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Use of Black Pepper Essential Oil to Produce a Healthier Chicken Pâté

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Abstract: This study aims to explore the effect of using black pepper essential oil (BPEO) to produce a healthier chicken pâté. Four different formulations were produced: a control formulation without back pepper and three with increasing BPEO contents. To test the effect of using BPEO, physiochemical analyses were performed at two different moments, 8 and 21 days after production. Microbiological analyses were performed 2, 9, 16, and 23 days after production. Sensory analysis to evaluate the pleasantness of the pâtés to consumers was performed 21 days after production. Finally, total phenol and flavonoid content and antioxidant activity were evaluated. Results show no significant physicochemical differences. Pâtés with no BPEO or black garlic were the most pleasant, but 0.3 or 0.5% of BPEO were not significantly less appreciated, while 1% of the EO caused a decrease in taste and global appreciation. The higher the BPEO content, the higher the phenol content, antioxidant (with an increase from 1.58 to 2.27 mg eq. Fe II/g of sample, in the Control at T23 and V3 at T23, respectively), and microbial activity (with total mesophiles count reduction from 5.91 to 5.21 log CFU/g sample in V3 from T9 to T16). The use of 1% of BPEO showed a significant effect on the reduction in mesophile counts for at least two weeks. These results highlight the potential for optimizing BPEO or black garlic content to ensure both consumer acceptance and enhanced functional properties. While further analysis will help pinpoint the best formulation, the current findings are a promising step towards achieving an optimal balance.

Keywords: chicken; pâtés; olive oil; black pepper oil; black garlic

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1. Introduction

Pâté is a widely produced and economically accessible meat product, recognized for its global popularity. It is formulated utilizing secondary meat industry by-products, such as adipose tissue, liver, or lower-grade meat cuts, which undergo fine grinding and seasoning based on specific proprietary formulations [1], allowing the mixture of different ingredients with particular functions. In countries like Spain, France, Germany, and Denmark, liver pâtés are traditional gastronomic products. They are esteemed for their superior organoleptic properties, high consumption rates, and cultural significance [2].

The global demand for healthier food options has increased, driven by increasing consumer awareness and a growing preference for nutritious and natural products. Some popular delicatessen products, such as pâtés, have garnered attention due to their rich flavor and versatility. However, traditional pâté recipes often contain high levels of saturated fats [3] and preservatives, with relatively low nutritional value [4], which can harm health.

Within this broader trend, delicatessen products like pâtés have gained attention for their rich flavor and versatility, appealing to consumers seeking both indulgence and nutritional value. This growth is attributed to the increasing popularity of gourmet and artisanal food products, as well as the rising demand for protein-rich snacks and spreads. Consumers are particularly drawn to pâtés made with natural ingredients, free from artificial additives, and those offering functional benefits, such as high omega-3 content or low sodium levels [5].

Essential oils (EOs) are volatile components that have distinct and characteristic aromas. Generally recognized as safe (GRAS) [6], these oils are derived from aromatic plants through methods like hydro-distillation or cold-pressing from the peels of citrus fruits. EOs primarily consist of terpenoids located in various plant structures, including glands, trichomes, and waxy channels. Essential oils are known for their antioxidant and antimicrobial qualities [7] and their ability to enhance food flavors in meat products [8]. Black pepper essential oil (BPEO) is a natural compound derived from the berries of the *Piper nigrum* plant. It is known for its antioxidant, antimicrobial, and anti-inflammatory properties, making it a promising candidate for food preservation and enhancement [9]. The bioactive compounds in BPEO, such as piperine, have been shown to inhibit the growth of pathogenic bacteria and extend the shelf life of food products [10]. There have been studies introducing thyme and oregano essential oils into pork meatballs [11] and BPEO in fresh pork [12]; however, applying BPEO in meat products, such as chicken pâté, is underexplored in scientific literature.

Black Garlic (BG) is created through a "fermentation process" where whole bulbs or cloves are maintained under specific temperature (60–90 °C) and humidity (70–90%) conditions for several weeks. Garlic experiences both enzymatic and non-enzymatic browning reactions throughout this extended heat treatment, significantly altering its taste, aroma, physicochemical, organoleptic, and bioactive properties [13]; among them, antimicrobial and antioxidant properties are well-recognized [14,15].

This study aims to address the existing information gap regarding the use of black pepper essential oil (BPEO) in meat products. Specifically, it investigates whether incorporating BPEO can enhance the taste and aroma of pâté while also extending its shelf life by inhibiting pathogenic microorganisms and preventing lipid oxidation. Additionally, the study explores the effects of BG addition on the product. The research methodology includes sensory acceptance tests to evaluate consumer preferences, microbiological analyses to assess food safety, and chemical evaluations to monitor potential changes in the pâté's nutritional composition. By combining these approaches, the study provides a comprehensive understanding of how BPEO and BG can improve the quality and safety of pâté.

2. Materials and Methods

2.1. Pâté-Making Process

For the preparation of the pâtés studied in this work, the commercial chicken breast was purchased from a local market. In the Laboratory of Carcass and Meat Quality (LTQCC) of the Agricultural School of the Polytechnic Institute of Bragança, the meat was minced using a butcher's mincer with a plate with 0.3 cm holes. Then, the ingredients, meat, salt (NaCl), cooking milk, olive oil, and starch in the same quantity were mixed for 10 min. Four formulations were prepared according to Table 1. The water content of the control formulation was higher and was replaced by BG and black pepper essential oil in formulations V1, V2, and V3 to obtain the same final weight. Formulations V1, V2, and V3 contained 15 g of BG. V1 had 5 g of black pepper essential oil, V2 had 10 g, and V3 had 15 g. Both BG and BPEO were subjected to a prior pasteurization (72 °C for 10 min) treatment to reduce possible contamination. The pâtés were placed in glass jars and sealed with a metal lid. The jars of the different formulations were correctly identified. The product was then placed in a water bath in an oven with a temperature controlled by a thermometer so that the thermal center reached 75 °C, for approximately 30 min. After removal from the oven, the product was placed in running water to reduce the temperature and stored in a freezer (4 °C) until analysis. Figure 1 summarizes the production of the pâtés. The concentrations used in this study were obtained after (preliminary) studies of the product's characteristics and the ingredients involved in this manufacturing process.

Table 1. Formulation pâtés.

	Control (g)	%	V1 (g)	%	V2 (g)	%	V3 (g)	%
Meat	750	52.1	750	52.1	750	52.1	750	52.1
Salt	15	1.0	15	1.0	15	1.0	15	1.0
Cooking milk	165	11.5	165	11.5	165	11.5	165	11.5
Water	150	10.4	130	9.0	125	8.7	120	8.3
Olive oil	300	20.8	300	20.8	300	20.8	300	20.8
Starch	60	4.2	60	4.2	60	4.2	60	4.2
BG powder	0	0,0	15	1.0	15	1.0	15	1.0
BP eo	0	0.0	5	0.3	10	0.7	15	1.0
Total	1440	100.0	1440	100.0	1440	100.0	1440	100.0

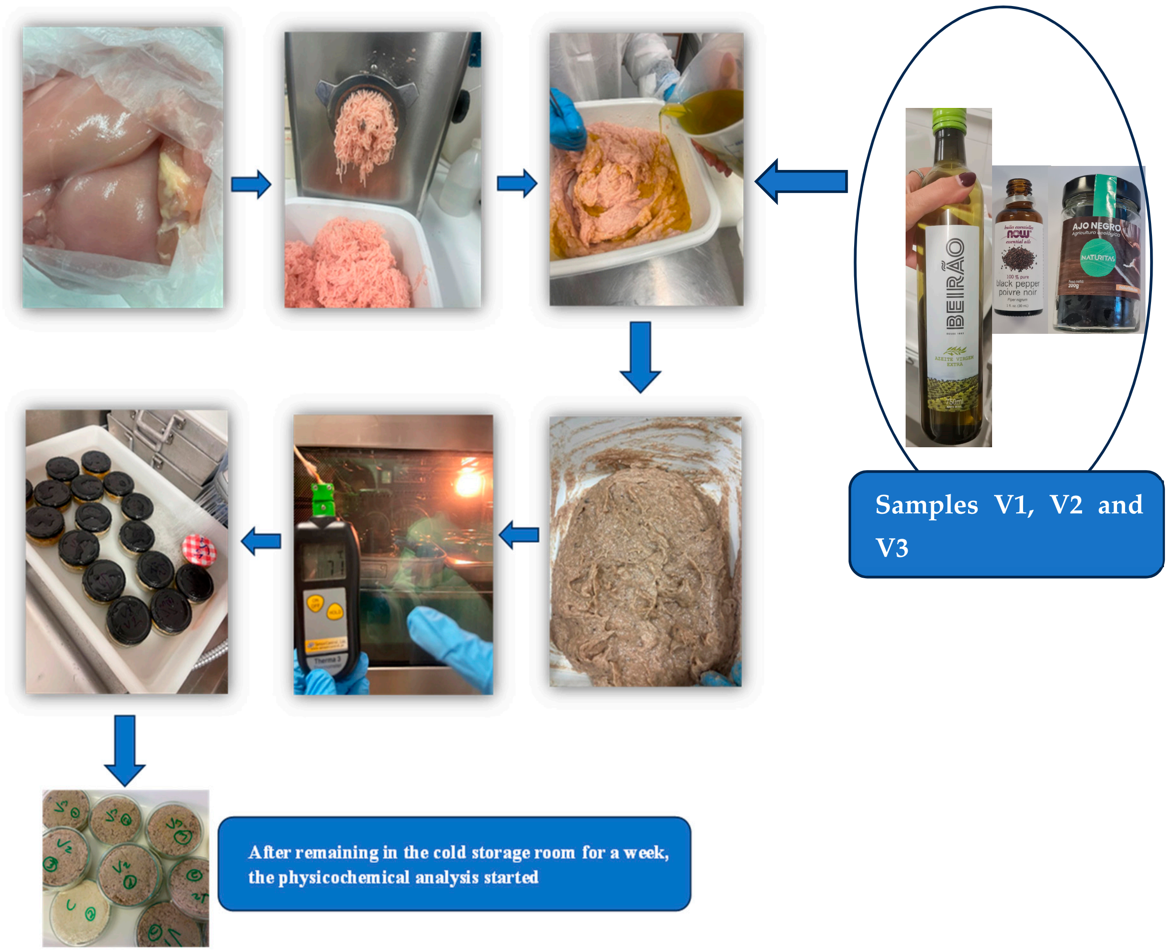

Figure 1. Production process for chicken pâtés.

To understand the contribution of the used meat (chicken) on the fatty acid profile of the pâtés, an analysis of the chicken meat fatty acid profile was carried out at the carcass and meat technology laboratory of the Polytechnic Institute of Bragança. The following fatty acid fractions were obtained: 34.44% saturated fatty acids, 48.74% monounsaturated fatty acids, and 16.82% polyunsaturated fatty acids. Olive oil also featured highly in the fat used in pâtés. The extra virgin olive oil used was a commercial oil (Cidacel, S.A.®—Coimbra, Portugal), whose technical data sheet was provided by the quality department. Concerning the percentage of monounsaturated fatty acids, this oil can present up to 85%.

2.2. Chemical Composition and Physicochemical Analysis

The following analyses were made in triplicate at two different times (8–21 days) after production. The pâtés' physicochemical analyses were conducted using the following Portuguese standards [16]. Water activity (aw) was assessed according to AOAC [17] using a HigroPalmAW1 Rotronic 8303 probe (Bassersdorf, Switzerland). The color parameters, obtained by CIELab coordinates as lightness (L), redness (a*), and yellowness (b*), were determined with a Lovibond RT Series—SP62 spectrophotometer (The Tintometer Limited, Wiltshire, UK) [18]. The determination of pH was according to the Portuguese Standard NP 3441/2008 [19], with a Crison 507 pH-meter equipped with a 52–32 puncture electrode (Crison Instruments, Barcelona, Spain). Moisture content was determined according to the Portuguese standard NP 1614/2002 [20]. To 3 g of sample, 5 mL of ethanol (96% v/v) was added and dried in a drying oven (Raypa DO-150, Barcelona, Spain) at 103 $\pm$ 2 °C for 24 h. Ash content was determined according to the Portuguese standard NP-ISO-1615/2002 [21]. The samples were then heated to 550 °C $\pm$ 25 °C for 5 h in a muffle furnace (Vulcan BOX Furnace Model 3-550, Yucaipa, CA, USA). To test the protein content, we followed the Portuguese standard NP 1612/2002 [22], the Kjeldahl Sampler System (K370, Flawil, Switzerland), and the Digest System (K-437, Flawil, Switzerland). In 25 mL of sulfuric acid (97%), two catalyst tablets and 2 g of sample were placed in mineralization tubes. Following the completion of mineralization, the distillation procedure was performed. Subsequently, the distillate was titrated using a hydrochloric acid solution, and the necessary volume was registered. The collagen by hydroxyproline determination was carried out by Portuguese Standards NP 1987/2002 [23]. The haem pigment content [24] was determined by measuring the reflectance on the exposed surface using spectroscopy with a Spectronic Unicam 20 Geneys instrument. The results are expressed as mg myoglobin/g fresh muscle. Total chloride content was assessed following the methodology specified in the Portuguese Standard NP 1845/1982 [25], expressed as a percentage by mass of sodium chloride. Additionally, the thiobarbituric acid reactive substances (TBARS) were determined by the extraction of malondialdehyde (MDA) as stated in NP-ISO-3356/2009 [26] with modifications. The results were expressed as mg of MDA/kg of the sample.

2.3. Fatty Acid Analysis

Fatty acids in pâté samples were analyzed in the Carcass and Meat Quality Laboratory of ESA—IPB. The total lipids were extracted from 25 g of meat sample according to the Folch procedure [27]. The fatty acid profile was determined using 50 mg of fat. The fatty acids were transesterified according to the method described by Domínguez et al. [28]; after adding 4 mL of a sodium methoxide solution and vortexing for 5 min at a time of 15 min at room temperature, 5 mL of H_2SO_4 solution (in methanol at 50%) was added. Then, we added 2 mL of distilled water and vortexed once more. The organic phase (with the methyl esters of fatty acids) was extracted with 2.35 mL of hexane. The fatty acid methyl esters separation and quantification were performed using a gas chromatograph (GC-Shimadzu 2010Plus; Shimadzu Corporation, Kyoto, Japan) provided with a flame ionization detector and an automatic sample injector AOC-20i and using a Supelco SP TM -2560 fused silica capillary column (100 m length, 0.25 mm i.d., 0.2 µm film thickness). The fatty acid contents were calculated using chromatogram peak areas and were expressed as g per 100 g of total fatty acid methyl esters. In addition, the percentage of saturated fatty acids (ΣSFA), monounsaturated fatty acids (ΣMUFA), polyunsaturated fatty acids (ΣPUFA), the ratio PUFA n-6/n-3, and Σtrans were calculated according to Vieira et al. [29]. To measure the lipid quality, the index of atherogenicity (IA) and the index of thrombogenicity (IT) were calculated according to Ulbricht and Southgate [30] formulas:

$$IA = \frac{\text{C12}:0 + 4 \times \text{C14}:0 + \text{C16}:0}{\Sigma\text{MUFA} + \Sigma\text{PUFA}}$$

$$IT = \frac{\text{C14}:0 + \text{C16}:0 + \text{C18}:0}{0.5 \times \Sigma\text{MUFA} + 0.5 \times \Sigma\text{PUFAn} - 6 + 3 \times \Sigma\text{PUFAn} - 3 + \frac{\text{PUFAn}-3}{\text{PUFAn}-6}}$$

2.4. Microbiological Analysis

Microbial analyses were performed to evaluate the food security of the pâtés. These analyses also allow us to check on the antimicrobial activity of BPEO and BG. For the search and counting of total coliforms and *E. coli*, the Simplate kit, developed by BioControl and approved by the AOAC 2005.03 [31], was used. The dehydrated medium provided by the supplier was hydrated with 100 mL of sterile distilled water. Subsequently, 9 mL of the hydrated medium and 1 mL of the respective decimal dilution of the sample were pipetted into a sterile test tube. The liquid preparation was poured into the Simplate plate, and with circular movements, the 84 wells were filled, pouring the excess liquid onto the sponge. Plates were incubated at 37 °C from 24 h to 48 h. After incubation, total coliforms were counted by counting each well with a change in the initial color of the culture medium. Regarding the quantification of *E. coli*, the Simplate plate was subjected to a UV lamp at 365 nm, counting the wells with fluorescence. Total coliform and *E. coli* counts were calculated using the conversion table provided by the manufacturer. The results were expressed in colony-forming units per gram of sample (CFU/g).

The search for *Salmonella* spp. was conducted using the 1-2TEST kit approved by AOAC Official Method 989.13 [32], developed by BioControl and Ambifood. The method consists of pre-enriching the sample in peptone water at 37 °C for 24 h. After this period, the kit is prepared according to the manufacturer's instructions and placed at 37 °C for 24 h. Results are interpreted visually by detecting an immunoprecipitation band.

Bacillus cereus was quantified using the plate counting technique according to ISO 7932:2004 [33], by spreading 0.1 mL of each decimal dilution on the surface of Petri dishes containing selective agar for B. cereus (MYP). Plates were incubated at 30 °C for 24–48 h. The results were expressed in colony-forming units per gram of sample (CFU/g).

The total aerobic mesophilic bacteria count followed Portuguese Standard (NP) 4405:2002 [34], using the plate count method by incorporating the inoculum. The culture medium used was Plate Count Agar (PCA), to which the culture medium was added to 1 mL of each decimal dilution in a Petri dish. After the medium solidified, the plates were incubated at 30 °C for 48 to 72 h, after which colonies were counted. The results were expressed in colony-forming units per gram of sample (CFU/g).

2.5. Phenols, Flavonoids, and Antioxidant Activity (FRAP Method)

For the analysis of phenols, flavonoids, and antioxidant activity, a sample portion of the pâtés was lyophilized. From the lyophilized sample, 1 g was weighed, and 25 mL of a hydroalcoholic (ethanol 80%) solution was added. This solution was agitated for 1 h, filtrated, and evaporated using a rotative evaporator (IKA RV8, Staufen im Breisgau, Germany). The obtained extract was dissolved in 10 mL of the hydroalcoholic solution previously used. From this solution, phenol and flavonoid content, and antioxidant activity were determined, as described below.

2.5.1. Determination of Total Phenolic Compounds

To determine total phenolic compounds, the Folin–Ciocalteu method was used as described by Singleton et al. [35]. To analyze total phenols, 0.5 mL of sample, 2.5 mL of Folin–Ciocalteu reagent at 10% (*v*/*v*), and 2 mL of sodium carbonate at 75 g/L were pipetted. The resulting solution was kept in the dark for 2 h. After this time, the absorbance of the solutions was measured at 760 nm in a spectrophotometer (UV-3100PC). The calculations were carried out using a calibration curve performed with the standard gallic acid (GA), and the results were expressed in mg GA equivalents per g of sample.

2.5.2. Determination of Total Flavonoids

The method of Woisky and Salatino [36] was used to determine total flavonoids. This analysis involved pipetting 2.5 mL of sample and 2.5 mL of 2% (*w*/*v*) AlCl3. The obtained solution was left to rest for 1 h in the dark, and the absorbances of the solutions were measured at 420 nm. A calibration curve with the quercetin standard (Q) was used to perform the calculations. The results were expressed in mg Q equivalents per g of sample.

2.5.3. Determination of Antioxidant Activity by the FRAP Method

The antioxidant activity was carried out using the FRAP method as reported by Berker et al. [37]. The FRAP reagent was prepared by mixing 0.3 M acetate buffer solution (pH 3.6), 10 mM TPTZ [2,4,6-Tri(2-pyridyl)-1,3,5-triazine], and 20 mM FeCl3 in a ratio of 10:1:1, respectively.

A volume of 0.1 mL of the sample solution was pipetted, then, 3 mL of the FRAP reagent and 0.3 mL of deionized water were added. The solutions were placed in the dark for 6 min, and then the absorbances were read on a spectrophotometer at 595 nm. The results were expressed as mg eq Fe II per gram of sample, based on a calibration line made with iron sulfate heptahydrate.

2.6. Sensorial Analysis

This test aims to assess consumers' appreciation of the products studied. To simulate product consumption by real consumers, the choice of individuals was not controlled. Thus, the consumer panel comprised randomly selected, untrained individuals who evaluated the samples by comparing them and indicating their pleasantness considering appearance, odor, texture, taste, and global appreciation.

This analysis was carried out in a controlled environment to ensure that all samples were consumed under the same preparation conditions and with the same accompaniments. Consumers were voluntary members of the IBP community, including staff, teachers, and students.

The tastings occurred in a laboratory at the IPB School of Agriculture, where the venue was prepared. Participants filled in an evaluation form shared using Google® forms, indicating their evaluations. Consumers were informed about the products they were tasting and the practical procedure for testing. Five attributes were assessed using a 1 (very unpleasant) to 9 (very pleasant) scale. In addition, the consumers consented to participate and were surveyed for sociodemographic information (age, sex, and eating habits related to pâtés). Consumers were given water to cleanse the palate and remove residual flavors at the beginning of the session and between samples. Each treatment was evaluated once by each consumer, who had the opportunity to choose which sample to start with.

Sensory evaluation was approved by the Ethics Committee of the Instituto Politécnico de Bragança through internal procedures using the documental management system implemented by the institution.

Approximately 30 min before the tastings, the pâtés were removed from the refrigerator and left at room temperature. Samples were prepared around 15 min before the tasting, and the pâtés were served spread on small pieces of toast, as this tasting aimed to simulate the usual consumption of this product [38].

2.7. Statistical Analysis

Data were statistically analyzed using SPSS software from IBM®, version 25. Univariate ANOVA using formulation as a fixed factor was used to test differences in physicochemical characteristics and fatty acids profile. Time and formulation were also used as fixed factors for testing microbiology, phenols, flavonoids, and antioxidant activity. Normal distributions and variance homogeneity were assumed. The Tukey test was used to check for differences between formulations and times. The significance levels considered were 5, 1, and 0.1% as provided by the statistical package.

Sensory data were analyzed using nonparametric ANOVA applying the Friedman test. Formulations were compared using the Kruskal–Wallis pairwise test.

3. Results and Discussion

3.1. Physicochemical Characteristics

The physicochemical composition of chicken pâtés with added BG and BPEO is presented in Tables 2–4. Table 2 illustrates the pH values, water activity (a_w), and color parameters. This table shows the effect of BG and the percentage of BPEO added to chicken pâtés. Concerning water activity (a_w), the values obtained for the pâtés ranged from 0.945 to 0.966. Other authors have observed similar values of aw in pâtés [39]. The water activity of a food product is a significant factor affecting meat products' safety. It is a fundamental indicator of shelf life, ensuring nutritional stability and identifying the types of present microorganisms [40]. The combination of water and salt creates osmotic changes that result in dehydration, which removes water from the meat [41]. Water can facilitate the attachment of a radical species and the removal of hydrogen from the fatty acids, thereby initiating the oxidation process [42]. Therefore, the pâté formulations studied in this work have high aw values, with the control having a significantly lower value than the V3 formulation. It should be noted that the V3 pâté formula has a higher BPEO value. We can also see that as the BPEO content increases, so does the a_w value. Pâtés are short-term storage products.

Table 2. Physical properties and color parameters of chicken pâte with added BPEO and BG.

	C	V1	V2	V3	Sig.
a_W	0.945 ± 0.02 ^{b}	0.959 ± 0.01 ^{ab}	0.961 ± 0.01 ^{ab}	0.966 ± 0.005 ^{a}	*
pH	6.05 ± 0.04	5.96 ± 0.08	6.00 ± 0.15	5.94 ± 0.10	NS
Color parameters					
L*	78.91 ± 6.59 ^{a}	62.79 ± 2.33 ^{b}	60.12 ± 2.01 ^{bc}	51.27 ± 9.47 ^{c}	***
a*	0.56 ± 0.25 ^{c}	5.04 ± 0.21 ^{b}	5.51 ± 1.43 ^{ab}	4.69 ± 1.31 ^{b}	***
b*	18.58 ± 3.58	17.74 ± 0.33	19.15 ± 3.52	16.33 ± 3.72	NS
C*	18.59 ± 3.57	18.45 ± 0.37	19.93 ± 3.78	17.00 ± 3.93	NS
H*	90.91 ± 2.10 ^{a}	74.14 ± 0.41 ^{b}	74.13 ± 1.12 ^{b}	74.15 ± 0.97 ^{b}	***

a, b, c, means with the same superscript within the row are not significantly different. NS not significant, * $p < 0.05$, *** $p < 0.001$. C, control chicken pâté; V1, chicken pâté with 1% of BG + 0.3% of BPEO; V2, chicken pâté with 1% of BG + 0.7% of BPEO; V3, chicken pâté with 1% of BG + 1% of BPEO. L* brightness; a* redness; b* yellowness; C* chroma; H* hue.

Table 3. Chemical properties of chicken pâte with added BPEO and BG.

	C	V1	V2	V3	Sig.
TBARS	3.66 ± 0.54 a	1.82 ± 1.12 b	1.28 ± 0.49 b	1.44 ± 0.79 b	**
Haem Pigments	0.103 ± 0.052 b	0.318 ± 0.065 a	0.304 ± 0.12 a	0.306 ± 0.08 a	*
Moisture (%)	61.53 ± 1.71	60.91 ± 1.31	61.05 ± 0.98	60.58 ± 0.61	NS
Ashes (%)	1.76 ± 0.06	1.66 ± 0.17	1.80 ± 0.04	1.76 ± 0.03	NS
NaCl (%)	1.29 ± 0.03 ab	1.20 ± 0.09 b	1.26 ± 0.06 ab	1.40 ± 0.13 a	*
Collagen (%)	0.185 ± 0.05 a	0.228 ± 0.07 a	0.199 ± 0.04 a	0.069 ± 0.04 b	**
Protein (%)	10.10 ± 1.70	10.26 ± 1.64	9.93 ± 2.21	11.88 ± 0.47	NS
Total fat (%)	21.22 ± 2.46	22.49 ± 4.59	22.91 ± 4.26	21.19 ± 2.47	NS

a, b means with the same superscript within the same row did not differ significantly. NS not significant, * $p < 0.05$, ** $p < 0.01$. TBARS (mg of MDA/kg of sample). Haem pigments in mg myoglobin/g fresh sample. (%) g/100 g sample. C, control chicken pâté; V1, chicken pâté with 1% of BG + 0.3% of BPEO; V2, chicken pâté with 1% of BG + 0.7% of BPEO; V3, chicken pâté with 1% of BG + 1% of BPEO.

Table 4. Fatty acids profile of chicken pâte with added BPEO and BG.

	C	V1	V2	V3	Significance
C4:0	0.00 ± 0.00 b	0.042 ± 0.05 b	0.150 ± 0.13 ab	0.295 ± 0.07 a	**
C6:0	0.00 ± 0.00	0.00 ± 0.00	0.022 ± 0.03	0.038 ± 0.03	NS
C8:0	0.00 ± 0.00	0.00 ± 0.00	0.022 ± 0.03	0.038 ± 0.03	NS
C10:0	0.00 ± 0.00 b	0.012 ± 0.03 b	0.059 ± 0.05 ab	0.097 ± 0.05 a	*
C11:0	0.00 ± 0.00	0.00 ± 0.00	0.025 ± 0.02	0.037 ± 0.03	NS
C12:0	0.00 ± 0.00 b	0.009 ± 0.02 ab	0.061 ± 0.04 ab	0.086 ± 0.07 a	*
C14:0	0.083 ± 0.005	0.082 ± 0.005	0.068 ± 0.04	0.081 ± 0.01	NS
C14:1	0.00 ± 0.000	0.00 ± 0.00	0.004 ± 0.008	0.008 ± 0.02	NS
C15:0	0.010 ± 0.01	0.006 ± 0.01	0.013 ± 0.02	0.00 ± 0.00	NS
C16:0	11.87 ± 0.03	11.67 ± 0.28	11.79 ± 0.20	11.67 ± 0.13	NS
C16:1n-7	0.90 ± 0.01 ab	0.89 ± 0.01 b	0.91 ± 0.02 ab	0.92 ± 0.007 a	*
C17:0	0.050 ± 0.002	0.048 ± 0.005	0.047 ± 0.004	0.036 ± 0.02	NS
C17:1n-7	0.075 ± 0.001	0.070 ± 0.006	0.073 ± 0.007	0.058 ± 0.04	NS
C18:0	3.90 ± 0.05	3.87 ± 0.09	3.87 ± 0.04	3.87 ± 0.08	NS
9t-C18:1	0.091 ± 0.007	0.090 ± 0.01	0.090 ± 0.008	0.074 ± 0.05	NS
C18:1n-9	75.89 ± 0.11	76.24 ± 0.60	75.64 ± 0.80	75.85 ± 0.80	NS
C18:2n-6	5.70 ± 0.08	5.61 ± 0.13	5.73 ± 0.16	5.63 ± 0.25	NS
C20:0	0.286 ± 0.02	0.262 ± 0.05	0.272 ± 0.07	0.190 ± 0.13	NS
C18:3n-6	0.140 ± 0.01	0.119 ± 0.04	0.116 ± 0.08	0.100 ± 0.07	NS
C20:1n-9	0.517 ± 0.03	0.528 ± 0.03	0.517 ± 0,05	0.497 ± 0.11	NS
C18:3n-3	0.0037 ± 0.007	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	NS
C20:2n-6	0.033 ± 0.04	0.015 ± 0.03	0.030 ± 0.04	0.016 ± 0.03	NS
C22:1n-9	0.452 ± 0.02	0.441 ± 0.02	0.454 ± 0.04	0.410 ± 0.09	NS
C22:2n-6	0.008 ± 0.015	0.00 ± 0.00	0.006 ± 0.01	0.00 ± 0.00	NS
SFA	16.20 ± 0.07	16.00 ± 0.38	16.39 ± 0.40	16.44 ± 0.20	NS
MUFA	77.92 ± 0.10	78.26 ± 0.54	77.69 ± 0.67	77.82 ± 0.52	NS
PUFA	5.88 ± 0.13	5.75 ± 0.17	5.92 ± 0.29	5.75 ± 0.33	NS
n-6	5.88 ± 0.13	5.74 ± 0.17	5.88 ± 0.26	5.75 ± 0.33	NS
AI	0.146 ± 0.0007	0.143 ± 0.004	0.145 ± 0.003	0.145 ± 0.001	NS
TI	0.378 ± 0.002	0.372 ± 0.01	0.375 ± 0.006	0.374 ± 0.006	NS
h/H	6.83 ± 0.02	6.97 ± 0.21	6.87 ± 0.16	6.94 ± 0.12	NS

a, b means with the same superscript within the row are not significantly different. NS not significant, * $p < 0.05$, ** $p < 0.01$. SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; AI, index of atherogenicity; TI, index of thrombogenicity; h/H, Hypocholesterolemic/hypercholesterolemic index; C, control chicken pâté; V1, chicken pâté with 1% of BG + 0.3% of BPEO; V2, chicken pâté with 1% of BG + 0.7% of BPEO; V3, chicken pâté with 1% of BG + 1% of BPEO.

Water activity is a measure of the water activity of a food product and is a predictor of shelf life. The water activity values in food products affect sensory indicators, microbiological stability, and manufacturing processes [39].

No significant differences ($p > 0.05$) were observed in the pH value between the various formulations. The pH values were between 5.94 and 6.05 for all the formulations. Therefore, we can see that the introduction of BPEO and BG does not influence the pH value of the final product. Similar pH values were observed in goat burgers with sunflower and olive oil hydrogel emulsions [43]. Higher pH values (6.20) were obtained by other authors in chicken patties [44] and pork pâté with hemp oil-gelled emulsion [45].

A product's stability is affected by pH and water activity in the food environment. The free water available to participate in the chemical or biological processes might deteriorate the products in terms of physicochemical, nutritional, and microbiological aspects [43]. Higher pH values were also obtained in pâtés with various percentages of spirulina added [46] and pork liver pâtés [47].

The CIELAB color coordinates and attributes parameters showed significant differences between the various types of pâtés for some of the indices. The luminosity index (L*), red index (a*), and hue (H*) were significantly different between the various types of pâtés. The color characteristics of the pâtés were affected by the incorporation of BPEO and BG. The pâtés with the addition of these ingredients were significantly darker (L* = 62.79 and 51.27) when compared to the control pâtés.

It should also be noted that the higher the amount of BPEO (V3), the lower the L* value. Lower values (L* = 50 and 54) were obtained for chicken and pork pâtés [48]. Pâtés with added BPEO and BG were significantly redder, with a* value between 4.96 and 5.51 for formulations V1, V2, and V3. Similar values were obtained for chicken and pork pâtés [48]. The formulation without these ingredients (control) obtained a significantly lower value for the redness index (a*). For the yellow index (b*) and Chroma (C*), no significant differences ($p > 0.05$) were obtained between the various types of formulations. Unlike the brightness (L*) and redness index (a*), these indexes (b* and C*) were not affected by the introduction of BG and BPEO. The yellow index (b*) values ranged from 16.33 to 19.15, and the Chroma index (C*) values ranged from 17.00 to 19.93. As for the hue value (H*), significant differences were obtained for the pâtés with added BPEO and BG, compared to the control. For the control pâtés (without adding BPEO and BG), the average H* value was 90.91. For the V1, V2, and V3 formulations, the H* value decreased significantly, with values between 74.13 and 74.15.

Table 3 shows the values obtained for the chemical composition of the chicken pâtés and their formulations. Significant differences existed in the oxidation index, haem pigments, NaCl, and collagen content. Adding BPEO and BG did not significantly influence the other parameters.

Regarding the TBARS index, significant differences were observed between the control and the formulations with BPEO and BG. The control pâté formulation obtained values of 3.66 MDA/kg, much higher than those obtained in the V1, V2, and V3 formulations. In this case, increasing the amount of BPEO did not significantly influence lipid oxidation parameters. According to other authors, the threshold limit for meat and meat product acceptability concerning fat oxidation is a value of 2 mg MDA/Kg for the TBARS index [49].

Significant differences ($p < 0.05$) were found in the haem pigments. The myoglobin content in the control pâté was significantly lower than the pâtés with added BG and different percentages of BPEO. An average value of 0.103 was obtained for the control and average values of 0.318, 0.304, and 0.306 for formulations V1, V2, and V3, respectively.

Moisture is one of the technological parameters that indicate the maturation of the product and how it can affect the shelf life [50]. No statistical differences were obtained for this parameter between the different pâté formulations. The average values obtained were between 60.58 and 61.53 % moisture. Lower moisture values (52–53%) have been observed by other authors in pork liver pâtés [51] and chicken liver pâtés [52]. Other authors obtained similar values in pork pâtés [53] and liver lambs' pâtés [54]. No significant differences were obtained between the different pâté formulations for the ashes. Values between 1.66 and 1.80 were obtained for this parameter. Similar values were observed in liver lambs' pâtés [54]. Higher values of between 3 and 4% were obtained in pork pâtés [53], chicken liver pâtés [52], and foal liver pâtés [51]. This value is directly related to the salt content of these products. The higher the mineral content, the higher the as content of this final product. There were significant differences between the formulations in the case of salt content. Formulation V1 had the lowest sodium chloride content (1.20%), and formulation V3 had the highest (1.40%). Higher sodium values were obtained by other authors in chicken pâtés (1.92–3.39 g/kg) [55].

Significant differences were observed between the various pâté formulas for the collagen value. The lowest collagen value was observed in the V3 formulation (0.069), which has a higher percentage of BPEO. There were no significant differences between the V1, V2, and control formulations, with average values ranging from 0.185 to 0.228. For the protein content of the chicken pâtés, no significant differences were observed between the various formulations. Average values of between 9.93 and 11.88% were obtained. Similar values were obtained in pork pâtés [53] and lambs' liver pâtés [56]. On the other hand, higher values were obtained in foal liver pâtés [51,56]. Lower protein content values (7–8%) were obtained in chicken liver pâtés [52].

Table 3 also shows the fat content for this type of product. The introduction of BPEO and BG did not significantly affect the total fat content of the pâté obtained. The product obtained had an average total fat value of approximately 22%. Similar values were obtained in foal liver pâtés [8]. Higher values were obtained in chicken liver pâtés [52]. On the other hand, lower values were obtained in liver lambs' pâtés [54].

3.2. Fatty Acid Profile

The fatty acid profile (FA) of the pâtés is shown in Table 4. The most abundant saturated fatty acids (SFA) were palmitic (C16:0), in monounsaturated fatty acids (MUFA), fractions were oleic (C18:1n-9), and in polyunsaturated fatty acids (PUFA) fractions, linoleic (C18:2n-6). According to the individual fatty acids content, the highest amounts were observed for the C18:1n-9 (75–76%), followed by C16:0 (11–12%), followed C18:2n-6 (5–6%), and C18:0 (3–4%). Therefore, the sum of these four fatty acids represents about 98% of the total fatty acid of chicken pâtés. Considering this, the most abundant fatty acids were MUFA, followed by SFA and PUFA.

As seen in Table 4, the fatty acid profile was not significantly influenced by adding BPEO and BG to the pâté formulation. As mentioned above, monounsaturated fatty acids (MUFA) are the main FA for all pâté formulations. The values obtained for these FA range from 77.69 to 78.26, with no significant differences. The MUFA contents are due to the high amount of oleic acid in the pâté samples, common in the control and the formulations with BPEO and BG. That said, the olive oil used to make the pâtés is responsible for this amount of oleic acid and, consequently, the MUFA content. All the formulations produced in this study (Control, V1, V2, and V3) contain 20 g of olive oil per 100 g. Oleic acid is the main component of olive oil. Depending on the olives' ripeness, variety, and growing conditions, oleic acid can make up between 55 and 83% of the total fatty acids in olive oil [57–59]. Other authors who have studied the chemical composition of other types of pâtés have also observed that oleic acid is the most abundant FA. However, the percentage of MUFA is not as high as in the case of pork liver pâtés [51], pâtés with the addition of oregano (Origanum vulgare) essential oil [60], nitrite-free liver pâtés [61], and pork pâté using a gelled emulsion [45]. The fat source used in the pâté formulation increased MUFA and PUFA while reducing SFA. Concerning PUFA, the total content of this fraction is due to the linoleic acid content obtained for all formulations. Like the other fractions of fatty acids, this fraction did not obtain any significant difference ($p > 0.05$) from BPEO and BG. Unsaturated fats, especially PUFAs, are well-known as healthy fats with critical bodily functions, such as cell growth and development and disease prevention [62]. Although linoleic acid is an essential fatty acid, it should be noted that an excessively high intake of this PUFA may not be beneficial. Studies [63,64] have shown that excessive intake of linoleic acid has a pro-inflammatory effect. Fatty acids n-6 promote vasoconstriction and the formation of blood clots.

The index of atherogenicity (AI) and the index of thrombogenicity (TI) characterize, respectively, the atherogenic and thrombogenic potentials of fatty acids [30]. A lower AI value is indicative of a reduced saturated-to-unsaturated fatty acid ratio, whereas a lower TI value is associated with a diminished risk of developing blood clots [65]. The addition of BPEO and BG did not influence the nutritional quality indices (AI and TI). Although no entity or organization provides reference values for these indices [66], it is generally accepted that lower AI and TI values indicate better diet quality, which may reduce the risk of coronary heart disease. The AI index values for the pâté formulas developed in this study ranged from 0.143 to 0.146. As for the TI index, the values ranged from 0.372 to 0.378. Higher AI and TI values, with poor nutritional quality, were obtained in pork pâté using a gelled emulsion [45].

The h/H ratio is based on the functional effects of fatty acids on cholesterol metabolism, and the higher the h/H ratio, the more nutritionally adequate the oil or fat in the food [67]. The h/H ratio varied between 6.83 and 6.97, and no significant differences were recorded between formulation pâtés. A healthy animal product can be characterized by low AI and TI and a high h/H index [62].

The fatty acid profile of the pâtés did not change with the introduction of BPEO and BG. What characterizes the lipid profile of this product is the high percentage of oleic acid present in this oil (approximately 80%, according to the product's technical data sheet).

3.3. Microbiological Analysis

Chicken pâté is known for having a short shelf-life [68]. Hence, conservatives are needed to increase its stability and safety. Microbial analyses were performed to check the effect of using BPEO and BG. Results, shown in Table 5, disclose the measurements of various microbial parameters for the chicken pâté formulations (Control, V1, V2, V3) at different times after production (T2, T9, T16, T23).

Table 5. Results from the microbiology analyses of the chicken pâtés.

Time	Formulation	*Salmonella*	Coliforms	*E. coli*	Total Mesophiles †	*B. cereus*
T2	Control	Absent	<1	<1	<1	Absent
	V1	Absent	<1	<1	<1	Absent
	V2	Absent	<1	<1	<1	Absent
	V3	Absent	<1	<1	4.32 ± 0.270	2.90 ± 0.038
T9	Control	Absent	<1	<1	<1	Absent
	V1	Absent	<1	<1	5.67 ± 0.043	Absent
	V2	Absent	<1	<1	5.84 ± 0.017	Absent
	V3	Absent	<1	<1	5.91 ± 0.024	Absent
T16	Control	Absent	<1	<1	5.94 ± 0.046	Absent
	V1	Absent	<1	<1	5.89 ± 0.083	Absent
	V2	Absent	<1	<1	5.46 ± 0.047	Absent
	V3	Absent	<1	<1	5.10 ± 0.075	Absent
T23	Control	Absent	<1	<1	5.84 ± 0.032	Absent
	V1	Absent	<1	<1	5.94 ± 0.002	Absent
	V2	Absent	<1	<1	5.83 ± 0.060	Absent
	V3	Absent	<1	<1	5.27 ± 0.041	Absent
Significance						
Time		NA	NA	NA	***	NA
Formulation		NA	NA	NA	***	NA
Time × Formulation		NA	NA	NA	***	NA

Days after production: T2, 2 days, T9, 9 days, T16, 16 days, T23, 23 days after production. † Means ± standard deviation; Units: log CFU/g of sample. Significance: NA, not applicable, *** $p < 0.001$.

Salmonella was consistently absent in all samples, suggesting that the formulations comply with food safety standards concerning this pathogenic bacterium, which is often associated with serious food-borne illnesses, according to the European Center for Disease Prevention and Control (ECDC). In fact, according to current legislation, this bacterium must be absent in 25 g of the product.

Coliforms and *Escherichia coli* presented values <1, confirming that the production conditions were well controlled and that there was no proliferation of these microbial indicators, often used to assess the hygienic and sanitary conditions during processing or the techniques used to preserve food products.

Total mesophiles, non-pathogenic indicator microorganisms that, when present in food, can cause spoilage or reduced shelf-life, presented variation in their counts between formulations and with time. At T2, only V3 presented total mesophile counts, suggesting contamination of the BPEO, which was not eliminated by the initial pasteurization. It was observed (Table 5) that total mesophiles significantly increased from T2 to T9, but their counts significantly decreased at T16 and T23, with values not significantly different between them. On the other hand, there were significant differences between formulations, with the Control and V1 presenting the highest values, with no significant differences between them. V2 presented a significantly lower value than C and V1, and V3 had the significantly lowest value of all formulations, suggesting that the increase in BPEO decreased the total mesophile count. The interaction between formulation and time was significant, showing that in V3 samples, total mesophile counts increased from T2 to T9 but then decreased to T16 and slightly increased at T23. A similar tendency was observed in V2 samples, but the decrease from T9 to T16 was inferior to that in V3 samples. Also, the increase was superior. This suggests that the BPEO content of 1% in V3 samples can reduce the mesophile microorganism counts for at least nearly two weeks, while in the V2 samples, the antibacterial effect is more limited. The antimicrobial properties of BPEO were previously referred to [7,69]. In this study, the use of BPEO shows the potential to guarantee food safety for at least a two-week period.

Except for the V3 formulation at T0, *B. cereus* was always absent in all formulations. This result suggests the possibility of remote contamination. Overall, we can say that the new products have been properly pasteurized and stored outside the danger zone (41 °F to 135 °F) [70].

3.4. Phenols, Flavonoids, and Antioxidant Activity (FRAP Method)

Phenols and flavonoids content is presented in Table 6. Phenol content was significantly different between formulations. The Control presented the lowest value, V1 and V2 had higher values and were not significantly different, and V3 presented the highest. Samples evaluated at T23 presented higher values than at T2, particularly evident in V3. This increase can be due to non-controlled fermentations promoted by microorganisms, such as mesophiles, for example, that occurred in the pâtés during the storage time that converted phenolics of different classes into compounds that are often more bioactive, leading to a higher phenolic content [71].

Table 6. Phenols and flavonoids content, and antioxidant activity evaluated by FRAP method in the chicken pâtés.

Time	Formulation	Phenols †	Flavonoids ‡	Antioxidant Activity (FRAP) ‡
T2	Control	0.143 ± 0.0103	0.0195 ± 0.000734	1.95 ± 0.0486
T2	V1	0.165 ± 0.0063	0.0207 ± 0.000805	2.11 ± 0.0433
T2	V2	0.177 ± 0.0192	0.0196 ± 0.003356	2.09 ± 0.0443
T2	V3	0.191 ± 0.0053	0.0197 ± 0.001934	2.03 ± 0.0661
T23	Control	0.130 ± 0.0043	0.0187 ± 0.001226	1.58 ± 0.0472
T23	V1	0.193 ± 0.0313	0.0249 ± 0.002305	2.00 ± 0.0705
T23	V2	0.178 ± 0.0199	0.0199 ± 0.001134	2.12 ± 0.0438
T23	V3	0.287 ± 0.0505	0.0207 ± 0.002410	2.27 ± 0.0721
Significance				
Time		*	NS	*
Formulation		***	*	***
Time × Formulation		**	NS	***

NS not significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. † mg eq. of galic acid/g of sample; ‡ mg eq. of Quercetine/g of sample; ‡ mg eq. Fe II/g of sample.

Flavonoid content had a small but significant ($p < 0.05$) increase from T2 to T23, probably due to the same reason as phenols. Results show significant differences between formulations. It was observed that the Control, with the lowest, and V1 samples, with the highest, were significantly different. V2 and V3 samples were not significantly different from one or the other.

The antioxidant activity evaluated by the FRAP method (Table 6) revealed a significant decrease in the antioxidant activity from T2 to T23. Formulations presented significantly different antioxidant activity. V3 samples had the highest antioxidant activity, followed by V2, which was not significantly different from V3, then, V1, which was not significantly different from V2. Finally, Control samples had the lowest antioxidant activity. These results were expected, given the BPEO and BG antioxidant properties [5]. It should be noted that in samples V2 and V3, antioxidant activity increased over the storage period.

Control values of phenols, flavonoids, and antioxidant activity are mostly probable due to extra-virgin olive oil, which confers those properties [72].

Phenols are suggested to provide plant extracts [68] and essential oils [73] with antimicrobial properties.

Globally, the results from this study indicate that the use of BPEO and BG can confer functional properties to meat products, which give added value and help promote their consumption considering the clean label trend, where consumers prefer healthier, more natural meat products with fewer additives.

3.5. Sensorial Analysis

As sensory analysis progresses as a science, more attention is being paid to the relationship between the properties of food and the sensations derived from eating it. Sensory attributes are considered essential quality indicators among all the quality attributes. Still, they only really affect the product's success in terms of sales on the market if the end consumer accepts it. In this way, consumer acceptability is an essential prerequisite for the financial sustainability of new food products by including new food ingredients.

Food science today places a high value on product characterization and matters pertaining to identifying certain chemicals linked to sensory qualities. The product's flavor, aroma, and appearance are the main determinants of consumer choice [4,73–75].

Sensory evaluation of the chicken pâtés made by a group of consumers indicates that, on a scale of 1 to 9, the evaluated attributes had good acceptability, with average scores between 5.82 and 7.32 and medians between 6 and 8 (Table 7). The group comprised 26 female and 12 male consumers, ranging between 21 and 57 years old, mostly between 21 and 31. Understanding the preferences of young adults (20–30 years old) is crucial for tailoring products, staying ahead of food trends, and crafting effective marketing strategies that align with their health-conscious values and cultural preferences. Pâtés' consumption habits varied from never (2), rarely (14), occasionally (19), to frequently (3).

Table 7. Mean (median) and significance of the differences for the sensory evaluation of the chicken pâtés.

	Control	V1	V2	V3	Significance
Appearance	6.61 (7.0)	6.95 (7.0)	6.76 (7.0)	6.50 (6.0)	NS
Odor	6.68 (7.0)	6.63 (7.0)	6.82 (7.0)	6.68 (7.0)	NS
Taste	7.21 (8.0)	6.32 (7.0)	6.29 (7.0)	5.82 (6.0)	*
Texture	7.32 (7.5)	6.92 (7.0)	7.16 (7.0)	6.68 (7.0)	NS
Global	7.24 (8.0)	6.68 (7.0)	6.71 (7.0)	6.16 (6.0)	**

NS not significant, * $p < 0.05$, ** $p < 0.01$; C, control chicken pâté; V1, chicken pâté with 1% of BG + 0.3% of BPEO; V2, chicken pâté with 1% of BG + 0.7% of BPEO; V3, chicken pâté with 1% of BG + 1% of BPEO.

The number of consumers that participated in this study is insufficient to draw final conclusions given the prerequisites for consumer studies in sensory evaluation, which requires at least 60 individuals, which can lead to some bias. Still, some considerations can be taken from the collected data (d. Taste and global appreciation scores showed significant differences ($p < 0.05$) in the four assessed formulations. Control pâtés presented significantly higher taste and global appreciation than V3. The other formulations were not significantly different from each other, Control, and V3.

Figure 1 shows the boxplots of sensory parameters of chicken pates and their data variability. It allows us to verify that the variables have data gaps within their range of values due to the presence of extreme values, which were considered acceptable results.

The outcomes of the sensory assessment (Table 7 and Figure 2) allow us to conclude that the appearance, odor, and texture did not show significant statistical differences ($p > 0.05$) for any of the five evaluated attributes, probably because they presented higher variability in the assessment by the consumers.

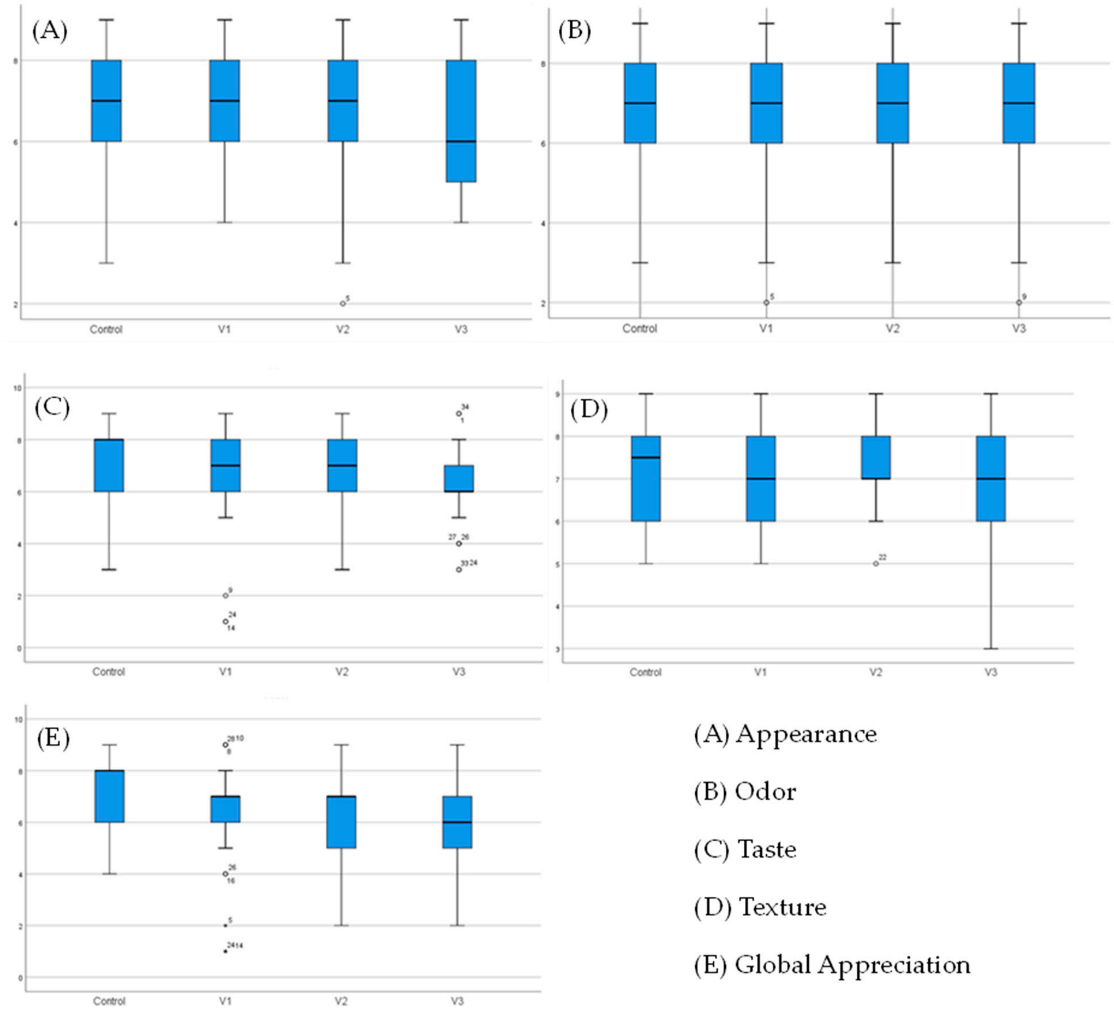

Figure 2. Boxplots of the sensory variability of the chicken pâtés.

In terms of appearance, mean scores are relatively close for all samples: control (6.61), V1 (6.95), V2 (6.76), and V3 (6.50). The median is 7.0 for most groups, except for V3 (6.0). Although the color characteristics of the pâtés were affected by the incorporation of black pepper essential oil and BG, showing the formulations with these components were significantly darker (Section 2.1) when compared to the control pâtés, it did not influence the consumers' evaluations. The means' differences are not significant, which can mean that the consumers did not evaluate the different formulations differently if we look at the blue part of the boxplot representing the mean 50% of evaluations. Still, it can also be due to the range of evaluations between 1 and 9. It must be considered that we are not evaluating color differences but appearance pleasantness, which is a subjective issue.

The results for odor are also similar between the control (6.68) and the variants: V1 (6.63), V2 (6.82), and V3 (6.68). The median was 7.0 for all groups. The differences in odor are not significant, suggesting that the modification of the formulations did not significantly affect the perception of the pâté odor. The authors believe that regardless of the amount of black pepper essential oil added, in terms of consumer evaluation, it can be included in chicken pâté formulations as a new ingredient.

Texture scores (Table 7) vary slightly: control (7.32), V1 (6.92), V2 (7.16), and V3 (6.68), with an overall median of 7.0, except for the control (7.5). This is not significant in terms of consumer perception, possibly due to the amount of olive oil added to the formulations.

Chicken pâtés are a finely ground meat product consisting of a mixture of proteins, fat globules, water, salt, and spices, which together, present a uniform mass. Some factors can influence the texture parameters of a meat-based product such as pâté, namely the raw materials used (type and quantity), the source of fat used, and the way it is incorporated into the mixture (animal fat, gelled emulsion, oleogel, liquid oil, encapsulated oil), the way the meat proteins interact with the fat and their behavior during processing/confection determine the final texture of the product obtained [76,77]. The introduction of oils influences the final texture profile. However, the increase in the amount of black pepper essential oil might not be enough among formulations to cause a significant change in their texture. Either way, personal judgment can influence the pâté's evaluations.

Taste and overall appreciation were significantly affected by the formulation changes: the results for taste show a slight decrease between the control (7.21) and the variants V1 (6.32), V2 (6.29), and V3 (5.82), suggesting that the change in ingredients has a noticeable impact on the taste of the pâtés, especially for the V3 formulation. These results follow those reported by Lishianawati et al. [78], who found a decrease in the aroma and overall acceptability of duck nuggets when adding 1% BG powder. The most appreciated formulation in this study was the Control, which had no garlic or BPEO. On the other hand, Kim et al. [79] improved the sensory properties (color, flavor, and overall desirability) of pork chops, and Augustynska-Prejsnar [80] improved taste and aroma in minced poultry products, both adding 2% of BG. Shin et al. [81] indicated the ideal addition of BG extract is around 15~22% in the sausage preparation.

The median for taste fell progressively from 8.0 for the control to 6.0 for V3. For overall acceptability scores, the assessment is higher for the control (7.24) than for the variants V1 (6.68), V2 (6.71), and V3 (6.16). The median also fell from 8.0 for the control to 6.0 for V3. The differences in overall rating are highly significant ($p < 0.01$), indicating a perceptible and significant change in overall consumer satisfaction with the modified formulations, especially between the Control and V3. The negative impact of the use of 1% BPEO on taste and overall appreciation, particularly in V3, merits formulation re-evaluation to improve these aspects without compromising other sensory characteristics.

The study demonstrates that incorporating spices can facilitate the creation of a new meat product with an acceptable sensory quality. However, the amount of BPEO added can pose a limitation due to its strong aroma. The results underscore the challenges in balancing functional and sensory properties. Therefore, strategies to mitigate the sensory impact of higher BPEO concentrations should be considered in future formulations, such as dairy products, which can soften the paste, or some other natural ingredients that can mask the strong effect of pepper.

4. Conclusions

Adding black pepper essential oil (BPEO) and black garlic (BG) to chicken pâté affected some physicochemical properties, although differences were not very relevant. The study reported varying pH values, water activity (aw), and other color parameters based on the amount of BPEO incorporated into the pâté formulations. The water activity of the pâtés ranged from 0.945 to 0.966, highlighting its importance for food safety and shelf life.

This exploratory study on incorporating black pepper essential oil (BPEO) and BG in chicken pâté demonstrated the potential of these functional ingredients to create a healthier meat product. Including 1% BPEO in this study exhibited antimicrobial and antioxidant properties, contributing to the food safety and extended shelf life of meat products, including pâtés. While BPEO provides health benefits, its strong sensory attributes require careful management to ensure consumer acceptance. The sensory evaluations revealed that pâté formulations without BPEO or black garlic were generally more pleasant to consumers. Although 0.3% and 0.5% BPEO concentrations were not significantly less appreciated, a higher concentration of 1% BPEO resulted in decreased taste and overall appreciation among consumers. This suggests that further investigations must be performed to find ways to mitigate the BPEO's strong sensory attributes. Ingredients such as dairy products, acids, fats, and sweeteners can be alternatives to mask the detrimental sensory effect of pepper.

The findings indicate the potential for using essential oils like BPEO in processed meat products, with implications for creating healthier, more natural, and sustainably produced food items that meet consumer demands for nutritious options. Additional research is necessary to fully assess BG's impact on meat products.

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Informed Consent Statement: When assessing the samples, consumers consented to their participation by choosing the respective option on the evaluation sheet.

Data Availability Statement: All data were presented in the manuscript. Data can be requested from the corresponding author via email.

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