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A Comparison of Physicochemical Properties of an Emulsion Containing Chemically Interesterified Fat for Demanding Skin with Commercial Formulations for Atopic Skin

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Synopsis

The aim of the work was to evaluate and analyze the functional properties of a new emulsion product made according to our recipe containing interesterified fat with the properties of selected popular preparations used in the care of atopic skin. Also, the composition of all tested preparations was analyzed for active substances contained in these preparations. Skin hydration level and transepidermal water loss (TEWL) after application of commercial formulations as well as of our own preparation on the basis of interesterified fat were assessed. Determination of droplets' size and their distribution was performed for our own preparation using dynamic laser diffraction technique. Stability of the prepared emulsion in different storage conditions was evaluated by the Turbiscan test. The highest average skin hydration increase was observed after the application of cream C5, which contained a unique component—evening primrose oil. The highest decrease in TEWL was obtained after the application of our own formulation. Sensory analysis showed that the highest scores were obtained for creams. Respondents evaluated our own preparation as not fully satisfying. The obtained results showed the possibility of producing an emulsion with interesterified fat application as a formulation for atopic skin care. Its physical characteristics showed stability of the dispersion. However, parameters such as color, smoothing, cushion effect, and absorption should be improved.

INTRODUCTION

Atopic dermatitis (AD) is one of the skin diseases characterized by chronic inflammation (1,2). Recently, increasing incidence of this disorder has been observed (3). On the basis of a World Health Organization survey, it can be concluded that this genetically contributed disease has a great impact on the quality of patients' lives (4,5) by causing mental and

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physical discomfort. The symptoms of AD are dry skin, pruritus, and numerous defects in the skin structure—which can often be accompanied by asthma and allergic rhinitis (4). A whole range of these factors reduces the natural immune response of the skin, which causes problems with its regeneration.

The clinical symptoms of AD consist in a disorder in the normal functioning of the skin barrier manifested by dry skin and excessive transepidermal water loss (TEWL). It occurs because of the damage of the epidermis and abnormalities in its structure. Reconstruction of the skin barrier is said to be the most important factor in preventing recurrence and progression of inflammatory processes (6,7).

A factor that has a significant effect on epidermal barrier defect is the genetic disorder of structural proteins and stearic proteases and their inhibitors. It has been found that by the mutation of the filaggrin gene, the deficiency of these proteins in the skin is observed. Their deficiency causes abnormalities in the shape of corneocytes, while simultaneously affecting the degeneration of lipid grouping. The consequence of these mutations is not only the natural moisturizing factor (NMF) deficiency and reduced hydration of the stratum corneum but also increased TEWL. Moreover, the mutation results in an increased skin pH because of the heightened stearic protease activity and impairment of enzymes affecting lipid metabolism (6,8).

Another determinant of the epidermal defect is a total lipids reduction in the epidermis, both in altered and unchanged skin. One of the abnormalities of lipid barrier composition is the reduction in polyunsaturated fatty acids in the epidermis and increase in monounsaturated fatty acids. Oleic acid adversely affects the proper functioning of the epidermis.

In the atopic skin, there are also higher cholesterol levels with regard to the concentration of this component in the unaltered skin (9). Defects in individual components of the lipid barrier include a reduced amount of ceramides (mainly one and three) in the epidermis, resulting in the incorrect production of laminar lamellas. In effect, excessive skin dryness and increase in TEWL are observed. Deficiency of these compounds minimizes the content of sphingosine, the key metabolite of ceramides (9). Both moisturizing substances and emollients are used to improve the atopic skin's comfort. These compounds help to alleviate symptoms, restore normal epidermal barrier function, and replenish ceramide defects and valuable unsaturated fatty acids in the skin.

The aim of the study was to propose a new emulsion product composition containing interesterified fat for atopic skin care. The assumption was to obtain a model system based on interesterified fat containing a minimum amount of the remaining components responsible for the system stability. Properties of own formulation and common commercial products for atopic skin care were compared.

MATERIAL

During chemical interesterification, the following chemicals were used: sodium methoxide (Merck, Darmstadt, Germany), diethyl ether (Chempur, Piekary Śląskie, Poland), phosphoric acid (Chempur), and magnesium sulfate (Chempur).

The emulsion (own formulation) was prepared using the following components: distilled water, sesame oil (Oleofarm, Wrocław, Poland), Mutton Tallow (Meat-Farm,

Stefanów–Wólka Kosowska, Poland), soy lecithin (Hortimex, Konin, Poland), carboxymethylcellulose (Barentz, Hoofddorp, Netherlands), sodium benzoate (Galfarm, Kraków, Poland), and aloe vera leaf pulp (own breeding).

The following 10 commercial products (five creams and five balms) for AD obtained from local pharmacies and drugstores were used:

(a) Cream (C1) and balm (B1) producer: Pierre Fabre
(b) Cream (C2) and balm (B2) producer: DermaProfil
(c) Cream (C3) and balm (B3) producer: Nepentes
(d) Cream (C4) and balm (B4) producer: Oceanic
(e) Cream (C5) and balm (B5) producer: Pierre Fabre

METHODS

FATS INTERESTERIFICATION

Mutton tallow and sesame oil in the ratio 2:3 (w/w) were interesterified using sodium methoxide (0.6%) as a catalyst. The reaction was performed at 90°C (in an oil bath) for 2 h. The process was stopped by the addition of diluted H_3PO_4 to neutralize the catalyst. The fats were extracted with diethyl ether and dried with anhydrous magnesium sulfate. The detailed description of the aforementioned procedure is given in (10).

EMULSION PREPARATION

The accurately weighed fat and lecithin blend was transferred to a beaker and heated in a water bath to about 50°–55°C. After melting of the components, the blend was mixed to obtain a uniform consistency. Constant temperature was maintained during the whole process. Carboxymethylcellulose was dispersed in water using a mechanical stirrer, and the solution was heated to about 50°–55°C in a water bath. The oil phase was slowly added to the aqueous phase by manual stirring; then, homogenization was performed. The aloe vera leaf pulp was added, previously prepared by aloe leaf crushing. After cooling the emulsion to 30°C, a preservative was added. Table I shows composition and homogenization parameters of the prepared emulsion.

Table I
Composition and Homogenization Parameters of the Prepared Emulsions

Component (% w/w)	
Interesterified mutton tallow with sesame oil in the ratio (2:3 w/w)	30.0
Lecithin	5.2
Carboxymethylcellulose	1.0
Water	Up to 100.0
Aloe vera	0.8
Sodium benzoate	0.3
Homogenization parameters	
Time (min)	4.0
Speed (rpm × 1,000)	18.5

DROPLET SIZE MEASUREMENTS

Microtrac Particle Size Analyzer (Leeds and Northrup, Philadelphia, PA) was used to determine droplets' size and their distribution of our own formulation. The measurement was based on dynamic laser diffraction and performed 24 h after the emulsion preparation (the emulsion was stored at 7°C). The result was given as an average of three measurements.

TURBISCAN TEST

Stability of our own preparation was evaluated using Turbiscan Lab (Formulaction, Toulouse, France). The device enables to detect invisible, unfavorable physicochemical changes occurring in a sample. The instrument uses pulsed near infrared light (880 nm) and measures the intensity of transmitted and backscattered light as a function of sample height (11). Our own formulation was divided into three samples stored for the same time (1 mo) in different conditions (8°C, 40°C, and room temperature). The results were presented as a delta backscattered light intensity (ΔBS) in the reference mode ($\Delta BS = BS_t - BS_0$).

SKIN HYDRATION MEASUREMENTS

Skin hydration (skin capacitance) was measured by means of Cutometer MPA (Multi Probe Adapter) using Corneometer probe (CM 825; Courage & Khazaka, Cologne, Germany). The device is used to determine the degree of stratum corneum hydration up to 0.45 μm of skin depth (12). Measurements are carried out by means of a capacitive method, based on a dielectric constant of water and other substances (usually >7). Corneometer shows variations of skin capacitance depending on moisture level changes.

The measurements were performed under standard conditions of temperature and humidity (T°C = 20°–22°C, humidity 40–60%), away from direct sunlight. A control point was pure skin without any preparation. The test included measurements performed immediately after a time t 30 min, 60 min, and 120 min of product application (~0.01 g) on a forearm skin fragment. Ten women participated in the test, with no special symptoms of atopic skin but having dry and sensitive skin because of the fact that presented own preparation was model emulsion. Research was conducted by a trained person.

To have valid results, the readout was always taken three times. To obtain the results of skin hydration percentage difference, the following formula was used:

$$\Delta SH_{\%} = \frac{(SC_t - SC_0)}{SC_0} \times 100\%$$

$\Delta SH_{\%}$—skin hydration percentage difference (%), SC_t—skin capacitance after a time t (AU), and SC_0—skin capacitance of the control point (AU).

The results are presented as a mean value of skin hydration percentage increase for all the respondents after t for each commercial product and the authors' formulation.

TEWL MEASUREMENTS

Transepidermal water loss was determined by means of Cutometer MPA using Tewameter probe (TM 300; Courage & Khazaka). The measurement was based on Fick's diffusion

law. Two sensors (thermometer and hygrometer) were placed in the open chamber of the measuring probe collect data from the density gradient of the water evaporation.

The measurements were performed under standard conditions of temperature and humidity (T°C = 20°–22°C, humidity 40–60%), away from direct sunlight. A control point was pure skin without any preparation. The test included measurements performed immediately after 30 min, 60 min, and 120 min of application of the product (~0.01 g) on forearm skin fragments. Ten women participated in the test, with no special symptoms of atopic skin but having dry and sensitive skin because of the fact that presented own preparation was model emulsion. Research was conducted by a trained person.

To have valid results, the measurement was performed in triplicate. To obtain the results of TEWL percentage difference, the following formula was used:

$$\Delta \mathrm{TEWL}_{\%} = \frac{(\mathrm{TEWL}_t - \mathrm{TEWL}_0)}{\mathrm{TEWL}_0} \times 100\%$$

$\Delta \mathrm{TEWL}_{\%}$—transepidermal water loss percentage difference (%), TEWL_t—transepidermal water loss after t (g/h/m^2), and TEWL_0—transepidermal water loss of the control point (g/h/m^2).

The results are presented as a mean value of TEWL percentage difference for all the respondents after t for each commercial product and the authors' formulation.

SENSORY EVALUATION

The sensory parameters evaluation was conducted by nine previously trained volunteers—students at Kazimierz Pulaski University in Radom, Poland, using a 5-point scoring scale (0—lowest and 5—highest). The volunteers were asked to fill in a questionnaire assessing the sensory attributes of the tested products, without knowledge about evaluated product type. The acceptability of 10 commercial products and our own preparation was assessed in constant and proper laboratory conditions. Sensory attributes were evaluated between two fingers or when applied on the forearm skin, using a 5-point scoring scale (0—lowest and 5—highest). The products were evaluated for the following sensory characteristics: consistency (density and cohesion of the product), homogeneity (absence of clots or air bubbles), cushion effect (palpability of the product when rubbed between two fingers), distribution (ease of spreadability on the skin), smoothing (smoothing effect on the skin), stickiness (degree of palpable viscosity left on the skin), greasiness (the greasy feel perceived after product application), absorption (the moment when the product is no longer felt on the skin), color, and odor. The detailed procedure and questionnaire with instructions of the sensory evaluation are described in (13).

STATISTICS

Statistics were performed using Excel software (Microsoft Inc., Redmond, WA).

RESULTS AND DISCUSSION

ANALYSIS OF THE COMMERCIAL PRODUCTS' COMPOSITION

A significant diversity was observed when analyzing the composition of common drugstore products for AD skin care. Cream (C1) contained most of the synthetic components (Table II). Evening primrose oil is the only natural emollient. It should be mentioned that this preparation contained oat extract, which has a significant role in AD therapy. It has soothing anti-inflammatory effect, strengthens the epidermal barrier, and primarily has antipruritical properties (14,15).

Balm (B1) formula (Table II) also consists mostly of synthetic components. Mineral oil and a mixture of lauric acid and sorbitan esters are its basic ingredients. The usage of the latter in the formulation is a result of its good stabilizing, emulsifying, or solubilizing properties (16). A polyethylene glycol present in B1 is a moisturizing and water-binding polymer (17). Niacinamide is well known for its anti-inflammatory properties (18). Shea butter, glycerin, and tocopherol have positive effects on skin condition (19).

The main components of cream (C2) are water, hemp oil, and petrolatum (Table II). This is the only formulation containing hemp oil. Rich in essential unsaturated fatty acids, hemp oil applied on the skin reconstructs defects of the natural lipid barrier and has an anti-inflammatory effect (20). Other anti-inflammatory components are present in this formulation (bisabolol and allantoin), although in lower amounts (21).

Balm (B2) (Table II) contains comparable amounts of natural and synthetic ingredients. Components alike hemp oil, glycerol, shea butter, and urea have moisturizing, nourishing, and occlusive properties. Moreover, urea is responsible for the regulation of the keratinization process (20,21). Lanolin, natural animal wax, was used as an emulsifier. Xanthan gum, a natural polysaccharide, is responsible for consistency and rheology of the product. As aforementioned, bisabolol and allantoin show anti-inflammatory and soothing effects. In the authors' opinion, Vaseline, which is a mixture of synthetic hydrocarbons obtained from petroleum and attributed with comedogenic action, is an adverse ingredient. Vaseline inhibits excretion of sweat and sebum (22). Sodium hydroxide and phenoxyethanol belong to substances which may cause skin irritation (23). In general, sodium hydroxide is responsible for maintaining the correct cosmetic pH, whereas phenoxyethanol microbiologically secures the product (24).

The cream (C3) can be distinguished by ingredients having a broad spectrum of activity (Table II). Natural components characterized by forming a protective film on the skin (*Macadamia ternifolia* seed oil and shea butter) are dominant. Synthetic origin components (paraffinum liquidum, dimethicone, trimethylsiloxysilicate, and ethylhexylglycerin) support the greasing effect. In this formulation, substances such as glycerin, sodium hyaluronate, polyethylene glycol, and hydroxyethyl urea have strong moisturizing and water-binding properties. A component like lactic acid has exfoliating effect and regulates the keratinization process. The presence of vitamins E (tocopherol) and C (ascorbic acid and ascorbyl palmitate) in the preparation inhibits the oxidation processes of the labile compounds found in the cream. Occurrence of synthetic substances, that is, phenoxyethanol and edetate disodium (EDTA), in the cream may contribute to skin irritation (25).

Balm (B3) and cream (C3) contain a natural ingredient—*Macadamia ternifolia* seed oil. Most of the remaining ingredients in the balm are of synthetic origin. From the moisturization

Table II
Composition of Commercial Products Used in AD

Preparation/INCI (International Nomenclature of Cosmetic Ingredients) composition	
C1 Water (aqua), mineral oil (paraffinum liquidum), Peg-12, glycerin, cyclopentasiloxane, glyceryl stearate, Peg-100 stearate, *Oenothera biennis* (evening primrose) oil, myreth-3 myristate, polyacrylamide, niacinamide, 10-hydroxydecanoic acid, *Avena sativa* (oat) leaf/stem extract, BHT, (Butylated hydroxytoluene) C13-14 isoparaffin, disodium EDTA, laureth-7, sodium acetate, and tocopherol	B1 Water (aqua), mineral oil (paraffinum liquidum), *Butyrospermum parkii* (shea butter), glycerin, polysorbate 60, cetearyl alcohol, dimethicone, Peg-12, oenothera biennis (evening primrose) oil, butylene glycol, squalane, niacinamide, 10-hydroxydecenoic acid, *Avena sativa* (oat) leaf/stem extract, BHT, C13-14 isoparaffin, cetearyl glucoside, disodium EDTA, laureth-7, maltodextrin, polyacrylamide, sodium acetate, and tocopherol
C2 Aqua, *Cannabis sativa* seed oil, petrolatum, glycerine, cetearyl alcohol, stearic and palmitic acid, dimeticone, glyceryl stearate, Peg-12, phenoxyethanol, tocoferol acetate, magnesium oxide, dehydroacetic acid, silica, allantoin, and bisabolol	B2 Aqua, *Cannabis sativa* seed oil, glycerine, cetearyl alcohol, *Vaselinum album*, glyceryl stearate, polysorbate-60, *Butyrospermum parkii* (shea butter), dimeticone, urea, phenoxyethanol, tocoferol acetate, adeps lanae, acrylates/vinyl isodecanoate crosspolymer, ascorbyl palmitate, allantoin, bisabolol, dehydroacetic acid, xanthan gum, sodium hydroxide, and parfum
C3 Aqua, paraffinum liquidum, cetearyl alcohol, *Butyrospermum parkii* (shea butter), caprylic/capric triglyceride, *Macadamia ternifolia* seed oil, methylpropanediol, glycerin, hydroxyethyl urea, polysorbate 60, dimethicone, trimethylsiloxysilicate, biosaccharide gum-1, sodium hyaluronate, allantoin, stearic acid, sodium acrylate/sodium acryloyldimethyl taurate copolymer, isohexadecane, polysorbate 80, phenoxyethanol, ethylhexylglycerin, lactic acid, disodium EDTA, Peg-8, tocopherol, ascorbic acid, ascorbyl palmitate, and citric acid	B3 Aqua, paraffinum liquidum, *Butyrospermum parkii* (shea butter), caprylic/capric triglyceride, cetearyl alcohol, *Macadamia ternifolia* seed oil, methylpropanediol, glycerin, hydroxyethyl urea, polysorbate 60, biosaccharide gum-1, dimethicone, trimethylsiloxysilicate, allantoin, stearic acid, phenoxyethanol, ethylhexylglycerin, xanthan gum, sodium hyaluronate, disodium EDTA, Peg-8, tocopherol, ascorbic acid, ascorbyl palmitate, and citric acid
C4 Aqua, ethylhexyl stearate, *Butyrospermum parkii* butter, cetearyl alcohol, dicaprylyl carbonate, *Adansonia digitata* seed oil, *Oenothera biennis* oil, caprylic/capric triglyceride, glycerin, glyceryl stearate citrate, *Perilla ocymoides* seed oil, squalane, lecithin, tocopheryl acetate, tocopherol, palm kernel glycerides, ceramide NP (ceramide 3), behenyl alcohol, palmitic acid, stearic acid, cetyl alcohol, lauryl alcohol, myristyl alcohol, glyceryl caprylate, allantoin, xanthan gum, isohexadecane, polysorbate 80, sodium acrylate/sodium acryloyldimethyl taurate copolymer, and parfum	B4 Aqua, llycerin, *Butyrospermum parkii* butter, cetearyl alcohol, glyceryl stearate citrate, myristyl myristate, dicaprylyl carbonate, dicaprylyl ether, glyceryl stearate, palmitic acid, coco-caprylate/caprate, *Persea gratissima* oil, betaine, *Adansonia digitata* seed oil, *Prunus amygdalus* dulcis oil, glyceryl caprylate, *Oenothera biennis* oil, tocopherol, *Perilla ocymoides* seed oil, panthenol, tocopheryl acetate, palm kernel glycerides, squalane, behenyl alcohol, allantoin, stearic acid, lecithin, cetyl alcohol, lauryl alcohol, hydroxyacetophenone, myristyl alcohol, ceramide NP, xanthan gum, disodium phosphate, citric acid, and parfum

Table II
Continued

Preparation/INCI (International Nomenclature of Cosmetic Ingredients) composition	
C5 Avene thermal spring water (avene aqua), glycerin, mineral oil (paraffinum liquidum), *Oenothera biennis* (evening primrose) oil, caprylic/capric triglyceride, evening primrose oil/palm oil aminopropanediol esters, *Aquaphilus dolomiae* extract, arginine, glycine, cetearyl alcohol, cetearyl glucoside, carbomer, and sodium hydroxide	B5 Avene thermal spring water (avene aqua), glycerin, mineral oil (paraffinum liquidum), *Oenothera biennis* (evening primrose) oil, caprylic/capric triglyceride, evening primrose oll/palm oil aminopropanediol esters, *Aquaphilus dolomiae* extract, arginine, glycine, Peg-12, glyceryl stearate, myreth-3 myristate, Peg-100 stearate, polyacrylate-13, citric acid, polyisobutene, polysorbate 20, sodium acetate, and sorbitan isostearate

point of view, sodium hyaluronate, which is a sodium salt of hyaluronic acid naturally present in the skin, is an important component. Besides the moisturizing properties, it is responsible for skin elasticity (26). Disodium EDTA, PEG-8 (Polyethylene Glycol), and phenoxyethanol are seen as potential allergens (25,27) (Table II).

Analyzing the composition of (C4) cream, it should be mentioned that this preparation contains the highest quantity of different emollients when compared with the remaining formulations (Table II). According to the producer, this cream is called as "barrier cream," thus suggesting a primary occlusion effect. However, the use of excessive amounts of film-forming ingredients can be comedogenic and lead to efflorescence of the skin. Water, ethylhexyl stearate and dicaprylyl carbonate (vegetable origin), shea butter, and cetearyl alcohol (derived from palm and coconut oil) are the predominant components in (C4) formulation. These ingredients are natural substances that do not constitute a threat to the atopic skin. Rare and distinctive ingredients in this cosmetic are the *Perilla ocymoides* seed oil and *Adansonia digitata* seed oil. The former has antimicrobial activity and anti-inflammatory properties (28). The latter shows high penetrability and nourishing properties (29). Parfum was identified as a controversial component which can be an allergen (30).

Persea gratissima oil (avocado oil), lecithin, panthenol, palm kernel glycerides, *Prunus amygdalus* dulcis oil (sweet almond oil), betaine, and ceramide are the components of balm (B4) (Table II). These substances have beneficial properties for the skin. The rebuilding of the lipid barrier of the skin occurs because of palm kernel glycerides, avocado oil, and ceramides. Lecithin is responsible for proper stabilization and emulsification of the emulsion. Panthenol soothes skin irritations. Betaine strongly moisturizes and also binds water in the skin. This formulation also contains components with hydroxyl group. Some of them are not always seen as beneficial skin-interacting compounds. For example, lauryl alcohol may be comedogenic and behenyl alcohol can cause allergy (31,32). The presence of parfum in preparations for atopic skin, according to the authors (30), may also adversely affect the skin, that is, cause allergy.

Cream (C5) is characterized by the lowest amount of ingredients present in the formulation (Table II). These are mostly synthetic components. The predominant ingredients in the cream are water, glycerin, and mineral oil. The unique component in the formulation is evening primrose oil, which has anti-inflammatory effects, accelerates wound healing, and restores a defective skin barrier (14).

The basic ingredients of balm (B5) water phase were glycerol and water (Table II). The oil phase consisted of, among others, evening primrose oil, palm oil, caprylic/capric triglyceride, and mineral oil. The lotion contained two amino acids: arginine and glycine. The former is responsible for effective epidermis moisture. The latter stimulates synthesis of collagen (33).

According to the authors (34), synthetic ethoxylated polyethylene glycol and ethoxylated stearic acid in atopic skin care preparations may adversely affect the skin's structure, causing dryness and irritation. The presence of a mixture of lauric acid esters and ethoxylated sorbitan found in the preparation may be responsible for skin interactions (35). This component is used as an emulsifier and stabilizer (36).

Taking into account the aforementioned, there are synthetic compounds in most of the presented preparations. Because of the requirements and needs of atopic skin, the introduction of these compounds differs in function and purpose. Generally, this kind of skin requires proper hydration, nourishment, and protection against excessive water loss (37). Creating a formulation composition with a minimum amount of components, which are nonirritating, preventive, and caregiving, while also offering long shelf life, that is, high physical and antimicrobial stability, is extremely difficult. The study proposes a model emulsion system based on natural skin-related ingredients, without fragrances or irritants. A comparison was performed of its properties with the commercial products for atopic skin available in the market.

ANALYSIS OF THE AUTHORS' OWN FORMULATION COMPOSITION

In the study, an emulsion was prepared on the basis of chemically interesterified mutton tallow with sesame oil. The choice of fats was dictated by compatibility of the ingredients with human skin and by the ability to minimize unfavorable skin effects on application of the preparation. The proposed fat blend contained 75% of solid fat (mutton tallow) and 25% of liquid fat (sesame oil). Mutton tallow was selected because of its conditioning, greasing, and moisturizing properties, whereas the use of sesame oil was intended to enrich the fat blend with the following fatty acids, important to atopic skin: oleic, linoleic, palmitic, and stearic acids, as well as phospholipids and natural antioxidant—lignan sesame (38). Other advantageous components used in our own preparation were natural emulsifiers—soy lecithin and aloe vera leaf pulp. According to the authors (39,40), aloe vera leaf pulp contains the following: monosaccharides and polysaccharides, 13 vitamins (including B2, B6, and C), NMF such as amino acids, EFAs (essential fatty acids), and mineral compounds of organic origin. The use of this ingredient was also associated with its anti-inflammatory, soothing, healing properties, and NMF effect on the skin rebuilding and improvement of lipid barrier function (39).

DROPLETS' SIZE AND THEIR DISTRIBUTION

Figure 1 shows the presence of only one fraction. The range of droplet sizes for this emulsion was 0.58–11 μm and 95% of the present droplets had a diameter below 7.7 μm. The average droplet size was 4.63 μm. Because of the fact that the range of droplets in emulsions is of 0.1–100 μm (41), it can be considered that the obtained result indicates the presence of small droplets in the emulsion, which demonstrates proper homogenization and hence

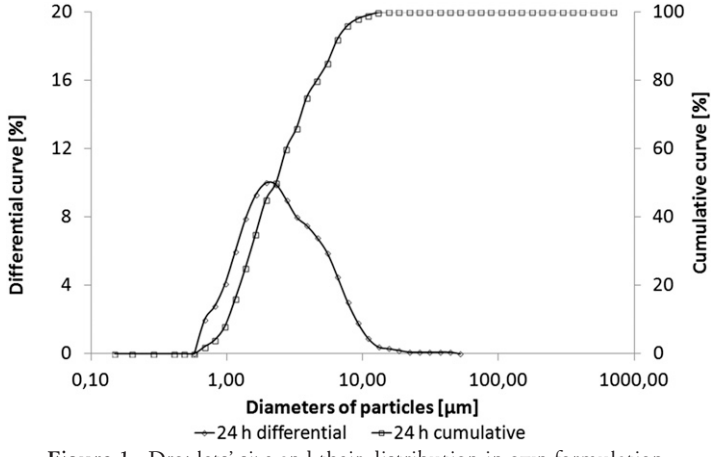

Figure 1. Droplets' size and their distribution in own formulation.

good dispersion stability. Time, temperature, and other storage conditions can affect changes in the system, thus maintaining the proper stability.

TURBISCAN TEST

Analyzing the results of the Turbiscan test, it was found that the samples A—stored in a refrigerator—and C—stored at room temperature—were characterized by the highest stability. On the other hand, significant destabilization changes were observed for the sample B—stored in the heater. Backscattered light intensity values decreased in the bottom and the top of the measuring cell. This profile suggests occurrence of the creaming process. Moreover, variance of BS light intensity in the middle of the sample was observed, which indicates variation in emulsion droplet size (Figure 2B). In the case of emulsions stored at room temperature and in the refrigerator, the changes of BS light intensity curves were slight. The curves overlapped in the middle of the measuring cell; thus the emulsions showed no change due to coagulation and resizing of the droplets (Figure 2A and C).

SKIN HYDRATION ANALYSIS

The longest hydration effect after application was observed for cream (C5) among the five tested commercial creams for AD (C1–C5). The hydration level was significantly different from that of the remaining products after 30 min from application as well as after 60 and 120 min. The highest value was obtained after 30 min—74.6%. The value decreased over the successive test points: 99.3% was noted after 60 min, and after 120 min—84.1%. These results indicate a high protection and appropriate atopic skin care. The lowest increase in skin hydration was observed after the application of cream (C4), after 30 min—27.3%, after 60 min—30.9%, and after 120 min—26.2% (Table III).

In case of the analyzed balms, balm (B5) proved the most beneficial for the skin. The increase in skin hydration was 68.4%, 72.8%, and 64.2%, respectively. The effect of the remaining balms was weaker, although without significant variations.

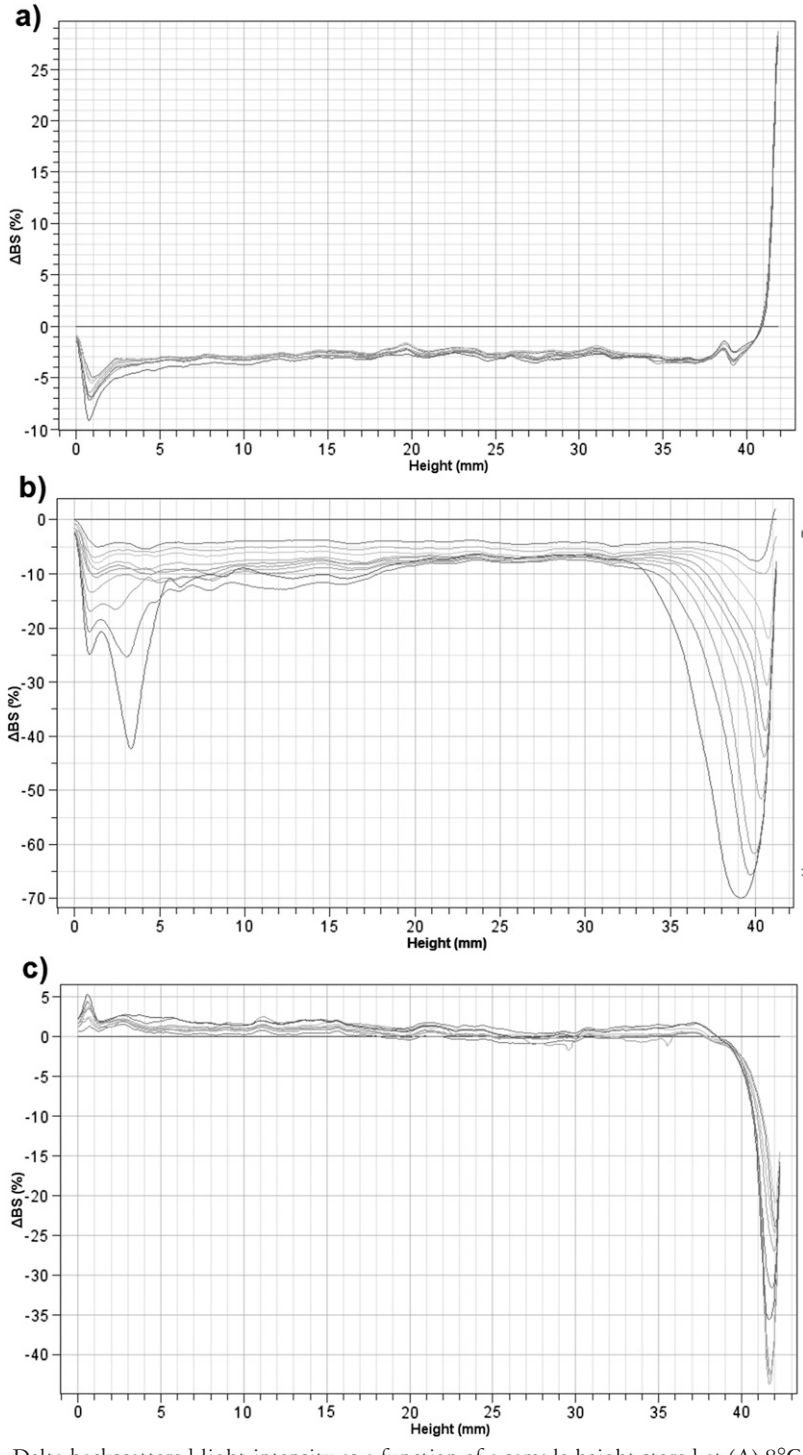

Figure 2. Delta backscattered light intensity as a function of a sample height stored at (A) 8°C, (B) 40°C, and (C) 23°C.

Table III
Mean Value of Skin Hydration Percentage Increase for All the Respondents Commercial Products and the Authors' Formulation

Preparation		Increase in skin hydration after 30 min (%)	Increase in skin hydration after 60 min (%)	Increase in skin hydration after 120 min (%)
Cream	C1	45.6 ± 0.5	56.7 ± 0.5	45.9 ± 0.3
	C2	37.5 ± 0.4	61.1 ± 0.4	52.5 ± 0.2
	C3	37.8 ± 0.4	45.8 ± 0.4	37.7 ± 0.2
	C4	27.3 ± 0.2	30.9 ± 0.3	26.2 ± 0.1
	C5	74.6 ± 0.4	99.4 ± 0.6	84.1 ± 0.5
Balm	B1	44.9 ± 0.4	72.9 ± 0.4	60.2 ± 0.3
	B2	52.9 ± 0.4	61.0 ± 0.4	45.9 ± 0.2
	B3	53.8 ± 0.4	56.3 ± 0.4	33.4 ± 0.2
	B4	50.7 ± 0.3	46.8 ± 0.4	31.9 ± 0.2
	B5	68.4 ± 0.5	72.8 ± 0.4	64.2 ± 0.4
–	Own preparation	58.7 ± 0.4	59.8 ± 0.4	34.2 ± 0.4

Our own formulation showed a high moisturizing effect—58.7%—after 30 min from its application, ranking it third among all tested formulations. After 60 min of application, the skin hydration remained on the same level of 59.8%. During the second hour from the application, a significant decrease in skin hydration was noted down to 34.2% (Table III).

TRANSEPIDERMAL WATER LOSS

One of the most important and fundamental criteria for analysis of atopic skin care products is a parameter defined as TEWL through the skin.

As a result of the TEWL measurements, it was noted that the most effective formulation was cream (C2) containing hemp oil as an active ingredient. The difference of TEWL after 30 min was 26.6%, whereas after 60 min, the value decreased to 10.0%. 120 min after cream (C2) application, the value of the percentage difference of TEWL gently increased to 14.2%. For other commercial preparations, the percentage difference of TEWL after 30 min was between 26.8% and 40.3%. After 120 min, excluding the cream (C2), the lowest percentage differences of TEWL were obtained for cream (C4) and balm (B3) (Table IV).

Analyzing the results obtained for the emulsion containing interesterified fat application, it was found that the mean percentage difference of TEWL in the first and second measurement was comparable, 36.7% and 38.9%, respectively. However, after 120 min, the value was reduced to 23.0%, which at this point placed our formulation fourth in terms of the protective effect of the formulation.

COMPARISON OF SKIN HYDRATION AND TEWL VALUES FOR OUR OWN FORMULATION AND COMMERCIAL PRODUCTS

Figure 3 shows a comparison of skin hydration and TEWL percentage difference obtained for commercial products (creams and balms in general) and the authors' formulation. Values are presented as means for all the time points of the measurement (during 120 min).

Table IV
Mean Value of TEWL Percentage Difference for All the Respondents for Commercial Products and the Authors' Formulation

Preparation		TEWL percentage difference after 30 min from application (%)	TEWL percentage difference after 60 min from application (%)	TEWL percentage difference after 120 min from application (%)
Cream	C1	26.8 ± 0.4	32.1 ± 0.3	33.4 ± 0.3
	C2	26.6 ± 0.4	10.0 ± 0.5	14.2 ± 0.4
	C3	36.3 ± 0.3	29.7 ± 0.3	30.1 ± 0.3
	C4	28.9 ± 0.2	27.7 ± 0.3	19.2 ± 0.3
	C5	34.0 ± 0.4	24.5 ± 0.4	38.5 ± 0.4
Balm	B1	33.6 ± 0.4	26.7 ± 0.5	33.2 ± 0.3
	B2	29.9 ± 0.4	27.0 ± 0.4	25.1 ± 0.3
	B3	40.9 ± 0.3	27.6 ± 0.3	21.1 ± 0.3
	B4	36.2 ± 0.2	28.3 ± 0.3	26.3 ± 0.2
	B5	29.3 ± 0.3	24.9 ± 0.4	27.0 ± 0.4
–	Own preparation	36.7 ± 0.2	38.9 ± 0.2	23.0 ± 0.3

It has been found that the values of both skin hydration and TEWL percentage difference for our own preparation and commercial formulations are similar. Considering the effectiveness of skin hydration, it was found that the increase in hydration was the same as after application of the commercial creams. In the case of the TEWL results, the authors' preparation produced 3.8% and 5.4% lower values than the balms and creams by, respectively.

SENSORY EVALUATION

Figure 4 presents results of a sensory analysis of all the applied formulations, including our own formulation. In general, the results for consistency, homogeneity, distribution, and odor were consistent for all the tested products and scored greater than 4 points. Respondents also highly rated the color of all the commercial preparations. The authors' emulsion (1.5 points) scored the lowest.

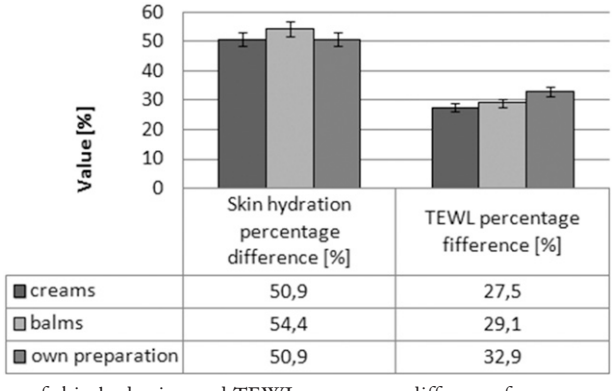

Figure 3. Comparison of skin hydration and TEWL percentage difference for commercial products (creams and balms in general) and the authors' formulation.

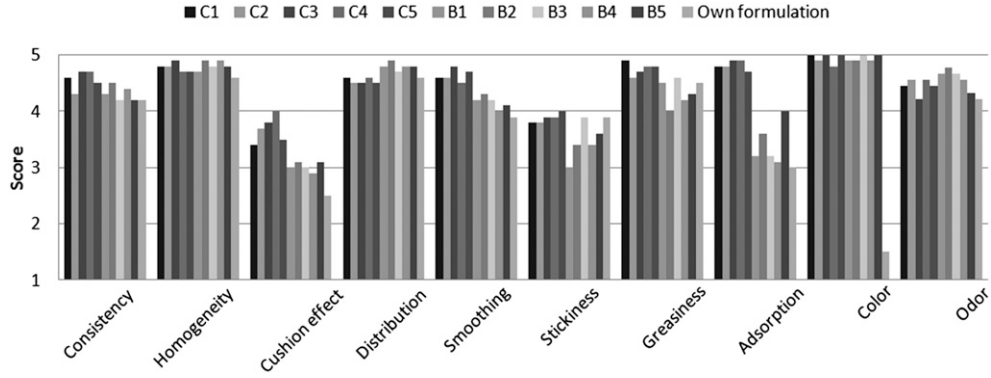

Figure 4. Results of a sensory analysis of all the applied formulations (as a mean value for all respondents).

The lowest score for the cushion effect was awarded to our own emulsion (2.5 points). According to the respondents, this emulsion was the least noticeable formulation between the fingers. Cream (C4) was best rated (4.0 points). In the case of assessment of the next parameter, smoothing, the highest score was obtained by cream (C3), with the result of 4.8 points. Our own formulation received the lowest score—3.9 points.

According to the respondents, slight skin stickiness was sensed after application of all the preparations. The smallest skin stickiness was sensed after application of cream (C5) (4 points). After application of cream (C1), no greasy film on the skin was sensed. On a 5-point scale, the skin condition was assessed at 4.9 points. Respondents rated the worst skin after balm (B2) application. The evaluators found that balm (B2) was characterized by excessive and uncomfortable greasiness.

Generally, creams showed the best absorption among the tested products. The scores received ranged from 4.7 points to 4.9 points. The weakest absorption, according to the respondents, was displayed by our own preparation (3 points).

The sensory analysis of commercial products showed that the respondents generally gave higher scores for creams than lotions in respect of the following parameters: consistency, cushion effect, smoothing, stickiness, greasiness, and absorption (Figure 5). On the other hand, balms were found to have better spreadability (distribution) on the skin. The average

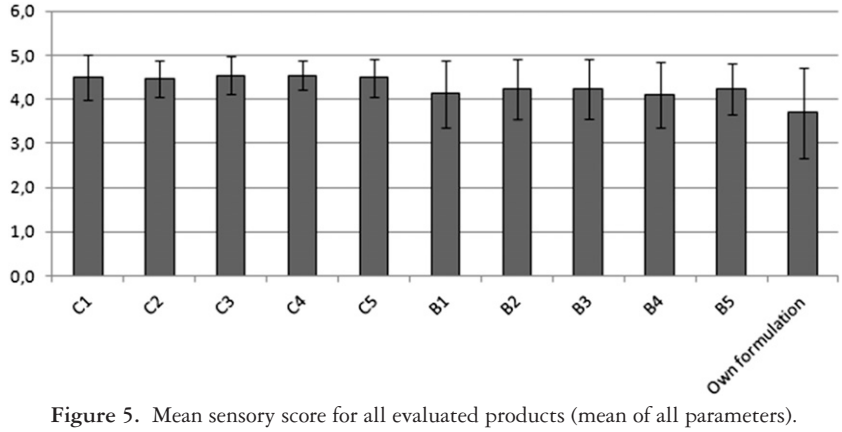

Figure 5. Mean sensory score for all evaluated products (mean of all parameters).

score for each of the creams was 4.50 ± 0.05. The weakest assessed product was the authors' formulation.

CONCLUSIONS

Market analysis of selected 10 commercial products for atopic skin care popular among consumers showed that components of synthetic origin are prevalent in them.

It was observed that the highest average increase in skin hydration was achieved after cream (C5) application on the skin. The formula contained, among others, mineral oil, glycerine, and a unique ingredient—evening primrose oil. The greatest percentage decrease in TEWL was noted after application of the authors' formulation. Thus, the selection of ingredients and the fat modification allowed to form an ingredient which properly protects the skin from water loss. Therefore, it can be stated that the emulsion containing interesterified fat had good moisturizing properties and formed a protective barrier against skin evaporation and commercial preparations.

Sensory analysis showed that the highest scores were obtained for creams. The highest scores were awarded to creams (C4) and (C3). Balm (B2) was evaluated the best among the balms. The respondents evaluated the preparation based on interesterified fat as not fully satisfying.

The results showed that the emulsion with interesterified fat based on natural components as sesame oil and mutton tallow can applicate as a formulation for atopic skin care. Physical characteristics showed proper stability of the dispersion. However, parameters such as color, smoothing, cushion effect, and absorption should be improved in that model preparation.

Taking into account the amount of ingredients contained in the presented commercial preparations, it can be concluded that there is a very wide area in which authors can modify the composition to improve the final product proposed for atopic skin care, thus fulfilling the criteria and requirements of consumers.

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