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Plant-Origin Additives from *Boswellia* Species in Emulgel Formulation for Radiotherapy Skin Care

Agnieszka Kulawik-Pióro [1,*], Weronika Goździcka [1,2], Joanna Kruk [3] and Anna Piotrowska [4]

[1] Department of Organic Chemistry and Technology, Faculty of Chemical Engineering and Technology, Cracow University of Technology, Warszawska 24, 31-155 Cracow, Poland; weronikagozdzicka@windowslive.com
[2] Management of Technology, Technische Universiteit Delft, Postbus 5, 2600 AA Delft, The Netherlands
[3] Department of Engineering and Machinery for Food Industry, Faculty of Food Technology, University of Agriculture in Krakow, Balicka 122, 30-149 Krakow, Poland; joanna.kruk@urk.edu.pl
[4] Department of Chemistry and Biochemistry, Institute of Basic Sciences, Faculty of Rehabilitation, University of Physical Education in Krakow, Jana Pawła II 78, 31-571 Cracow, Poland; anna.piotrowska@awf.krakow.pl
* Correspondence: agnieszka.kulawik-pioro@pk.edu.pl; Tel.: +48-12-628-27-59

Abstract: The research objective of this study was to include plant-origin additives of the *Boswellia* species in the formulation of topical preparations for skin care after radiotherapy. The main factor damaging the skin during radiotherapy is the free radicals that form from water molecules and granulocytes in the inflammatory area; hence, the use of substances with antioxidant properties, including plant extracts rich in antioxidants, seems to be an alternative therapy in radiodermatitis treatment. A series of cosmetic preparations containing plant-origin additives from *Boswellia* species and corresponding placebo formulations were prepared. In order to assess the applicability of emulgels as oncocosmetics, their stability, physicochemical properties, rheological properties, and antioxidant capacity were determined. Somatosensory analysis was also performed. An attempt was also made to correlate the effect of plant-derived additives on the functional properties of the product determined via instrumental methods and the sensory properties. The most promising preparation was the emulgel containing the Soxhlet extract and essential oil (Em_SO) due to its high antioxidant properties compared to other preparations (% inhibition of 11.69) and polyphenol content (3.63 mg/dm^3). Additionally, probands positively assessed all its features, including consistency (4.00), absorption (4.43), and hydration (4.71). The presence of significant correlations for % inhibition and polyphenols content with sensory and physicochemical characteristics of samples was indicated. There were low ratings for placebo preparations by probands, and the demonstrated correlations of odor with moisturization and distribution, oiliness and hydration with the % inhibition of the sample, and the content of polyphenols with the pH and size of the dispersed phase droplets proved the positive effect of the addition of plant-origin additives from *Boswellia* to the emulgel formulation on the functional and sensory properties.

Keywords: emulgels; radiotherapy skin care; *Boswellia* species; antioxidant properties

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1. Introduction

Radiotherapy is one of the basic methods used in cancer treatment of the prostate, breast, lung, cervix, and head, which uses ionizing radiation to destroy cancer cells. With this type of therapy, it is possible to prevent recurrence, slow down, or completely stop tumor growth; hence, radiotherapy is currently included in most comprehensive cancer control plans [1–3]. According to the World Health Organization (WHO), over 50% of oncology patients require radiotherapy as part of their treatment. It is therefore used together with surgery, both before and after the surgery, and with systemic chemotherapy [3]. The widespread use of radiotherapy in oncological treatment is connected with its high efficiency [4]. Unfortunately, patients undergoing radiotherapy suffer from a number of side effects that lower their quality of life and impede their daily functioning.

Among the most common types of side effects of therapy affecting approximately 95% of patients are skin reactions—radiodermatitis [2,5]. These skin manifestations range from slight to severe skin damage. The most vulnerable areas are those parts of the body where two skin surfaces meet (breasts, crotch), those with thin and smooth skin (crotch, face, armpits), and areas of skin where the integrity of the skin layers has already been compromised [2]. The skin reactions observed during treatment depend both on the radiation dose and duration of treatment but also on comorbidities, age, general health, addictions, and other drugs used [2,6]. The most common skin reactions include transient and persistent erythema, moist and dry desquamation accompanied by serous effusion, persistent epilation, hyperpigmentation, ulceration, spots and/or rash, skin atrophy, and others [2,7–9]. Radiodermatitis also causes burning, pain, and discomfort among patients [2,8,9]. This decreases the quality of patients' lives, causing pain, treatment delay, or aesthetic defects. Radiotherapy causes damage to Langerhans cells, basal cells, and the vascular endothelium. The decreased number of Langerhans cells and the depletion of basal layer stem cells lead to impaired barrier and immune function, increasing the risk of wound infection. Damage to vasculature can induce hypoxia and TGF-β production, further driving fibrosis. Tissue hypoxia with associated necrosis and inflammation can lead to the generation of significant amounts of reactive oxygen species (ROS). Additionally, the ROS can drive the production of cytokines, perpetuating the cycle of inflammatory changes [10,11]. Radiotherapy breaks down the body's immune system and leads to an excess of ROS in the body, which is why patients use alternative methods of treatment that include antioxidants [10]. Therapies targeting the elimination of ROS include both systemic and topical delivery of antioxidants, but systemically derived antioxidants could disrupt radiation treatment therapy by preventing the formation of ROS within the tumor. The topical application of antioxidants allows for the concentrated therapy to the skin, minimizing systemic levels [10].

The ability of skin to regenerate decreases significantly when the patient's treatment lengthens or when the received radiation dose increases. The patient's skin after radiation therefore requires a special course of treatment due to its sensitivity and susceptibility to external factors such as UV radiation [2,12].

There are many skin care products on the market for use on the skin after radiotherapy that are commonly called oncocosmetics or oncology skin care products. They can be divided according to their mode of action. They include moisturizing, emollient, anti-inflammatory, cleansing, and antiseptic agents but also drying agents and barrier measures. The preparations should also stimulate the proliferation of fibroblasts and keratinocytes in order to accelerate cell renewal and, consequently, skin regeneration, and they should not include potentially allergenic ingredients [2,12–14]. The products are available on the market in such physicochemical forms as aqueous solutions, foams, gels, emulsions, suspensions, oils, pastes, and others. They have a number of advantages, including the relief of side effects such as itching, burning, redness, and retention of moisture in the skin. By improving the barrier functions of the skin, they reduce potential friction and mechanical skin damage. Disadvantages include being too oily to feel, difficulty in spreading on painful skin, comedogenic action, skin pH disruption causing irritation and unpleasant odor, intensifying nausea, and vomiting [2,12,15–17].

The most common active ingredients in the formulation of oncocosmetics include ceramides, phospholipids, hyaluronic acid, urea, D-panthenol, allantoin, vegetable and animal oils, lipids, proteins, vitamins, and essential unsaturated fatty acids, but also plant and herbal extracts and essential oils [2,18]. The beneficial effect of plant-origin additives is due to the presence in their composition of phytochemicals such as saponins, flavonoids, tannins, alkaloids, and terpenoids. These compounds are known for their anti-inflammatory, antibacterial, and anticancer properties [19]. Due to these properties, many plants and herbs can support the natural repair mechanisms of the skin and exhibit great therapeutic potential in wound care [20].

The main factor damaging the skin during radiotherapy is the free radicals that form from water molecules and granulocytes in the inflamed area; hence, the use of substances with antioxidant properties, including plant and herbal extracts rich in antioxidant substances, seems to be a complementary therapy in radiodermatitis treatment [2,17,21,22]. Plant and herbal extracts introduced to the formulations of topical medicinal and cosmetic preparations show antioxidant effects, reducing irritation and redness. They can also promote healing processes or protect against UV radiation, improving the quality of life of patients suffering from radiodermatitis [23].

A previously conducted literature analysis of the use of plant and herbal extracts as ingredients in topical formulations in the prevention and treatment of radiodermatitis [2] showed the promising effects of numerous plant and herbal extracts on skin affected by radiodermatitis, particularly *Boswellia* oleoresin, which has antioxidant, anti-inflammatory, and antimicrobial properties. The research objective of this study was therefore to include plant-origin additives of the *Boswellia* species in the formulation of topical preparations for skin care after radiotherapy. A representative belonging to the polymeric gels, i.e., emulgel, was chosen as the physicochemical form of the preparation. In order to assess the applicability of emulgels as oncocosmetics, their stability, physicochemical properties, rheological properties, and antioxidant capacity were determined. Sensory analysis was also performed.

2. Materials and Methods

The effect of the addition of plant-origin additives from *Boswellia* species on the physicochemical properties of the formulation for topical use—while maintaining antioxidant properties, which are a measure of the effectiveness of the product in skin care during radiotherapy—was analyzed using instrumental–sensory analysis. The general research procedure is presented in Figure 1.

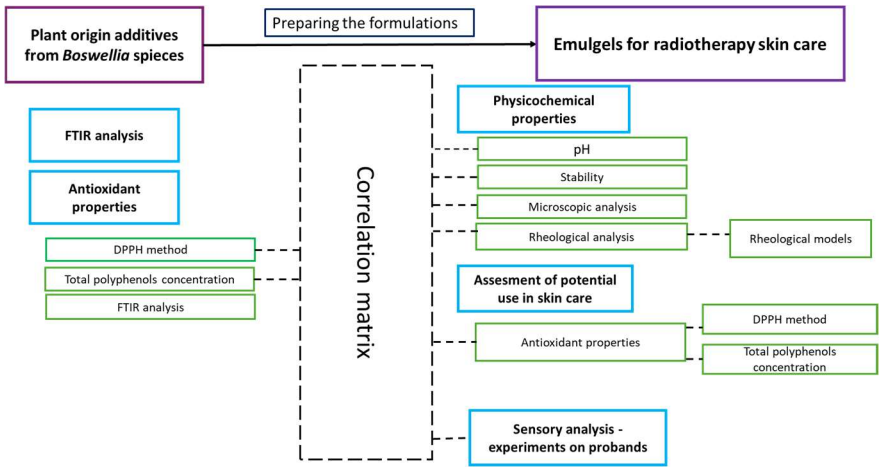

Figure 1. General research procedure.

2.1. Materials

In this research, cosmetic raw materials, such as refined sunflower oil (EOL Polska Sp. z o.o., Szamotuły, Poland), milk thistle oil (unrefined) (VitaFarm, Lipno, Poland), glyceryl monostearate (Zrób Sobie Krem, Prochowice, Poland), vegetable glycerin anhydrous (CHEMPUR, Piekary Śląskie, Poland), cetyl alcohol (Zrób Sobie Krem, Prochowice, Poland), D-panthenol (Zrób Sobie Krem, Prochowice, Poland), Euxyl PE 9010 (INCI: Phenoxyethanol (and) Ethylhexylglycerin) (Ashland Specialties Poland Sp. z o.o, Warszawa, Poland), essential oil from *Boswellia carterii* Birdw. (magiczneindie.pl, Warszawa, Poland), select-extract CO_2 (*Boswellia serrata* Roxb.) (Ecospa, Warszawa, Poland), powdered frankincense (*B. serrata*) (Nanga, Błękwit, Poland), and carbomer (Zrób Sobie Krem, Prochowice, Poland), were used. The chemical reagents used in the assessment of antioxidant properties were

methanol anhydrous 99.8%, ethanol 96%, 2,2-diphenyl-1-picrylhydrazyl (DPPH), sodium bicarbonate, and Folin–Ciocalteu reagent (CHEMPUR, Piekary Śląskie, Poland).

2.2. Characteristics of Extracts and Essential Oil from Boswellia Species

Three types of plant raw materials obtained from the *Boswellia* family were used in this study. The ethanol extract from *B. serrata* was obtained by extracting powdered frankincense with 96% ethanol in a Soxhlet apparatus for 20 h. The obtained extract was a light yellow liquid with an intense odor. The remaining two raw materials, i.e., selective CO_2 extract and essential oil, were commercial products.

Each of the plant raw materials was subjected to Fourier transform infrared spectroscopy (FTIR) analysis and assessment of its antioxidant properties and polyphenol content.

2.2.1. FTIR Spectrum

FTIR spectra in a wavenumber range from 4000 cm^{-1} do 400 cm^{-1}, at resolution 1 cm^{-1}, were recorded at 22 °C on an FTS−165 spectrophotometer (FTIR Biorad, Krefeld, Germany). For each spectrum, 125 scans were registered. Pure plant raw materials were used in this study.

2.2.2. Antioxidant Activity by 1,1-Diphenyl-2-Picrylhydrazyl (DPPH) Assay

The free radical scavenging activity of plant-origin additives from *Boswellia* was determined using the DPPH method. Three cm^3 of methanolic DPPH solution (2.8 mg/50 cm^3) was added to 0.4 cm^3 of analyzed extract/essential oil or water (in the case of a blank sample) and were stored in dark place. After 30 min, the absorbance at a wavelength of λ = 517 nm was measured on the NANOCOLOR UV–Vis spectrophotometer (Macherey-Nagel, GmbH & Co, KG, Düren, Germany). Absorbance measurements were repeated three times. The inhibition percentage was calculated using Formula (1):

$$\%Inhibition = \frac{A_0 - A_{sample}}{A_0} \cdot 100\%, \quad (1)$$

where:

A_0—absorbance of blank sample;
A_{sample}—average absorbance of samples.

2.2.3. Total Phenolic Content Assay

The Folin–Ciocalteu reagent (diluted 10 times) was used to determine the total phenolic content in analyzed extract or essential oil from *Boswellia* spp. Five cm^3 of Folin–Ciocalteu reagent was added to 1 cm^3 of extract or essential oil (or 1 cm^3 of water in case of blank sample). After 4 min, 4 cm^3 t sodium bicarbonate solution (7.5% m/m) was added. The mixture obtained in this way were stored at 22 °C in dark place for another 2 h. The absorbance values at λ = 765 nm were measured using a NANOCOLOR UV-Vis (Macherey-Nagel, GmbH & Co, KG, Düren, Germany) spectrophotometer. Each measurement was repeated three times, and the absorbance values obtained were averaged. Based on the calibration curve for gallic acid, the obtained results were presented as the concentration of gallic acid (mg/dm^3).

2.3. Composition and Obtaining of Topical Formulations

A detailed recipe of the obtained formulations is presented in Table 1. Plant-origin additives from the *Boswellia* species were introduced into both the hydrogel and emulsion recipes. For comparative purposes, placebo systems were also created, i.e., formulations without active substances originating from the *Boswellia* spp.

Table 1. Recipe of topical formulations with plant-origin additives from Boswellia species. E—emulsion; Em—emulgel; P—placebo; CO_2—addition of CO_2 extract; O—addition of essential oil; S—addition of Soxhlet extract; h—plant raw material was introduced to the hydrogel.

Ingredient	E_P	Em_P	E_SCO$_2$	Em_SCO$_2$	E_SO	Em_SO	Em_hSCO$_2$	Em_hSO
	% Mass.							
Distilled water	59.60	29.80	56.10	28.05	55.10	27.55	28.05	27.55
Hydrogel	-	50.00	-	50.00	-	50.00	50.00	50.00
Sunflower oil	10.00	5.00	10.00	5.00	10.00	5.00	5.00	5.00
Milk thistle oil	10.00	5.00	10.00	5.00	10.00	5.00	5.00	5.00
Glyceryl monostearate	8.00	4.00	8.00	4.00	8.00	4.00	4.00	4.00
Glycerin	7.00	3.50	7.00	3.50	7.00	3.50	3.50	3.50
Cetyl alcohol	3.00	1.50	3.00	1.50	3.00	1.50	1.50	1.50
Soxhlet extract from *B. serrata*	-	-	2.50	1.25	2.50	1.25	1.25	1.25
Select CO_2 extract from *B. serrata*	-	-	1.00	0.50	-	-	0.50	-
Essential oil from *B. carterii*	-	-	-	-	2.00	1.00	-	1.00
D-panthenol	2.00	1.0	2.00	1.00	2.00	1.00	1.00	1.00
Mixture of phenoxyethanol and ethylhexylglycerin	0.40	0.20	0.40	0.20	0.40	0.20	0.20	0.20

2.3.1. Emulsion

The ingredients of the oil phase (sunflower oil, milk thistle oil, and cetyl alcohol) were melted in a water bath. The aqueous phase (distilled water, vegetable glycerin, and preservative) was heated to 60 °C. When both phases had the same temperature (approx. 60 °C), the oil phase was poured into the water phase in small portions, stirring intensively with an IKA RW 20 digital 450 rpm mechanical mixer (IKA Poland Sp. z o.o., Warsaw, Poland). After combining the phases, mixing was continued for 10 min and the cooling stage was started. After cooling the mixture to 40 °C, D-panthenol was added. The whole mixture was mixed until a homogeneous consistency and room temperature were obtained. In the case of emulsions containing *Boswellia* spp. extracts, the Soxhlet extract was added to the water phase of the emulsion and, when hot, combined with the oil phase, whereas the CO_2 extract—or, respectively, the essential oil—was added to the obtained emulsion at a temperature below of 40 °C.

2.3.2. Emulgel

A 1% carbomer solution was obtained using a Sunlab SU1150 450 rpm magnetic stirrer (Bionovo, Legnica, Poland) by dispersing carbomer in distilled water. Subsequently, 3–4 drops of triethanolamine were added to adjust the pH, which led to a gel consistency. *B. serrata* extracts and/or essential oil were added to the hydrogel at room temperature. The obtained emulsion and hydrogel were mixed with a mechanical mixer at 450 rpm at 25 °C in a weight ratio of 1:1 until a homogeneous mixture was obtained.

2.4. Physicochemical Analysis of Formulations

2.4.1. Visual Assessment and pH

In order to check the quality of the prepared formulations and possible changes in their visual appearance after adding plant-origin raw materials, they were visually assessed

by a qualified person during quality control. The visual assessment concerned odor, color, consistency, and homogeneity. A total of 5 g of the analyzed sample was placed in the weighing dish and hermetically closed. During the evaluation, the container was opened, and the odor, color, and homogeneity of the cosmetic sample were evaluated. To evaluate consistency of sample, a finger was dipped in the formulation at an angle of 45–60° and pulled out quickly. During the test, it is necessary to pay attention to sample resistance when dipping the finger into the formulation and to the contact of the finger and the cosmetic when pulling it out.

The pH of the preparations was determined by immersing the measuring electrode of a pH meter (Ezodo 7200, Chemland, Stargard, Poland) directly in the preparation. The measurement was repeated three times. The obtained results constitute the arithmetic mean of the obtained results.

2.4.2. Stability

In order to confirm that the obtained formulations are stable, accelerated aging tests (variable temperature test) and long-term stability tests were conducted. The variable temperature test included three cycles of 24 h at each temperature (4/40 °C) for a single sample (Cultura® M 70708 Mini Incubator, Almedica AG, Galmiz, Switzerland). After this time, we assessed whether there were any unfavorable changes in color, odor, and consistency in the sample and whether phase separation occurred. Moreover, the prepared preparations were stored for 3 months at 4 °C and 25 °C in ambient humidity.

2.4.3. Microscopic Structure

The microscopic structures of the obtained emulsions and emulgels were determined under a Motic Advanced B1 optical microscope (Motic Asia, Hong Kong, China) at 40× magnification. To determine the mean particle diameter of the dispersed phase, Motic Images Advances 3.2 software was used.

2.4.4. Rheological Properties

For the obtained formulations, a flow curve and viscosity curve (shear rate range 1–1000 s^{-1}, 60 s, 60 measurement points) were determined using rotational rheometer RS Plus Brookfield (LaboPlus, Warszawa, Poland). The measurements system was cone–plate C25-2. The presented test results are the arithmetic means of the three measurements. The obtained rheological data results were approximated with the Herschel–Bulkley model:

$$\tau = \tau_0 + k \cdot \dot{\gamma}^n, \quad (2)$$

where:

τ_0—yield stress, Pa;
τ—shear stress, Pa;
k—consistency index, $Pa \cdot s^n$;
$\dot{\gamma}$—shear rate, s^{-1};
n—flow index, -.

2.5. Antioxidant Properties and Polyphenols Content

To determine antioxidant properties and polyphenols content in the preparations, 1 g of each sample was dissolved in 5 cm^3 methanol then centrifuged for 15 min at 3500 rpm in a Hettich EBA 200 S centrifuge (Marazet, Poznan, Poland). The obtained filtrate was analyzed spectrometrically via the DPPH method and with Folin–Ciocalteu reagent. The same methodology as for the analysis of the plant extracts and essential oils was used.

2.6. Sensory Analysis

Sensory analysis for all obtained formulations was performed in a cosmetic laboratory. The oncocosmetic evaluation was carried out by persons trained in cosmetic product

evaluations. The test involved 7 testers (participants): women with healthy skin, not undergoing radiotherapy treatment, aged 22–41. The participants were familiarized with the research procedures and the assessment of individual features before the assessment. The research was carried out using a scale of 1–5 points, where 1 is the lowest rating. The following features of the preparations were assessed: odor, consistency, cushion effect, spreadability, oiliness, absorption, and hydration. The detailed research procedures and definitions of the assessed features is presented in our previous publication [24].

All participants gave their informed consent for inclusion before they participated in this study. The scope of this study is in line with Regulation (EC) No 1223/2009 of the European Parliament and Council; Cosmetics Europe—The Personal Care Association Guidelines: "Product Test Guidelines for the Assessment of Human Skin Compatibility 1997"; Cosmetics Europe—The Personal Care Association: "Guidelines for the Evaluation of the Efficacy of Cosmetic Products 2008"; and the World Medical Association (WMA) Declaration of Helsinki's ethical principles for medical research involving human subjects.

2.7. Statistical Analysis

Whenever applicable, the obtained results were expressed as mean ± standard deviation. Analyses of variance (ANOVA) were conducted to check differences among pH, polyphenol concentrations, % of inhibition, and the sensory attributes of the obtained formulations. A value of $p < 0.05$ was considered statistically significant. In case of significant differences at 95%, Tukey's HSD post hoc comparison tests were then carried out. To show these differences, lowercase letters of the alphabet were used. Samples marked with different letters are statistically significantly different. Samples with the same letter do not differ significantly from each other. Samples with mixed letters (e.g., "ab") do not differ significantly from any of the samples marked with the letters "a" and "b".

The correlation matrix was used in order to establish and interpret the relationship between sensory and instrumental measurements.

3. Results

3.1. Physicochemical Properties of Obtained Formulations

The physicochemical properties of the obtained topical formulations are given in Table 2.

Table 2. Physicochemical properties of obtained topical formulations.

Sample	Odor	Color	Consistency	Stability	pH	Mean Droplet Size of Dispersed Phase μm
E_P	none	white	creamy	stable	6.69 ± 0.01 a	19.0 ± 1.5
Em_P	none	white	cream–gel	stable	5.88 ± 0.03 b	10.9 ± 0.5
E_SCO_2	intense herbal scent	white	creamy	stable	5.64 ± 0.01 bc	8.1 ± 0.6
Em_SCO_2	intense herbal scent	white	creamy	stable	6.12 ± 0.01 ab	15.1 ± 0.9
E_SO	intense herbal scent	white	creamy	stable	4.92 ± 0.06 cd	6.6 ± 0.7
Em_SO	intense herbal scent	white	creamy	stable	4.57 ± 0.03 cd	8.6 ± 0.3
Em_hSCO_2	intense herbal scent	white	creamy	stable	5.51 ± 0.01 cd	20.9 ± 0.8
Em_hSO	intense herbal scent	white	creamy	stable	4.77 ± 0.03 d	7.0 ± 0.6

E—emulsion; Em—emulgel; P—placebo; CO_2—addition of CO_2 extract; O—addition of essential oil; S—addition of Soxhlet extract; h—plant raw material was introduced to the hydrogel. Different letters in the same category indicate significant difference between samples at $p < 0.05$.

Under the analyzed storage conditions, the obtained samples were stable; no changes in their color, consistency, or odor were noted. There was also no phase separation. Samples E_P and Em_P, without active substances from the *Boswellia* spp., were white in color, had a uniform, smooth, creamy or cream–gel consistency, respectively, and were odorless.

After adding plant raw materials from the *Boswellia* spp. to the product recipe, there were no changes in their color or consistency. There was a change in the odor, which became intense, and a herbal scent was noticed. The pH of the obtained formulations was 4.57 ± 0.03–6.69 ± 0.01. Preparations E_SO, EmhSO, and Em_SO, with the addition of *B. carterii* essential oil, had a lower pH than Em_SCO_2 (with Soxhlet extract and CO_2 extract) and placebo formulations. Moreover, it has been shown that the method of the addition of the *Boswellia* raw material (either to the emulsion or to the hydrogel) did not affect the pH of the formulation.

Microscopic images of the preparations confirmed the structure of the oil in water macroemulgel (o/w macroemulgel) (Figure 2), where the continuous phase is a hydrogel matrix, and the dispersed phase is an oil-in-water emulsion (o/w emulsion). The structure of the emulgel was also preserved when the extract and/or oil were added to the hydrogel rather than to the emulsion. The obtained formulations were characterized by different droplet sizes of the dispersed phase: 6.6 ± 0.7–20.9 ± 0.8 µm.

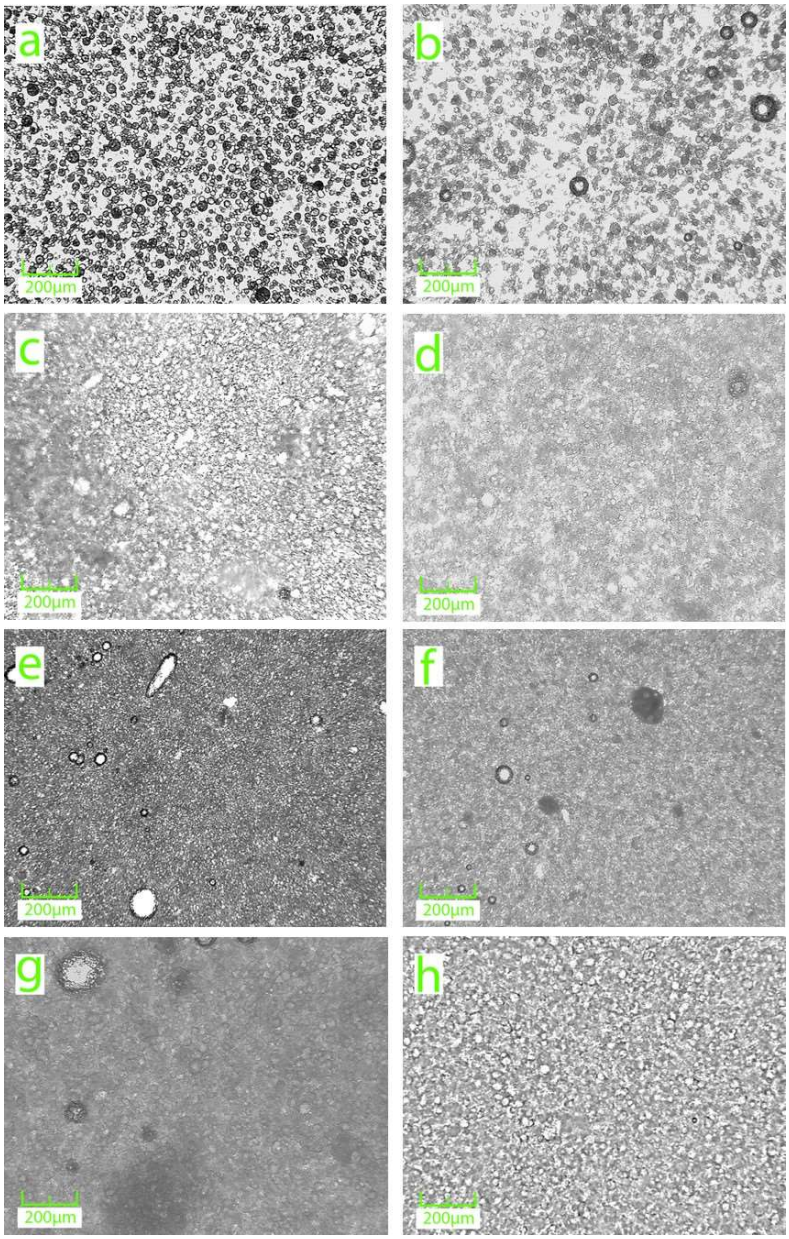

Figure 2. Microscopic images of the obtained formulations: (**a**) E_P; (**b**) Em_P; (**c**) E_SCO_2; (**d**) Em_SCO_2; (**e**) E_SO; (**f**) Em_SO; (**g**) Em_hSCO_2; (**h**) Em_hSO.

3.2. Rheological Properties

Figure 3 shows the flow curves of the prepared formulations. The flow curves were approximated by the Herschel–Bulkley model (Table 3).

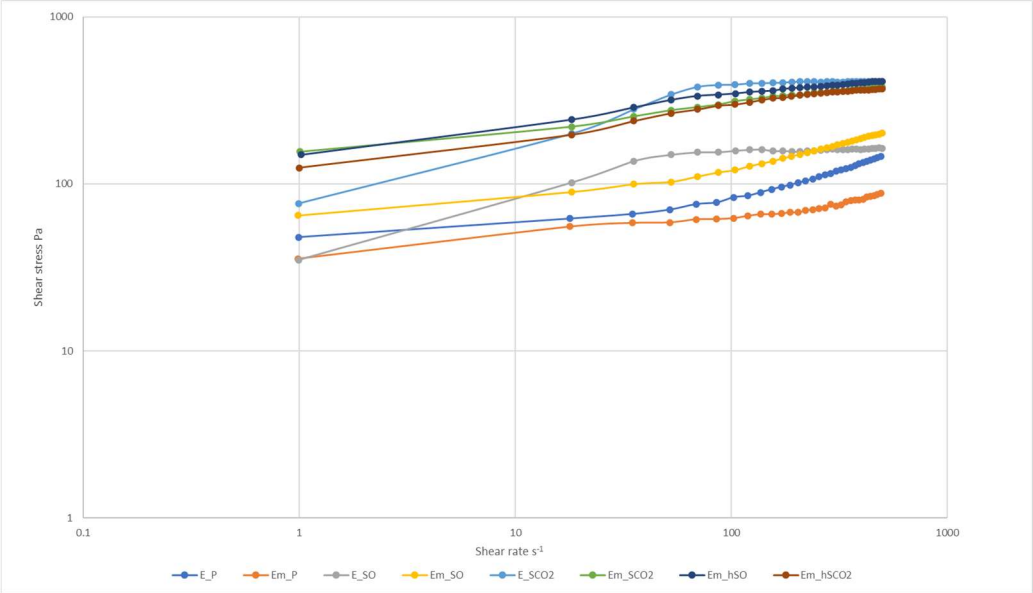

Figure 3. Flow curves of obtained samples. E—emulsion; Em—emulgel; P—placebo; CO_2—addition of CO_2 extract; O—addition of essential oil; S—addition of Soxhlet extract; h—plant raw material was introduced to the hydrogel.

Table 3. Parameters of the Herschel–Bulkley model and viscosity of samples.

Sample	τ_0, Pa	k, Pa·s^n	n, -	R^2	η, Pas at $\dot{\gamma}$ = 50 s^{-1}
E_P	49.27	1.372	0.686	0.999	1.35 ± 0.04
Em_P	36.03	4.629	0.378	0.976	1.20 ± 0.08
E_SO	16.96	66.53	0.136	0.925	3.21 ± 0.20
Em_SO	61.44	5.291	0.528	0.999	1.95 ± 0.12
E_SCO_2	24.07	154.3	0.161	0.929	6.50 ± 0.58
Em_SCO_2	122.6	57.19	0.247	0.990	5.62 ± 0.23
Em_hSO	116.8	80.47	0.214	0.982	6.05 ± 0.43
Em_hSCO_2	84.90	70.22	0.234	0.986	5.03 ± 0.30

E—emulsion; Em—emulgel; P—placebo; CO_2—addition of CO_2 extract; O—addition of essential oil; S—addition of Soxhlet extract; h—plant raw material was introduced to the hydrogel.

The obtained samples belonged to the group of non-Newtonian fluids shear thinning with a yield point, which, in the case of emulgels, results from the use of carbomer as a hydrogelator. Emulgels with the addition of *Boswellia* raw materials had a higher yield point than emulsions. Among them, the highest yield points were those of emulgels in which plant-origin additives were introduced into the hydrogel, not into the emulsion. The Em_P sample had the lowest viscosity, and E_SCO_2 had the highest. Moreover, despite the constant mass ratio of emulsion to hydrogel in the obtained emulgels, they differed in viscosity. The type of shear thinning flow property for the obtained samples can be described by the Herschel–Bulkley model ($R^2 > 0.980$).

3.3. Antioxidant Properties and Polyphenols Content of Formulations

Table 4 lists the types of the most important vibrations and the corresponding wavenumber for the tested plant materials of the *Boswellia* spp. The FTIR spectra of extracts from *Boswellia* spp. showed characteristic peaks at 3357 cm^{-1} and 3578 cm^{-1} (OH stretching); 2969 cm^{-1} and 2957 cm^{-1} (C-H stretching); 1712 cm^{-1} and 1642 cm^{-1} (C=O stretching); 1453 cm^{-1} and1381 cm^{-1} and at 879 cm^{-1} and 778 cm^{-1} (OH deformation), respectively, for Soxhlet and the select CO_2 extract. For essential oil from *B. carterii*, characteristic peaks were at 3446 cm^{-1} (OH stretching), 2957 cm^{-1} (C-H stretching), 1738 cm^{-1} (C=O stretching), 1447 cm^{-1}, and 778 cm^{-1} (OH deformation).

Because the intensity of the bands depended on the type of extraction method used, the *Boswellia* spp. raw materials used in this research were characterized by different concentrations of biologically active compounds, which translates in their different antioxidant activity and polyphenol contents (Figure 4).

The select CO_2 extract and essential oil (OE) had the highest % inhibition of the DPPH radical, amounting to 54.8%, and 49.9% respectively, while the essential oil had the highest polyphenol content of 57.3 mg/dm^3, expressed as gallic acid. α-pinene, α-thujene, β-pinene, and limonene may be responsible for such a high content of polyphenols, as well as the high % inhibition of the DPPH radical, while the high % inhibition in the case of the CO_2 extract may be due to the presence of *Boswellia serrata* resin extract, as well as compounds such as limonene and linalool, which have proven antioxidant properties. Although the essential oil itself had a higher polyphenol content, among the formulations, the highest concentration of polyphenols were had by sample E_SCO_2 (3.88 mg/dm^3) and sample Em_SO (3.64 mg/dm^3). This may be related to the fact that in recipe of emulsion, one of the components is milk thistle oil, which has polyphenols in its composition [25]. When comparing the % inhibition of the preparations, the E_SO containing essential oil had the highest value (18.5%). All preparations—except Em_hSO (its % inhibition of the DPPH radical was 7.29)—showed a higher % inhibition of the DPPH radical compared to the placebo preparations. In the case of polyphenol content, the statistical differences was shown for placebo formulation and samples: E_SCO_2, E_SO, Em_SO, and Em_hSO. This means that the addition of extracts and essential oil increased the antioxidant activity and polyphenol content in preparations containing plant-origin additives from the *Boswellia* species.

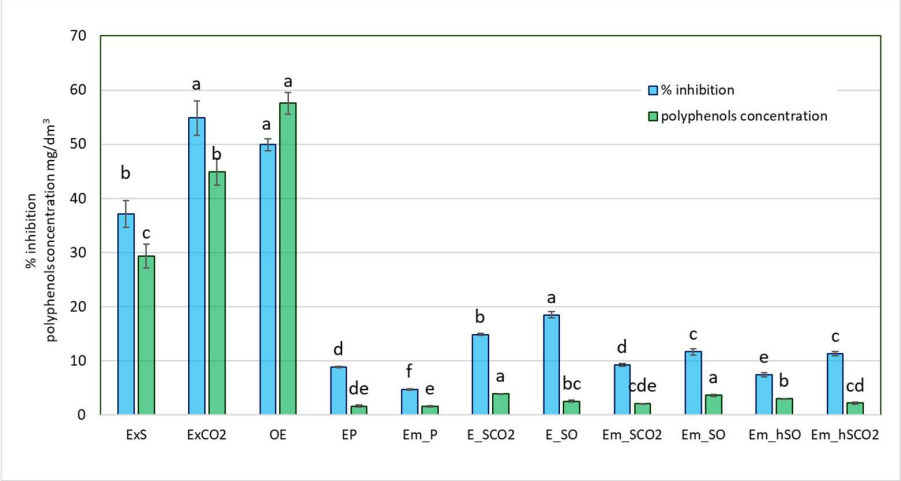

Figure 4. Results of antioxidant activity and polyphenols concentration in plant-origin additives from *Boswellia* species and topical formulations for skin care. ExS—Soxhlet extract; ExCO_2—CO_2 extract; OE—essential oil; E—emulsion; Em—emulgel; P—placebo; CO_2—addition of CO_2 extract; O—addition of essential oil; S—addition of Soxhlet extract; h—plant raw material was introduced to the hydrogel. Different letters in the same category (separately for raw materials and separately for preparations) indicate significant difference between samples at $p < 0.05$.

Table 4. Types of vibrations and corresponding wavenumber for analyzed plant-origin additives from *Boswellia* species. ***ν***—stretching vibrations; ***δ***—deformation vibrations.

Sample	Type of Vibrations and Corresponding Wavenumber cm^{-1}								
	ν-OH Alcohols, Phenols 3000–3500 cm^{-1} Wide Band at 3500–3550 cm^{-1} for Carboxylic Acids	**ν C-H Aromatic 3030 cm^{-1}**	**ν C-H Aliphatic Compound 2850–3000 cm^{-1}**	**ν C=O Aldehydes, Ketones, Acids, Esters 1600–1870 cm^{-1}**	**ν C=C in Alkenes 1600–1680 cm^{-1}**	**ν C=C Aromatic 1500–1610 cm^{-1}**	**δ OH Phenols, Alcohols 1330–1420 cm^{-1}**	**ν C-O 1050–1430 cm^{-1}**	**δ OH Phenols Alcohols 650–770 cm^{-1} or ν C-Cl 600–800 cm^{-1}**
Soxhlet extract	3357.19	-	2969.41	1712.12	-	-	1453.57 1377.26	1046.90	879.38
Select CO_2 extract	3578.17	3042.48	2957.32	1642.94	1642.94	1511.20	1381.69	1242.79	778.44
Essential oil from *B. carterii*	3446.06	3043.90	2957.74	1738.03	1643.38	1511.52	1447.08 1381.46	1242.57	778.30

3.4. Sensory Analysis

Results of the sensory analysis are presented in Figure 5.

The ANOVA statistical analysis did not show statistically significant differences for parameters such as odor, consistency, and hydration. The low scores in the odor category (the highest score was 3.29 ± 0.88 points) are related to the intense herbal smell of the used extracts and essential oil. Emulgels are known from their lighter consistency compared to emulsion, but in this case, the consistency of both types of formulations was rated good; the average score was 3.86–4.3 points. Also, the hydration for all preparations (even the placebo) was rated good; the averages score was 3.86–4.71 points. The average score for the cushion effect was in the range of 1.71–3.71 points. The statistical differences were noted for emulsions E_SCO_2 and E_P and emulgels Em_P, Em_hSCO_2, and Em_hSO. The increase in the yield point did not have a negative impact on the spreadability of the preparations. The lowest score in this category was had by the placebo emulsion (3.86 points), which was confirmed by the ANOVA statistical results. The most diverse assessments concerned the oiliness of the preparation (average score 1.0–3.86 points). Statistical differences were noted for placebo emulsion (E_P) and emulgels, namely, Em_P, Em_SO, Em_hSO, and Em_hSCO_2, which indicates that emulgels are less greasy than emulsions. The E_P formulation was rated the worst, which results from the fact that it is a placebo emulsion without the addition of any active substances. Statistical differences were also demonstrated for the placebo emulgel (Em_P) and the following samples: E_P, E_SO, Em_SO, E_SCO_2, Em_SCO_2, and Em_hSCO_2. The best rated in this category was Em_P, based on E_P. Statistically significant differences in absorption were observed between the placebo emulsion (E_P) and the emulgels in which the extract and/or essential oil were introduced into the hydrogel.

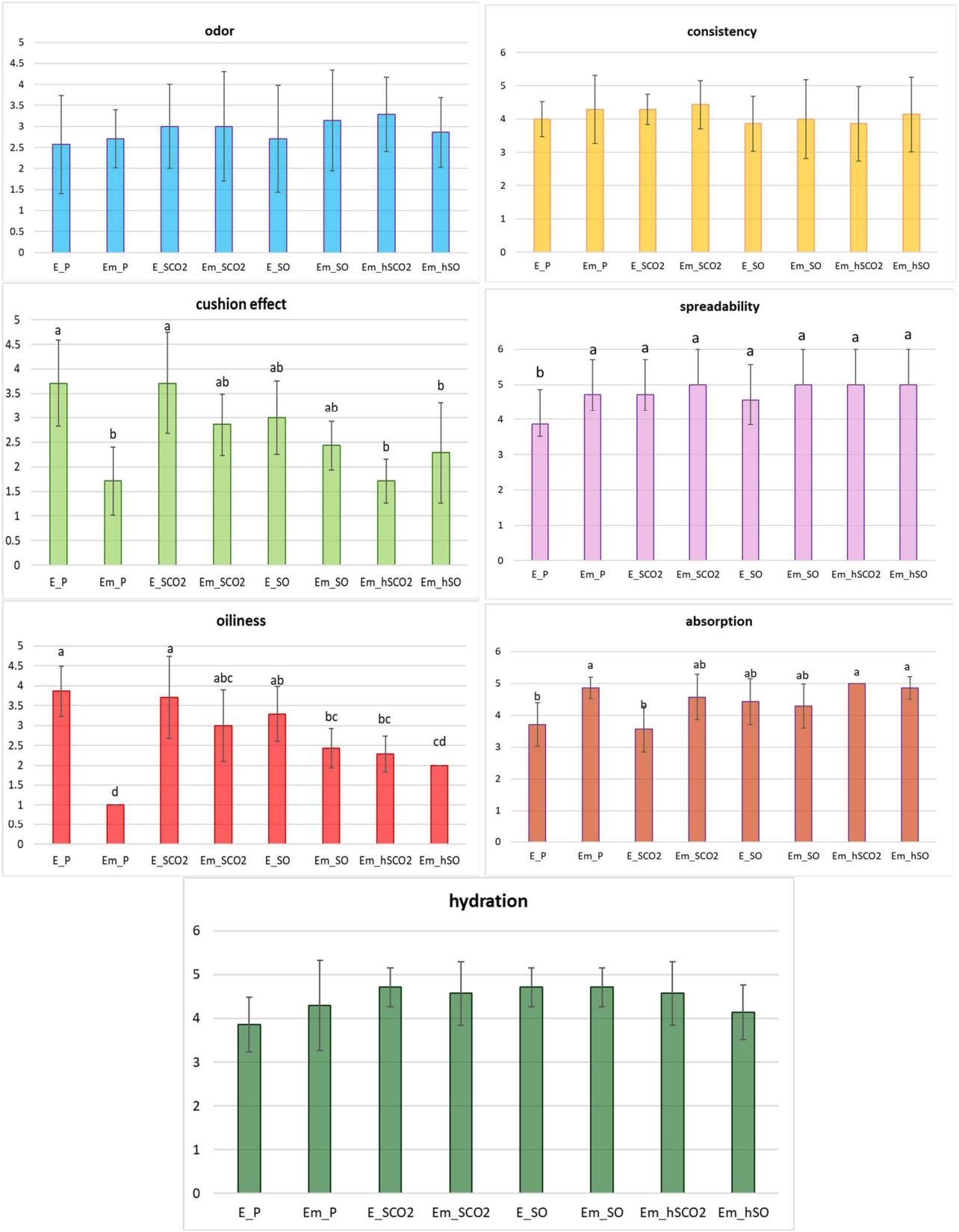

Figure 5. Sensory evaluation of obtained preparations. Different letters in the same category indicate significant differences between samples at $p < 0.05$. E—emulsion; Em—emulgel; P—placebo; CO_2—addition of CO_2 extract; O—addition of essential oil; S—addition of Soxhlet extract; h—plant raw material was introduced to the hydrogel.

4. Discussion

4.1. Composition and Characterization of Formulations

The clinical success in the antioxidants studied in radiodermatitis achieved with topical superoxide dismutase has stimulated interest in exploring naturally occurring and more-affordable antioxidant substances, especially those rich in polyphenols [10,26]. One of the plants that possesses therapeutic components is *Boswellia*. There are four main species of *Boswellia*, which include *Boswellia carterii*, *B. frerana*, *B. sacra*, and *B. serrata* [27].

This work is the first study indicating the possibility of using raw materials from *Boswellia* spp. as an antioxidant in topical preparations, i.e., emulgels and emulsions intended to care for the skin and limit unwanted skin reactions during radiotherapy.

Apart from being used in medicine, *Boswellia* is also an important cosmetic ingredient. There are 25 cosmetic ingredients in the CosIng database that can be obtained from the *Boswellia* species. These are resin extract, resin water, bark powder, gums, gum water, oils, and gum ferment extract.

Our research used select CO_2 extracts obtained via the extraction of supercritical carbon dioxide, which works as a solvent for naturally occurring plant ingredients. The CO_2 select extracts contain mainly volatile components typical for essential oils (with molecules ranging from C5 to C25). They have intensive, perceptible odors; heavier waxes, resins and color compounds are generally not present in this raw material, as reflected in the visual assessment and sensory analysis of samples. The CO_2 extract used, according to the manufacturer's data (INCI name: Boswellia Serrata Resin Extract, alpha-Pinene, Limonene, beta-Pinene, alpha-Terpinene, Terphinolene, Linalool, Limonene), contains approx. 70–90% essential oil, sesquiterpenes, diterpene alcohols (serratol, incensol), and boswellic acid. The allowable concentration of the extract for use in cosmetics ranges from 0.1 to 1% and from 0.4 to 0.75% in facial cosmetics.

Another ingredient was an essential oil obtained via the steam distillation of oleoresin *Boswellia carterii*. According to the manufacturer, the raw material came from India. It is a dark yellow liquid with an intense odor. It contains, among other ingredients, α-pinene, limonene, α-thujene, linalool, and cithrol. An extract rich in carbohydrates, tannins, glycosides, terpenes, flavonoids, and alkaloids can be obtained via Soxhlet extraction [28,29]. According to the literature data, they exhibit skin care effects, including anti-aging (reducing lines and wrinkles), anti-acne (anti-bacterial, anti-fungal properties), hair care (preventing hair loss), and nail care effects; they smooth, tonify, and protect skin, as well as providing fragrance. Due to their antioxidant properties, they prevent the formation of post-sun discoloration and reduce redness [30].

On the European Union market, there are no products dedicated to post-radiotherapy skin containing plant-origin additives from *Boswellia* species. However, all products available on the market containing this plant raw material are intended for very dry, damaged skin that requires regeneration, hydration, and soothing. Moreover, the market offers products in various physicochemical forms, such as bar soap, shower gel, serum, cream or sheet mask; however, there are no emulgel formulations.

Emulgels belong to the polymeric gels group: semi-solid formulations obtained by immobilizing the external phase of the emulsion (o/w or w/o type) using suitable gelators [31]. Therefore, they exhibit the properties of gels, which are characterized by a faster and better release of the active ingredient compared to an ointment or cream base. Due to their physicochemical form, they are characterized by higher stability than emulsions. In these systems, the risk of phase separation and the creaming phenomenon that occurs in emulsions is reduced. In addition, they are simple and economical to produce. The disadvantages of emulgels may include the poor absorption of macromolecules through the skin and the appearance of air bubbles after the preparation process [32].

4.1.1. Visual Assessment and pH

In the literature, the use of *B. serrata extracts* in emulgels as topical delivery systems (drug) was studied by Chandak et al. [33]. The *Boswellia-serrata*-loaded emulgel (BS-loaded

emulgel) was an anti-rheumatoid agent. Carbomer was used as a hydrogelator. The obtained formulations were creamy, with a smooth homogeneous appearance. Also in this study, the produced emulgels were characterized by a creamy consistency and white color, which is a desirable feature in preparations for sore, damaged skin [34].

The odor of the obtained formulations was intense and herbal. At a later stage of modifying the formulation's recipe, the odor should be slightly eliminated as it could disturb people using this preparation after radiotherapy, for whom strong odors may enhance the effect of nausea.

According to Auerswald et al. [35], the pH of skin subjected to radiotherapy is close to the pH of non-irradiated skin, whereas in the area of the treatment wound, the pH increases significantly and is higher (above 7.5) than that of non-irradiated skin (pH in the range of 4.5–6.7). pH-gradients play a crucial role in recruiting keratinocytes inwards from the wound edges. Also, the radiation-induced damage of epidermis and adnexal structures may impair the maintenance of an acidic pH in the stratum corneum. The alkalization of the stratum corneum following radiotherapy may impair skin barrier function and may also impair wound healing and predispose radiation-damaged skin to bacterial (especially *Staphylococcus aureus*) and fungal (*Candida albicans*) infections, which grow better at neutral pH [35]. Thus, it is important that formulations used in skin care after radiotherapy have an acidic pH [36], which is consistent with our results. The acidic pH of the prepared formulations containing plant-origin additives from *Boswellia* species is also consistent with the results of research by Chandak et al. [33]; the obtained emulgels had a pH of 6.3–7.09. In this case, *Boswellia serrata* extract was added to the aqueous phase at a concentration of 1%.

4.1.2. Microscopic Structure

The mean droplet size of the dispersed phase depended on the physicochemical form of the obtained formulations as well as on the addition and concentration of plant-origin additives from *Boswellia* species. The placebo emulgel (Em_P) has lower values of the mean droplet size of the dispersed phase compared to the placebo emulsion (E_P). The hydrogelator used in the study—polyacrylic polymer—effectively immobilizes the emulsion within the network structure, reduces the motion of the droplets, and prevents the droplets from colliding [37].

The situation is different for samples with the addition of raw materials from the *Boswellia* species. For emulgels in which the Soxhlet extract and essential oil or the CO_2 extract was added to the emulsion, an increase in the droplet size was observed compared to the emulsions from which they were prepared. For emulgels in which active substances from *Boswellia* were added to the hydrogel, the size of the dispersed phase droplets depended on the type of active substances used. The lowest values of the mean droplet size of the dispersed phase were recorded for formulations containing essential oil, both for emulsion systems and emulgels (regardless of whether it was added to a gelified emulsion or to a hydrogel). The changes in droplet sizes in systems belonging to polymeric gels when plant extracts have been added to the systems are consistent with our previous observations [38] and the literature data [39]. Additionally, according to Arshad et al. [40], the globule size analysis in this study indicated that the emulgel had a small globule size in the range desirable for topical products.

4.1.3. Rheological Properties

The shear-thinning behavior of the obtained samples affects the product's resistance to incompatibilities such as creaming, flocculation, or coalescence [41]. Additionally, shear thinning behavior is necessarily important for developing a viscous film over the skin as well as increasing the absorption of active molecules via the topical route [40]. The type of shear thinning flow property of the obtained samples can by described by the Herschel–Bulkley model. This is consistent with the research results published by Dong et al. [37] and Ergin et al. [42].

The consistency index (k), shown in Table 3, reveals higher values when plant-origin additives are added to the systems. A decrease in the value of the k parameter is observed when the emulsion is immobilized inside the hydrogel. This parameter is also directly related to the viscosity of samples; when the k parameter increases, the viscosity also increases. The values of flow index n < 1 confirm that these are shear-thinning fluids. The least-plastic system (n is the highest) is the placebo emulsion. The value of the flow index is influenced by the presence and type of plant raw material used, as in the research results obtained by Di Mambro [43]. The effect we observed of the addition of plant extract on the decrease/increase in the viscosity of the formulation is also consistent with the results published by Di Mambro [43]. Moreover, the observed changes in viscosity are influenced by the viscosity of the extract used and/or the presence of proteins in the extract [44]. Proteins spontaneously adsorb to oil–water interfaces, essentially due to the hydrophobic properties of these interfaces. Adsorption then results in the decrease in the interfacial tension and a formation of a large interface area in emulsion [43]. The high yield point in the Em_SCO_2, Em_hSO, Em_hSCO_2, Em_hSCO_2, and E_SCO_2 formulations did not have a negative impact on the spreadability assessed in the sensory analysis. This parameter was evaluated positively by the probands for all preparations. The average rating was in the range of 3.57–5.00.

4.2. Antioxidant Properties and Polyphenols Content

The chemical composition of *Boswellia* oleoresin depends on its botanical origin, while the type and concentration of compounds present in the extract depends on the extraction method used and the type of solvent [29]. According to the literature data, the oleoresin consists of carbohydrates, terpenoids, phytosterols, phenolic compounds, flavonoids, and tannins, including α- and β-boswellic acids belonging to pentacyclic triterpenes, which may constitute 30–60%, and essential oils amounting to 5–10% (with the main component of essential oils being α-pinene) [45,46]. The data presented in Table 4 prove that the tested extracts and essential oils of the *Boswellia* species contain compounds from the following groups: alcohols, phenols, carboxylic acids, including boswellic acid, esters, alkenes, alkanes, aliphatic amines, halides, cycloalkanes, which is consistent with literature data [47–50].

The pure extract samples and essential oil tested in the present study for their H-donor ability, measured by the stable free radical DPPH$^{\bullet}$ assay, showed a higher antioxidant activity when compared to formulation samples. The content of polyphenols for plant raw materials is also higher than for the tested preparations. According to [51], the reason for the much lower antioxidant activity and polyphenol content for the preparations compared to pure plant raw materials may be adding of the Soxhlet extract to the formulation at a high temperature, which could have caused a decrease in its activity as a result of the thermal degradation of some antioxidant compounds, such as phenolic compounds, that are present in the extract. A negative effect of heat on the stability of some polyphenolic antioxidants was also previously described in [52,53]. However, according to Di Mambro [43], these differences may result from the assay method used. In the author's opinion, the chemiluminescence assay shows a similar activity profile for extracts and samples, which cannot be observed in the DPPH analysis. These results may be due to the presence of the formulation components in the reaction mixture. The formulation components may interfere with the antioxidant measurements.

4.3. Correlation Matrix of Instrumental Analysis Results and Sensory Analysis

The use of sensory analysis to determine not only the maximum concentration but also the impact of the addition of plant extracts on the sensory characteristics of a product—while maintaining its antioxidant properties without deteriorating these characteristics, which as important for consumers—is being studied in the food industry [54,55]. This is due to the fact that plant extracts, especially those rich in phenolic compounds, may

have taste, color, and odor, and all such aspects should be taken into consideration prior to any use in the formulation of foods.

In the case of cosmetic and pharmaceutical preparations, sensory characteristics such as smell, consistency, spreadability, and greasiness after application are important to consumers, especially for people with skin diseases or injuries [32,35]. When it comes to assessing the antioxidant capacity of topical preparations containing plant extracts in their formulations, the authors approach the issue in two ways. The first method involves evaluating the extracts and the prepared formulations separately.

The extracts are analyzed for their antioxidant capacity (usually via the DPPH or FRAP method), and their chemical composition is determined. The release of phenolic compounds from the gel matrix is also studied [56]. For the formulations, however, in vivo tests on probands are carried out, which include instrumental tests on the skin concerning skin melanin level, skin erythema, skin moisture content, skin sebum content, and skin elasticity [57].

The second method involves the assessment of the antioxidant potential of extracts and formulations using the same in vitro methods, although this approach is less popular in the literature. An example of such research is the work of Di Mambro et al. [43], where emulsions containing plant extracts for antioxidant activity tests were diluted 1:2.5 in a suitable buffer for each assay. All diluted formulations were mixed for 20 min prior to the measurements of their antioxidant activity.

In this research, the second approach was used, i.e., the assessment of antioxidant properties for both plant raw materials and formulations. For the emulsions and emulgels, the in vitro method of obtaining filtrates proposed in studies of bigels [38] containing *Centella asiatica* was used.

Additionally, an attempt to correlate the impact of plant-origin additives on the product functional properties determined via instrumental methods with the sensory characteristics determined in the sensory analysis was made.

In addition to the basic physicochemical characteristics, the analyzed functional properties included those regarding the effectiveness of the preparation as a potential product in post-radiotherapy skin care, i.e., % inhibition and the content of polyphenols in the formulation composition. The obtained results are presented in the form of a correlation matrix in Table 5.

The presence of an essential oil and/or a select CO_2 extract rich in volatile ingredients (such terpenoids, as well as aliphatic octyl acetate [44]) in the formulation influences the product's odor, which is correlated with hydration (correlation coefficient 0.625 $p \geq 0.1$) and spreadability (correlation coefficient 0.760 $p \geq 0.05$). The literature data [30,44] indicate the presence of moisturizing ingredients such as polysaccharides, proteins, and boswellic acids, which help maintain the proper level of hydration. *Boswellia* species also have a proven anti-inflammatory effect, which affects the condition of dry, irritated skin, and skin with dermatoses [58]. In addition, it has been reported that *Boswellia* can be an effective topical agent with which to soften facial lines and relax the skin [59]. However, in the case of the correlation between odor and spreadability, it can be presumed that the probands spread the formulation with an intense odor faster more effectively and also more willingly. The odor dissipates faster during vigorous movements. Moreover, according to Mun et al., the presence of thickening substances in the system, especially carbomer in emulgels and cetyl alcohol in emulsions, can affect the perception of odor by the probands [60]. The cetyl alcohol present in the formulation of products also enhances the odor of the product and perfumes the skin.

Table 5. Correlation matrix of the results of physicochemical, rheological, sensory, and functional properties of formulations. * significance at $p < 0.001$; ** significance at $p < 0.01$; *** significance at $p < 0.05$; **** significance at $p < 0.1$.

Correlations	Odor	Consistency	Cushion Effect	Spreadability	Oiliness	Absorption	Hydration	% Inhibition	Polyphenol Content	pH	Mean Droplet Size	Viscosity	Yield Point	k	n
Odor	1.00														
Consistency	−0.07	1.00													
Cushion effect	−0.39	0.11	1.00												
Spreadability	0.760 ***	0.22	−0.62	1.00											
Oiliness	−0.15	−0.14	0.920 **	−0.53	1.00										
Absorption	0.28	−0.09	−0.919 **	0.62	−0.808 ***	1.00									
Hydration	0.625 ****	−0.03	−0.08	0.60	0.07	0.04	1.00								
% inhibition	0.15	−0.45	0.45	−0.04	0.624 ****	−0.38	0.662 ****	1.00							
Polyphenol content	0.44	0.01	0.26	0.39	0.23	−0.37	0.58	0.50	1.00						
pH	−0.38	0.36	0.36	−0.62	0.30	−0.33	−0.51	−0.35	−0.644 ****	1.00					
Mean droplet size	0.18	−0.16	−0.09	−0.27	0.12	0.08	−0.34	−0.30	−0.628 ****	0.677 ****	1.00				
Viscosity	0.43	0.31	0.11	0.48	0.20	0.07	0.29	0.21	0.36	−0.12	−0.09	1.00			
Yield point	0.36	0.24	−0.36	0.49	−0.27	0.54	−0.21	−0.50	−0.20	−0.04	0.30	0.39	1.00		
k	0.45	0.39	0.22	0.35	0.22	−0.21	0.27	0.16	0.53	−0.03	−0.11	0.874 **	0.10	1.00	
n	−0.30	−0.14	0.15	−0.57	0.07	−0.33	−0.57	−0.43	−0.29	0.38	0.39	−0.764 ***	−0.05	−0.57	1.00

The strongest correlation (correlation coefficient closest to 1 $p \geq 0.01$) was obtained for the cushion effect and oiliness (0.920) and for the cushion effect and absorption (correlation coefficient −0.919). The cushion effect is the amount of product felt between the fingers (forefinger and thumb) when rubbing them together. The more product you feel between your fingers, the stronger the cushion effect. The strongest cushion effect was reported by the probands for emulsions and was smallest for emulgels, which is related to their physicochemical form. This effect is typical for emulsions and less noticeable for emulgels due to their excellent spreading properties combined with fast and easy absorption [61], hence the negative correlation observed; the smaller the cushion effect (lower numerical value), the higher the absorption (higher score from the probands), as less formulation between the fingers will result in faster absorption. The smaller the amount of preparation between the fingers, as in the case of emulgels, the less oiliness felt, i.e., the degree of oily deposit left on the skin immediately after application.

Oiliness is correlated with absorption (correlation coefficient −0.808 $p \geq 0.05$). Samples of preparations that are too viscous and oily in feel may have poorer absorption for the probands. Hence, the lowest oiliness values were recorded for emulgels. This is desirable because the skin affected by radiodermatitis is sore, and patients with dermatoses and skin injuries have a negative opinion of oily, sticky preparations such as ointments and creams that they have to use [32,34].

The obtained tests results also showed that oiliness is correlated with the % inhibition of the sample. The % inhibition of the sample value is related to the presence of active substances in its composition. They are capable of neutralizing free radicals, the main sources of which are essential oil and select CO_2 extract, with an inhibition capacity of 49.9% and 54.8%, respectively. These raw materials themselves are not greasy because they are volatile; the essential oil evaporates without leaving a greasy stain. However, in this research, they have been introduced into the recipe of emulsions and emulgels. Low oiliness was recorded for emulgels where the essential oil and select CO_2 extract were added to the hydrogel. Moreover, according to Tasneem et al. [57], in the case of carbomer-based emulgels containing plant extracts with antioxidants and lipid lowering activity, such as *Boswellia* [62], it is possible to decrease the production of sebum. The obtained research results are surprising, and it should be emphasized that correlations of sensory-assessed features with the results of physicochemical tests of preparations for topical use are not a common topic of scientific studies.

Hydration is also correlated with the % inhibition of the sample, as confirmed by the moisturizing effect of plant-origin additives from *Boswellia* species, mentioned earlier and proven in the literature. However, the polyphenol content was correlated with the pH of the formulation (correlation coefficient: −0.644, $p \geq 0.1$). This is a further confirmation of the research results by Spiegel et al. [63], i.e., that an increase in pH—and hence the deprotonation of hydroxyl groups—increases the antiradical activity of polyphenols.

The correlation coefficient of the polyphenol concentration with the mean droplet size of the dispersed phase was −0.628 ($p \geq 0.1$). As was shown in research on polymeric gels [38,39], the addition of essential oils/plant extracts affects the mean droplet size of the dispersed phase.

Also, according to the literature data [64,65], pH can be a factor influencing the mean droplet size of the dispersed phase. The correlation coefficient of sample pH with the mean droplet size of the dispersed phase in the analyzed systems was 0.677 ($p \geq 0.1$).

The viscosity of the sample is correlated with the consistency coefficient (0.874, $p \geq 0.01$) and the flow index (−0.764. $p \geq 0.01$). This is due to the nature of the flow of the obtained formulations, which is discussed in detail in the discussion section on the rheological properties of formulations. Formulations with a pseudoplastic flow produce a coherent film covering the skin surface, and this is important for better antioxidant protection of the skin surface.

The produced preparations had the desired characteristics of formulations intended for oncological patients undergoing radiotherapy as they meet the requirements of cosmetics

intended for sensitive skin (i.e., they have the appropriate pH [66]); injured skin and skin painful to the touch (the physicochemical form of emulgel has an appropriate soft consistency, leaves a slightly greasy feeling on the skin, and has good lubricity [32,34]); and skin treated with ionizing radiation beams (the substances present in the composition, such as milk thistle oil and a mixture of extracts and essential oil from *Boswellia* species with antioxidant properties, play a key role in protecting the skin against the harmful effects of free radicals and thus accelerate the regeneration of the injured epidermis [2,10]).

5. Conclusions

The possibility of using plant extracts in the care of oncological patients, particularly in terms of preventing dermatoses accompanying radiotherapy, is a relatively new and current issue being addressed by the scientific community and by research and development departments of cosmetic and pharmaceutical companies. Plant-origin additives from *Boswellia* species exhibiting anti-inflammatory, antioxidant, antibacterial, and regenerative properties have great potential to become key ingredients in the formulation of oncocosmetics, especially in the form of emulgels absent from the European market.

The most promising preparation is the emulgel containing the Soxhlet extract and essential oil (Em_SO) due to its high antioxidant properties and polyphenol concentration compared to other preparations. Also in favor of the preparation is its physicochemical form, which may represent an advantage in terms of transporting the active substance deep into the skin, and its sensory characteristics, which were also positively rated by the probands.

Low ratings from the probands were awarded to the placebo preparations, particularly Em_P. The demonstrated correlations of odor with hydration and spreadability, oiliness and hydration with the % inhibition of the sample, and the content of polyphenols with the pH and the size of the dispersed phase droplets—all these factors proved the positive effect of the addition of plant-origin additives from *Boswellia* species to the emulgel formulation on functional and sensory properties.

The results of our research will enable the development and production of new, innovative topical dosage forms which can be used in radiodermatitis prevention and treatment.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki. Ethical review and approval were waived for this study. According to the EU cosmetic Regulation no. 1223/2009, the cosmetic product must not cause damage to human health when applied under normal or reasonably foreseeable conditions of use and must be assessed for its safety of use before human subjects are exposed to it, and as such, further ethical approval is not required.

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

Data Availability Statement: The authors confirm that the data supporting the findings of this study are available within the article.

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