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New Fat Bases in Model Emulsion Systems in Physicochemical and Consumer Evaluation

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Abstract: The purpose of this study was to indicate the validity of using enzymatically interesterified fats as a fat emulsion base. A study was conducted to determine the stability of emulsion systems based on enzymatically interesterified fats and fats containing mixed fats. The fats used in the modifications were mutton tallow and hemp oil. It was found that emulsions based on esterified fats, regardless of the type of modified fat, showed a higher shelf life and had high homogeneity. On the other hand, emulsions based on mixed fats already showed destabilization characteristics in the first days. Their structure was heterogeneous. Microscopic evaluation clearly showed large droplets of the dispersed phase, indicating a tendency to delaminate. Consumer evaluation showed that the sensory quality of the presented emulsion systems based on enzymatically interesterified fats was fully accepted by the participating consumers. Based on the results of the study, it was concluded that all of the consumer-evaluated emulsions received good or very good acceptance in terms of the sensory characteristics evaluated.

Keywords: consumer's evaluation; emulsions; viscosity modifiers; interesterified fat; new product

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1. Introduction

Modern research on emulsion bases is being conducted in an effort to create more stable, efficient and customized products. The proper selection of raw materials in the development of formulations is essential to achieve stable and acceptable products [1,2]. In this context, enzymatic interesterified fats are an interesting area of research because interesterification can affect the physicochemical properties of fats]. By analyzing the interactions between emulsion components, such as oils, surfactants and thickeners, it is possible to understand the stabilizing mechanisms [3–5] and predict the properties of emulsions with different applications. Such research can help optimize emulsion formulations for application and use. No less important is sensory research, which focuses on the consumer perception of products [6]. The proper selection of emulsion components and the optimization of technological processes allows researchers to obtain products with the desired organoleptic qualities [1]. Sensory testing makes it possible to assess consumer acceptability and preference, which is crucial to the commercial success of new products [7]. In a highly competitive market, involving consumers in the product evaluation process from the design stage is an important factor in the future success of a product. As Arrieta-Escobar et al. [8] point out, due to the infinite number of possible combinations of ingredients and their corresponding concentrations, an important issue is how to reduce the search space at early stages to speed up the design process. In addition to the most relevant physicochemical properties of a product, it is important to consider its performance as perceived by the consumer. Well-chosen sensory properties can improve consumer acceptance and product

sales. The aim of the study was to indicate the validity of using enzymatically interesterified fats as a fat emulsion base and to test whether they can form a stable system with selected thickeners without additional emulsifiers.

2. Materials and Methods

2.1. Research Material

In this investigation, unrefined cold-pressed hemp seed oil sourced from Oleofarm, Wrocław, Poland and mutton tallow obtained from Meat-Farm Radosław Łuczak, Stefanowo, Poland served as the primary lipidic substrates. The purification process of the mutton tallow involved the utilization of bleaching earth procured from HRT Polska, Kołobrzeg, Poland. Enzymatic interesterification reactions were facilitated by employing a lipase derived from Rhizomucor miehei, which was immobilized on immobead 150 with an activity of $\geq$300 U g^{-1}, sourced from Sigma Aldrich, Saint Louis, MO, USA. For the development of emulsion-based products using enzymatically modified fats, five distinct types of texture modifiers, delineated in Table 1, were incorporated. To ensure preservation in the emulsions, the commercial formulation Euxyl K712, supplied by Schülke & Mayr GmbH, Norderstedt, Germany, containing an aqueous blend of sodium benzoate and potassium sorbate, was utilized.

Table 1. Viscosity modifiers used in the work.

Trade Name	Texture Modifier	Manufacturer	Symbol
NA	Carboxymethylcellulose	Barentz International BV (Hoofddorp, The Netherlands)	CMC
Methocel 40-0101	Hydroxypropyl methylcellulose	Dow (Midland, MI, USA)	HPMC
Rheocare XGN	Xanthan gum	BASF (Ludwigshafen, Germany)	XG
Actigum VSX 20	Xanthan gum and scleroglucan	Cargill (Krefeld, Germany)	XGSG
Vivapur CS 032 XV	Xanthan gum and microcrystalline cellulose	J. Rettenmaier & Söhne (Rosenberg, Germany)	XGCM

NA—not applicable.

2.2. Preparation of Research Material

2.2.1. Treatment of Mutton Tallow

The first process to which mutton tallow was subjected was rendering, which was intended to separate the fat from the remains of other tissues. The tallow was then subjected to a bleaching process to remove unwanted haem pigments. For this purpose, the rendered tallow in the amount of 150 g was transferred into a 250 mL round-bottomed flask and heated to 80 °C by means of a heating mantle, and bleaching earth was added in an amount equal to 2% *w*/*w* of the mass of fat to be bleached. The process was carried out at 80 °C for one hour under reflux. After the process the bleaching earth was separated from the fat using hot filtration (70 °C).

2.2.2. Procedure for the Enzymatic Modification of the Fatty Blends of Mutton Tallow and Hemp Seed Oil

The blends used in the research part of the work were prepared by weighing 150 g of fats into 250 mL Erlenmeyer flask. The fat blends used in this study contained the following mass ratios of mutton tallow and hemp seed oil: 3:1, 3:2, 3:3. The blends were then placed in a shaker (SWB 22N, Labo Play, Bytom, Poland) equipped with a water bath and stirred for 20 min at a rotation rate of 200 rpm at 70 °C to obtain homogeneity in the systems. Each of the blends prepared in this way was divided into two parts, one of which was subjected to the enzymatic interesterification reaction and the other one being the control sample (hereafter referred to as non-interesterified blend or unmodified blend).

The fat blends were thermostated at 60 °C for 15 min in a shaker (SWB 22N, Labo Play, Bytom, Poland) equipped with a water bath. Then, an enzyme catalyst (immobilized lipase) was added to the heated blends in an amount of 5% *w*/*w* relative to the weight of the reaction substrates and a precalculated amount of distilled water to produce a sufficient amount of a mixture of incomplete acylglycerols as an emulsifier for the subsequently produced emulsions. The reaction was carried out for 6 h at 60 °C in a shaker using a stirring rate of 200 rpm. To complete the reaction, the enzyme was filtered off on a Büchner funnel using paper filters at the reaction temperature. The blends were dried with anhydrous sodium sulphate, which was then filtered as described above.

2.2.3. Parameters and Procedure for Producing Emulsion Systems

The fat phase was a mixture of an enzyme-modified fat mixture of sheep tallow and hemp oil or a physical mixture of these fats, prepared in different ratios (Table 2). The aqueous phase of the emulsions consisted of aqueous solutions of texture modifiers, which were prepared by adding the thickeners in portions to a beaker with water placed on a magnetic stirrer (Table 3). The solution was stirred on the stirrer for 30 min, then homogenized for 1 min and left for 24 h. The homogenization of the aqueous phase with the fatty phase was carried out after bringing them to 50–55 °C using an ULTRA-TURRAX T18 rotor-stator homogenizer equipped with a S18G-19G dispersing tool (IKA, Shanghai, China). The preservative was added as the last component of the emulsion. The weight of each emulsion was 100 g.

Table 2. Characteristic of emulsions E1–E5.

Emulsion Symbol	Type of Fatty Phase	Texture Modifier Content % *w*/*w*	Texture Modifier Type	Emulsifier Content % *w*/*w* *	Type of Emulsifier
E1/E1′	T1/T1′	0.6	HPMC	7.4	DAG and MAG produced during interesterification/hydrolysis of mutton tallow and hemp seed oil blends
E2/E2′	T2T2′		XGSC	7.2	
E3/E3′	T2/T2′		CMC	7.4	
E4/E4′	T3T3′		XGMCC	7.4	
E5/E5′	T3/T3′		XG	7.4	

Legendary: T1—interesterified fat mixture with a mutton tallow to hemp oil ratio of 3:1; T2—interesterified fat mixture with a mutton tallow to hemp oil ratio of 3:2; T3—interesterified fat mixture with a mutton tallow to hemp oil ratio of 3:3; * only for emulsions with interesterified fats, no emulsifier for emulsions containing mixed fat.

Table 3. Composition of emulsions E1–E5.

General Composition of the Emulsion	
Fatty phase:	
- unmodified fat blends or enzymatically modified fat blends with emulsifiers (mono- and diacylglycerols)	30% *w*/*w*
Water phase:	
- Texture modifier (CMC or HPMC or XG or XGSG or XGCM)	70% *w*/*w* 0.6 or 0.8 or 1.0% *w*/*w*
- Water	up to 100 g q.s.
Preservative (Euxyl K712)	
Phase temperature before homogenisation	
Water phase	50–55 °C
Fatty phase	50–55 °C
Homogenisation parameters	
Type of homogenization Homogenization time Speed of rotation	mechanical 4 min 18,500 rpm

q.s.—(quantum satis) as much as necessary.

2.3. Methods

2.3.1. Evaluation of Processes Occurring in Emulsions during Storage and Microstructure Evaluation of Emulsion Systems

A detailed evaluation methodology evaluation of the processes occurring in emulsions during storage and a microstructure evaluation of emulsion systems are provided by Kowalska et al. [9].

2.3.2. Consumer Evaluation of Emulsions

Consumer evaluation was performed on selected emulsions with different types of texture modifiers, selected from systems E1–E75, which showed the least progress in destabilization processes during their storage (2–7 °C, 30 ± 1 days). The study was conducted in the sensory analysis laboratory of the Krakow University of Health Promotion. Both the planning and the execution of the consumer assessment took into account the assumptions of international standards, sensory analysis literature [10,11] and the general requirements of ISO 11136 [12] for conducting hedonic tests with consumers in a controlled area. The recruitment of consumers performing the assessment followed the requirements of the aforementioned standard. Participation in the tests was voluntary; it was possible to resign from the tests at any stage of the study. The criteria for exclusion comprised pregnant or lactating women, as well as individuals exhibiting skin sensitivities. The inclusion criteria for the study were: informed consent and willingness to actively participate in the study, age ≥18, use of cosmetic emulsions. 107 women aged 19–25 years (average age—21.4) were recruited among cosmetology students at the Krakow University of Health Promotion. The following residence structure was observed among the consumers: village—22%, town up to 20 thousand inhabitants—9%, town 20 thousand–100 thousand inhabitants—16%, town 101 thousand–500 thousand inhabitants—8%, town above 501 thousand inhabitants—45%. Consumers performed the assessment on a voluntary basis, having previously expressed their interest in the subjects presented.

Beforehand the test samples were placed in identical containers for each assessor and coded with three random numbers to prevent identification by respondents. Assessors were given samples in a set of five in a randomized order to avoid the sequence of sample administration affecting their mean score. No information about the characteristics of the samples was given to the assessors during the session. The test was conducted at room temperature, in a comfortable environment for consumers with uniform lighting in the station. The assessors did not communicate with each other, and any distractions were eliminated.

After expert analysis conducted by specialists in the field of cosmetology and the cosmetic industry, five significant characteristics related to cosmetic emulsions were selected. These features have been recognized as crucial in the context of product evaluation by consumers. The evaluation was carried out to determine which of the five samples tested achieves higher desirability in terms of the characteristics tested, such as consistency, spreading, greasiness, absorption and hydration. A five-point hedonic verbal scale was used. In assessing all the attributes, consumers were asked to rank the tested samples according to their own preference from the most preferred product to the least.

2.3.3. Statistical Analysis of the Results

Statistica 13 software (Statsoft, Krakow, Poland) was used to perform the statistical analysis of the results. One-way analysis of variance (ANOVA) was used to analyze the experimental results, and Tukey's test was used to determine the significance of differences between means ($p \leq 0.05$). The non-parametric Kruskal–Wallis test and the multiple comparisons test were used to assess differences between the samples in the case of consumer evaluation.

3. Results and Discussion

Emulsion stability is the primary factor that determines the quality of these systems [13]. In this study, emulsions prepared on the basis of modified and unmodified fats containing different thickeners were evaluated. In general, emulsions based on modified fat in the evaluation of changes causing destabilization in the emulsion system were evaluated positively. Regardless of the thickener used, the emulsions did not show clear destabilizing changes (evaluation by Turbiscan test). After 30 days of storage, the emulsions were stable (Figure 1). In order to evaluate the effect of the fat phase modification process on the quality of the obtained emulsions, the behavior of the same emulsions but containing mixed fat was verified.

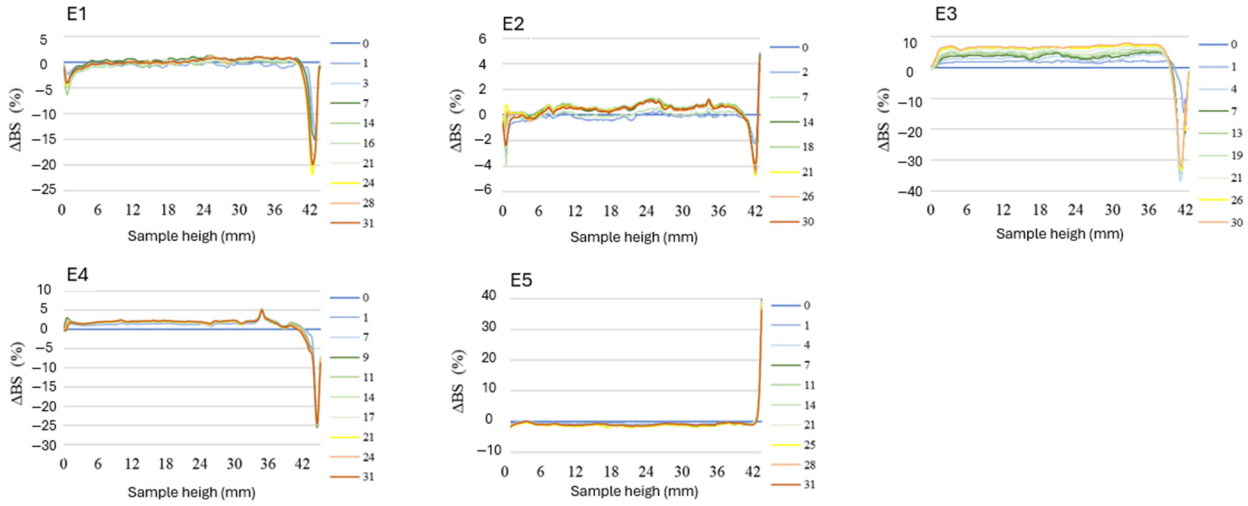

Figure 1. Profiles of changes in backscattered light intensity as a function of sample height for emulsions E1–E5 when stored for 30 days at 25 °C. Legendary: The colors of the lines represent the day of the test.

The profiles of ΔBS as a function of sample height in the reference mode for emulsions E1′–E5′ are presented in Figure 2. Analyzing the changes in the backscattered light intensity for the E3′ emulsion, it was observed that this system was characterized by significant destabilization changes that had already started in the first days after preparation. The course of ΔBS curves from successive scans did not overlap with each other. This clearly indicated flocculation and coalescence processes that led to an increase in the mean droplet size of the dispersed phase. The averaged ΔBS values in the middle of the graphs significantly exceeded 10.0% after storage (17.6%), suggesting that the system was highly unstable [14]. This emulsion also had the highest TSI value after the storage period, which exceeded the value of 16.0 (Figure 3). On this basis, this system was classified as category C, indicating its poor stability.

Analysis of the ΔBS profiles of the E1′ system showed that several destabilization processes occurred simultaneously in this system. Increased fluctuations in the parts of the graph corresponding to the upper and lower zones of the measurement vial indicated that a gravitational separation process had started in this system [15]. It was also found that the mean ΔBS values in the middle part of the graphs exceeded 2.0%, indicating that flocculation or coalescence processes had occurred in this system. The obtained TSI value of the E1′ system was around 6.1, which qualified this emulsion for category C, indicating its poor stability.

Analyzing the ΔBS profiles of systems E2′, E4′ and E5′, it was found that the BS changes in the parts of the graphs corresponding to the central zone of the measurement vials were insignificant, reaching a value below 2.0%. Such a value may suggest that in these systems flocculation or coalescence processes did not occur [14]. However, due to the changes in BS values in the parts of the graphs corresponding to the upper levels of

the measuring vials, it was concluded that creaming was the dominant process in these systems. TSI values determined after 30 days of storage for systems E5′ and E2′ were 4.7 and 4.6, respectively. On this basis, they were classified in category C, indicating poor stability. On the other hand, the value of the stability coefficient of emulsion E4′ was not consistent with the TSI results determined for emulsions E2′ and E5′, as it was 2.6, which classified this system in category B (satisfactory stability).

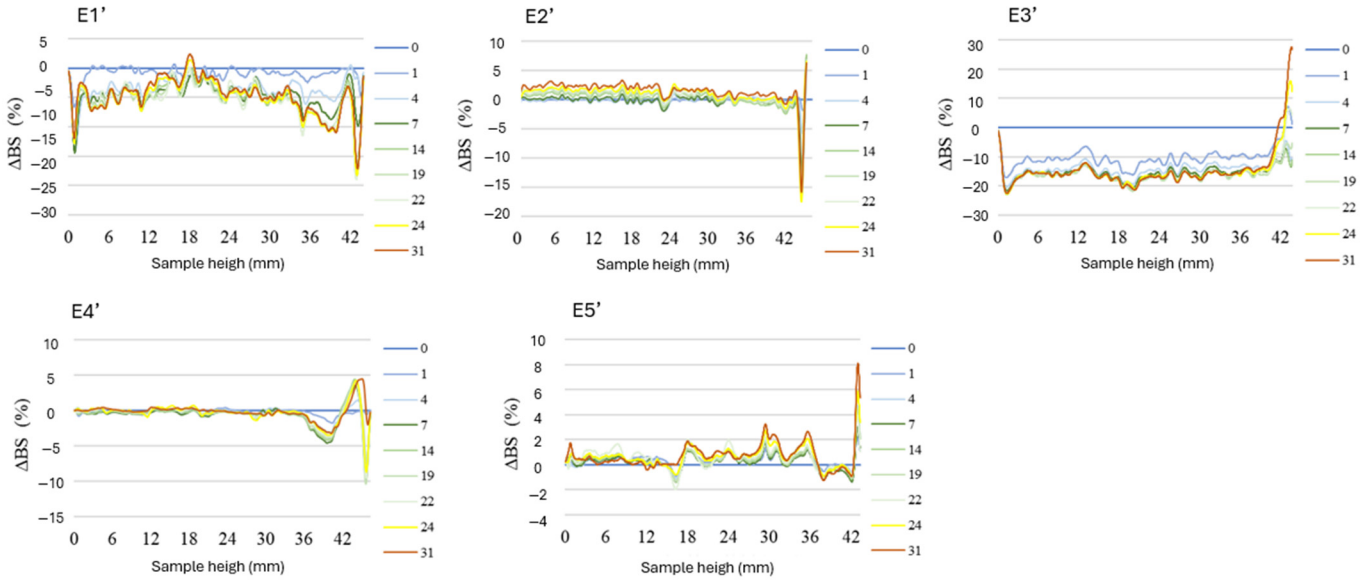

Figure 2. Profiles of changes in backscattered light intensity as a function of sample height for emulsions E1′–E5′ when stored for 30 days at 25 °C. Legendary: The colors of the lines represent the day of the test.

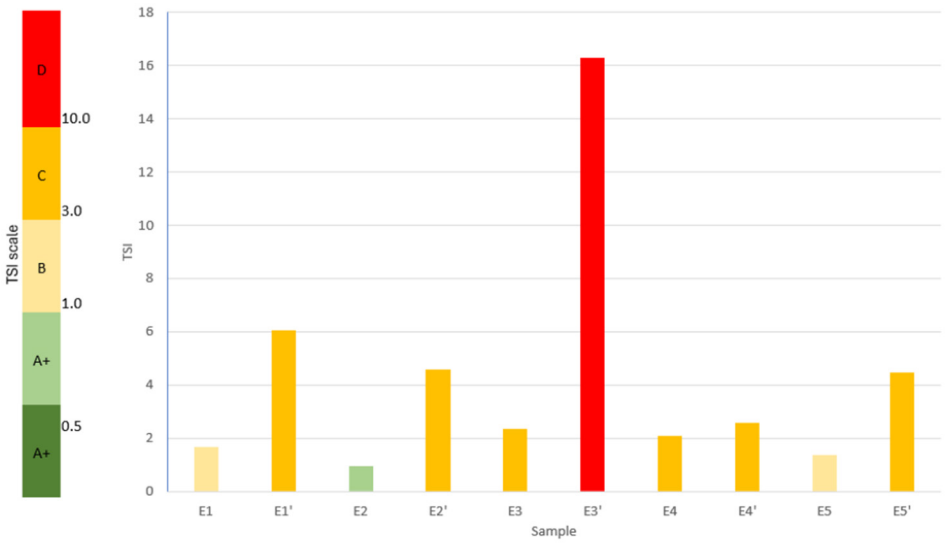

Figure 3. TSI values of emulsions E1–E5 and E1′–E5′ stored for 30 days at 25 °C.

Analyzing the stability coefficient values obtained for emulsions E1′, E2′, E3′ and E5′ it was found that they were characterized by statistically significantly ($p \leq 0.05$) higher TSI values than the corresponding emulsions containing modified fat with an assumed amount of emulsifiers (mono- and diacylglycerols) obtained during modification (E1, E2, E3, E5). Among the analyzed systems, only emulsion E67′ was characterized by a TSI value that did not differ statistically significantly ($p > 0.05$) from the corresponding emulsion E4. This means that in the case of selected systems stabilized with CMC, HPMC, XG and

XGSG, the application of a modified fatty phase increased the stability of these emulsion systems significantly.

Photographs of vials of emulsions E1–E5 and their equivalents E1′–E5′ taken after 30 days of storage are shown in Figure 4. After the storage period, no changes visible to the naked eye were observed for either emulsions containing interesterified fat or those containing mixed fat. Nevertheless, it could be observed that emulsions E1–E5 were characterized by a uniform, light color and a homogeneous, smooth structure. On the other hand, systems produced on the basis of unmodified fat blends were characterized by color inhomogeneity clearly visible on photographs, and their structure clearly showed strong granulation (the form of fine porridge). This observation is consistent with the information given by Zhu et al. [16], who reported that the process of interesterification is a process that improves the structure and consistency of fats, making them more homogeneous (without clear boundaries, i.e., cracks) in contrast to the modification of the physical mixing of fats. Hence, the choice of fat in this case as the fatty base of an emulsion was crucial for the evaluation and quality of these systems.

Figure 4. Photograph of emulsions E1–E5 and E1′–E5′ after 30 days storage at 25 °C.

Photographs showing the microstructure of all systems are shown in Figure 5. In general, it can be concluded that the systems based on the interesterified fats (E1–E5) were characterized by a favorable microstructure image, where droplets of the dispersed phase with similar dimensions could be observed, which were uniformly distributed throughout the sample. After the storage period no clear changes in the microstructure image of these emulsions were recorded. Analyzing photographs of emulsions containing unmodified fat, it was found that their microstructure was clearly different from that observed for emulsions prepared on the basis of interesterified fats. The microstructure of systems E1′ and E2′ was most similar to that observed for the corresponding emulsions containing modified fat (E1 and E2). The microstructure image of the E1′ and E2′ systems recorded 24 h after their preparation was characterized by uniformly distributed droplets of similar but large diameter. After storage, the microstructure of these systems (E1′ and E2′) did not change significantly. The microstructure of systems E3′, E4′ and E5′ observed 24 h after their preparation was characterized by droplets of varying sizes, irregularly distributed throughout the sample. Additionally, for these systems, no significant changes in the microscopic image were observed after the storage period.

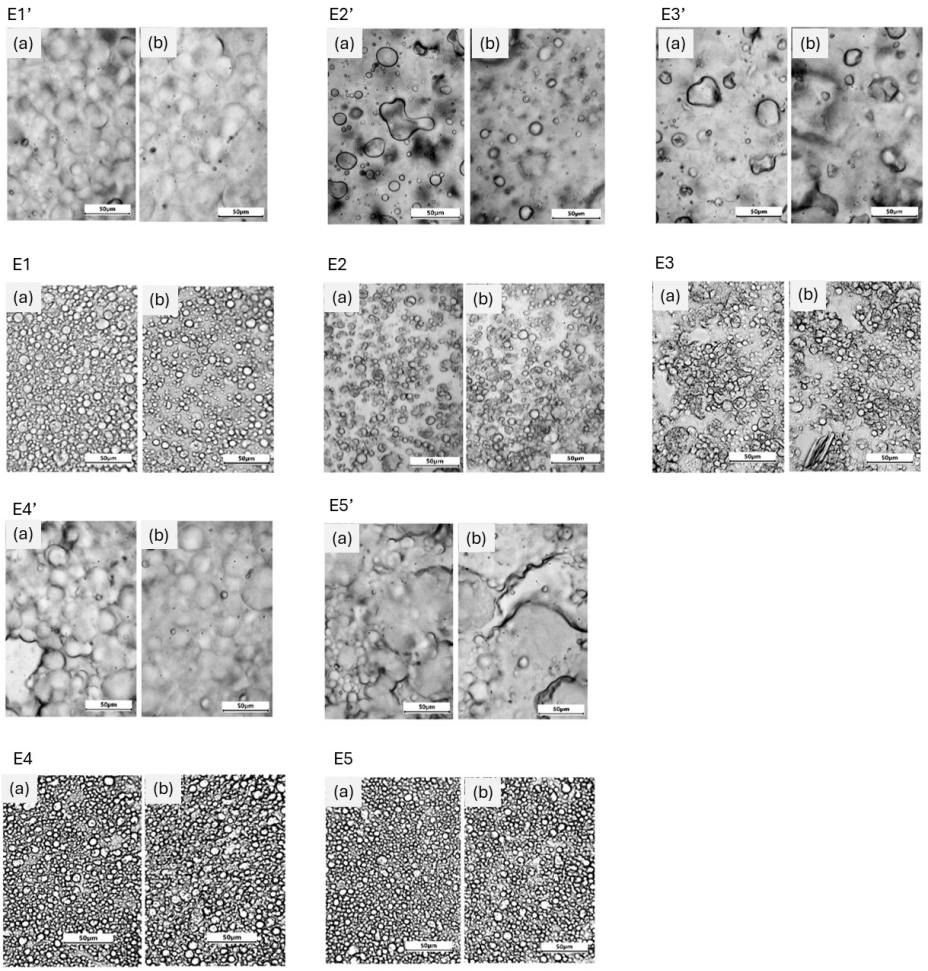

Figure 5. Microstructure of emulsions E1–E5 and E1′–E5′ (**a**) 24 h after preparation and (**b**) after 30 days of storage (G × 400).

Figure 6 shows the mean droplet diameter of the dispersed phase of the modified fat-based systems (E1–E5) and their corresponding mixed fat-based systems (E1′–E5′) when stored for 30 days at 25 °C. After the storage period, emulsions containing interesterified fat were characterized by a dispersed phase droplet diameter ranging from 3.4 to 7.7 µm. Of these systems, the lowest value was recorded for emulsion E5 stabilized with xanthan gum, and the highest for system E4 stabilized with xanthan gum and microcrystalline cellulose. Emulsions containing unmodified fat were characterized by significantly higher dispersed phase droplet diameter values than their counterparts containing modified fat, both after manufacture and throughout storage. Considering the systems containing unmodified fat blends, the lowest value of the dispersed phase droplet diameter after the storage period (18.5 µm) was recorded for system E1′ stabilized with hydroxypropyl methylcellulose. Meanwhile, the highest value for the same time point (33.5 µm) was recorded for system E3′, in which carboxymethylcellulose was used as thickener. The mean droplet size of systems E1′, E2′, E3′ and E4′ remained unchanged during storage; only system E3′ showed a significant increase.

The influence of the enzymatic modification of fatty phases on the viscosity of the analyzed emulsion systems varied (Figure 7). Emulsions E3′ and E1′ were characterized by lower viscosity values than their counterparts containing modified fat (E3 and E1), regardless of the spindle speed used. System E5′ was characterized by lower viscosity values than emulsion E5 only at a spindle speed of 2 rpm, while at a higher spindle speed the viscosity values obtained for this system were lower than for the E system. Emulsions

E2′ and E4′ were characterized by significantly higher viscosity values than emulsions E2 and E4.

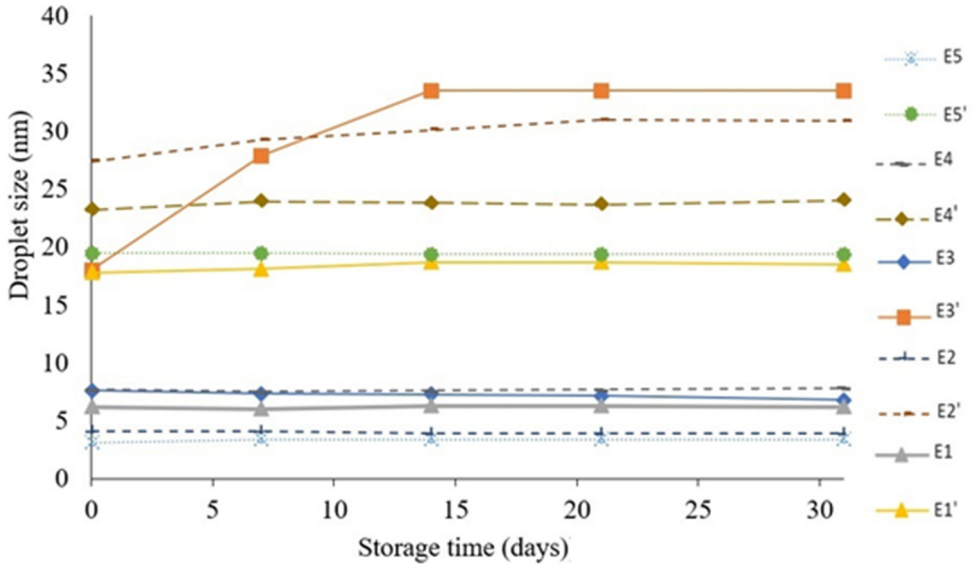

Figure 6. Droplet diameter of dispersed phase of emulsions E1–E5 and E1′–E5′when stored for 30 days at 25 °C.

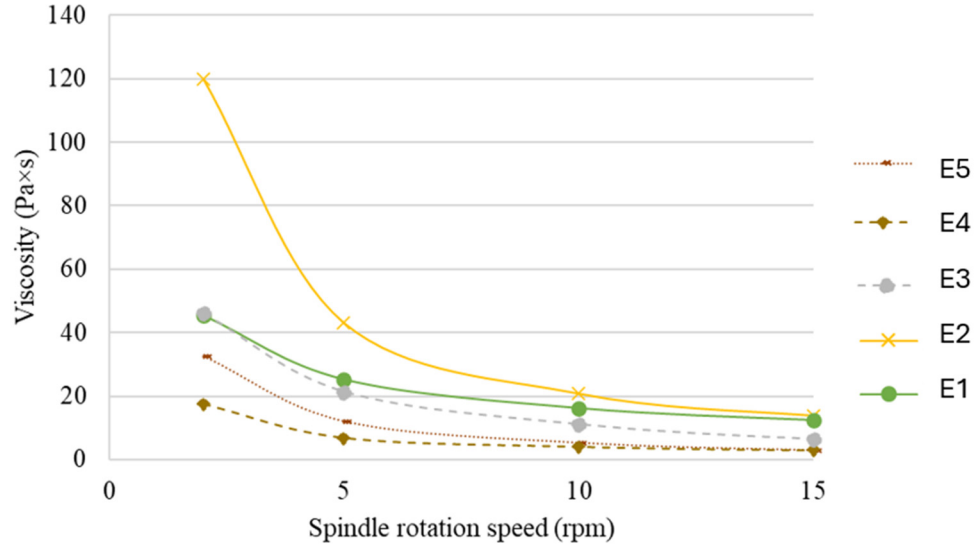

Figure 7. Viscosity of emulsion systems E1–E5 and E1′–E5′ determined 48 h after their preparation.

Based on the above results, it can be concluded that the applied interesterified fat significantly affected the quality of emulsion systems. The analysis showed that the use of an interesterified fat blend containing in its composition incomplete acylglycerols allows for a more stable and durable system to be obtained. The systems prepared on the basis of unmodified fats stabilized only with texture modifiers, i.e., CMC, HPMC, XG, XGSG and XGMCC, were characterized by significantly lower quality. These systems clearly differed in their appearance from emulsions containing modified fat.

Due to the limited shelf life of systems containing mixed fat, it was not reasonable to subject these emulsions to sensory evaluation. Therefore, only emulsions based on interesterified fat were sensory evaluated.

As Szakiel and Turek [17] point out, both organoleptic and sensory tests are among the most effective tools for product evaluation from the consumer's point of view. These authors mention that sensory impressions play a large role in consumers' perception of

product quality. Consumer evaluation in the context of sensory testing is one of the most valuable ways to indicate desirability as well as preference for products [18].

Figure 8 shows the appearance of the produced emulsions in the same vessels. As noted earlier in the work, the emulsions were compact and did not delaminate. They differed slightly in color. The most yellow shades in the visual evaluation were observed for emulsion E4. In general, this is one of the two emulsions where the proportion of hemp oil is the same as that of tallow in the fat mixture of the emulsion. The consumer evaluation of the emulsions prepared on the basis of interesterified fats and containing a fixed amount of different thickeners was carried out in terms of such tested characteristics as consistency, spreading, greasiness, absorption and hydration.

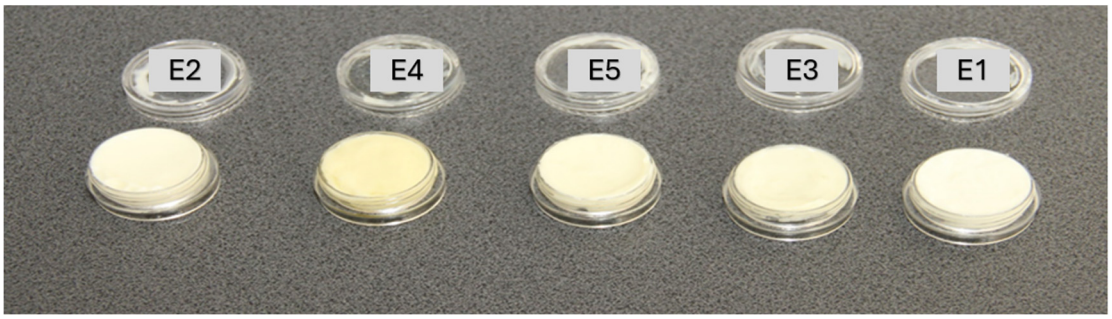

Figure 8. Appearance of samples of emulsion systems submitted for consumer evaluation.

The distribution of consumer responses in terms of the studied characteristics of emulsion systems E1–E5 is shown in Figure 9. Most responses, on a five-point scale, were at the level of four or five points. The distribution of responses varied for individual samples, but it can be concluded that the sensory quality of all tested emulsions evaluated by consumers was at a high level. The determination of the significance of differences between the analyzed parameters was performed using the non-parametric Kruskal–Wallis test. In turn, in order to verify between which of the analyzed samples of emulsion systems there were statistically significant differences in their evaluation, a multiple comparison test was performed. The p-value ≤ 0.05 obtained for this test indicated statistically significant differences between the systems tested. The E2 and E3 systems had the highest consumer desirability for the consistency parameter (Figure 9). The data obtained suggest that CMC and XGSG were the most favorable thickeners to the consumers of this study. Scores for the consistency of systems E2 and E3 were statistically significantly different ($p \leq 0.05$) from those obtained for systems E4 and E5 (Table 4). In contrast, the scores obtained for system E1 were not statistically significantly different from the other systems analyzed (E2, E3, E4, E5) ($p > 0.05$).

Table 4. Multiple comparison values for the consistency parameter.

	E1	**E2**	**E3**	**E4**	**E5**
E1	-	0.054	0.092	1.000	1.000
E2	0.054	-	1.000	0.013	0.011
E3	0.092	1.000	-	0.023	0.020
E4	1.000	0.013	0.023	-	1.000
E5	1.000	0.011	0.020	1.000	-

Emulsion E1 received the lowest scores for the spreadability parameter (Figure 9). The obtained mean value of the spreading score for this system was statistically significantly ($p \leq 0.05$) lower than the scores obtained for all other emulsions (Table 5). Systems E3 and E4 was characterized by the highest consumer desirability in the field of spreadability. The mean evaluation of the analyzed parameter for these systems did not differ statistically

significantly ($p > 0.05$). The mean evaluation of spreadability obtained for emulsion E2 did not differ statistically significantly ($p \leq 0.05$) from the mean values obtained for emulsions E3, E4 and E5. The high score in terms of the spreadability of the E3 and E4 systems was correlated with their viscosity, as they had the highest values of this parameter among all the systems evaluated by the consumer (Figure 9). Viscosity, on the other hand, is a parameter that is clearly dependent on the type and amount of thickener. Thus, in our consideration, it is clear that the desired consistency and then the distribution parameter can be reached or refined not only by the addition of a given modifier but also by introducing an appropriately modified fat phase.

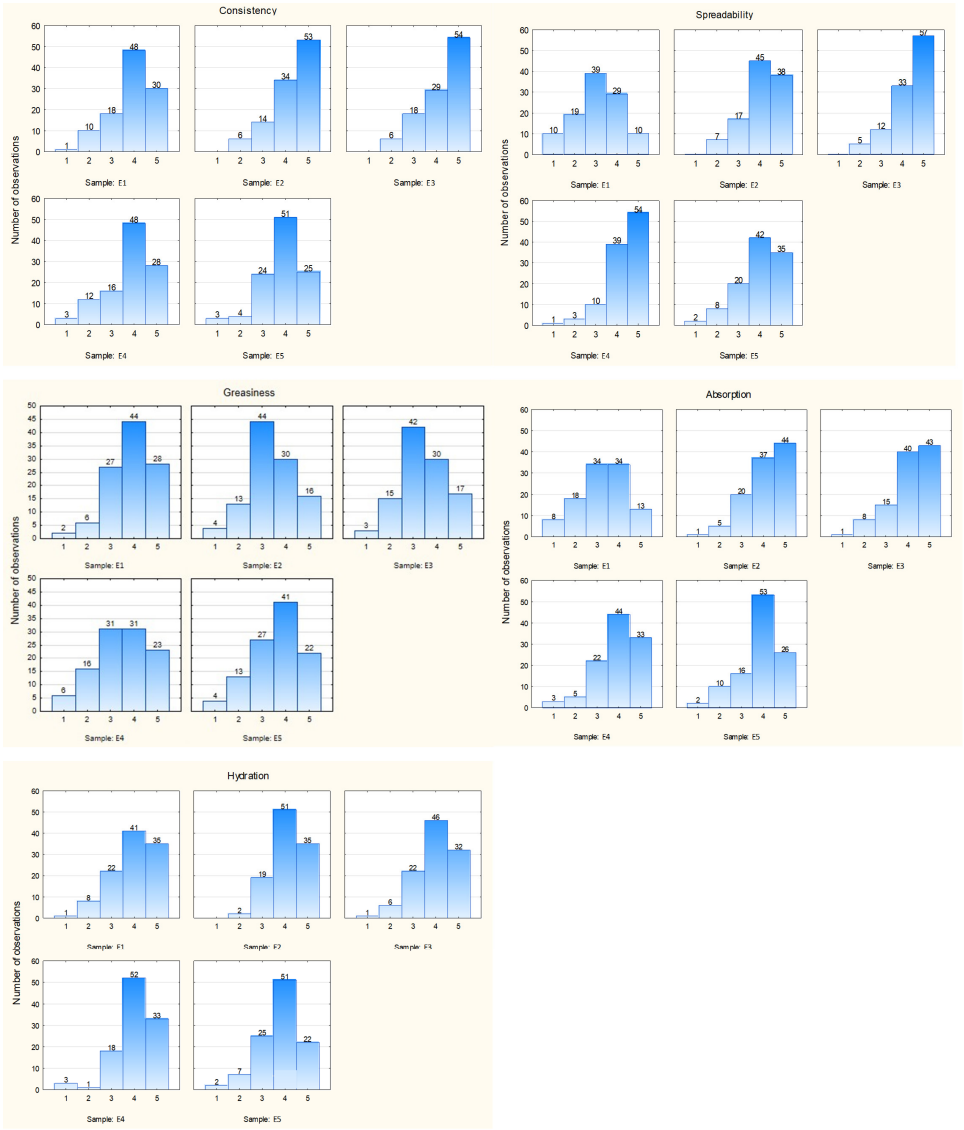

Figure 9. Distribution of consumer responses for the studied characteristics of emulsion systems E1–E5.

The highest number of scores of four and five points for the greasiness parameter was obtained for emulsion E1 (Figure 9). The mean value of this parameter for the E1 system was statistically significantly ($p \leq 0.05$) different from the mean values obtained for the E2 and E3 systems (Table 6). On the other hand, the mean values of the greasiness evaluation obtained for the other systems were not statistically significantly different ($p > 0.05$).

Table 5. Multiple comparison values for the spreadability parameter.

	E1	**E2**	**E3**	**E4**	**E5**
E1	-	0.000	0.000	0.000	0.000
E2	0.000	-	0.349	0.390	1.000
E3	0.000	0.349	-	1.000	0.042
E4	0.000	0.390	1.000	-	0.049
E5	0.000	1.000	0.042	0.049	-

Table 6. Multiple comparison values for the greasiness parameter.

	E1	**E2**	**E3**	**E4**	**E5**
E1	-	0.012	0.017	0.128	1.000
E2	0.012	-	1.000	1.000	0.933
E3	0.017	1.000	-	1.000	1.000
E4	0.128	1.000	1.000	-	1.000
E5	1.000	0.933	1.000	1.000	-

Considering the composition of the emulsion, this seems consistent with the type of fat used for the emulsion. In emulsion E1, animal fat was used the most in the fat blend, which may also have resulted in the poorer distribution indicated by consumers. In contrast, the other two emulsions, E2 and E3, used a fat with a higher percentage of vegetable oil, so the greasiness sensation was comparable for both emulsions.

The E1 emulsion had the lowest consumer desirability in terms of the absorption parameter (Figure 9). This system received the highest number of three- and four-point ratings. The mean value of the evaluation of the absorption of the E1 system was statistically significantly ($p \leq 0.05$) different from the mean scores obtained for all other systems (Table 7). In contrast, the mean absorption scores of all other systems (E2, E3, E4 and E5) were not statistically significantly different ($p > 0.05$). These results again confirm that the use of an emulsion containing a higher proportion of mutton tallow in the fatty mixture results in a worse absorption effect. Such systems are more directed as a preparation, having the task of insulating the skin against, for example, atmospheric agents.

Table 7. Multiple comparison values for the absorption parameter.

	E1	**E2**	**E3**	**E4**	**E5**
E1	-	0.000	0.000	0.000	0.001
E2	0.000	-	1.000	1.000	0.691
E3	0.000	1.000	-	1.000	0.759
E4	0.000	1.000	1.000	-	1.000
E5	0.001	0.691	0.759	1.000	-

Skin hydration after the application of the tested emulsions was evaluated the highest for systems E3, E1, E2 and E4 (Figure 9). These systems received the highest number of scores of four and five points. Only in the case of the assessment of skin hydration after the application of emulsion E5 was the predominance of three- and four-point ratings observed. However, statistical analysis showed that the parameter hydration did not significantly ($p > 0.05$) differentiate evaluated emulsion systems between each other (Table 8).

Table 8. Multiple comparison values for the parameter hydration.

	E1	E2	E3	E4	E5
E1	-	1.000	1.000	1.000	1.000
E2	1.000	-	1.000	1.000	0.185
E3	1.000	1.000	-	1.000	1.000
E4	1.000	1.000	1.000	-	0.428
E5	1.000	0.185	1.000	0.428	-

On the basis of the overall evaluation, it was found that the best evaluated emulsion was system E3 containing carboxymethylcellulose as a thickener, and the worst evaluated system was E5 stabilized with xanthan gum (Table 9). However, it should be noted that the mean overall assessment of all emulsions did not differ from each other in a statistically significant manner ($p > 0.05$). Systems E2, E3, E4 and E5 were characterized by the highest number of four- and five-point ratings (Figure 10). In contrast, the hedonic evaluation of the E1 system was ambiguous. Consumers mainly scored it three and five points. The obtained mean overall assessment of the E1 system was also characterized by the highest standard deviation among all analyzed emulsions.

Table 9. Values of the average overall assessment for E1–E5 emulsions.

Emulsion System	Overall Assessment (Mean ± Standard Deviation)
E1	4.0 a ± 1.2
E2	4.2 a ± 0.7
E3	4.2 a ± 0.7
E4	4.1 a ± 0.7
E5	3.9 a ± 0.9

a—the same letters indicate that there are no significant differences between the means, ($p \leq 0.05$).

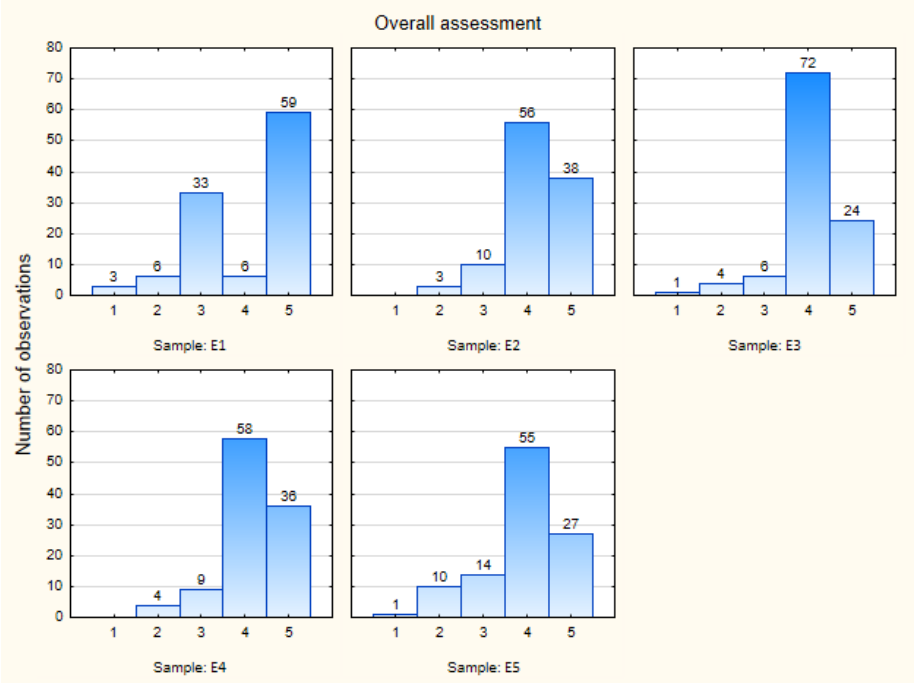

Figure 10. Overall assessment of emulsions E1–E5.

The evaluation of consumer preferences concerning the analyzed emulsion systems consisted in ranking the samples from the most to the least preferred product. The distribution of responses obtained for emulsion E1 differed significantly from the distribution obtained for the other systems (Figure 11). Consumer preferences for emulsion E1 were extreme. This system was most frequently indicated both in first and last place. However, the values of multiple comparisons for the evaluation of preferences indicated the absence of statistically significant differences ($p > 0.05$) between the obtained means for all analyzed emulsions.

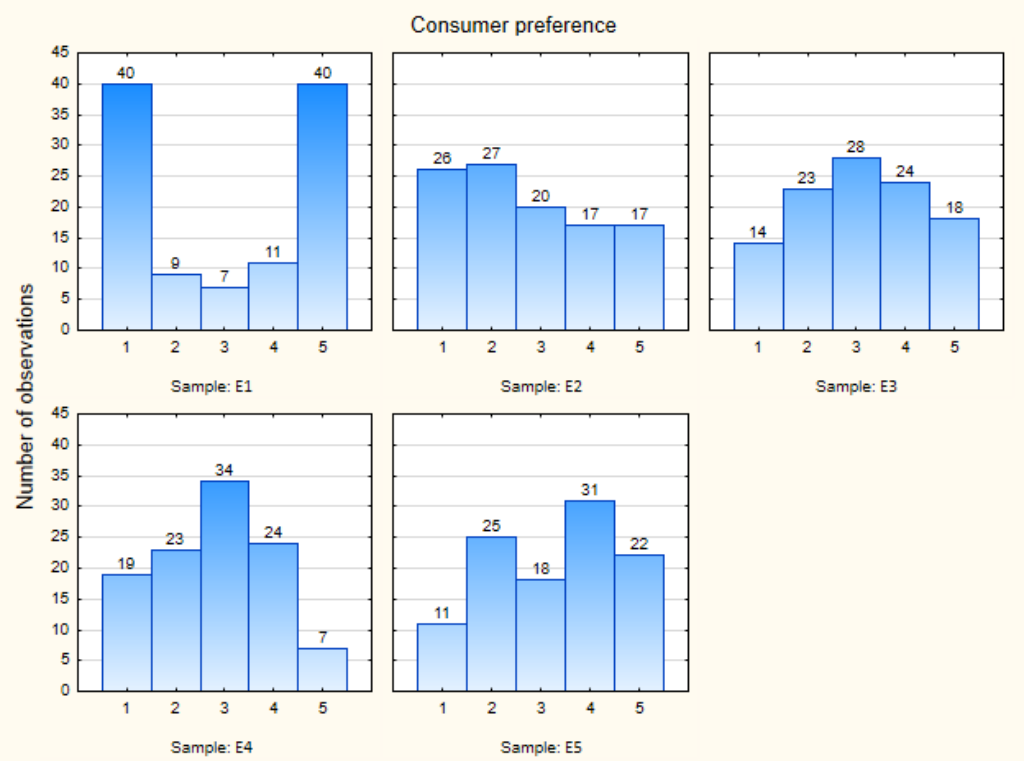

Figure 11. Consumer preference for emulsions E1–E5.

Based on the results obtained, it was concluded that the sensory quality of the studied emulsion systems prepared on the basis of modified blends of mutton tallow and hemp seed oil was fully accepted by consumers. No statistically significant differences were found between the samples in the overall assessment and in the preference evaluation (Table 10).

Table 10. Multiple comparison values for the parameter preference.

	E1	E2	E3	E4	E5
E1	-	1.000	1.000	1.000	1.000
E2	1.000	-	1.000	1.000	0.160
E3	1.000	1.000	-	0.787	0.079
E4	1.000	1.000	0.787	-	1.000
E5	1.000	0.160	0.079	1.000	-

Thus, it can be concluded that all analyzed emulsion samples were good or very good in their sensory characteristics.

4. Conclusions

The work confirmed that the process of enzymatic esterification can be an appropriate modification to obtain a new fat containing an added amount of emulsifiers which, consequently, can be used to build a stable emulsion system. Compared with emulsions based on mixed fat, the differences and advantages of systems based on enzymatically interesterified fat were clearly indicated. In addition to the greater stability of these emulsion systems, it was possible to indicate a completely different structure—a more advantageous, more homogeneous emulsion. The use of different thickeners confirmed the usefulness of these substances depending on the preference of obtaining the final emulsion system. Thus, the process of enzymatic interesterification yields not only a new fat but also a new beneficial ingredient for emulsions.

The consumer evaluation showed that the sensory quality of the selected most stable emulsion model products was fully accepted by the consumers surveyed. On the basis of the results of this stage of the research it was concluded that all the emulsions subjected to consumer evaluation obtained good or very good acceptance in terms of the assessed sensory characteristics. Overall, the evaluation and preference assessment did not show statistically significant differences between analyzed emulsions. The results of the consumer evaluation study allowed for the fourth hypothesis, assuming that emulsion products based on modified fats containing emulsifiers produced by enzymatic modification and selected viscosity modifiers may meet consumer preferences, to be verified.

However, it is clearly evident, in line with consumer sentiment and preference, that the evaluation in terms of the parameters set in the work indicates that there is, or is not, an acceptance of the product and that this is related to the viscosity modifier introduced. Therefore, it is reasonable to periodize not only how effective the thickener is but also its acceptance by consumers.

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Institutional Review Board Statement: The study was approved by the University Research Ethics Committee of the Cracow University of Economics, decision number EBN/71/0044/D1/2021. Participation in the tests was voluntary, with participants having full right to withdraw from the experiments at any stage. Prior to participation in the study, each participant gave his or her informed consent in writing, in accordance with the provisions of Article 6 of Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 concerning the protection of personal data and the free flow of such data. All testing procedures were conducted in accordance with relevant International Organization for Standardization (ISO) guidelines and standards for sensory analysis.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data may be found in https://doi.org/10.58116/UEK/CFTO8T, Krakow University of Economics, V1.

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References

1. Korać, R.; Krajišnik, D.; Milić, J. Sensory and instrumental characterization of fast inverting oil-in-water emulsions for cosmetic application. *Int. J. Cosmet. Sci.* **2016**, *38*, 246–256. [CrossRef] [PubMed]
2. Calixto, L.S.; Maia Campos, P.M.B.G. Physical-Mechanical characterization of cosmetic formulations and correlation between instrumental measurements and sensorial properties. *Int. J. Cosmet. Sci.* **2017**, *39*, 527–534. [CrossRef] [PubMed]

3. Terescenco, D.; Hadj Benali, L.; Canivet, F.; Benoit le Gelebart, M.; Hucher, N.; Gore, E.; Picard, C. Bio-sourced polymers in cosmetic emulsions: A hidden potential of the alginates as thickeners and gelling agents. *Int. J. Cosmet. Sci.* **2021**, *43*, 573–587. [CrossRef] [PubMed]
4. Niu, F.; Zhao, M.; Tu, W.; Li, Z.; Gao, Y.; Du, Y.; Pan, W. Fabrication and stability of W/O/W emulsions stabilized by gum arabic and polyglycerol polyricinoleate. *J. Sci. Food Agric.* **2024**, *104*, 797–808. [CrossRef] [PubMed]
5. Xiao, A.; Yang, Y.; Liu, X.; Shen, C.; Meng, Q. Formulation of rhamnolipid-containing cosmetics without sulfate surfactants: A rheology and stability study. *J. Surfactants Deterg. Early View*. 2024. [CrossRef]
6. Talavera, M.; Chambers IV, E. Using sensory sciences help products succeed. *Br. Food J.* **2017**, *119*, 2130–2144. [CrossRef]
7. Martins, V.B.; Bordim, J.; Bom, G.A.P.; Carvalho, J.G.D.S.; Parabocz, C.R.B.; Mitterer Daltoé, M.L. Consumer profiling techniques for cosmetic formulation definition. *J. Sens. Stud.* **2020**, *35*, e12557. [CrossRef]
8. Arrieta-Escobar, J.A.; Camargo, M.; Morel, L.; Bernardo, F.P.; Orjuela, A.; Wendling, L. Design of formulated products integrating heuristic knowledge and consumer assessment. *AIChE J.* **2021**, *67*, e17117. [CrossRef]
9. Kowalska, M.; Woźniak, M. Proposal of New Emulsion Systems Containing Hydroxypropylmethylcellulose as a Viscosity Modifier and Diacylglycerols from Mutton Tallow and Hemp Seed Oil. *Appl. Sci.* **2023**, *13*, 10289. [CrossRef]
10. Stone, H.; Bleibaum, R.N.; Thomas, H.A. *Sensory Evaluation Practices*, 4th ed.; Elsevier: Amsterdam, The Netherlands, 2012. Available online: https://shop.elsevier.com/books/sensory-evaluation-practices/stone/978-0-12-382086-0 (accessed on 9 February 2024).
11. Rogers, L. *Sensory Panel Management. A Practical Handbook for Recruitment, Training and Performance*; A Volume in Woodhead Publishing Series in Food Science, Technology and Nutrition; Woodhead Publishing: Cambridge, MA, USA, 2018; ISBN 978-0-08-101001-3.
12. *ISO 11136*; Sensory Analysis—Methodology—General Guidance for Conducting Hedonic Tests with Consumers in a Controlled Area. ISO: Geneva, Switzerland, 2014. Available online: http://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/05/01/50125.html (accessed on 23 April 2019).
13. Kovács, A.; Erős, I.; Csóka, I. Optimization and development of stable w/o/w cosmetic multiple emulsions by means of the Quality by Design approach. *Int. J. Cosmet. Sci.* **2016**, *38*, 128–138. [CrossRef] [PubMed]
14. Celia, C.; Trapasso, E.; Cosco, D.; Paolino, D.; Fresta, M. Turbiscan lab expert analysis of the stability of ethosomes and ultradeformable liposomes containing a bilayer fluidizing agent. *Colloids Surf. B Biointerfaces* **2009**, *72*, 155–160. [CrossRef] [PubMed]
15. Domian, E.; Brynda-Kopytowska, A.; Oleksza, K. Rheological properties and physical stability of o/w emulsions stabilized by OSA starch with trehalose. *Food Hydrocoll.* **2015**, *44*, 49–58. [CrossRef]
16. Zhu, T.; Zhao, Y.; Zong, M.; Li, B.; Zhang, X.; Wu, H. Improvement of physical properties of palm stearin and soybean oil blends by enzymatic interesterification and their application in fast frozen food. *RSC Adv.* **2017**, *7*, 34435–34441. [CrossRef]
17. Szakiel, J.; Turek, P. Sensoryczna ocena jakości kosmetycznych produktów nawilżających przeznaczonych do pielęgnacji skóry rąk. *Zesz. Nauk. Uniw. Ekon. Krakowie* **2019**, *6*, 239–252. [CrossRef]
18. Bombol, M.; Dąbrowska, A. Zachowania konsumentów na rynku produktów żywnościowych. *Handel. Wewn.* **2006**, *24*, 31.