

Article

Biscuits with Oleogels and Green Tea Extract Addition—Sensory Evaluation and Consumer Perception

Sylvia Onacik-Gür ¹, Anna Zbikowska ^{2,*}, Iwona Szymańska ² and Małgorzata Kowalska ³

¹ Department of Meat and Fat Technology, Prof. Wacław Dąbrowski Institute of Agriculture and Food Biotechnology—State Research Institute, 36 Rakowiecka Street, 02-532 Warsaw, Poland; sylvia.onacik-gur@ibprs.pl

² Department of Food Technology and Assessment, Warsaw University of Life Sciences—SGGW, 159C Nowoursynowska St., 02-776 Warsaw, Poland; iwona_szymanska@sggw.edu.pl

³ Faculty of Applied Chemistry, Casimir Pulaski Radom University, Chrobrego St. 27, 26-600 Radom, Poland; m.kowalska@urad.edu.pl

* Correspondence: anna_zbikowska@sggw.edu.pl

Featured Application

Biscuits with oleogels and green tea extract have very good sensory properties. However, appropriate labeling on the packaging may be required to encourage consumers to purchase such products, which will positively influence consumer decision-making and improve nutritional choices.

Abstract

Oleogels are a new trend in food technology aimed at enhancing the nutritional value of products that contain solid fats. Solid fats are rich in nutritionally unfavorable saturated fatty acids (FAs), but oleogels (lipid systems derived from oleogelator and oils) are in unsaturated FAs. The use of oils rich in oxidation-prone unsaturated FAs in pastry products requires the use of an antioxidant, such as green tea extract (GTE). However, new products with altered composition should also be acceptable to consumers. The purpose of this study was to carry out a sensory evaluation of short-dough biscuits obtained with 1% of GTE and high-oleic oleogels and to find what may influence consumers' anticipated perception. Products with monoacylglycerols (MAG) and candelilla wax (CLX) oleogels and non-gelled high-oleic rapeseed oil (HORO) were found to have equal or better sensory quality compared to products with traditional baker's (palm) fat (PF). In terms of sensory attributes, products with ethyl cellulose oleogels were the most distinct from the other biscuits. Their sensory qualities were significantly lower, with a more noticeable rancid odor and taste. Products with CLX and MAG oleogels were more preferred than those with PF, as consumers were more likely to purchase them based on sensory impressions. Information about the presence of GTE and HORO in the formulation was shown to affect the perception of the product. Similarly, the information about the low saturated fat content encouraged consumers to purchase such products. Based on this, it can be concluded that displaying this type of information can help educate consumers, support better decision-making, and promote the selection of more nutritious options.

Keywords: green tea extract; oleogels; biscuits; sensory analysis; consumer acceptance



Academic Editor: Alessandro Genovese

Received: 31 August 2025

Revised: 29 September 2025

Accepted: 3 October 2025

Published: 5 October 2025

Citation: Onacik-Gür, S.; Zbikowska, A.; Szymańska, I.; Kowalska, M. Biscuits with Oleogels and Green Tea Extract Addition—Sensory Evaluation and Consumer Perception. *Appl. Sci.* **2025**, *15*, 10728. <https://doi.org/10.3390/app151910728>

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1. Introduction

Oleogels are a novel lipid system with promising applications as a solid fat substitute in food products [1,2]. Solid fats rich in saturated FAs are commonly used in bakery products due to their technological properties such as plasticity, hardness, solid phase content, and high-temperature resistance [1,3,4]. Oleogels are made of liquid oils (solvents) and oleogelators (structuring agents) [2,5,6]. The direct approach utilizes various hydrophobic gelators, including low-molecular-weight substances (e.g., waxes, fatty acids, alcohols, fatty acid esters, sterols), as well as high-molecular-weight substances (e.g., ethylcellulose) [7,8]. Edible oleogels are created through a controlled process that includes the mixing, heating, and cooling of components. In the final phase, the gelator molecules solidify and self-organize into a crystalline or fibrillar network. This process leads to the formation of a three-dimensional structure that immobilizes oil molecules [9,10]. The structured colloidal system is a self-standing lipid that visually resembles semi-solid or solid fat. Direct oleogelation by physical methods results in thermoreversible lipids, stabilized by non-covalent bonds, such as hydrogen bonds, hydrophobic interactions, and van der Waals forces [11,12]. The properties of oleogels are influenced by several factors, including the types and concentrations of gelling agents, the composition of oils, chemical interactions, and the parameters of the processing methods employed. By regulating these factors, it becomes feasible to design lipids that are tailored for specific applications within the food industry [13,14].

Many studies have demonstrated that oleogels are suitable as a bakery fat substitute [15–20]. The advantage of oleogels is that oils that are used for their production can be a source of bioactive unsaturated FAs and can improve the nutritional value of the final food product [2,20]. Moreover, oleogelation enables controlled digestion and absorption of lipids. Therefore, substituting solid fats with oleogels in foods could positively affect the prevention of obesity and overweight [9,21,22].

However, despite the effective structural stabilization of the oil, such new fats are still more susceptible to oxidation than solid fats. The oxidation of oils rich in unsaturated FAs, during term processing and storage, or consumption, has raised major concerns regarding their quality and safety [23,24]. At the beginning of the oxidation process, primary oxidation products are formed before secondary oxidation products (aldehydes and ketones) [25]. The latter negatively impacts the product's sensory characteristics and nutritional value [4]. Consequently, besides ensuring the physical stabilization of edible oils, protecting unsaturated FAs from oxidative transformations is crucial.

Oleic acid has the best oxidative stability compared to other unsaturated FAs [26]. Oils obtained from high-oleic crops contain over 70% of this fatty acid and may increase oil stability compared to conventional crops 1.5 to 3 times [27]. It should be emphasized that replacing saturated fatty acids with oleic acid in the diet lowers the risk of heart disease [28]. A good way to limit oxidation and degradation of fatty acids can be the application of synthetic or natural antioxidants [29]. Long-term consumption of synthetic antioxidants (e.g., BHT, BHA, TBHQ) may lead to major health problems (e.g., carcinogenesis and cancer) and, therefore, these substances are not included in the Generally Recognized as Safe List of Compounds (GRAS) [30–32].

With growing consumer concerns and pressing environmental challenges, the food production industry is decisively shifting toward using natural sources for food-grade components [33–35]. Many studies highlight the biologically active properties (antioxidant, antimicrobial, anti-inflammatory, antimutagenic, and even anticarcinogenic) of plant extracts obtained from various sources (e.g., fruits, vegetables, herbs, tea, coffee, or legumes) [36–39]. Antioxidants from plant extracts suppress the oxidative effects of pro-oxidants and free radicals, thus potentially reducing the risk of chronic diseases such

as cardiovascular, metabolic, and autoimmune diseases. The primary antioxidants in various plant extracts are polyphenols, including flavonoids, phenolic acids, lignans, and stilbenes [39–42]. Many scientists have used other forms of plants or other extracts with polyphenols in bakery products such as olive leaves [43], chokeberry [44,45], strawberry, raspberry, sour cherry [46], and herbal extracts [47].

A significant source of polyphenols is green tea extract (GTE), derived from the leaves of *Camellia sinensis*. Its antioxidant properties are attributed mainly to a high concentration of catechins, including epicatechin, epigallocatechin, epicatechin gallate, and epigallocatechin gallate. These compounds play a crucial role in reducing reactive oxygen forms, chelating prooxidant metal ions, regulating enzyme activity, disrupting cell membranes, and impeding the metabolism of pathogens [48–51]. GTE can be highly applicable in the food industry thanks to its beneficial and diverse properties. Its effectiveness is particularly notable in foods prone to oxidative changes, such as fat, meat, and confectionery products [49,51,52].

Baked products like biscuits are becoming more popular thanks to their availability, good sensorial properties and long shelf-life [46,53]. They are foods with high consumer acceptance [54]. The global biscuits market was valued between USD 108.75 billion and USD 130.14 billion (in 2024). The market is forecast to grow significantly. Some reports project it will reach USD 202.77 billion by 2032, showing a Compound Annual Growth Rate of around 5.70% [55].

Due to the low nutritional value of classic bakery products (e.g., high fat content), they are considered unhealthy. In their composition, fat is a source of saturated fatty acids and sometimes trans isomers [56,57]. The World Health Organization (e.g., WHO., EFSA) recommends limiting the consumption of unhealthy FAs [58,59].

According to many researchers, as consumer preferences evolve, there is an increasing demand for healthier biscuit-type snacks free from fats rich in saturated FAs [60–62]. However, there is a lack of information in the literature on the effect of green tea extract on the sensory characteristics of biscuits with oleogels. Consequently, it is essential to perform comprehensive research to enhance the nutritional profiles of the lipid components in these products while also considering consumer preferences, and this is the novelty of the presented work. Previous studies have proven that biscuits with oleogels and GTE exhibited similar oxidative stability to the conventional products with palm fat [17]. However, the introduction of a new product requires sensory and consumer studies. It is also important to know how to communicate the pro-health properties of novel food products. Therefore, further research should be conducted based on available scientific studies with this type of product.

Therefore, this research aimed to carry out a sensory evaluation of short-dough biscuits obtained with 1% of GTE and high-oleic oleogels and to find what may influence consumers' "anticipated perception".

2. Materials and Methods

2.1. Materials

Materials used to obtain oleogels and biscuits were: high-oleic rapeseed oil (HORO) (Bunge Poland sp. z o.o., Kruszwica, Poland) (fatty acids profile [%]: C16:0 3.6, C16:1 0.2, C18:0 1.9, C18:1 75.7, C18:2 8.9, C18:3 6.7, C18:3*trans* 0.1, C20:0 0.7, C20:1 1.6, C24:0 0.2), palm fat (PF) (Bunge Poland sp. z o.o., Poland) (fatty acids profile [%]: C14:0 1.0, C16:0 43.5, C16:1 0.2, C18:0 4.4, C18:1 40.8, C18:1*trans* 0.2, C18:2 8.6, C18:3 0.2, C18:3*trans* 0.2, C20:0 0.4, C20:1 0.1, C24:0 0.1), candelilla wax (CLX) (obtained from Strahl & Pitsch, New York, NY, USA), monoglycerides (MAG) (Verol n-90, Lasenor, Barcelona, Spain), Ethylcellulose (EC) (DOW Chemical Company, Midland, MI, USA),

wheat flour type 500 (Wrocławska, Zakłady Przetwórstwa Zbożowo-Młynarskiego sp. z o.o., Kruszwica, Poland), rapeseed lecithin (Bunge Poland sp. z o.o., Poland), green tea extract (Bulk Powders, Colchester, UK) (polyphenol content— 135.3 ± 1.48 mg GA/g, DPPH value— 2.83 ± 0.01 mmol Trolox/g [17]), baking powder (Gellwe, FoodCare sp. z o.o., Zabierzów, Poland), sugar (Diamant, Pfeifer&Langen sp. z o.o., Poznań, Poland).

2.2. Oleogels Preparation

Oleogels were prepared according to the method described in previous studies [16,17]. Briefly, candelilla wax (CLX), 3 g/100 g of oleogel, and monoglycerides (MAG) were added at the level of 5 g/ 100 g of oleogel and mixed with high-oleic rapeseed oil (HORO) at 90 °C until complete dissolution. Ethylcellulose (EC) 8 g/ 100 g of oleogel was constantly mixed for 20 min with high-oleic rapeseed oil at 140–150 °C. Oleogels were cooled down at ambient temperature (22 ± 2 °C).

2.3. Preparation of Short-Dough Biscuits

Short-dough biscuits were prepared according to the method described in reported earlier works [16,17]. The variants used in this research are described in Table 1. Baked biscuits after cooling down were stored for 24 h at ambient temperature in polyethylene bags before analysis.

Table 1. Recipes for short-dough biscuits.

Ingredients	PF (Control)	HORO (Control 2)	EC (with Ethylcellulose Oleogel)	CLX (with Candelilla Wax Oleogel)	MAG (with Monoacylglycerol Oleogel)
Wheat flour type 500	48%	48%	48%	48%	48%
Palm fat	24%	-	-	-	-
High-oleic rapeseed oil	-	24%	-	-	-
Oleogel (HORO + oleogelator)	-	-	24% (10% EC)	24% (3% CLX)	24% (5% MAG)
Sugar	17%	17%	17%	17%	17%
Lecithin	1%	1%	1%	1%	1%
Baking powder	1%	1%	1%	1%	1%
Water	9%	9%	9%	9%	9%
Green tea extract (GTE)	-	-		1% of the fat weight	

2.4. Sensory Analysis

Short-dough biscuits were analyzed by the quantitative analysis (QDA) (ISO 13299:2016-05 standard [63]). The set of sensory attributes was discussed, defined, and verified by a preliminary test. The group of panelists consisted of 16 trained people—the laboratory staff and master students from the Department of Food Technology and Assessment at Warsaw University of Life Sciences. 13 members of the panel were women and 3 were men, aged 23–55, and all of them had theoretical and practical experience in sensory analysis ranging from 2 to 35 years. All of the panelists were selected according to the ISO standard (ISO 8586:2012 [64]). 1 biscuit (average weight 15 g) of each sample was placed in odorless jars covered with a lid and coded with 3-digit numbers 30 min before assessment. Each panelist got 6 samples for evaluation (PF, HORO, EC, CLX, and MAG) in random order. Evaluation took place in ambient temperature 22 ± 1 °C and evaluators were separated from each other in order to get their full focus.

Before starting the analysis, the panelists got acquainted with the features to be measured during sensory evaluation. First, the smell and external appearance of the products were evaluated. Next, texture and taste characteristics were analyzed. During the first bite, the panelists evaluated hardness, which is perceived when the teeth (incisors)

are dipped into the product. The taste of the products, on the other hand, can only be described as a result of moistening the bite with saliva and working the tongue [65]. Finally, the evaluators expressed their overall opinion of the quality and desirability of the products without knowing their composition. An additional differentiator was to determine the predicted nutritional value of the sample based on sensory evaluation impressions. Panelists marked their sensations on a 10 cm scale, where 0 (on the left) meant the lowest value and 10 (on the right) meant the highest value.

2.5. Survey and Consumer “Blind” Test

The survey was conducted in the form of a questionnaire consisting of two parts. Forty people participated in the survey, with 80% of them being women. The survey was aimed only at people who consume biscuits, so that the results would not be distorted by people who do not buy or consume this type of product. All survey participants declared an interest in food issues and were between the ages of 20 and 50. The survey took a face-to-face form and was conducted on the Warsaw University of Life Sciences (WULS) campus. The purpose of its first part was to test respondents’ knowledge of the importance of unsaturated FAs and their effects on the human body, associations regarding palm fat, and the influence of information on packaging (e.g., addition of green tea extract, low in saturated FAs, with high-oleic canola oil, with palm fat added) on their willingness to purchase the product.

The purpose of the second part of the questionnaire, the “blind” test, was to determine to what extent the composition of the cookie product proposed in the paper aligns with consumers’ expectations (overall quality and “healthiness”) and whether it can positively influence their choice.

2.6. Fatty Acids Analysis

Fatty acids were determined by the method described in a previous study [17]. Briefly, lipid fraction of biscuits was extracted using the cold method. Hexane was used as a solvent and evaporated by vacuum evaporator. Lipid fraction was used to prepare methylated fatty acids according to ISO 12966-1:2014 standard [66]. Fatty acid profile was determined using gas chromatographer TRACE 1300 device (Thermo Scientific, Waltham, MA, USA) equipped with a FID detector and BPX 70 capillary column. The analysis was performed in duplicate.

2.7. Nutritional Index of HORO and PF

In order to determine the nutritional value of lipids used in the biscuits, the nutritional Health-Promoting Index (HPI) [67] was calculated based on the fatty acid profiles of HORO and PF in Section 2.1.

$$HPI = \frac{\Sigma UFA}{[C12 : 0 + (4 \times C14 : 0) + C16 : 0]}$$

where

- UFA—unsaturated fatty acids;
- C 12:0—lauric acid;
- C 14:0—myristic acid;
- C 16:0—palmitic acid.

2.8. Statistical Analysis

To compare the obtained results, a one-way analysis of variance (ANOVA) was performed using Statistica 12.0 statistical software (StatSoft Poland, Kraków, Poland). The

significance of the differences between the mean values was determined using Tukey's test, with a significance level of $\alpha = 0.05$.

Principal Component Analysis (PCA) was carried out to test for the presence of relationships between variables and to illustrate the differences and similarities of pastry brittle products. The analysis was carried out on the arithmetic means. The results were presented as a projection of variables and cases on the plane of factors. The number of factors considered was 70%.

3. Results and Discussion

3.1. Nutritional Value of Palm Fat and High-Oleic Rapeseed Oil

Most of the biscuits and other pastry products available on the market are made of palm fat (PF). From a nutritional point of view, it is not recommended due to the high content of saturated fatty acids. In this study, PF was used as a control sample. In other samples, palm fat was fully replaced by high-oleic rapeseed oil (HORO) and HORO-based oleogels. To indicate the advantage of such replacement, the Health-Promoting Index (HPI) was calculated. This index is focused on the effect on cardiovascular diseases [67]. It was found that the HPI of lipid fraction of biscuits with HORO and oleogels is over 20 times higher than PF (Table 2). Slightly higher content of palmitic acid in MAG biscuits is a result of the addition of oleogelator. Monoglyceride used to obtain oleogels was a palm fat derivative. High-oleic rapeseed oil does not contain lauric (C12:0) and myristic acid (C14:0), and it is rich in unsaturated fatty acids (UFA). Consuming oils and fats with high content of unsaturated fatty acids and low content of saturated fatty acids, which are characterized by high HPI, is recommended and may be beneficial in prevention of cardiovascular diseases [67,68]. Analysis of commercial cookies available in Portugal showed that, on average, they contained 53% of saturated fatty acids (SFA). It has also been noted that due to regulations regarding the elimination of trans fatty acids, the content of saturated fatty acids (SFA) has increased by replacing unsaturated fatty acids (UFA) [69]. In the study of Kaur et al. [70] analyzed Indian biscuits available in the market were made of fats rich in saturated fatty acids, where the most dominant was palmitic acid, and ranged from 28.37 to 60.84%.

Table 2. Nutritional value of lipid fraction of biscuits.

	PF	HORO	EC	CLX	MAG
C 12:0 lauric acid	0.2	0.0	0.0	0.0	0.0
C 14:0 myristic acid	0.9	0.0	0.0	0.0	0.0
C 16:0 palmitic acid	41.9	3.4	3.4	3.5	3.7
UFA	55.2	94.8	94.1	93.2	93.1
HPI	1.2	27.9	27.7	26.6	25.2

PF—biscuits with palm fat; HORO—biscuits with high-oleic rapeseed oil; EC—biscuits with ethylcellulose oleogel; CLX—biscuits with candelilla wax oleogel; MAG—biscuits with monoglyceride oleogel; UFA—unsaturated fatty acid; HPI—Health-Promoting Index.

3.2. Sensory Analysis Results

The sensory analyzed characteristics were as follows: smell, appearance, texture, taste, and overall quality.

The EC biscuits differed significantly from the others regarding rancidity (5.4). Although the GTE was used as a natural antioxidant, the off-flavors were developed in the oleogel before its addition. During the production of EC oleogel, oil is heated up to 150 °C and constantly mixed. However, GTE played an important role in the inhibition of lipid fraction oxidation of biscuits with oleogels, making them as resistant as the control sample with palm fat. These findings were reported in a previous study. GTE used in this study was

characterized by polyphenol content of 135.3 ± 1.48 mg GA/g, and antioxidative capacity expressed in DPPH value of 2.83 ± 0.01 mmol Trolox/g [17]. Similar results were obtained in the study of Mildner-Szkudlarz et al. [71]; researchers also confirmed the antioxidative properties of green tea extract by inhibition of lipid oxidation. Candelilla wax was only present in the products with CLX oleogel. However, the panelists also detected its odor in the remaining samples, and the differences were not statistically significant (Table 3). The wax odor in products with MAG oleogel may be due to the presence of monoacylglycerols, which can give off a slightly soapy and bland smell, similar to palm oil. In the case of products with EC oleogel, the waxy smell might come from various compounds (also with an odor) formed during oleogel production with ethylcellulose, such as those resulting from fat oxidation and transformations at high temperature.

Table 3. Sensory evaluation of short-dough biscuits.

	PF	HORO	EC	CLX	MAG
Odour					
Rancid	3.1 ± 2.2 ab	3.1 ± 2.2 ab	5.4 ± 3.1 b	3.0 ± 1.3 ab	2.4 ± 1.8 a
Waxy	3.6 ± 2.8 a	2.7 ± 1.9 a	3.7 ± 2.2 a	3.8 ± 2.2 a	4.1 ± 2.8 a
Tea	3.4 ± 2.4 a	3.4 ± 2.4 a	2.0 ± 2.3 a	3.2 ± 2.9 a	3.5 ± 2.8 a
Desired	4.8 ± 2.3 a	5.6 ± 2.2 a	4.2 ± 2.0 a	5.6 ± 1.8 a	5.6 ± 1.5 a
Appearance					
Greasiness	4.3 ± 2.5 b	6.7 ± 2.1 a	5.4 ± 1.8 ab	6.6 ± 2.0 a	6.7 ± 2.3 a
Color	2.3 ± 2.0 a	3.0 ± 1.7 a	3.4 ± 1.8 a	4.2 ± 1.9 a	3.8 ± 2.2 a
Cracks	5.2 ± 2.4 a	5.4 ± 3.1 a	4.8 ± 2.0 a	3.9 ± 2.5 a	3.6 ± 2.5 a
Texture					
Hardness	3.4 ± 2.1 a	3.8 ± 1.9 a	2.8 ± 2.4 a	4.7 ± 2.4 a	3.7 ± 2.8 a
Crispness	6.8 ± 2.2 ab	7.6 ± 1.3 a	5.7 ± 2.4 b	7.5 ± 1.2 ab	7.6 ± 1.7 a
Waxy mouthfeel	4.0 ± 2.0 a	4.1 ± 2.0 a	5.6 ± 2.6 a	5.0 ± 2.2 a	5.3 ± 2.4 a
Taste					
Foreign	3.8 ± 3.1 a	3.6 ± 2.4 a	6.4 ± 2.5 b	2.6 ± 1.9 a	2.5 ± 1.6 a
Sweet	5.7 ± 2.1 a	7.0 ± 1.8 a	5.0 ± 2.5 a	6.8 ± 2.1 a	6.8 ± 2.2 a
Rancid	3.1 ± 2.5 ab	2.8 ± 2.1 a	5.4 ± 3.2 b	2.4 ± 1.6 a	1.8 ± 1.8 a
Waxy	2.1 ± 1.6 a	2.6 ± 1.5 a	2.7 ± 2.2 a	2.7 ± 1.6 a	1.8 ± 1.0 a
Desired	5.7 ± 2.4 a	5.7 ± 1.9 a	2.7 ± 1.8 b	6.5 ± 1.7 a	6.3 ± 1.4 a

a, b—the same letters indicate homogeneous groups based on Tukey's test (p -value < 0.05); PF—biscuits with palm fat; HORO—biscuits with high-oleic rapeseed oil; EC—biscuits with ethylcellulose oleogel; CLX—biscuits with candelilla wax oleogel; MAG—biscuits with monoglyceride oleogel.

The addition of green tea extract was identical in all variants with oleogels, and the tea aroma intensity was rated at 2.0 (for EC) to 3.5 (for MAG). The lower detectability of this aroma may be due to it being masked by a rancid aroma. Products with EC oleogel were considered the least desirable in terms of aroma (4.2), while HORO, MAG, and CLX were considered the most desirable (5.6). However, these differences were not statistically significant.

In a study conducted by Onacik-Gür et al. [53], biscuits with shortening had a more typical aroma than those with high-oleic sunflower oil. In a study conducted by Mildner-Szkudlarz et al. [71], it was observed that with increasing fat degradation, the acceptability of the sponge-fat products' aroma decreased.

The assessment of the "greasiness" of the product surface was intended to reflect the empirical studies conducted in a previous study on fat migration [16]. As expected, products with HORO (6.7) were statistically significantly more "greasy" on the surface than those with palm oil (4.3) (Table 3). Among the products with oleogels, those with candelilla wax were considered the least "greasy." However, no statistically significant differences

were observed between products with oleogels and those with oil (HORO). On this basis, it can be concluded that empirical testing for fat migration is a more objective method than sensory assessment of surface “greasiness.” In the study conducted by Onacik-Gür et al. [53], biscuits with high-oleic sunflower oil were also sensorially assessed as more “greasy” than the control sample with shortening. The authors also observed that the addition of lecithin reduced the perception of the “greasiness” of the surface to the same level as in the case of biscuits with shortening.

The panelists rated the palm shortening products as the lightest (2.8). The addition of green tea extract caused the products to darken. However, the differences noted by evaluators were not statistically significant. Manohar and Rao [72] observed a more even surface and lighter color in cookies made with shortening and hydrogenated shortening compared to samples made with oil. The most cracked surfaces were found in products with high-oleic rapeseed oil (5.4), and the least cracked in those with MAG oleogel (3.6). This may be due to the properties of monoacylglycerols, which, as emulsifiers, made the dough more uniform and the finished products more evenly colored (Table 3).

Products with CLX oleogel (4.7) were considered the hardest, while those with EC (2.8) achieved the lowest value for this parameter (Table 3). Biscuits with HORO and MAG (7.6) were the most crispy, differing statistically significantly from biscuits with EC (5.7). Similar observations were presented by other researchers [73], where it was also found that cookies with HPMC (a cellulose derivative) had significantly lower crispiness in comparison to products with shortening or MAG and wax-based oleogels. In the study of Leahu et al. [74], it was found that the texture of cookies made with hemp oil oleogels structured by waxes, pea protein, sterols, or xanthan gum was perceived as less firm in comparison to control cookies with margarine. In a study conducted by Onacik-Gür et al. [53], biscuits with shortening and high-oleic sunflower oil had similar texture parameters, and the addition of lecithin (a natural emulsifier) reduced their hardness and increased their crispness. Similarly, Mamat and Hill [75] observed no differences in the sensory evaluation of the texture of cookies made with different fat types (butter, palm fat, olein fraction, and palm fat mid-fraction). In turn, the study by Manohar and Rao [72] found that cookies with shortening had better texture parameters (greater crispness) compared to those with oil.

The highest waxy mouthfeel values, defined as sticking to the teeth, were assigned to samples with EC (5.6), and the lowest to products with palm fat (4.0). Despite the lack of statistically significant differences for this parameter (Table 3), a certain trend can be observed. Products made with oleogelators received higher scores. These ingredients likely caused the product to feel stickier on the teeth.

The rancid flavor was most noticeable in samples with EC oleogel (5.4), and these biscuits differed significantly (p -value < 0.05) from the other products in this respect. Similarly, the foreign flavor was most noticeable in EC products (6.4), and they differed significantly from the other products in this respect. The intensity of the foreign flavor in these products was greater than that of the foreign aroma. Despite the lack of statistically significant differences, it was observed that products with EC oleogel were characterized by the lowest sweetness, according to the sensory panelists. In the study of Susanti et al. [76], it was presented that the addition of matcha powder (green tea) influenced the taste of cookies by lowering sweetness, which was not observed in our study. However, the observed difference in the sweetness of EC biscuits may be due to its masking by the rancid flavor. The waxy flavor was noticeable in all products, with the highest scores awarded to products with CLX oleogel (2.7). EC products also had the lowest taste desirability (2.7), which was most likely related to the perceived rancid and foreign flavors (Table 3). However, the study by Onacik-Gür et al. [53] demonstrated that biscuits with shortening had a more typical, desirable flavor than those with high-oleic sunflower oil. In the study of

Leahu et al. [74], it was also found that control cookies with margarine had higher flavour scores than the products with hemp seed oil oleogels. However, among cookies with oleogels, those structured by candelilla wax and xanthan gum were more appreciated for flavour. In another study [20] where beeswax oleogel was used as a partial substitution of bakery fat in cookies, it was found that products with 50% replacement were, on average, the most appreciated.

Based on overall acceptability, it can be concluded that the product's acceptability encompasses all sensory parameters. Studies by Calligaris et al. [77] and Mildner-Szkudlarz et al. [71] observed that as the peroxide content of the lipid fraction of cookies increased, i.e., the degree of fat degradation, their acceptability decreased. Products with EC oleogel (3.1) were, on average, characterized by the lowest overall acceptability. These were the biscuits with the strongest foreign taste, odor, and rancidity. The remaining products did not differ significantly (p -value < 0.05) in this parameter. Still, the highest score in this respect was achieved by products with CLX (6.8) (Figure 1). In the other studies [73,74], the highest score in terms of acceptability was received by cookies with bakery fats, not with oleogels. According to some studies, the addition of plant extracts, including green tea [78,79], may negatively influence the acceptability of cookies. However, this was not observed in our study. This may indicate that the size of the GTE addition was chosen correctly, not to influence the flavor.

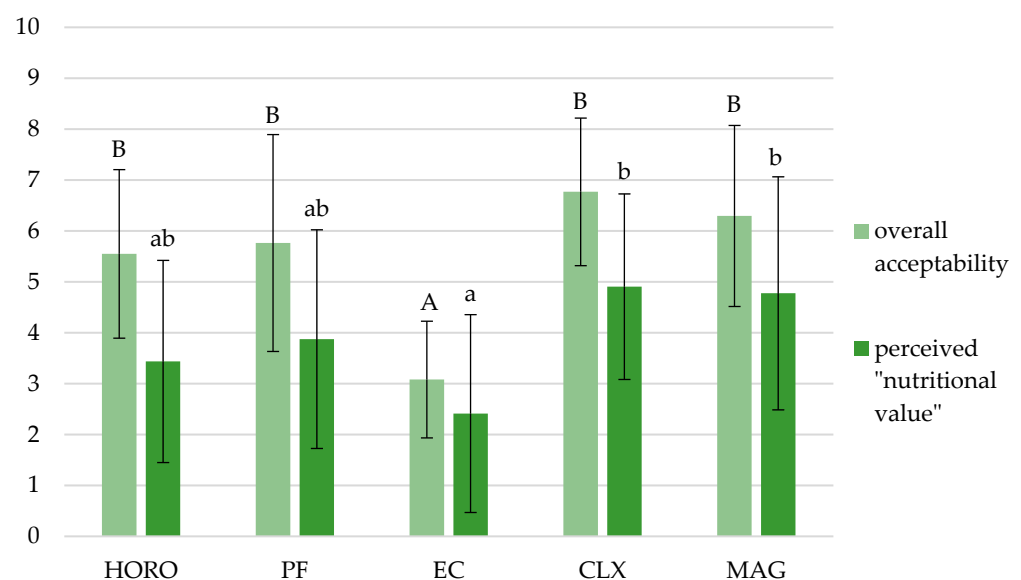


Figure 1. Overall sensory quality of short-dough biscuits and estimated nutritional value of products assessed based on sensory analysis. A, B; a, b, c—the same letters indicate homogeneous groups based on Tukey's test (p -value < 0.05); PF—biscuits with palm fat; HORO—biscuits with high-oleic rapeseed oil; EC—biscuits with ethycellulose oleogel; CLX—biscuits with candelilla wax oleogel; MAG—biscuits with monoglyceride oleogel.

Kumar et al. [80] observed that cookies with oryzanol oleogel did not differ statistically significantly in overall quality from products with shortening, which confirmed the results obtained in the discussed study. Another study [53] found that products with high-oleic sunflower oil were of lower overall quality than cookies with shortening. However, the addition of lecithin to the oil resulted in a significant increase in overall quality, comparable to the control sample (with shortening). In the study of Zulfiqar et al. [20], it was presented that cookies with 50% substitution of margarine by beeswax oleogel had, on average, the highest scores of sensorial acceptability during the 1 to 60 days of storage among other products with 0, 25, and 75% of oleogel. In opposition to our research, Leahu et al. [74]

showed significantly higher scores of acceptability of control cookies in comparison to oleogel cookies.

Based on sensory analysis, the evaluators expressed their opinion on the expected nutritional value of biscuits, which was related to the “healthiness” aspect of the product. EC products had the lowest nutritional value (2.4). In contrast, products with candelilla wax (CLX) and MAG had the highest, receiving twice as high scores in this regard, at 4.9 and 4.8, respectively (Figure 1). In a study conducted by Tarancón et al. [81], in which various fats were used to produce cookies (shortening, olive oil, sunflower oil), no differences were observed in the perception of the “healthiness” of the cookies based on sensory analysis.

The last question of sensory analysis can help determine a potential consumer’s attitude and acceptance toward innovative products. The sensory panel was asked, “Would you buy these biscuits?”. CLX and MAG products received the most responses, indicating high acceptance (56.25%). In comparison, EC were perceived most negatively (93.75%) (Figure 2). However, biscuits with CLX oleogels received more “definitely yes” responses (18.75%). At the same time, MAG products also received “d” responses, meaning that 6.25% of the evaluators declared they would “definitely not” buy such biscuits. Furthermore, it was observed that products from the control group (with palm fat and without GTE) received more negative responses (62.50%) than positive ones.

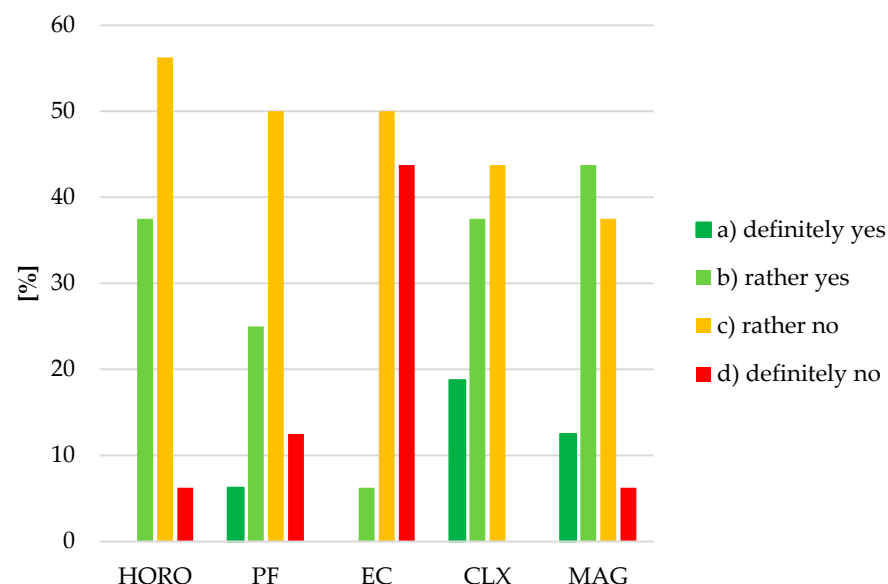


Figure 2. Structure of the sensory panel response to the question: “Would you buy these biscuits?”. PF—biscuits with palm fat; HORO—biscuits with high-oleic rapeseed oil; EC—biscuits with ethycellulose oleogel; CLX—biscuits with candelilla wax oleogel; MAG—biscuits with monoglyceride oleogel.

Similarly, a “blind” test, based on the assessment of sensory properties without additional product information, was conducted by Tarancón et al. [81]. The authors obtained similar results to those discussed in this study. Control cookies with shortening and cookies with sunflower oil and olive oil received similar positive responses from respondents: 37%, 37%, and 40%, respectively. However, in the case of reduced-fat cookies, the control sample received more positive responses (25%) than products with reduced olive oil (14%) or sunflower oil (17%).

3.3. Principal Component Analysis of Sensory Evaluation

A principal component analysis was performed to summarize the sensory properties of biscuits. Variables selected for analysis included those considered important in assessing

the overall quality of the products (desirable aroma, surface “greasiness,” and hardness) as well as those that demonstrated statistically significant differences (rancid odor, crispness, foreign and desired flavors, overall quality, and predicted nutritional value)—the selected variables defined the first two factors by 94.47%. The first factor was strongly positively correlated with rancid odor and foreign flavors, and strongly negatively correlated with desirable aroma, hardness, crispness, desired flavor, quality, and nutritional value (Table 4). The second factor was positively correlated with the surface “greasiness.” Based on the variable projection (Figure 3a), it can be observed that the overall sensory quality of the products is correlated with the predicted nutritional value (both variables are very close to each other). Moreover, desired taste also correlated strongly positively with these attributes and strongly negatively with foreign taste and rancid odor (Figure 3a). It can be assumed that these sensory attributes (desired taste, foreign flavor, and rancid odor) have the most significant impact on consumers’ overall product evaluation. In contrast, the “greasiness” of the product surface did not significantly affect product perception or acceptability, as this variable did not correlate with overall quality. A correlation was also demonstrated between texture parameters: hardness and crispness.

Table 4. Factor coordinates of variables based on correlation.

Variables	Factor 1	Factor 2
Rancid odour	0.888183	−0.390700
Desirable aroma	−0.932825	−0.316582
Greasiness	−0.549176	−0.807625
Hardness	−0.885510	−0.143157
Crispness	−0.955033	−0.163675
Foreign taste	0.992713	−0.104471
Desirable taste	−0.971955	0.194369
Overall acceptability	−0.976755	0.197269
Nutritional value	−0.938046	0.202122

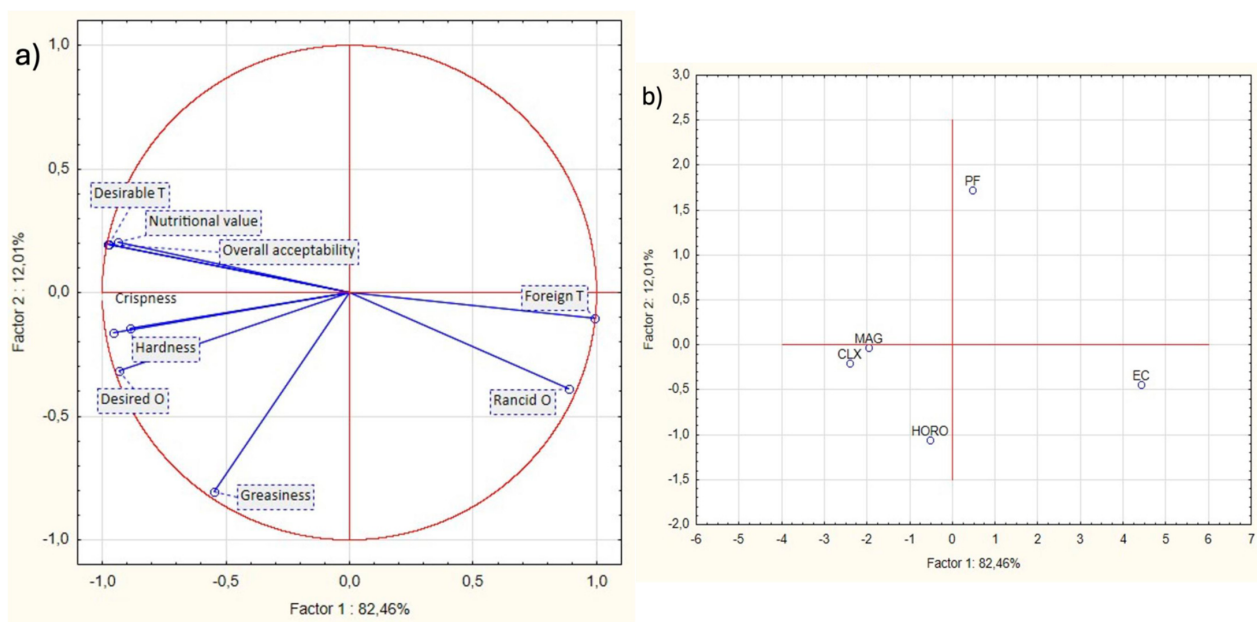


Figure 3. (a) Projection of variables—determinants of sensory analysis; (b) projection of cases—sample variants—on the factor plane. T—taste; O—odor; PF—biscuits with palm fat; HORO—biscuits with high-oleic rapeseed oil; EC—biscuits with ethycellulose oleogel; CLX—biscuits with candelilla wax oleogel; MAG—biscuits with monoglyceride oleogel.

Based on the PCA (Figure 3b), it was found that the products with PF were significantly different from the other products, primarily concerning the second factor, i.e., surface “greasiness.” The products with EC oleogel were also significantly different from the other samples concerning the first factor, which correlated with most variables. It can be concluded that the products made with EC oleogel differed most from the other biscuits in terms of sensory quality characteristics.

3.4. Analysis of Consumer Awareness and Preferences Regarding Short-Dough Biscuits

The first question aimed to assess basic knowledge about fats and concerned the impact of unsaturated fatty acids on the human body. As many as 95% of respondents answered correctly, indicating the positive importance of these FAs. Only 5% answered incorrectly. Nobody answered that the UFAs have no effect on the human body (Figure 4).

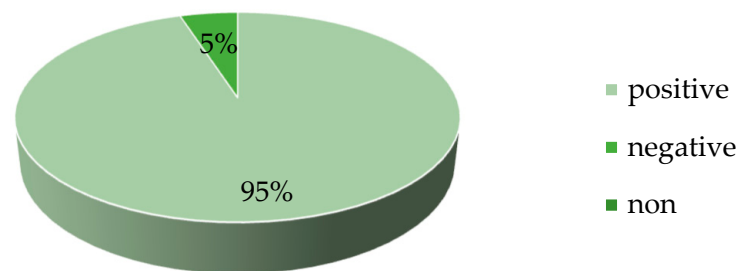


Figure 4. Distribution of responses regarding the importance of unsaturated fatty acids for the human body.

Tarancón et al. [81] also assessed knowledge about fats in their study. Approximately three-quarters of Spanish respondents (71%) were able to correctly identify fats essential for the human body and their dietary sources. In a study conducted by Onacik-Gür et al. [82], almost all respondents (98%) (Polish students) knew that unsaturated fatty acids are nutritionally important. In comparison, 89% of Dutch university students responded in this way.

Respondents could independently justify their chosen answer when asked about associations with palm oil. Approximately 3% of survey participants claimed to have positive associations. In their opinion, palm oil had good technological properties. 30% of respondents had no associations with this oil, and over two-thirds of respondents declared a negative attitude. Most of them (63%) justified their response by citing the low nutritional value of the oil due to its high content of saturated FAs, followed by reasons related to ecology and environmental protection (11%) and the presence of trans fatty acids (TFAs) (11%) (Figure 5). The media are paying increasing attention to ecology and the negative impact of oil palm cultivation on the natural environment. Even well-known brand manufacturers use graphic symbols emphasizing the absence of palm oil in their products or informing that the raw material comes from certified plantations [83]. Respondents' association of palm oil with TFAs is not entirely accurate. TFAs are not present in raw palm oil. Only after refining, due to high temperatures, TFAs may appear in this oil, but their content does not exceed a few percent [84]. Some respondents negatively associated this oil with processed foods (5%) and low quality (5%) (Figure 5). Due to its low price and good stability, palm oil is often used in highly processed products. Due to its relatively low nutritional value, it may be associated with low-quality products.

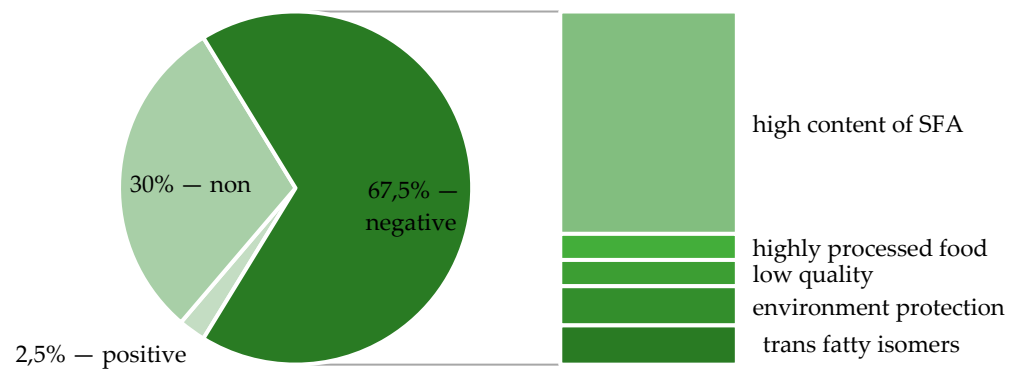


Figure 5. Distribution of responses regarding associations with palm oil.

Research conducted by Disdier et al. [85] indicates that French consumers consider the adverse health effects of palm oil to be as important as environmental protection. Both factors discourage them from purchasing products containing this oil. The authors also found that the price increase associated with the use of a different oil was still acceptable, and consumers maintained their willingness to boycott palm oil in food products. In the study of Borrello et al. [86], Italian consumers' main concerns regarding palm oil were environmental impact, such as damage to tropical forests and loss of biodiversity, and social implications, such as exploitation of workers.

The survey also attempted to determine consumer opinions on the advisability of using green tea extract in food. Half of the respondents claimed that information about such an additive would increase their willingness to purchase the product, while for 40% it would be irrelevant. However, for 10% of respondents, the declaration of the presence of such an ingredient could even negatively influence their choice (Figure 6). Such a high percentage of people with a positive attitude toward green tea extract may stem from their knowledge of publicly available information about the health-promoting properties resulting from the high antioxidant content of teas [87]. It was found that informing consumers about the high content of antioxidants in the product may increase the likelihood [88]. In the consumer studies of Moin et al. [89], it was found that the willingness to eat biscuits fortified with green tea was correlated with the attitude of health concern. Moreover, these people were willing to consume biscuits fortified with moringa extract.

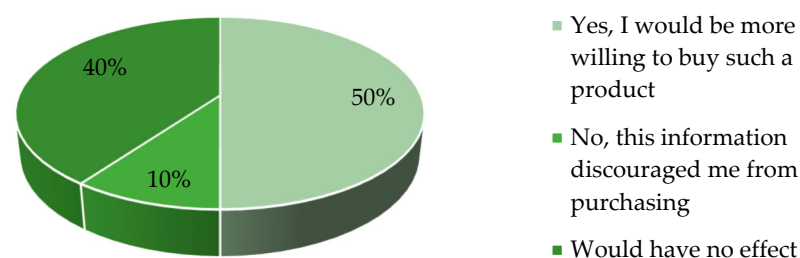


Figure 6. The influence of information about the addition of green tea extract on the decision to purchase a biscuit product.

The impact of on-package information on consumer purchasing decisions was examined. For 85% of respondents, a low-saturated fatty acids content claim would be an encouraging factor, but for 10%, it would be irrelevant. For 5% it could discourage them from choosing the product (Figure 7). Therefore, it can be assumed that 15% of respondents lack knowledge about the role of FAs in the human diet. Based on the results of research conducted by Tarancón et al. [81], using a nutritional label such as “low saturated fat” on packaging is particularly important for those with little knowledge of fats. For them,

this information is easier to read and understand than a list of ingredients or a table of nutritional values.

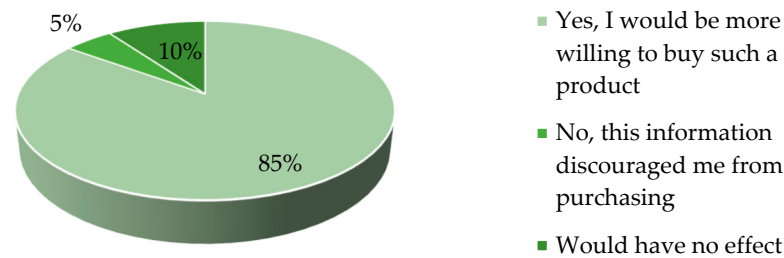


Figure 7. Distribution of responses to the question regarding the influence of information about the low content of saturated fatty acids on the decision to purchase the product.

It can be assumed that including the information “with high-oleic rapeseed oil” on the packaging (in addition to the ingredients) would positively impact consumer perception of the product, as two-thirds of respondents considered this information encouraging purchase. A quarter declared that this information had no impact on their purchase decision, and 8% even found it discouraging. Thus, the vast majority of respondents expressed a positive opinion of high-oleic rapeseed oil (Figure 8).

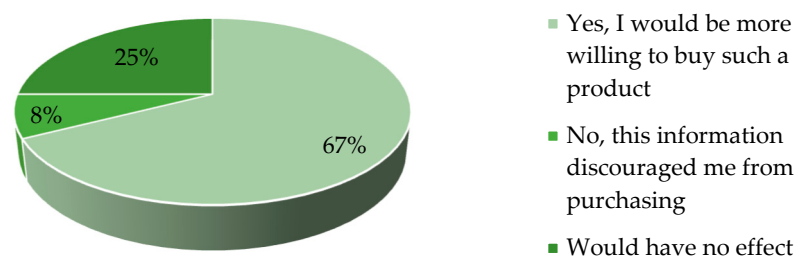


Figure 8. Distribution of responses to the question regarding the influence of information about the presence of high-oleic rapeseed oil on the decision to purchase biscuits.

For 18% of respondents, the presence of palm oil in a product was a deterrent to purchase, suggesting they are staunch opponents. Over half (60%) declared they preferred products without this ingredient and, if possible, chose foods without it. According to one-fifth of respondents, the presence of palm oil in a product did not influence their purchasing decisions. For 2% of respondents, its presence encouraged them to purchase the product (Figure 9).

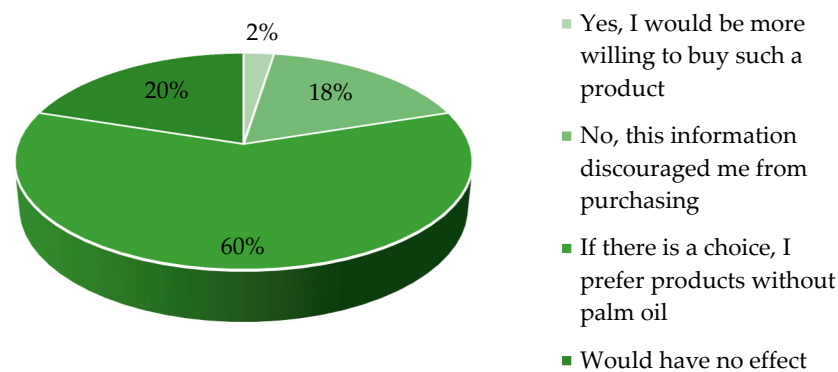


Figure 9. Distribution of responses to the question regarding the influence of information about the presence of palm fat in a product on the decision to purchase or select it.

In a study conducted by Onacik-Gür et al. [82], 38% of students found that the ingredients and information on the packaging had a significant impact on their food purchasing

decisions. In another study [86], 30% of Italian respondents declared that they buy palm oil-free products very often, 19% often, and 20% seldom. Their choices were primarily based on healthiness (38%), then lower environmental impact (25%), and preservation of tropical forests (14%).

3.5. Estimated Overall Quality, Nutritional Value, and Purchase Intention Based on the Composition of Short-Dough Biscuits

Respondents expressed their opinions on five short-dough biscuits based on their recipe compositions (Table 1). They concluded that biscuits with high-oleic rapeseed oil should have the highest overall quality (6.9). They predicted the lowest value of this parameter for short-dough biscuits with CLX oleogel (5.3). These biscuits differed statistically significantly in this respect (Figure 10).

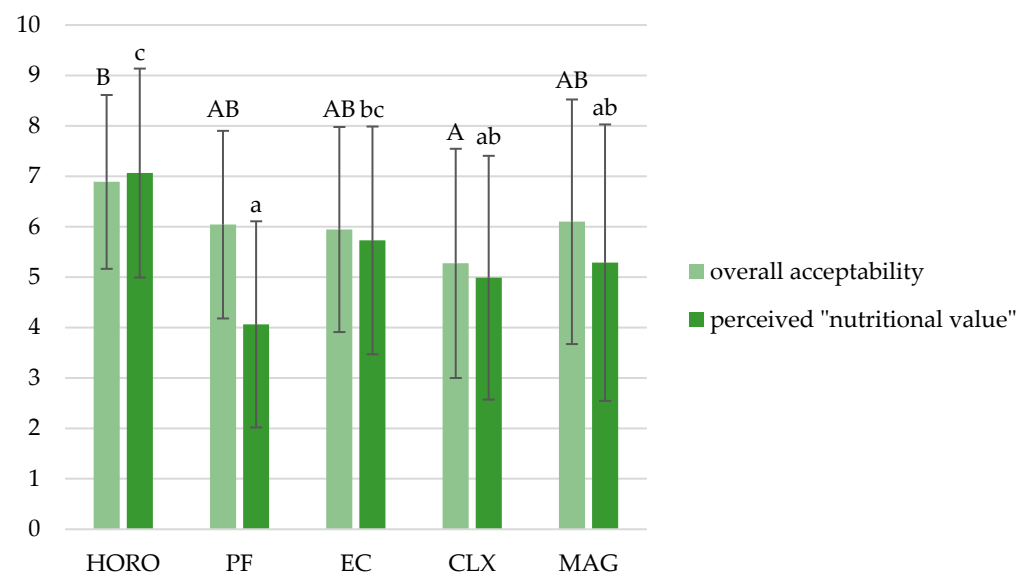


Figure 10. Overall acceptability and nutritional value of short-dough biscuits were predicted by respondents based on their composition. A, B; a, b, c—the same letters indicate homogeneous groups based on Tukey’s test (p -value < 0.05); PF—biscuits with palm fat; HORO—biscuits with high-oleic rapeseed oil; EC—biscuits with ethycellulose oleogel; CLX—biscuits with candelilla wax oleogel; MAG—biscuits with monoglyceride oleogel.

Regarding predicted nutritional value, understood as the so-called “healthiness” of the products, HORO biscuits received the highest ratings (7.1). At the same time, palm fat biscuits received the lowest ratings (4.1) (Figure 10). Statistically significant differences were also observed in this case, depending on the recipe composition. In the case of products with declared oleogels in their composition and oil (HORO), more minor differences between overall acceptability and nutritional value could be observed (the values were similar), unlike in products with palm fat (Figure 10). This confirms the responses provided earlier in the survey, in which a significant number of respondents indicated an unfavorable FAs composition of palm fat.

In a study conducted by Tarancón et al. [81], respondents who were provided with information (on the packaging) about shortening cookies, their composition, and nutritional value, considered them less “healthy” than those made with olive oil and sunflower oil. This study also demonstrated that products with lower fat content were considered “healthier.” Baixauli et al. [90] showed that simply informing consumers about the use of whole wheat flour in muffin production, a source of fiber with health benefits, increased the acceptance of these products. According to the study of Hagmann and Siegrist [91], nutritional value labels on the front of the package led to a better identification of snack healthiness.

HORO products had the highest acceptance among respondents, with 25% declaring they would buy such a product, and 65% being likely to buy it. The most negative associations were with products containing CLX oleogel (“no” declared by 10%, “rather not”—42.5%) and palm fat (“no”—7.5%, “rather not”—45%) (Figure 11).

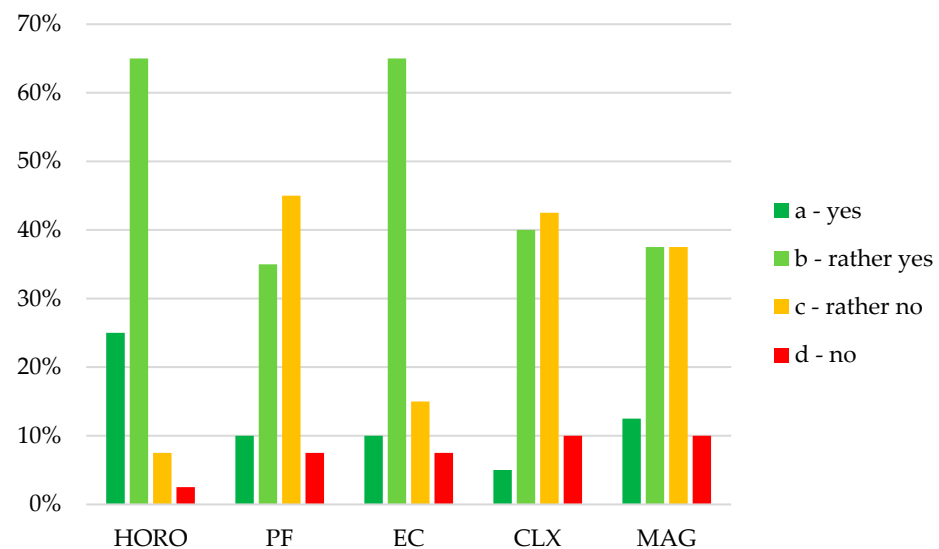


Figure 11. Distribution of respondents’ answers regarding their decision to purchase a given product based on its composition. PF—biscuits with palm fat; HORO—biscuits with high-oleic rapeseed oil; EC—biscuits with ethylcellulose oleogel; CLX—biscuits with candelilla wax oleogel; MAG—biscuits with monoglyceride oleogel.

Among products containing oleogels, the most positive responses were found for EC biscuits. The ethylcellulose used to produce the oleogel is a cellulose derivative, which respondents may associate with dietary fiber. This is likely why as many as 65% of respondents declared a strong willingness to purchase such a product, while 10% stated they would probably buy such biscuits (Figure 11).

Tarancón et al. [81] observed that consumers, knowing only the information on the product packaging, were more likely to purchase cookies with olive or sunflower oil than those with shortening. Furthermore, the fat content of the product also had a significant impact on the purchasing decision. The lower the fat content, the greater the product’s appeal and the willingness to purchase it.

4. Conclusions

The type of fat and oleogel used influenced the sensory properties of short-dough products with green tea extract (GTE). Biscuits with GTE and oleogels structured with candelilla wax or monoacylglycerols were more desirable and acceptable in the sensory evaluation than those with palm fat. Furthermore, the evaluators assumed that these products had the highest nutritional value. Statistical analysis (correlation coefficients, PCA) also demonstrated that the perception of the nutritional value of products, in the sensory evaluation, is strongly correlated with their overall quality.

Biscuits with ethylcellulose (EC) oleogel had statistically significantly poorer sensory properties and lower acceptability compared to the other products (with and without GTE). They were characterized by an intense rancid aroma and flavor, indicating severe fat degradation caused by the method used to prepare these oleogels.

As the conclusion of sensory evaluation, it can be assumed that biscuits with high-oleic rapeseed oil oleogels structured by candelilla wax and monoglycerides and the addition of green tea extract are the most acceptable.

For over two-thirds of the survey participants, palm oil had negative connotations and was perceived as an ingredient that reduced the nutritional value of products. Its presence in the ingredients discouraged choosing and purchasing short-dough products.

Information about the presence of green tea extract and high-oleic rapeseed oil was shown to have a positive impact on product reviews. Similarly, the presence of information about a low saturated fatty acid content on packaging encouraged purchases of such a product. This suggests that confectionery manufacturers should include this type of information, which can help educate consumers, make decisions, and choose nutritionally more beneficial products with natural antioxidants.

Since the usage of oleogels and natural antioxidants is an international trend in food technology, these studies should be taken in the future at the international level.

5. Patents

Method of producing a pastry product P.426674

Author Contributions: Conceptualization, S.O.-G. and A.Z.; methodology, S.O.-G. and A.Z.; validation, S.O.-G. and A.Z.; formal analysis, S.O.-G.; investigation, S.O.-G.; resources, S.O.-G.; data curation, S.O.-G. and I.S.; writing—original draft preparation, S.O.-G., I.S.; writing—review and editing, A.Z. and M.K.; visualization, S.O.-G. and I.S.; supervision, A.Z. and M.K.; project administration, S.O.-G.; funding acquisition, S.O.-G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was financed by the Polish Federation of the Food Industry.

Institutional Review Board Statement: Not applicable.

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

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to possible use in commercialization processes.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

HORO	High-oleic rapeseed oil
PF	Palm fat
EC	Ethylcellulose
CLX	Candelilla wax
MAG	Monoacylglycerol
GTE	Green tea extract
FA	Fatty acid
TFA	Trans fatty acid

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