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PHYSICAL AND CHEMICAL PROPERTIES OF EMULSIONS CONTAINING DIFFERENT KIND OF FAT AND DIFFERENT CONTENT OF AN INNOVATIVE PROTEIN WITH ALGAE®

Właściwości fizykochemiczne emulsji zawierających różny rodzaj tłuszczu i różną zawartość innowacyjnego białka z alg®

Celem pracy przedstwionej w artykule jest określenie wpływu rodzaju tłuszczu oraz zmiennej zawartości białka z alg na wybrane właściwości fizykochemiczne emulsji decydujące o stabilności układu. *Emulsje tłuszczowe wytworzono w trzech następujących wariantach: na bazie oleju konopnego, na bazie mieszaniny oleju konopnego i łoju baraniego (1:1) oraz na bazie tej samej mieszaniny tłuszczowej, ale poddanej procesowi enzymatycznego przeestryfikowania (1:1). Zakres eksperymentalnej części pracy obejmował przygotowanie tłuszczu zwierzęcego (łoju baraniego) przez poddanie go procesowi bielenia, a następnie przeestryfikowanie enzymatyczne z olejem konopnym. Następnie przygotowano 9 wariantów emulsji zawierających odpowiednio olej konopny, mieszaninę tłuszczową nieprzeestryfikowaną oraz mieszaninę tłuszczową przeestryfikowaną. Każda z emulsji zawierała inną zawartość białka z alg w ilości od 0.4 do 1,2% w stosunku do masy emulsji. Tak przygotowane emulsje poddano badaniom po 24 godzinach od ich sporządzenia oraz po 1 miesiącu przechowywania. Przeprowadzono ocenę następujących parametrów emulsji: barwy, tekstury, lepkości, struktury mikroskopowej oraz dokonano pomiaru intensywności światła wstecznie rozproszonego przez próbkę w czasie, z wykorzystaniem urządzenia Turbiscan Lab. Zauważono, że wraz ze wzrostem zawartości białka z alg w emulsjach, nastąpił wzrost wartości parametru b* odpowiadającego za żółty kolor dla wszystkich wariantów tych emulsji. Nastąpił również wzrost wielkości kropel w badaniu mikroskopowym i zmniejszenie stabilności emulsji na bazie tłuszczów przeestryfikowanych. Nie zauważono jednoznacznego wpływu białka z alg na następujące parametry: adhezyjność, lepkość oraz twardość emulsji.*

W pracy nie udało się wytypować emulsji o wysokiej stabilności, ani wskazać wyraźnego wpływu białka na właściwości reologiczne wytworzonych emulsji bez względu na

The aim of the work presented in the article is to determine the effect of the type of fat and the variable protein content of algae on selected physicochemical properties of emulsions determining the stability of the disersion systems. *Fat emulsions were prepared in the following three variants: based on hemp oil, based on a mixture of hemp oil and mutton tallow (1: 1) and based on the same fat mixture, but subjected to the enzymatic interesterification process (1: 1). The experimental part of the work included the preparation of animal fat by subjecting it to the bleaching process, and then enzymatic interesterification with hemp oil. Then, 9 variants of emulsions containing hemp oil, nonesterified fat mixture and interesterified fat mixture, respectively, were prepared. Each emulsion had a different algal protein content ranging from 0.4 to 1.2% by weight of the emulsion. The emulsions prepared in this way were tested 24 hours after their preparation and after 1 month of storage. The following parameters of the emulsion were assessed: color, texture, viscosity, and microscopic structure, and the intensity of the light backscattered by the sample was measured with the use of the Turbiscan Lab device. It was noticed that with the increase in the protein content of algae in the emulsions, there was an increase in the value of the b * parameter corresponding to the yellow color for all variants of these emulsions. There was also an increase in droplet size in microscopic examination and a decrease in the stability of the emulsions based on the interesterified fats. There was no unequivocal influence of the algae protein on the following parameters: emulsion adhesiveness, viscosity and hardness.*

In the study, it was not possible to select an emulsion with high stability, nor to indicate a clear influence of protein on the rheological properties of the emulsions produced, regardless of the type of fat used. In order to produce more stable systems, research should be extended to change the amount or type

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rodzaj zastosowanego tłuszczu. W celu wytworzenia bardziej stabilnych układów należy rozszerzyć badania w kierunku zmiany ilości lub rodzaju białka, czy wytypowania innego modyfikatora lepkości, który z białkiem z alg jest w stanie stworzyć układ synergistyczny oddziaływujący stabilizująco na wytworzone układy dyspersyjne.

Słowa kluczowe: emulsja, stabilność, białko z alg, Turbiscan test.

of protein, or to select a different viscosity modifier which, together with the algae protein, is able to create a synergistic system that stabilizes the dispersion systems produced.

Key words: emulsion, stability, alge protein, Turbiscan test.

INTRODUCTION

Currently, in times of advanced knowledge and technology, scientists are trying to meet the growing expectations of consumers regarding emulsion products on the market. On the basis of many experiences, researchers create more and more innovative products, as well as additions to tchem [1]. Natural ingredients are more and more often used in cosmetics, food or pharmaceutical products, which is dictated by the current trends in creating healthy products with more attractive properties. Due to their various applications, emulsions are a frequent subject of research aimed at improving the nutritional, performance and functional properties of these systems [3]. One of the key components of fat emulsions is fat. In recent years, due to the promotion of healthy eating, a decrease in the consumption of animal fats has been observed in favor of the consumption of vegetable fats. Vegetable oils provide the body with valuable unsaturated fatty acids (SFA), vitamins and do not contain cholesterol [2]. A common solution is to use the fat interesterification process which allows to change the rheological, nutritional and functional properties of the obtained fat [14]. Carrying out this process is related, inter alia, to the introduction of valuable unsaturated fatty acids derived from vegetable oils into the molecules of triacylglycerols of animal fat, i.e. tallow, mutton or lard [10]. By preparing such a fat mixture, it is often possible to obtain the fat phase of an emulsion ready for use in the formation of fat emulsions. As a result of the interesterification process, new triacylglycerols (TAGs) are obtained. The process management depends on the applied chemical catalyst or selective lipase and the application of appropriate process parameters.

An important vegetable oil recently chosen by scientists is hemp oil [13]. Due to its beneficial properties related to the presence of unsaturated fatty acids and bioactive compounds, this oil is a valuable component of cosmetic preparations with health and care properties, and can also be used for direct consumption. Despite the current trend of consuming unrefined oils and replacing animal fats with them, such fats appear in the food industry, often being a waste of this industry. Mutton tallow can be such fat [7]. This fat contains 52–64% of saturated fatty acids, 3–4% of trans fatty acids, including the valuable CLA acid. It consists of both symmetrical and unsymmetrical unsaturated triacylglycerols. The dominant fatty acids of mutton tallow are palmitic acid (C16: 0), stearic acid (C18: 0) and oleic acid (C18: 1).

The quality of emulsion food products depends on the proper selection of ingredients (oil, emulsifiers, thickeners, flavors, vitamins), as well as on the properly conducted production process (homogenization, pasteurization), and then storage and transport [12].

To obtain a stable emulsion, it is necessary to add an emulsifier, i.e. a substance that accumulates at the interface, reducing the surface tension and stabilizing the system [9]. Its presence in the system ensures that the particles of the dispersed phase are separated from each other, so that they do not merge with each other. The amount of emulsifier in the system must be sufficient to form films around all the beads. If it is not enough, the films will be too thin and the emulsion will be unstable.

Hydrocolloids are also added to increase the stability of the emulsion [6]. They are high molecular weight hydrophilic biopolymers. They are used as functional additives to products to improve their structure and stability. Hydrocolloids can regulate the stability of the emulsion by increasing the viscosity of the continuous phase as well as acting as a surfactant forming a thick film around the emulsion droplets [6]. Thanks to viscosity modifiers, it is possible to obtain a product with an acceptable viscosity for technical or commercial requirements. Commonly, these substances are divided into: natural and synthetic polymers, surfactants and inorganic compounds. In order to protect the natural environment, it is desirable to use biodegradable compounds.

Proteins can also be classified as viscosity modifying substances. One that is increasingly used in emulsion systems is algae protein. Algae are a source of valuable ingredients for the human body. They contain large amounts of proteins, lipids, carbohydrates, vitamins and microelements, essential fatty acids (EFAs), polyphenols, biogenic compounds and natural dyes [4]. Proteins found in algae constitute about 7-15% of their dry weight. They mainly include glycoproteins and metalloproteins containing essential amino acids. Algae are used in the food, pharmaceutical and cosmetic industries [4].

The aim of the presented study was to evaluate the stability of fat emulsions containing different types of fat and different algal protein content.

MATERIALS

Cold-pressed hemp oil (Oleofarm, Wrocław, Poland), mutton tallow (donated from Meat-Farm Radosław Łuczak, Stefanowo, Poland), lipase from *Rhizomucor miehei*, immobilized on immobead 150, ≥ 300 U/g (Sigma Aldrich, Saint Louis, Missouri, United States) were used at the interestrification process. Carboxymethylcellulose (Pronicel, Pionki, Poland), protein from algae, sunflower lecithin (Lasenor) and sodium benzoate (Orff Food Easter Europe) were used as additions into the emulsions (Table 1).

PROCEDURE

Mutton tallow bleaching

Tallow was bleached and deodorized before the reaction. The fat was melted, placed in a two-neck round-bottom flask and 2% wt. of bleaching earth was added. The mutton tallow was heated under reflux condenser at 80°C for 1 h. After that time sorbent was filtered at 70°C using paper filter.

Enzymatic interestrification

Emulsions' fat bases were prepared by mix of fats and enzymatic interesterification of mutton tallow (MT) and hemp seed oil (HO) blends in the following mass ratio (1:1). The fat blends were placed in a shaker equipped with a water bath (SWB 22N, Labo Play, Poland) at reaction temperature (60°C) for 15 min. After this time, enzymatic catalyst - lipase from *Rhizomucor miehei* was added to the blends, in the amount corresponding to 5% w/w of the fat blend mass and water was calculated and added in the amount of 22% w/w of the enzyme mass. Water was added to the reaction system to increase the catalytic activity of a lipase at a lipid-water interface to increase the content of mono and diacylglicerols in the fat blends, which were used as the only emulsifiers in dispersion systems (only then when interestrified fat was used as a fat base). The process was carried out for 6 h, the reaction was terminated by filtering the enzyme on a Büchner funnel at 60°C.

Emulsion preparation

The aqueous phase of each emulsion was prepared by dispersing an appropriate amount of carboxymethylcellulose (CMC) in water, while the oil phase (fat base) was respective oil, mixed fat or interesterified fat blend according to Table 1. Both phases were heated to about 50–55°C, combined and then homogenized. Sunflower lecithin was added when the fat phase of the emulsion was hemp oil and blended fat. Each formulation was prepared in duplicate and homogenized mechanically. Homogenization was carried out for 4 minutes at 18 500 rmp using a rotor stator homogenizer, model T18 digital ULTRA-TURRAX equipped with S18G-19G dispersing head (IKA, China). During homogenization, the appropriate amount of algae protein (producer Solazyme) was gradually added to each of the emulsions. Sodium benzoate was added to the thus prepared and cooled emulsions.

METHODS

Colour determination of emulsions

Colour determination was done using a Konica Minolta chromameter CR-400 (Konica Minolta Sensing Inc., Milton Keynes, UK) (Fig. 1a) after standardization with a white calibration plate. CIEL*a*b* system was used with following parameteres:

– L* – defined as lightness of the sample ranging from 0 (black) to 100 (white),
– a* and b* represents two perpendicular color axes, with the values ranging from -60 to +60. Parameter a* when (-) represents greenness, when (+) redness. Whereas b*, blueness when (-) and yellowness when (+)[15].The measurements were taken in triplicate.

Texture measurements

Emulsions were evaluated for the following texture parameters: hardness and adhesiveness using CT3 Texture Analyzer (Brookfield Eng. Laboratories, USA) (Fig 1b.). Following measurement parameters were applied: nylon sensor with a diameter of 25.4 mm, target 10 mm, trigger load 0.1 g, test and return speed 0.2 mm/s, temperature 20°C. The test was performed 24 hours after the emulsion was prepared and was repeated after a month of storage of the emulsion. The results were presented as a mean value of three measurements.

Viscosity determination of emulsions

The viscosity of the emulsions was determined using Brookfield DV-III Ultra rheometer, model HA with helipath spindle set (Brookfield Engineering laboratories, USA) (Fig 1c.). Measurements were carried out at a constant rotational spindle speed of 5 rpm using T-bar spindle no. 92 (T-B). The

Table 1. Compositions of the emulsions

Tabela 1. Skład emulsji

Component	Emulsion								
	E1	E2	E3	E4	E5	E6	E7	E8	E9
	HO			NIC			EIC		
Fat% wt.	24.8	24.8	24.8	24.8	24.8	24.8	30	30	30
Lecitin% wt.	5.2	5.2	5.2	5.2	5.2	5.2	-	-	-
CMC% wt.	0,6								
AP% wt.	0.4	0.9	1.2	0.4	0.9	1.2	0.4	0.9	1.2
Preservative% wt.	0.3								
Water% wt.	Up to 100.0								

Legend/Legenda:
NIC – non interestrified fat hemp oil and muton tallow (1:1)
NIC – mieszanina fizyczna oleju konopnego i łojo baraniego (1:1)
EIC – interestrified fat hemp oil and muton tallow (1:1)
EIC – mieszanina enyzmatycznie przeestryfikowana oleju konopnego i łoju baraniego (1:1)

Source: Own study

Źródło: Opracowanie własne

measurements were performed at 20°C in triplicate. The test was performed 24 hours after the emulsion was prepared and was repeated after a month of storage of the emulsion.

Determination of the emulsion structure

The emulsion structure was determined using the Delta Pro Trino optical microscope by DELTA Optical (Fig 1d). The test was performed by applying a small amount of the emulsion to a glass slide and covering it with a coverslip. The samples prepared in this way were observed under a microscope at a magnification of 400x. Photos of the tests were taken with a camera using the DLTCamViewer software. The test was performed 24 hours after the emulsion was prepared and was repeated after a month of storage in the fridge.

Determination of emulsion stability

Stability determinations of the produced emulsions were made using the Turbiscan LabCooler by Formulaction in which cylindrical glass measuring vials containing the appropriate variant of the emulsion were placed (Fig 1e). The possibility of occurrence at a very early stage of physicochemical phenomena (creaming, coalescence, sedimentation, flocculation, particle migration, particle size change) that could not be observed with the naked eye was analyzed. The instrument's measuring head scanned the slides from the bottom to the top of the vial. The test results are presented on the charts generated by the Turbisoft program. The examination was performed twice a week for one month. The samples were stored at room temperature.

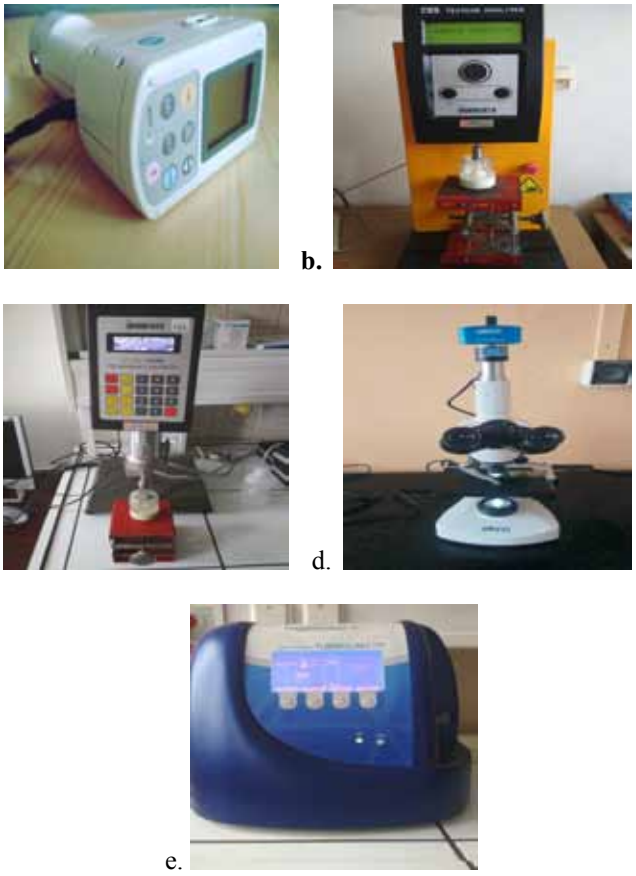

Fig. 1. Apparatus and devices used in research.
Rys. 1. Aparaty i urządzenia wykorzystane w badaniach.
Source: Own study
Źródło: Opracowanie własne

RESULTS AND DISCUSSION

Change of emulsion colour is one of the important determinants that inform about processes occurring in the product and can indicate destabilization changes [11].The results of the L * parameter recorded after 24h indicated that the emulsions based on the esterified fat were the brightest. After the storage period, an increase in the L* parameter was recorded in emulsions containing hemp oil or a mixture of non-esterified fats, which indicated a lighter shade of the emulsion. On the other hand, for samples with interesterified fat, a decrease in the value of the L* parameter was noted, indicating a darker color of these emulsions. No changes in the L* parameter values were found for emulsions containing different amounts of algae protein.

The analysis of the obtained results for the value of the a * parameter suggests that after manufactouring the emulsions had a green hue. Over time, the value of this parameter was higher, which suggested that the shade of green deepened. The least pronounced green color was observed for emulsions containing mixed fat. On the other hand, emulsions with interesterified fat showed a more intense shade of green. No clear effect of the addition of algae protein on the value of this parameter was observed.

Changes in the b* parameter value towards the yellow shade were observed for all emulsions. The smallest changes during the entire storage period were observed for the emulsions based on the interesterified fat. Moreover, within the emulsions containing the same fat base, the highest value of this parameter was observed when the protein content was higher. Thus, it can be assumed that the amount of protein contributed to the more pronounced yellow color of the emulsion. Emulsion 9 was the most intense in the shade of yellow.

Table 2. CIELAB L*, a*, b* values of the emulsions after manufactoring (24h) and stored 1 month

Tabela 2. Wartości CIELAB L*, a*, b* dla emulsji wytworzonych po 24 godzinach i przechowywanych przez 1miesiąc

Time	24h			1 month		
Emulsion	L*	a*	b*	L*	a*	b*
E1	13,91	-1,20	1,76	20,23	-1,63	4,65
E2	14,05	-1,26	2,02	19,41	-1,54	4,69
E3	19,42	-1,28	5,36	18,34	-1,49	4,27
E4	14,10	-1,01	1,77	18,48	-1,23	4,71
E5	15,50	-0,93	2,44	18,04	-1,43	4,73
E6	15,35	-1,11	3,13	19,23	-1,19	5,03
E7	22,07	-1,45	3,72	19,67	-2,00	4,79
E8	21,92	-1,70	5,15	21,17	-2,08	5,32
E9	21,56	-1,80	5,57	18,78	-2,24	6,42

Source: Own study
Źródło: Opracowanie własne

Texture is a group of physical properties of the body resulting from its structure. Measurement of texturometric properties makes it possible to objectively evaluate and compare features such as brittleness, hardness, ductility and

tackiness, which are usually determined subjectively by the senses. In the conducted texture study, the hardness and adhesiveness of the prepared emulsions were determined (Figure 2).

Analyzing the obtained results, it was found that the freshly prepared emulsions were characterized by higher hardness than those after a month of storage, especially in the case of emulsions (E3-E9). The lowest hardness values among the prepared preparations were characteristic for emulsions based on hemp oil (E1-E3), and the highest values for emulsions based on a physical mixture of fats (E4-E6). Emulsions whose fat base was an esterified mixture of fats (E7-E9) had comparable values of this parameter as emulsions based on hemp oil. Only one emulsion with the lowest algae protein content represented higher hardness values. The analysis of this parameter only shows that the interesterification process decreased the hardness of the blended fat. However, no effect of the amount of protein addition on the emulsion hardness was observed. However, it was observed that in an emulsion with a mixed fat 24 hours after production where the algae protein content was the lowest, the hardness parameter was the highest.

Sample adhesiveness can be identified as its' stickiness [8]. The analysis of the obtained results shows that emulsions based on mixed fats showed the highest values of adhesiveness of emulsions (Figure 3). The lowest values of this parameter were recorded for emulsions based on hemp oil. For the first four emulsions E1-E4, it was observed that after the indicated storage period (30 days), the value of this parameter decreased. However, for samples containing more algae protein and mixed fat, this parameter remained unchanged. Therefore, it can be concluded from the above data that the amount of protein in these emulsions had no influence on this parameter. On the other hand, when analyzing the values of this parameter for emulsions containing interesterified fat, its increase or not changing (E8) after the storage period was observed.

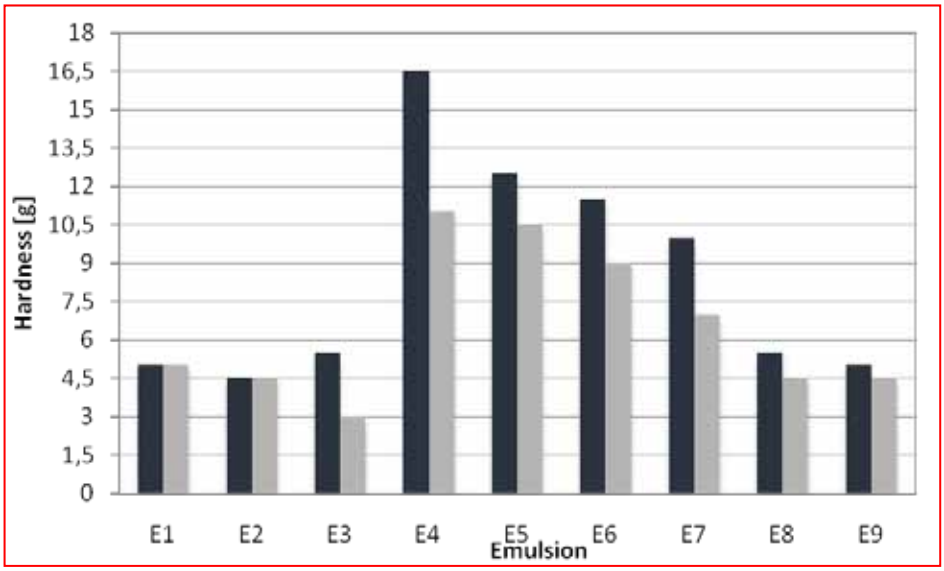

Fig. 2. Hardness of examined emulsions after 24 h and 30 days of storage.
Rys. 2. Twardość emulsji po 24 godzinach i 30 dniach przechowywania.
Source: Own study
Źródło: Opracowanie własne

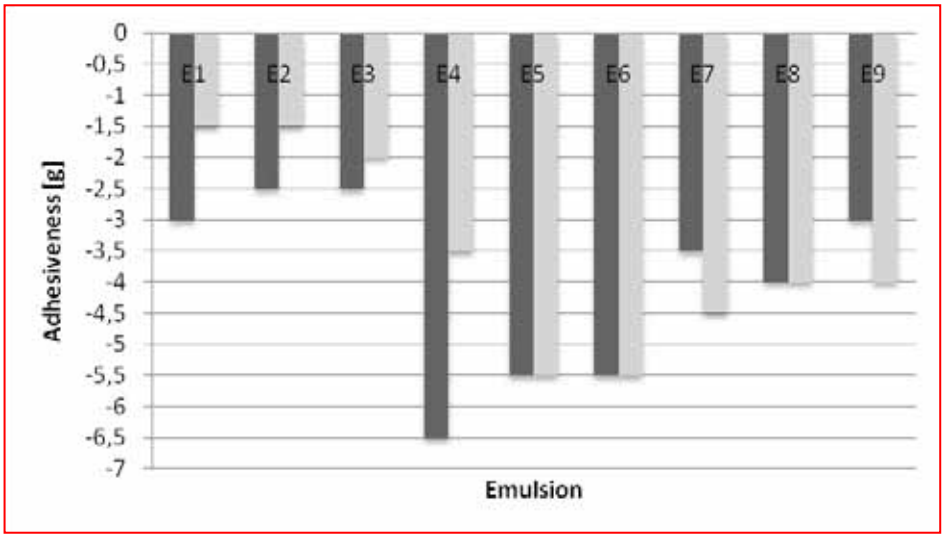

Fig. 3. Adhesiveness of examined emulsions after 24 h and 30 days of storage.
Rys. 3. Przyczepność emulsji do próbnika po 24 godzianch i 30 dniach od wytworzenia.
Source: Own study
Źródło: Opracowanie własne

Another parameter which was evaluated was the emulsions viscosity. The general factor affecting the emulsion viscosity value was the type of fat used as the base fat component. The emulsions containing the physical mixture of fats were characterized by the highest viscosity values (Figure 4). Their viscosity results were in the range of 52,533 – 68,400 cP. Emulsions based on the interesterified mixtures showed lower values of this parameter and ranged from 6667-12800 cP. On the other hand, the lowest values of this parameter were recorded for emulsions based on hemp oil. They ranged from 4,533 to 5,600 cP.

After one month of storage, a decrease in viscosity was observed for the following emulsions (E1, E2, E3 and E4, E5, E6). For emulsions containing interesterified fats, an upward trend of this parameter was observed. The study did not show a clear effect of the amount of protein from algae in the system on the value of the viscosity parameter. The emulsion E5 with 0.9 g of protein, containing mixed fat was characterized by the highest viscosity value.

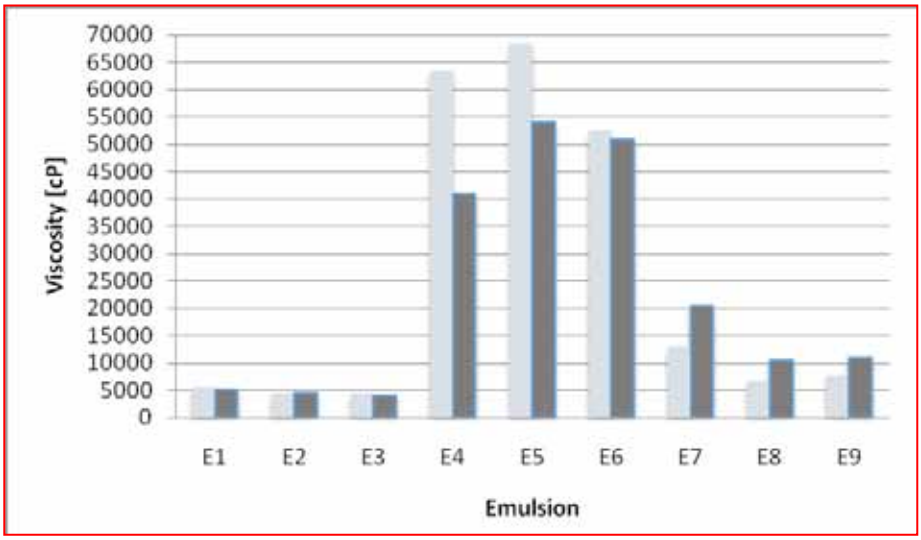

Fig. 4. Viscosity of the emulsions after 24 h from their manufacturing and 30 days of storage.

Rys. 4. Lepkośc emulsji po 24h od ich wytworzenia oraz po 30 dniach przechowywania.

Source: Own study

Źródło: Opracowanie własne

The microscopic analysis of the emulsion allows the observation of changes in the structure of the emulsion, e.g. changes in particle size. For an emulsion to be considered stable, it must have small droplets of similar size [5]. Figures 5,6,7 show photographs of the microscopic structure of the emulsion taken after 24 hours and after one month of storage.

Hemp oil emulsions (E1, E2, E3) were characterized by droplets of the smallest diameter after 24 hours from production. After one month of storage, no significant changes in droplet size were observed for these emulsions.

When analyzing the size and distribution of the dropets of emulsions containing mixed fat, it was observed that the emulsion dropets had a larger size than the dropets of the hemp oil-based emulsion (Figure 6). Numerous dropet clusters were also observed in the emulsions as a result of the merging of smaller individual drops. The droplet size was not affected by the amount of algae protein added to the emulsion.

The droplet size in the E7-E9 emulsions was also varied (Figure 7). The dropets had a different size after 24 hours from preparation and additionally changed their size after the storage period. The shape of the droplets after the storage period was definitely irregular and heterogeneous. The E8 and E9 emulsions were characterized by large dropets both after 24 hours and after one month of storage. The variant of the E7 emulsion was characterized by the smallest dropets among other emulsions based on interesterified fats. This emulsion contained the lowest amount of algae protein. On the other hand, the greatest heterogeneity of the system was observed for the emulsion with the highest addition of protein (1.2 g).

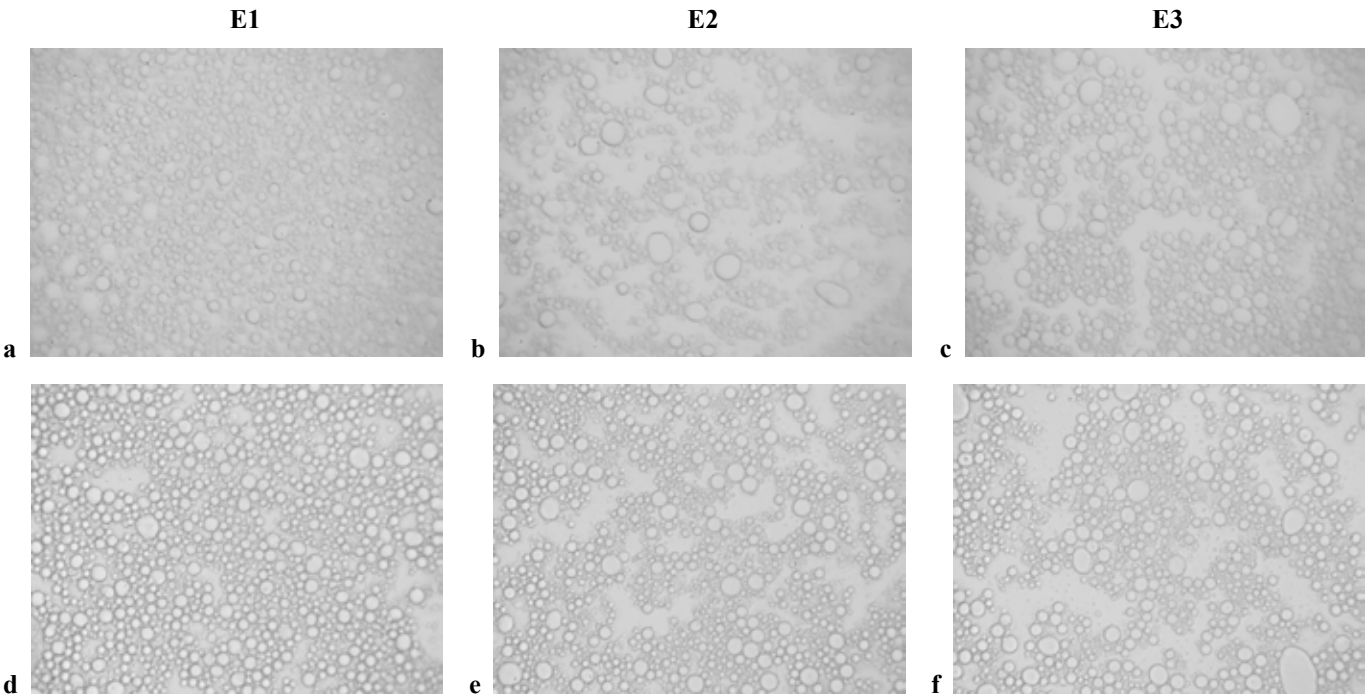

Fig. 5. Microphotographs of the prepared emulsions (E1, E2, E3) (G x 400) (a, b, c – after 24h from manufactoring and d, e, f – after 30 days).

Rys. 5. Zdjęcia emulsji (E1, E2, E3) wytworzonych po 24 godzinach (a, b, c) i po okresie 30 dniowym (d, e, f) (G x 400).

Source: Own study

Źródło: Opracowanie własne

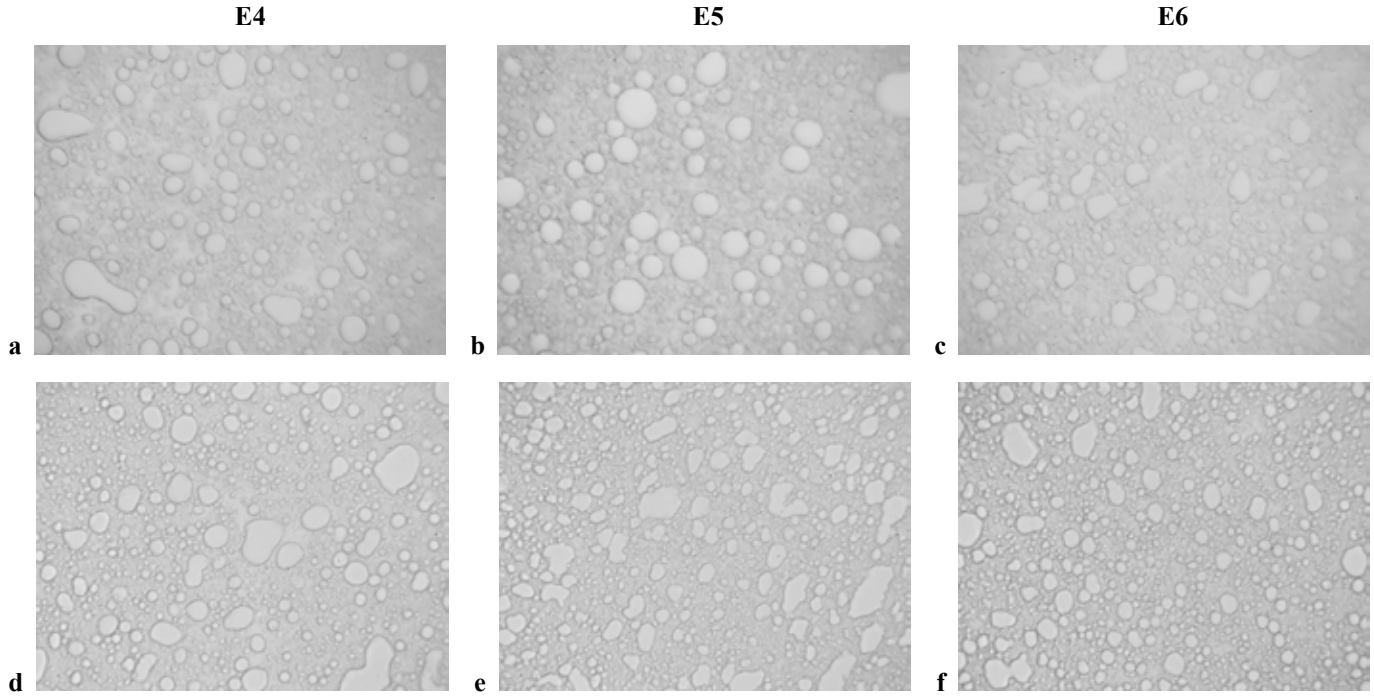

Fig. 6. Microphotographs of the prepared emulsions (E4, E5, E6) (G x 400) (a, b, c – after 24h from manufactoring and d, e, f – after 30 days).

Rys. 6. Zdjęcia emuslji (E4, E5, E6) wytworzonych po 24 godzinach (a, b, c) i po okresie 30 dniowym (d, e, f) (G x 400).

Source: Own study

Źródło: Opracowanie własne

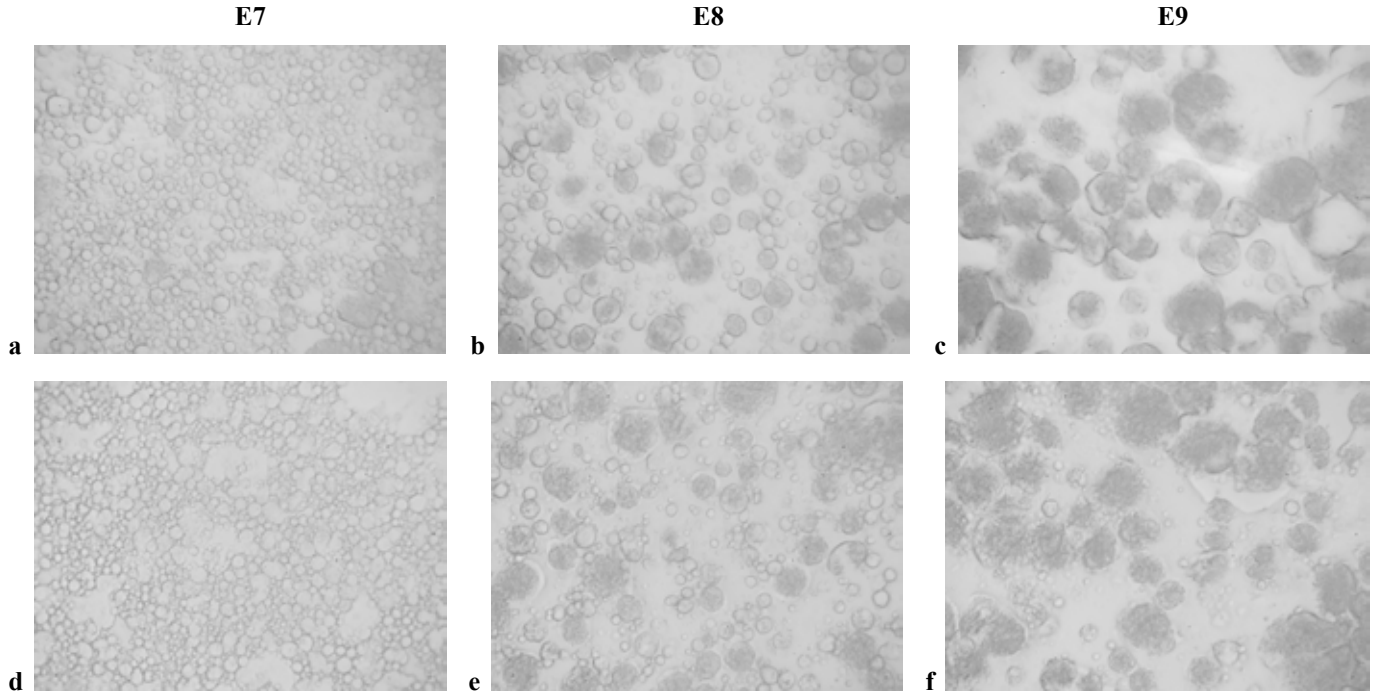

Fig. 7. Microphotographs of the prepared emulsions (E7, E8, E9) (G x 400) (a, b, c – after 24h from manufactoring and d, e, f – after 30 days).

Rys. 7. Zdjęcia emulsji (E7, E8, E9) wytworzonych po 24 godzinach (a, b, c) i po okresie 30 dniowym (d, e, f) (G x 400).

Source: Own study

Źródło: Opracowanie własne

The stability of the dispersion system is one of the most important parameters determining the possibility of its introduction to the market. Testing the emulsion with the Turbiscan test allows you to detect any instabilities in the early phase that are invisible to the naked eye. Turbiscan determinations, based on transmitted (T) and backscattered (BS) light intensity was used to analyze the stability or any instabilities occurring in manufactured emulsions. Figures 7,8,9,10 show backscattered light intensity profiles of the all emulsions. The backscattered light intensity is related to the stability of an emulsion – more precisely to the physical processes occurring during storage. The profiles are presented in a reference mode, which means that the initial scan is presented as a baseline (ΔBS = 0%). When analyzing the intensity of the backscattered light for the emulsions E1, E2, E3, a decrease in the intensity was observed, especially in the lower part of the vial (Figure 7). There was light transmission through the vial. Such changes determine creaming type instabilities. Generally, the destabilization process for all the mentioned emulsions started on the fifth day on average. The following days, with different dynamics, deepened these changes. There was no effect of protein content for these systems. The confirmation of the destabilization changes that occurred for these systems was the visual assessment, which showed a clear delamination of the emulsions E1, E2, E3 after a 30-day storage period (Figure 8).

In turn, for emulsions containing mixed fat, changes in the size of the emulsion particles were observed. The curves recording changes from individual measurements did not overlap. The center of the graphs clearly indicated the separation of individual lines, which confirmed that with each measurement of the particle size it increased. The graphs for the individual emulsions E4, E5, E6 looked similar, therefore it can be assumed that the variable content of protein from algae did not affect the stability of these systems. However, the above changes were not observable during the visual evaluation of these emulsions (Figure 10).

When analyzing the graphs for emulsions (E7, E8, E9), a decrease in the intensity of backscattered light was observed, similarly to the first three emulsions (Figure 11).

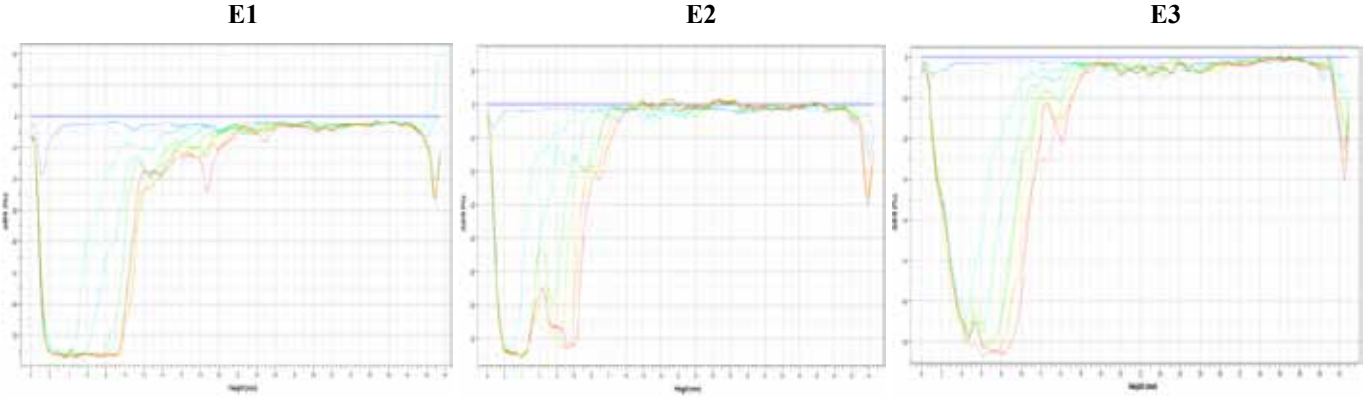

Fig. 8. Backscattered light intensity profiles of the prepared emulsions in reference mode E1, E2, E3.
Rys. 8. Krzywe przedstawiające natężenie światła wstecznie rozproszonego dla emulsji E1, E2, E3.
Source: Own study
Źródło: Opracowanie własne

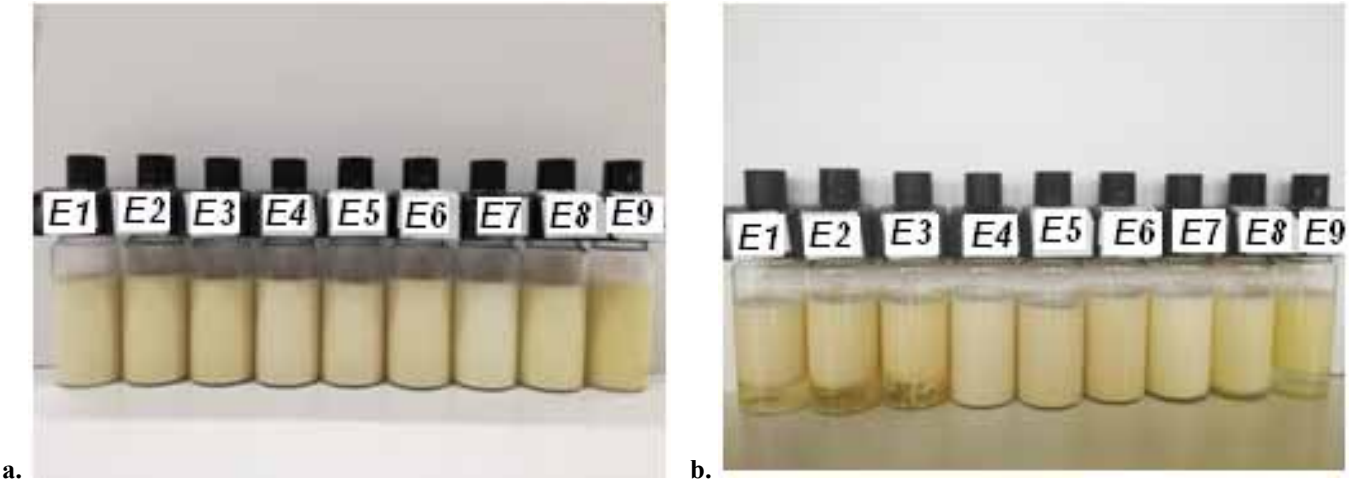

Fig. 9. Visual appearance of the emulsions a) after 24h, b) after 30 days of storage.
Rys. 9. Wizualna ocena emulsji a) po 24h b) po 30 dniach przechowywania.
Source: Own study
Źródło: Opracowanie własne

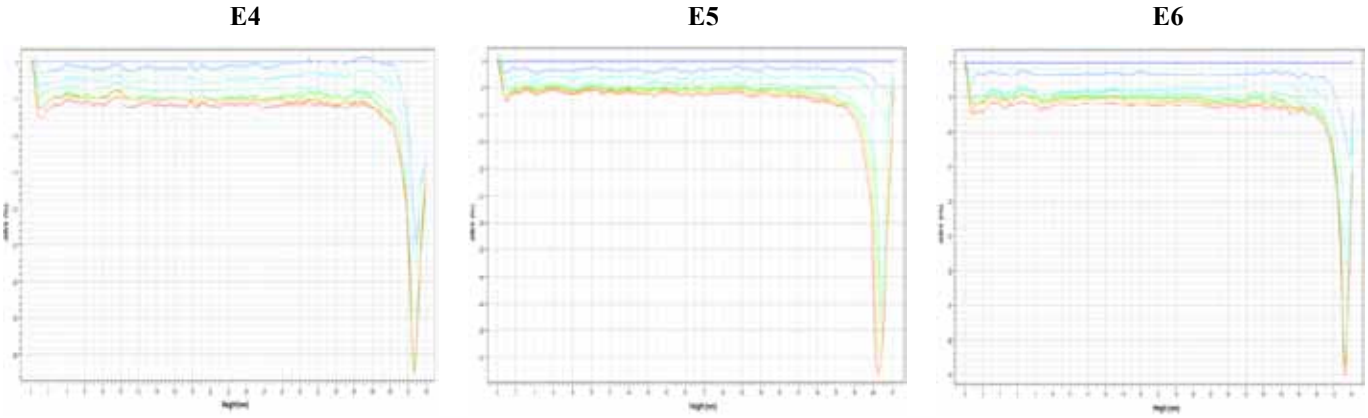

Fig. 10. Backscattered light intensity profiles of the prepared emulsions in reference mode E4, E5, E6.
Rys. 10. Krzywe przedstawiające natężenie światła wstecznie rozproszonego dla emulsji E4, E5, E6.
Source: Own study
Źródło: Opracowanie własne

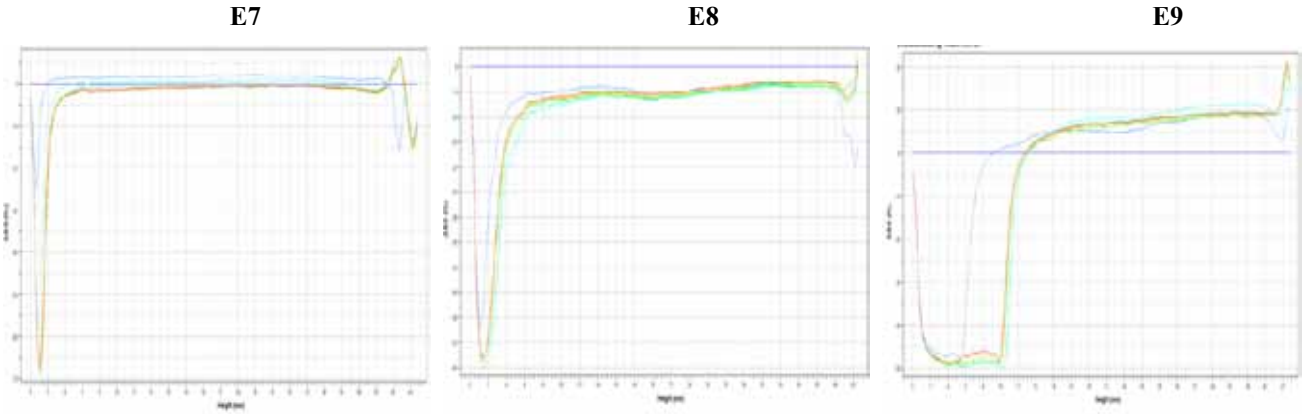

Fig. 11. Backscattered light intensity profiles of the prepared emulsions in reference mode E7, E8, E9.
Rys. 11. Krzywe przedstawiające natężenie światła wstecznie rozproszonego dla emulsji E7, E8, E9.
Source: Own study
Źródło: Opracowanie własne

For emulsions E7 and E8, these changes are subtle and poorly perceptible during visual assessment (Figure 8). On the other hand, the record for emulsion 9 is synonymous with the creaming process started early and it is deepened during subsequent determinations (increase in the transmission of light transmitted through the vessel, in the lower part). For emulsions where the fat phase was interesterified fat, the worse stability was observed when the protein content was the highest, i.e. 1.2 grams. Thus, the higher algae protein content was not a good stabilizer or viscosity modifier for these systems.

SUMMARY AND CONCLUSIONS

The colorimetric examination showed that all emulsion variants showed a distinct shade of green. As the algae protein content in the emulsions increased, the color approached yellow.

The highest hardness values among the prepared preparations had emulsions based on mixed fats, and the lowest ones based on hemp oil. In emulsions with the lowest content of algae protein (0.4 g) apart from E3 emulsion, the hardness was the highest.

The highest values of the adhesion force were characteristic for emulsions based on mixed fats, which means the best application properties of these systems. The lowest values were recorded for hemp oil-based emulsions. The variable amount of added algae protein to the emulsion had no major impact on this parameter.

The emulsions containing mixed fat as the fat base were characterized by the highest viscosity values. On the other hand, the lowest values of this parameter were recorded for emulsions based on hemp oil. The unequivocal effect of the algae protein in the systems on the viscosity was not determined.

In the microscopic examination, the dropets of the fat phase of the E7 emulsion containing the interesterified fat and 0.4 g of protein had the smallest particle. The droplet size increased with the addition of protein in all emulsions.

The analysis of the backscattered light intensity showed that all hemp oil based emulsions showed destabilization characteristics throughout the storage period. On the other hand, the results of the analysis of the turbiscan test for emulsions based on mixed fats showed an increase in the size of the emulsion particles over time, although no clear destabilization

of these systems was recorded. Poor emulsion stability was also observed for emulsions containing interesterified fats. Changes in the „creaming" type were observed in all systems. The higher addition of algae protein significantly worsened the stability of these systems.

The study did not manage to select an emulsion with high stability, therefore, in order to create more stable systems, the research should be extended to change the amount or type of protein, or to select a different viscosity modifier.

PODSUMOWANIE I WNIOSKI

Badanie kolorymetryczne wykazało, że wszystkie warianty emulsji wykazywały wyraźną tonację zabarwienia zielonego. Wraz ze wzrostem zawartości białka z alg w emulsjach barwa zbliżała się do żółtej.

Najwyższymi wartościami twardości spośród przygotowanych preparatów charakteryzowały się emulsje na bazie mieszaniny fizycznej, zaś najniższymi emulsje na bazie oleju konopnego. W emulsjach z najmniejszą zawartością białka z alg (0,4 g) poza emulsją E3, twardość była najwyższa.

Najwyższymi wartościami siły adhezji charakteryzowały się emulsje sporządzone na bazie tłuszczów mieszanych, co oznacza najlepsze właściwości aplikacyjne tych układów. Najniższe wartości zanotowano dla emulsji na bazie oleju konopnego. Zmienna ilość dodanego białka z alg do emulsji nie miała kluczowego wpływu na ten parametr.

Najwyższymi wartościami lepkości charakteryzowały się emulsje zawierające jako bazę tłuszczową mieszaninę fizyczną oleju konopnego z łojem baranim. Natomiast najniższe wartości tego parametru zanotowano dla emulsji na bazie oleju konopnego. Nie udało się określić jednoznacznego wpływu białka z alg w układach na wartość lepkości.

W badaniu mikroskopowym krople fazy tłuszczowej emulsji E7 zawierającej tłuszcz przeestryfikowany i 0,4g białka, posiadały najmniejszą cząstkę. Rozmiar kropel wzrastał wraz z dodatkiem białka we wszystkich emulsjach.

Analiza natężenia światła wstecznie rozproszonego wykazała, że wszystkie emulsje na bazie oleju konopnego wykazywały cechy destabilizacji w całym okresie przechowywania. Z kolei rezultaty analizy testu turbiscan dla emulsji na bazie tłuszczów mieszanych wykazały przyrost wielkości cząstek emulsji w czasie, aczkolwiek nie zarejestrowano wyraźnej destabilizacji tych układów. Słaba stabilność emulsji również została zaobserwowana dla emulsji zawierających tłuszcze. We wszystkich układach zaobserwowano zmiany typu „śmietankowania". Wyższy dodatek białka z alg wyraźnie pogorszył stabilność tych układów.

W pracy nie udało się wytypować emulsji o wysokiej stabilności, dlatego w celu stworzenia bardziej stabilnych układów należy rozszerzyć badania w kierunku zmiany ilości lub rodzaju białka, bądź wytypowania innego modyfikatora lepkości.

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