oil phase concentration, % (v/v) | 20 | 40 | 60 |

The independent variables were coded in accordance with the generally accepted methodology. The plan of the experiment is presented in Table 2. The stability of the resulting emulsions during centrifuging, the temperature method and the microscopic method were selected for target functions. Processing of experimental data and obtaining the mathematical models were performed using *Statgraphics XV Trial version*.

Table 2. Screening design experiment for emulsion optimization

| № | Alginate solution concentration, %(w/v) | | Homogenization rate, rpm | | Oil phase concentration, % (v/v) | |
|---|---|---|---|---|---|---|
| | Real value | Coded value | Real value | Coded value | Real value | Coded value |
| 1 | 1.5 | 0 | 15000 | 0 | 40 | 0 |
| 2 | 1.5 | 0 | 15000 | 0 | 40 | 0 |
| 3 | 1.5 | 0 | 15000 | 0 | 40 | 0 |
| 4 | 2 | +1 | 10000 | -1 | 60 | +1 |
| 5 | 1 | -1 | 10000 | -1 | 60 | +1 |
| 6 | 2 | +1 | 20000 | +1 | 20 | -1 |
| 7 | 1 | -1 | 20000 | +1 | 60 | +1 |
| 8 | 1 | -1 | 20000 | +1 | 20 | -1 |
| 9 | 2 | +1 | 20000 | +1 | 60 | +1 |
| 10 | 1 | -1 | 10000 | -1 | 20 | -1 |
| 11 | 2 | +1 | 10000 | -1 | 20 | -1 |

**Stability of the emulsions**

*Initial stability of the emulsions.*

The emulsions prepared according to 2.2.1 were poured in measuring cylinders with a volume of 100 $cm^3$ and were held at room temperature for 24 h. After that the emulsified phase volume and the separated phase volume were recorded. The stability of the emulsions was calculated according to the relationship (Chan, 2011):

$$ESt = \frac{V_{emul}}{V_{initial}}.100,\ \% \quad (1)$$

wherein: $V_{emul}$ - stable emulsion volume, $cm^3$; $V_{initial}$ - initial emulsion volume, $cm^3$ ($V_{initial}$ = 100).

*Centrifugal Test*

The emulsion stability was examined by centrifugation of 5 $cm^3$ of the emulsion for 10 min at 2500 rpm. The emulsion stability (ESt) was determined according to:

$$ESt = \frac{V_0 - V}{V_0}.100,\ \% \quad (2)$$

wherein: ESt - emulsion stability,%, $V_0$ – emulsion volume, $cm^3$, V - separated layer volume, $cm^3$.

The obtained data showed that the stability of the emulsion increased with the increase in the ESt (stability) value (Dłużewska et al., 2004; McClements, 2007; Reineccius, 1994).

*Microscopic Test*

The characteristics of the oil droplets were determined using microscopic pictures. Based on the results obtained the droplets were divided into 4 groups: I - 0-4 μm; II - 4-8 μm; III - 8-12 μm; IV- above 12 μm. $10^2 \div 10^3$ oil globules were used for statistical analysis. The following parameters that determined the emulsion stability were calculated (Vasileva, 2011; Dłużewska et al., 2004; McClements, 2007):

- Mean diameter of the oil globules for a certain group, μm:

$$d_{mean} = \frac{(X_{max} + X_{min})}{2} \quad (3)$$

wherein: $d_{mean}$ - mean diameter of the oil phase globules, μm; $X_{min}$ - the lower limit of the corresponding group; $X_{max}$ – the upper limit of the corresponding group.

- "Longueur-nombre" $d_{ln}$ of the oil phase globules:

$$d_{ln} = \frac{\sum M_n d_{mean}}{\sum n} \quad (4)$$

wherein: $d_{ln}$ - mean arithmetic diameter, μm; $M_n$ - number of oil globules in a group; $d_{mean}$ - average diameter of the oil phase globules in a group, μm; Σn – total amount of oil phase globules.

The amount of oil phase globules was defined using *DinoCapture software*.

*Temperature Test*

Three tubes, each containing 10 $cm^3$ of the emulsion were placed at three different temperatures - 4 °C, 23 °C and 45 °C for 24 h (Tan and WuHolmes 1988). The appearance of a visible oil phase ring showed that the emulsion was unstable. The creaming degree was evaluated as: "+" if there was an oil phase ring, "+/-" suspected creaming and "-" absence of an oil phase ring.

**Preparation of encapsulated preparations and evaluation of the retention ability of the capsules**

*Capsule preparation*

The emulsion selected previously with the corresponding concentrations of alginate and

olive oil was homogenized at the corresponding rate and dripped into a 2% $CaCl_2$ solution using a peristaltic pump. The gelling solution and the emulsion were stirred during the whole period of immobilization. After that the gel beads were held for further 30 min in the gelling solution to achieve the required mechanical stability.

*Evaluation of the retention capacity (RC) of the capsules.*

The retention capacity of the capsules was evaluated by determining the amount of oil phase in the gelling solution after the washing of the capsules with distilled water and during storage at various temperatures.

The gelling solution was poured into a measuring cylinder with a volume of 250 $cm^3$ and after a brief retention the quantity of the oil phase separated in it was determined. The capsules separated from the gelling solution were placed in a metal sieve and were washed with 100 $cm^3$ of distilled water to wash out the surface oil phase. The washing water was also put into a measuring cylinder and after a retention the oil phase amount was recorded.

The retention capacity of the capsules was determined according to the following relationship:

$$RC = \frac{V_{oil} - V_{oil}^{CaCl_2} - V_{oil}^{water}}{V_{oil}}.100\% \quad (5)$$

Depending on the resulting RC value the capsules were grouped in 4 groups: capsules with high RC - RC> 90%; capsules with good RC - RC = 70-90%; capsules with satisfactory RC - RC= 50-70%; capsules with poor RC - RC <50%.

The washed capsules were divided into several groups and were used for the preparation of various dairy products.

15 g of capsules were kept and used to determine their retention capacity during storage at various temperatures. 5 g of capsules were placed in Petri dishes which were incubated for 12-24 hours at 4 °C, 20 °C and 43 °C. After that the oil phase amount leaked from the capsules was determined visually. The results were recorded in accordance with the numerical scale already presented.

## RESULTS AND DISCUSSIONS

**Selection of alginate type and conditions for modeling of the encapsulation process.**

The choice of alginate type and the conditions for process modeling was performed by comparing the stability of the emulsions obtained by the application of low and medium viscosity alginate solutions with concentrations in the range of 0.5% to 3% and varying oil phase concentrations (in the range of 20-60%). The results are shown in Figure 1.

Data showed that emulsion stability depended to a great extent on alginate concentration and viscosity. The stability of the emulsions prepared with low viscosity alginate solution increased with the increase in the solution concentration and the oil phase concentration. The visual observations made during the study on the stability showed that the higher the concentrations of the alginate solution and the oil phase were, the better the emulsification of the oil phase in the alginate solution was. In the combination of low alginate concentration/low oil phase concentration and low viscosity of the forming solution, the emulsification was low, yielding high oil phase globules and areas of pure alginate, which subsequently led to low emulsion stability. Maximum stability was obtained for capsules prepared with 3% alginate solution and 60% oil phase but it did not exceed 72% (Figure1). The emulsions obtained with medium viscosity alginate solution had different characteristics. The emulsions obtained with 3% alginate solution were the most stable, yet they were too viscous and difficult to de dripped to form capsules. This made them inapplicable for the purposes of the present study. Similarly to the previous variant the stability increased with the increase in the oil phase concentration, but in oil phase concentrations of over 50% a reduction was observed. The combination of 2% alginate solution and oil phase concentration in the range of 20-50% provided the greatest possible stability (Figure 1b). This emulsion type was also difficult to handle in terms of the following immobilization procedure similar to the 3% alginate solution emulsions.

The selection process described selected the medium viscosity alginate for the further research due to the high initial stability of the emulsions. The results showed that the stability of the capsules was also influenced by homogenization rate and homogenization time. Based on the results obtained the research continued with a screening design experiment. The levels of experimental factors are summarized in Table 1.

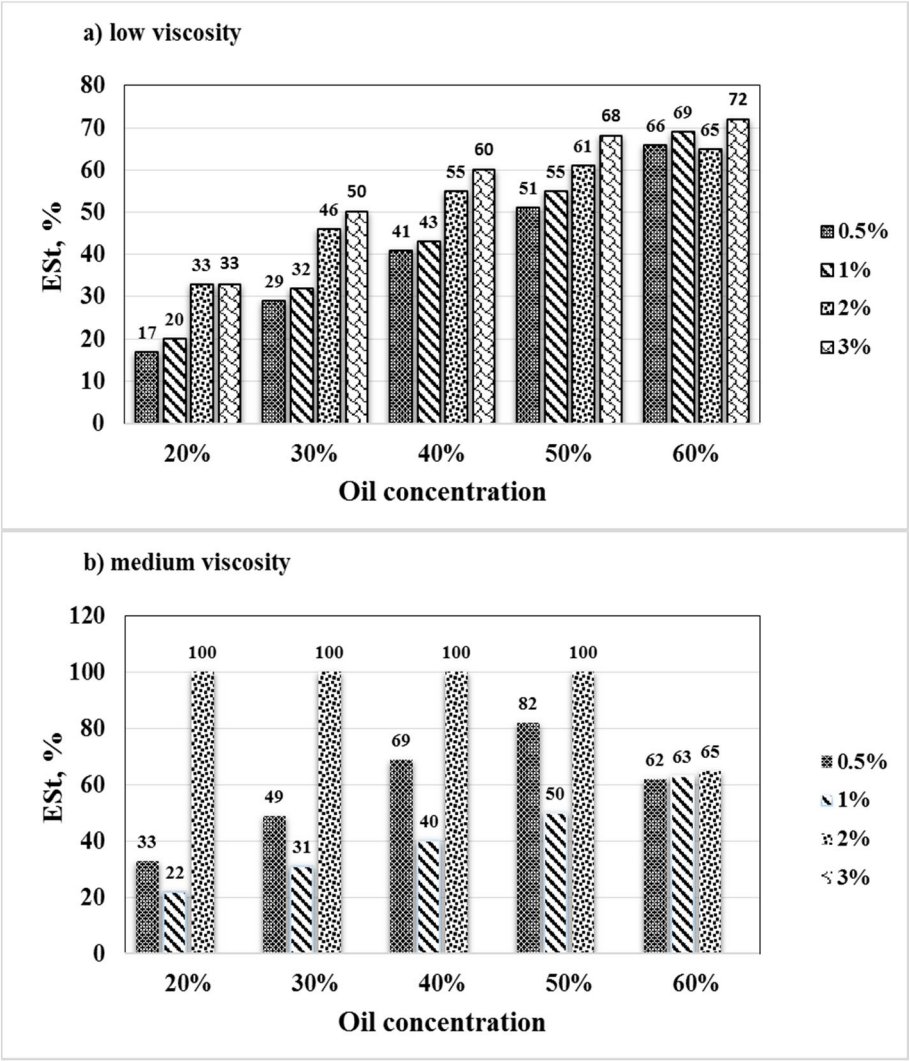


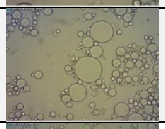
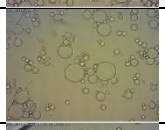
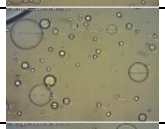
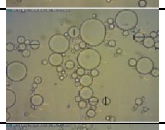
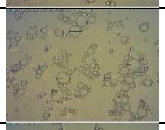
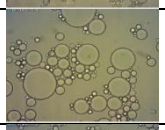
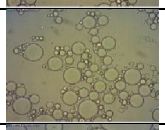
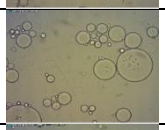
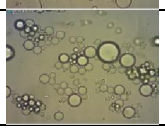

Figure1. Stability of the emulsions prepared using low and medium viscosity alginate

**Modeling and optimization of the emulsions for the preparation of capsules with high oil phase content.**

The results of the screening design experiment for the emulsion stability are presented in Table 3. It also includes a picture for each emulsion variant that helped the determination of the oil phase globule size in the composition of the emulsion. Based on the experiments conducted have been developed mathematical models for the stability, determined by the three methods (the stability was selected to be measured at 25 °C for the measurement of the temperature stability). Analysis of variables (ANOVA) was conducted (Table 4 to Table 6), and the insignificant influencing factors in the mathematical models were removed: The response curves for the respective model were obtained after removal of the insignificant influencing factors. Some of them are shown in Figure 2 to Figure 4.

The process of obtaining a stable emulsion is controlled not only by the basic factors, but also by their combined interaction. The temperature stability was the least influenced by the studied factors (equation 6, Figure 2 and Table 3 and Table 4). In most variants studied it was within 100%, except for variants 4 and 9 with average stability below 50%. Variant 9 had extremely low centrifugal stability and maximum oil phase globule size in the emulsion which was the reason for the low temperature stability of the emulsion. In variant 4 although yielding relatively small oil phase globules, there was low centrifugal stability, which also affected the temperature stability of the emulsion. In general, in this case the parameter temperature stability was not suitable for optimization of the emulsification conditions.

Table 3. Results from the screening design experiment for modeling the emulsification conditions

| Variant | Stability | | | | | Microscopic picture of the emulsion |
|---|---|---|---|---|---|---|
| | Temperature (Tstab, %) | | | Centrifugal (Cstab, %) | Microscopic (Dln), (Mstab, μm) | |
| | **4 °C** | **25 °C** | **42 °C** | | | |
| 1 | 100 | 100 | 100 | 98 | 0,88 |  |
| 2 | 100 | 100 | 100 | 98 | 0,98 |  |
| 3 | 100 | 100 | 100 | 98 | 1,06 |  |
| 4 | 54 | 60 | 40 | 34 | 1,11 |  |
| 5 | 100 | 100 | 97 | 85 | 1,19 |  |
| 6 | 100 | 100 | 100 | 100 | 0,7 |  |
| 7 | 100 | 99 | 98 | 98 | 1,26 |  |
| 8 | 100 | 100 | 100 | 100 | 1,17 |  |
| 9 | 20 | 30 | 25 | 35 | 2,8 |  |
| 10 | 100 | 100 | 100 | 100 | 1,37 |  |
| 11 | 100 | 100 | 100 | 100 | 1,17 |  |

More interesting results were obtained for centrifugal (equation 7) and microscopic (equation 8) stability. Centrifugal stability decreased with the increase in the alginate concentration and the oil phase concentration in the emulsion (Equation 7; Figure 3).

$$Tstability = 107,64 + 10,75*Alginate - 39,5*Oil\ load - 39,25*Alginate*Oil\ load \quad (6)$$

$$Cstability = 86,0 - 14,25*Alginate - 18,5*Oil\ load - 14,25*Alginate*Oil\ load \quad (7)$$

$$M_{stability}=1,245 + 0,244*Oil\ load + 0,266*Alginate*Oil\ load + 0,304*Homogenization\ rate*Oil\ load \quad (8)$$

The preparation of a loaded emulsions was related to the more difficult emulsification of the oil phase, which reduced the emulsion stability. According to the model maximum stability under this parameter was not achieved at maximum homogenization rate, but at intermediate homogenization rate - about 17,500 rpm, which, however, was associated with reduced concentrations of the two phases - alginate and olive oil.

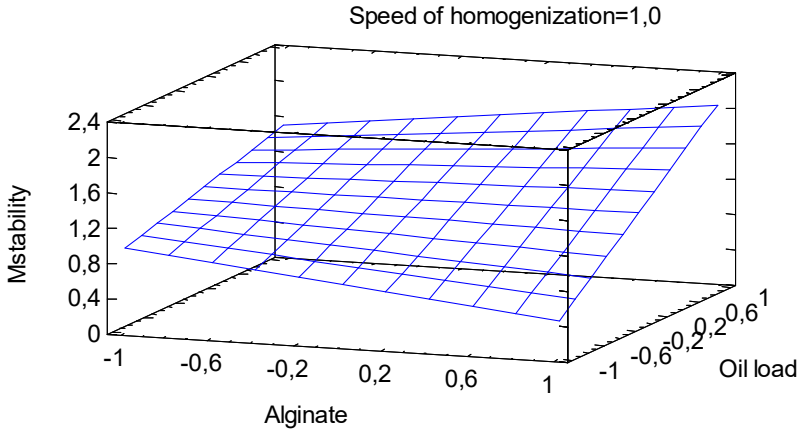



Figure 2. Response curve for the influence of the alginate and oil phase concentrations on the microscopic stability of the emulsions (parameters of presented in coded value; Mstab, μm)

Table 4. ANOVA for temperature stability (Tstability)

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | Significance |
|---|---|---|---|---|---|---|
| A:Alginate | 924.5 | 1 | 924.5 | 9.60 | **0.0363** | **Significant** |
| B:Speed of homogenization | 162.0 | 1 | 162.0 | 1.68 | 0.2643 | Insignificant |
| C:Oil load | 12482.0 | 1 | 12482.0 | 129.67 | **0.0003** | **Significant** |
| AB | 144.5 | 1 | 144.5 | 1.50 | 0.2877 | Insignificant |
| AC | 12324.5 | 1 | 12324.5 | 128.03 | **0.0003** | **Significant** |
| BC | 162.0 | 1 | 162.0 | 1.68 | 0.2643 | Insignificant |
| Total error | 385.045 | 4 | 96.2614 | | | |
| Total (corr.) | 26584.5 | 10 | | | | |

* (statistical parameters of the model before removing the insignificant factors) R-squared = 98.55 %; R-squared (adjusted for d.f.) = 96.38 %; Standard Error of Est. = 9.81; Mean absolute error = 5.17; Durbin-Watson statistic = 2.35946 (P=0.9669); Lag 1 residual autocorrelation = -0.331178

** (statistical parameters of the model after removing the insignificant factors)R-squared = 96.78 %; R-squared (adjusted for d.f.) = 95.41 %; Standard Error of Est. = 11.04; Mean absolute error = 6.83; Durbin-Watson statistic = 2.40468 (P=0.7108); Lag 1 residual autocorrelation = -0.270658

Table 5. ANOVA for centrifugal stability (Cstability)

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | Significance |
|---|---|---|---|---|---|---|
| A:Alginate | 1624.5 | 1 | 1624.5 | 10.62 | **0.0311** | **Significant** |
| B:Speed of homogenization | 24.5 | 1 | 24.5 | 0.16 | 0.7095 | Insignificant |
| C:Oil load | 2738.0 | 1 | 2738.0 | 17.90 | **0.0134** | **Significant** |
| AB | 18.0 | 1 | 18.0 | 0.12 | 0.7489 | Insignificant |
| AC | 1624.5 | 1 | 1624.5 | 10.62 | **0.0311** | **Significant** |
| BC | 24.5 | 1 | 24.5 | 0.16 | 0.7095 | Insignificant |
| Total error | 612.0 | 4 | 153.0 | | | |
| Total (corr.) | 6666.0 | 10 | | | | |

* (statistical parameters of the model before removing the insignificant factors) R-squared = 90.82 %; R-squared (adjusted for d.f.) = 87.0477 %; Standard Error of Est. = 12.3693; Mean absolute error = 6.54; Durbin-Watson statistic = 1.67647 (P=0.5612); Lag 1 residual autocorrelation = -0.0735294;

** (statistical parameters of the model after removing the insignificant factors) R-squared = 89.81 %; R-squared (adjusted for d.f.) = 85.44 %; Standard Error of Est. = 9.848; Mean absolute error = 6.909; Durbin-Watson statistic = 2.01252 (P=0.4580); Lag 1 residual autocorrelation = -0.218336

Table 6. ANOVA for microscopic stability (Mstability)

| Source | Sum of Squares | Df | Mean Square | F-Ratio | P-Value | Significance |
|---|---|---|---|---|---|---|
| A:Alginate | 0.0780125 | 1 | 0.0780125 | 0.41 | 0.5581 | Insignificant |
| B:Speed of homogenization | 0.148512 | 1 | 0.148512 | 0.78 | 0.4283 | Insignificant |
| C:Oil load | 0.475312 | 1 | 0.475312 | 2.48 | **0.1903** | **Significant** |
| AB | 0.227812 | 1 | 0.227812 | 1.19 | 0.3368 | Insignificant |
| AC | 0.567113 | 1 | 0.567113 | 2.96 | **0.1604** | **Significant** |
| BC | 0.738112 | 1 | 0.738112 | 3.85 | **0.1211** | **Significant** |
| Total error | 0.766198 | 4 | 0.191549 | | | |
| Total (corr.) | 3.00107 | 10 | | | | |

* (statistical parameters of the model before removing the insignificant factors) R-squared = 74.46 %; R-squared (adjusted for d.f.) = 36.17 %; Standard Error of Est. = 0.437; Mean absolute error = 0.245; Durbin-Watson statistic = 1.44228 (P=0.3311); Lag 1 residual autocorrelation = 0.16991

** (statistical parameters of the model after removing the insignificant factors) R-squared = 99.33 %; R-squared (adjusted for d.f.) = 91.90 %; Standard Error of Est. = 0.417; Mean absolute error = 0.294; Durbin-Watson statistic = 1.24081 (P=0.0911); Lag 1 residual autocorrelation = 0.311204

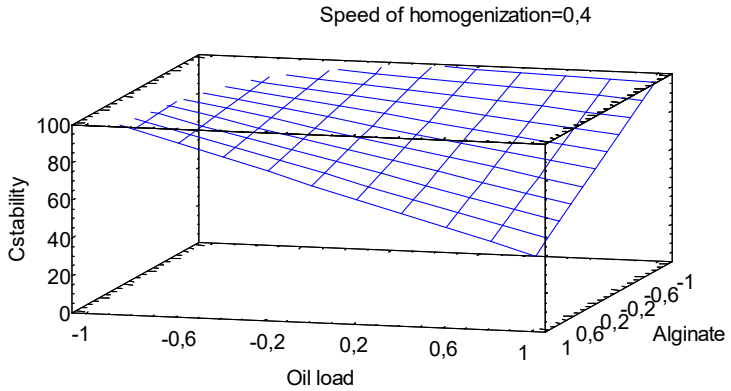



Figure 3. Response curve for the influence of the alginate and oil phase concentrations on the centrifugal stability of the emulsions (parameters of presented in coded value; Cstab, %)

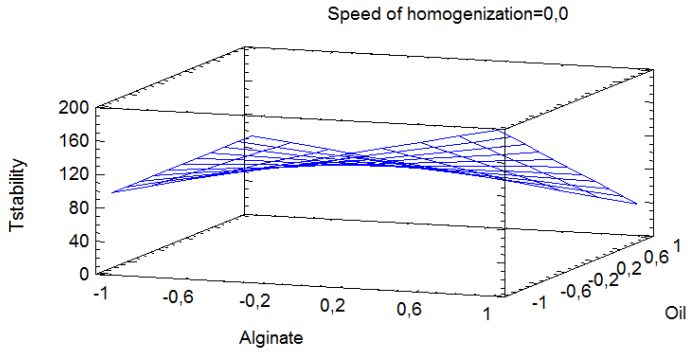



Figure 4. Response curve for the influence of the alginate and oil phase concentrations on the temperature stability of the emulsions (parameters of presented in coded value; Tstab, %)

Out of the three selected optimization parameters the biggest changes were observed in the parameter microscopic stability. The oil phase globule diameter ranged from 0.88 µm to 2.8 µm. The microscopic pictures of the emulsions (Table 3) showed varying degrees of emulsification of the product in alginate. The diameter of the oil phase in the emulsion increased with the oil load increase, as well as with the increase in the two combinations of influential factors - alginate/olive oil and homogenization rate/olive oil. Equation (8) showed that in order to achieve good emulsification the appropriate alginate and oil phase concentrations could not exceed a certain value. Interestingly, the model (8) showed that the homogenization rate could not exceed a certain limit as well (although it was not within the range of variation), since this also reduces the stability of the emulsion. To a certain extent

model data was contrary to the microscopic pictures, as best emulsification was obtained in variant 6 in which the alginate concentration and the homogenization rate were at the upper level and the oil phase concentration was at the lower level. Thus, to a large extent the degree of homogenization was determined by the oil load rather than the homogenization rate. Variants 1 and 3 also had a good degree of homogenization, although they were held in the center of the plan.

Figure 5 shows the influence of the parameters on the oil phase globule diameter. It can clearly be seen from the slope of the graphs that the strongest influence on the parameter had the oil load, the relationship being: the oil phase globule diameter quickly increased with the increase in the oil phase concentration in the capsules. The other two factors had comparable influence, which was weaker than the oil phase concentration in the emulsion. The joint influence of the three factors is reflected in Figure 6. It again favored the oil phase concentration in the emulsion formation, while the other two factors had weaker influence on the forming of the emulsion with a minimum oil phase globule diameter.

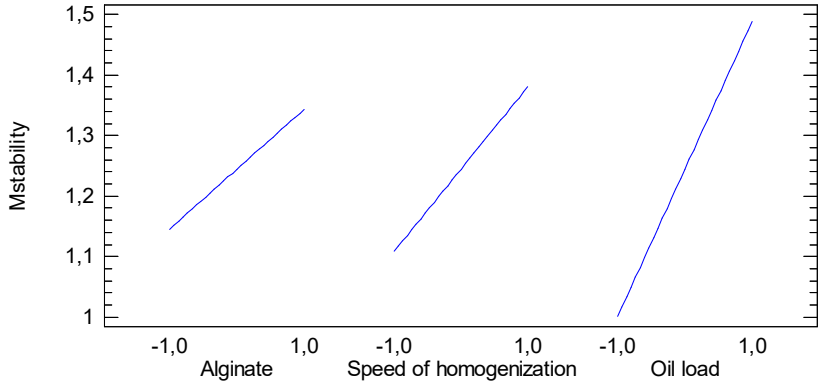



Figure 5. Effects of factors on the oil phase globule diameter

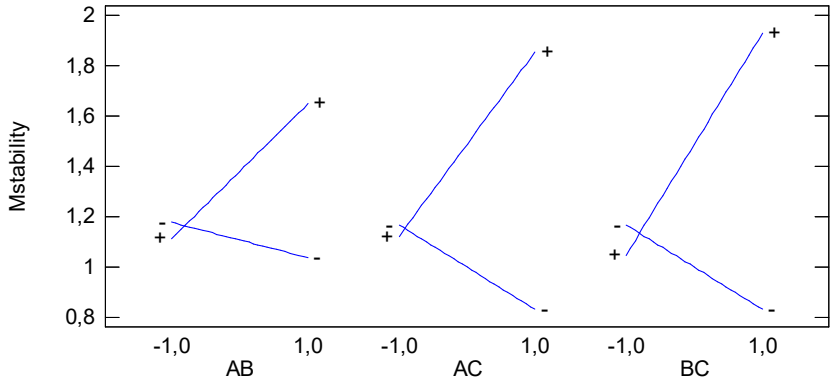



Figure 6. Joint influence of the factors on the oil phase globule diameter

From the results of the screening design experiment it can be seen that the three factors had a different impact on the emulsion parameters. Thus, an optimization procedure using the *Statgraphics XV Trial version* was carried out to minimize the globule diameter and to maximize the centrifugal stability. The results are shown in Table 7. Data in Table 7 makes it possible to choose two modes for emulsion preparation for capsules which were to be tested in terms of stability of the resulting preparations.

**3.3. Study of the stability of the capsules obtained from emulsions with optimized composition.**

Capsules were obtained according to the procedure described in 2.4.1 with the two emulsion variants, presented in Table 7. The capsule stability was evaluated according to the procedure in 2.4.3. Since the objective of the present work was the preparation of capsules with high oil phase content, the study was carried out with varying olive oil concentrations. The results are presented in Table 8.

Table 7. Optimize Response for emulsion stability (microspopic and centrufugal)

| Factor | Low | High | Optimum | Real value |
|---|---|---|---|---|
| **minimize Mstability - Optimum value = 0.431 µm** | | | | |
| Alginate | -1.0 | 1.0 | 1.0 | **2%** |
| Homogenization rate | -1.0 | 1.0 | 1.0 | **20000 rpm** |
| Oil load | -1.0 | 1.0 | -1.0 | **20%** |
| **maximize Cstability - Optimum value = 100 %** | | | | |
| Alginate | -1.0 | 1.0 | -0.26 | **1.37 %** |
| Homogenization rate | -1.0 | 1.0 | 0.409 | **17450 rpm** |
| Oil load | -1.0 | 1.0 | -0.708 | **25.8 %** |

The results in Table 8 showed that the capsules obtained in both modes had good stability in the range of oil phase concentration of up to 40%. Although the emulsions, prepared with high oil phase concentration had good stability, rapid leakage of oil phase in $CaCl_2$ was observed during capsule formation, which resulted in poor stability of the capsules. Table data did not show emphatically which variant should be selected. It is therefore necessary to take into account the time for capsule preparation. In the conduction of the experiment, the capsules prepared with alginate solution concentration of 1.37% were obtained about 1.5 times faster than those prepared with 2% alginate solution.

After the survey to obtain capsules with encapsulated oil phase (olive oil) were selected: medium viscosity alginate with concentration of 1.37%; olive oil concentration of 30%; homogenization rate - 20000 rpm.

Table 8. Stability of the capsules obtained from emulsions with optimized composition

| Oil phase concentration, % | 20 | 30 | 40 | 50 |
|---|---|---|---|---|
| **Variant: 1.37% alginate; 20000 rpm** | | | | |
| Stability | - | - | - | - |
| in $CaCl_2$ | H | H | H | H |
| in distilled water /after washing/ | H | H | H | H |
| during storage for 24 h at 4 °C | H | G | S | S |
| during storage for 24 h at 25 °C | S | S | S | S |
| during storage for 24 h at 43 °C | S | S | P | S |
| Overall | H/G | G/S | S/P | G/S |
| **Variant: 2.00 % alginate; 17450 rpm** | | | | |
| Stability | - | - | - | - |
| in $CaCl_2$ | H | H | H | P |
| in distilled water /after washing/ | H | H | H | P |
| during storage for 24 h at 4 °C | H | H | H | P |
| during storage for 24 h at 25 °C | G | S | S | P |
| during storage for 24 h at 43 °C | S | S | S | P |
| Overall | H/G | G/S | G/S | P |

*H – high; G - good; S – satisfactory; P – poor.

## CONCLUSIONS

A study was conducted to select the parameters for the formation of capsules with high olive oil content for application in the dairy industry. Based on the conducted mathematical and statistical analysis and analysis of the stability of the forming emulsions and capsules was selected the following variant: medium viscosity alginate - 1.37%; olive oil concentration - 30%; homogenization rate - 20000 rpm. This variant provided the preparation of capsules of high stability, without a high level of oil phase migration in the liquid phase. The prepared capsules can be added in the composition of dairy products. Initial studies (unpublished data) for the preparation of yogurt and spread cheese with the obtained capsules were carried out.

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