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Effect of Pork Meat Replacement by Fish Products on Fatty Acid Content, Physicochemical, and Sensory Properties of Pork Pâtés

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Abstract: The aim of the study was to assess the influence of the addition of fish raw materials (roe or fish meat) on the quality and nutritional value of pork pâtés. The control group (n = 4) consisted of pork pâtés, I experimental group (n = 6) of pâtés with 20% addition of roe (perch and pike), and II group of pâtés with 20% addition of fish (perch and pike meat) (n = 6). The pâtés' pH, color, and profiled texture analysis were instrumentally measured and water, protein, fat, ash, and fatty acid content were determined by reference methods. To assess the oxidative stability of lipids the measurement of peroxide number, thiobarbituric acid reactive substances and content of conjugated dienes and trienes was used. The degree of fat hydrolysis was determined on the basis of acid value. Sensory analysis was carried out using the scaling method, taking into account 12 unit quality characteristics. Products with roe and meat contained less fat (accordingly 15.9% and 14.1%) and showed lower calorific value (accordingly 225.6 and 208.6 kcal/100 g) compared to pork pâtés (20.2% of lipids, 267 kcal/100 g). Moreover, the addition of fish raw materials improved the index of nutritional quality for protein (from 3.2 to 3.9) and beneficially reduced the nutritional index for fat (from 2.2 to 1.9). Fish constituents modified, to a certain extent, the color, texture, and sensory properties of pâtés, while maintaining full acceptability in consumer assessment. The addition of fish roe significantly increased the healthful quality by improving the fatty acid profile of pâtés, in which the significantly highest content of n-3 fatty acids, including eicosapentaenoic and docosahexaenoic acids (accordingly 252.21, 43.17, and 107.94 mg/100 g product), as well the highest concentration of saturated branched chain fatty acids were determined (18.75 mg/100 g product).

Keywords: pâtés; fish; physicochemical properties; sensory properties; fatty acids; oxidative stability

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1. Introduction

Pâté is a very popular and cheap meat product produced all over the world. It is manufactured using by-products of the meat industry, such as lard, liver, or inferior category meat, which is finely ground and seasoned according to the manufacturer's recipe [1]. In countries such as Spain, France, Germany, or Denmark, for example, liver pâtés are traditional products with a high taste, high level of consumption, and an important part of gastronomic culture [2].

The nutritional value of pâtés depends mainly on the selection and quality of the main recipe ingredients, i.e., meat, fat, and functional additives, but usually it is relatively low [3]. Due to the high fat content (25–40%), high calorific value (approx. 300–400 kcal/100 g), and not very favorable profile of fatty acids, typical for animal fats, frequent consumption of these products may have adverse effects on health [2]. The meat industry is constantly looking for strategies that would improve the nutritional and health-promoting value of such products. One of these is to replace pork fat with meat, olive oil, or rapeseed oil, among others [4–6].

The trend observed for several years on the food market has been an increase in the interest of producers and consumers in products with lower fat and saturated fatty acids (SFA) and, at the same time, a higher proportion of monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA), including, omega-3 [7], which can prevent or inhibit the development of many diseases, in particular, heart diseases [8]. However, these products, due to their composition, are more susceptible to oxidation processes, negatively affecting their safety and quality, including primarily nutritional value, color, and texture [9].

Hydroperoxides are the first monitored products of lipid oxidation and are an indicator of initiation of this process. As a result of hydrogen peroxide's breakdown and electron regrouping, unsaturated α- and β-dicetones, β-ketones, and aliphatic aldehydes, which are secondary products of fat oxidation, are produced. These compounds not only cause a deterioration in the sensory quality of food, but, above all, pose a threat to human health. Their harmful properties are stressed, including carcinogenic effects, contributing to changes in the composition of cell membranes, and reducing the level of high-density lipoproteins (HDL) [10].

The aim of the study was to assess the influence of the addition of fish raw materials (roe or fish meat) on the quality, sensory characteristics, nutritional value, and oxidative stability of pork pâtés.

2. Materials and Methods

The study covered 16 pork pâtés with an average weight of 250 g. The control group (CON, n = 4) consisted of pork pâtés, I experimental group (R, n = 6) included pâtés with 20% addition of roe (perch and pike in ratio 1/1), and II experimental group consisted of pâtés with 20% addition of pike and perch meat (1/1) (F, n = 6). Fish raw material, both meat and roe, was obtained from fish (age 3+) purchased commercially from a local fish farm in winter and spring season. The share of particular ingredients is presented in Table 1.

Table 1. Composition of pork pâtés (%).

Ingredients	Pâté		
	CON	**R**	**F**
Pork jowl (without skin)	15	15	15
Pork shoulder	55	35	35
Pork liver	10	10	10
Broth	18	18	18
Roe	-	20	-
Fish meat	-	-	20
Sodium chloride		1.3	
Black pepper		0.15	
Herbal pepper		0.25	
Marjoram		0.15	
Nutmeg		0.15	

The research used a model meat product— "pork pâté", made from pork meat, pork fat, pork liver, meat stock, and a mixture of spices. Ingredients were cooked for about 25 min to a temperature of 75 °C in the geometric center and then minced twice using a HENDI meat mincer 198 (Rhenen, The Netherlands) and a mincing disc with 4 mm diameter holes. Spices and salt were added to the obtained mixture. In two model groups, 20% of the meat load (from the pork shoulder) was replaced with fish raw materials (roe or fish meat). The mixture was homogenized and put into glass jars (capacity 125 mL), which were placed in a water bath HENDI sous-vide system GN 1/1 (Rhenen, The Netherlands) at 90 °C and pasteurized to obtain 75 °C inside the product. After pasteurization, the pâtés were cooled to room temperature and stored for 12 h at 6 °C.

Cooled pâtés were evaluated by instrumentally measuring pH with the CP-401 pH meter with a glass electrode (Elmetron, Zabrze, Poland) and color (according to CIE L*a*b*) with the Minolta CR-310 colorimeter (Minolta Camera Co. Ltd., Osaka, Japan) using D65 as the standard light source. The L*, (lightness), a* (redness), b* (yellowness), C* (saturation), and h° (hue angle) values were recorded after 30 min of exposure to atmospheric oxygen. The texture parameters of the pâtés were measured and analyzed with the Zwick/RoellProLine BDO125 FB0.5TS (Zwick GmbH and Co, Ulm, Germany) and the testXpertII software. The profiled texture analysis (TPA) was performed using a penetrometer (5 mm diameter) by performing a double compression test to a depth of 10 mm at 5 different points of the product, determining the hardness, springiness, gumminess, chewiness, cohesiveness, and adhesiveness.

Sensory analysis of fish meat after heat treatment was carried out using the scaling method according to PN-ISO 4121:1998. Five unit quality characteristics were included in the study, including: texture, juiciness, smell, taste, and a general evaluation of pâtés. The intensity of each of the distinguishing marks was assessed on a 10 cm long unstructured linear graphical scale with specific edge points. The assessment was carried out by a panel of six people, appropriately trained in the application of the adapted analytical method.

Water (moisture) content was determined by drying (103 °C) using an universal oven Memmert UF30 (Schwabach, Germany) and according to PN-ISO 1442:2000, ash by ashing (at 550 °C) using laboratory muffle furnace Heraeus M110 (Heraeus, Hanau, Germany) in accordance with PN-ISO 936:2000, total protein content (N × 6.25) by the Kjeldahl method by means of the BüchiSpeedDigester K-436 (Flawil, Switzerland) and the BüchiDistillation Unit B-324 (Flawil, Switzerland) according to PN-A-04018:1975/Az3:2002, and fat content by the Soxhlet method (*n*-hexane was used as solvent) using the BüchiExtraction System B-811 (Flawil, Switzerland) in accordance with PN-ISO 1444:2000. The energy value of 100 g of product and the Nutritional Quality Index (NQI) [11] values were calculated using energy equivalents (for protein 4 kcal = 17 kJ, for fat 9 kcal = 37 kJ) and reference intakes of energy and nutrients listed in Regulation (EU) No 1169/2011 [12].

Analysis of the fatty acid profile of the meat was performed according to the methods described by Domaradzki et al. [13]. Briefly, fatty acid methyl esters (FAMEs) were analyzed chromatographically (CG 3900 gas chromatograph; Varian, Walnut Creek, CA, USA). The fatty acid composition was expressed as percentage of total FA (%FA) and as mg/100 g of product [13]. Indices and ratios of fatty acids were calculated according to the methods of Ulbricht and Southgate [14] (S/P—saturation, TI—trombogenic, and AI—atherogenic index), Santos-Silva et al. [15] (h/H—the ratio of hypo- and hypercholesterolemic acids), and Estévez et al. [16] (NV—nutritional value of lipids).

The oxidative stability of lipids was evaluated on the basis of peroxide value (PV) measurement, thiobarbituric acid reactive substances (TBARS) value, and content of conjugated dienes (CD) and trienes (CT). The degree of fat hydrolysis was evaluated using acid value (AV) measurement. Peroxide value and acid value were determined by the Koniecko method [17] with Joseph et al.'s modification [18]. Peroxide value was expressed in milliequivalents (mEq) of active oxygen per 1 kg of fat and the acid value was expressed in mg KOH per 1 g of fat. TBARS were determined according to Witte et al. [19] using Varian Cary 300 Bio spectrophotometer (Varian Australia PTY, Ltd., Mulgrave, Australia) at wavelength 530 nm and expressed in mg of malondialdehyde (MDA) per 1 kg of muscle tissue. The conjugated dienes and conjugated trienes were determined according to Pegg [20] and the results were expressed in mmol hydrogen peroxides per 1 kg of fat.

For different parameters each pâté was analyzed in duplicate. All data were analyzed using Statistica 13 software (TIBCO Software Inc., Palo Alto, CA, USA). One-way analysis of variance (ANOVA), followed by Tukey's (HSD) test, was used to compare mean values of physicochemical properties and chemical compounds obtained for each product. The equality of variances for organoleptic characteristics was verified using Levene's test. In case of unequal variance the nonparametric Kruskal–Wallis test was reported for comparisons between independent groups. Statistical significance was set at $p \leq 0.05$ or $p \leq 0.01$. In tables, means and standard deviations are given.

3. Results

Table 2 shows the results of measurements of physicochemical properties of the pâtés. A significant ($p \leq 0.01$) effect of the product formula on pH and color parameters was found. The control pâté (CON) had a significantly higher pH value compared to the product with roe (R) and fish meat (F). The CON pâté showed significantly the lowest lightness, and the lowest proportion of yellowness and hue among all products, while the proportion of redness was significantly higher. Pâté R was significantly the brightest, the most yellow, and its color was significantly more saturated. The lightness and saturation of the color of the F product was similar to that of the CON pâté, but it was characterized by the lowest redness. The partial replacement of pork meat with roe (pâté R) resulted in a higher total color difference ($\Delta E = 3.59$) than the addition of fish muscle tissue (pâté F; $\Delta E = 2.22$) compared to the CON pâté.

Table 2. Physicochemical properties of pork pâtés (mean ± s.d.).

Parameters	Pâté		
	CON	**R**	**F**
pH	6.67 ^{C} ± 0.01	6.43 ^{A} ± 0.01	6.63 ^{B} ± 0.01
L*	61.27 ^{A} ± 0.53	63.94 ^{B} ± 0.30	62.18 ^{A} ± 0.88
a*	5.94 ^{C} ± 0.13	4.97 ^{B} ± 0.13	4.11 ^{A} ± 0.33
b*	11.70 ^{A} ± 0.15	14.07 ^{C} ± 0.05	12.65 ^{B} ± 0.10
C*	13.12 ^{A} ± 0.19	14.92 ^{B} ± 0.09	13.30 ^{A} ± 0.18
h°	63.13 ^{A} ± 0.21	70.63 ^{B} ± 0.42	72.12 ^{B} ± 1.24
ΔE (vs. CON)	–	3.59	2.22

Mean values in rows with different letters differ statistically significantly: ^{A}, ^{B}, ^{C}—$p \leq 0.01$.

The basic chemical composition, calorific value, and NQI of the analyzed pates are presented in Table 3. The differences in raw material composition significantly ($p \leq 0.01$) affected the determined lipid and moisture contents of the pâtés. The R and F products contained significantly less fat and significantly more water than the CON product.

Table 3. Proximate composition, calorific value, and nutritional quality index (NQI) for protein and fat of pork pâtés (mean ± s.d.).

Parameters	Pâté		
	CON	**R**	**F**
Moisture%	58.47 ^{A} ± 1.87	63.50 ^{B} ± 1.21	65.48 ^{B} ± 2.03
Fat%	20.18 ^{B} ± 11.58	15.93 ^{A} ± 0.36	14.11 ^{A} ± 2.01
Protein%	21.35 ± 0.98	20.57 ± 1.31	20.42 ± 3.41
Ash%	1.42 ± 0.39	1.46 ± 0.44	1.72 ± 0.18
Energy			
kJ	1109.6 ^{B} ± 61.1	939.1 ^{A} ± 21.0	869.1 ^{A} ± 40.4
kcal	267.0 ^{B} ± 14.8	225.6 ^{A} ± 5.0	208.6 ^{A} ± 9.9
NQI			
Protein	3.2 ± 0.20	3.6 ± 0.18	3.9 ± 0.76
Fat	2.2 ± 0.06	2.0 ± 0.06	1.9 ± 0.22

Mean values in rows with different letters differ statistically significantly: ^{A}, ^{B}—$p \leq 0.01$.

Replacing part of pork meat with fish products resulted in significantly ($p \leq 0.01$) lower calorific value of pâté R (by 15%) and pâté F (by 20%) compared to the CON product. The values of the Nutritional Quality Index (NQI) for protein and fat did not differ significantly between the evaluated products, although higher NQI values for protein and lower values for fat were found in pâtés with fish raw materials.

Table 4 shows the effect of the addition of fish raw materials on the distinguishing features of the profiled texture analysis of the evaluated pâtés. The F product was significantly ($p \leq 0.01$) the toughest, most gummy, and most chewy of all the products. The lowest values of these parameters were recorded in the R pâté, but they did not differ significantly from those recorded in the control pâté. No significant differences between the tested products were found in the case of springiness, cohesiveness, and adhesiveness.

Table 4. Texture parameters of pork pâtés (mean ± s.d.).

Parameters	Pâté		
	CON	R	F
Hardness	1.035 ^{AB} ± 0.06	0.597 ^{A} ± 0.09	1.654 ^{B} ± 0.09
Springiness	0.830 ± 0.04	0.947 ± 0.02	1.047 ± 0.08
Cohesiveness	0.417 ± 0.05	0.487 ± 0.06	0.470 ± 0.04
Gumminess	0.433 ^{A} ± 0.03	0.290 ^{A} ± 0.05	0.777 ^{B} ± 0.07
Chewiness	0.357 ^{A} ± 0.01	0.273 ^{A} ± 0.04	0.823 ^{B} ± 0.05
Adhesiveness	0.867 ± 0.11	0.840 ± 0.17	0.824 ± 0.20

Mean values in rows with different letters differ statistically significantly: ^{A}, ^{B}—$p \leq 0.01$.

Figure 1 shows the effect of the addition of fish raw materials on the results of the organoleptic assessment of pâtés. Statistical analysis has confirmed the significant differences between products only in terms of three traits. Pâtés from the control group differed significantly from F pâtés in terms of their typical scent notes, i.e., meat (6.72 pts vs. 2.73 pts, $p \leq 0.05$) and fish (0.02 pts vs. 4.35 pts, $p \leq 0.01$). Moreover, the panelists found no fish flavor in CON samples compared to pâtés with roe (1.78 pts) or fish meat (3.55 pts). The highest overall score for structure and consistency was given to CON pâté (7.8 pts), while R and F products were rated lower (6.5 pts and 6.3 pts respectively). However, given the overall quality and overall acceptability, pâtés with roe were rated similarly to the CON product. The R pâté was also the most juicy and the fish taste and smell were much less noticeable in it than in F pâté. The lowest juiciness was found in pâté F.

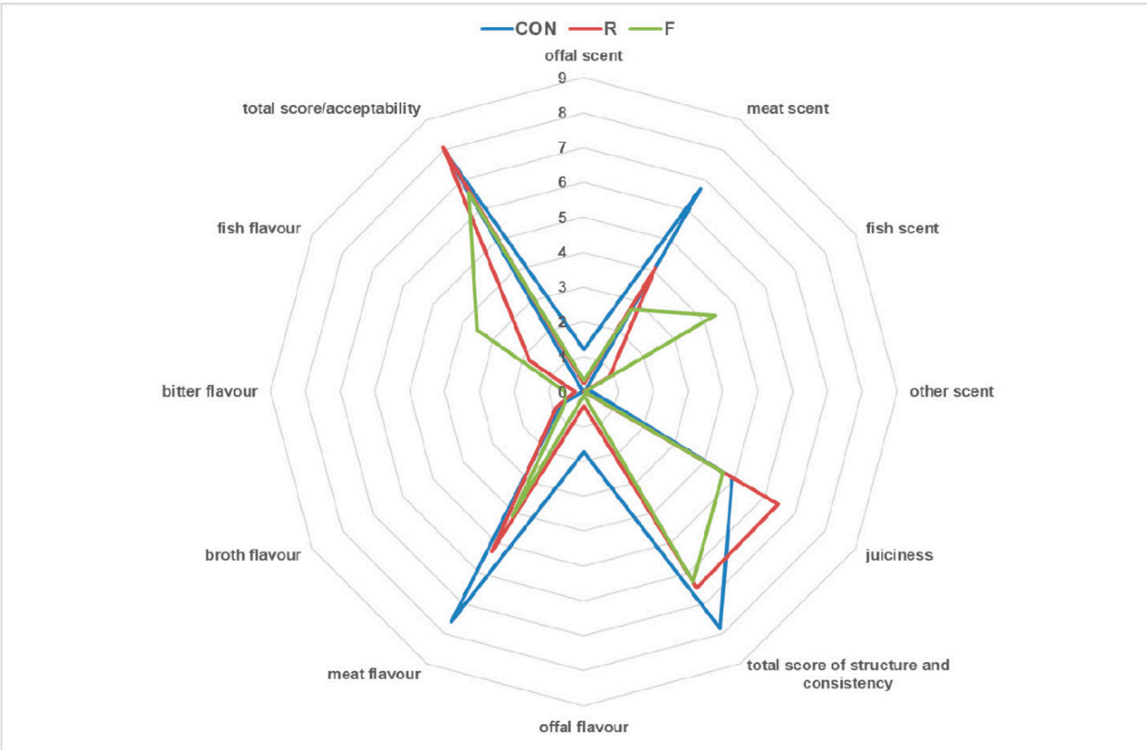

Figure 1. Organoleptic assessment of pork pâtés.

The raw material composition significantly ($p \leq 0.01$) differentiated the fatty acid profile of the evaluated pâtés (Table 5). Pâté R contained the most polyunsaturated fatty acids (PUFA) by a significant amount, including n-3 acids such as eicosapentaenoic (EPA) and docosahexaenoic (DHA). At the same time, the lowest value of saturated to polyunsaturated acids (SFA/PUFA) ratio and n-6/n-3 ratio were found for R pâté. The percentage of PUFA in F and CON pâtés was comparable, while the level of SFA and the SFA/PUFA ratio were significantly higher. However, F product contained significantly less n-6 fatty acids and significantly more n-3 acids (including DHA) compared to the CON product, which resulted in a significantly lower value of n-6/n-3 ratio. No significant differences were found in the proportion of saturated branched chain fatty acids (BCFA) and trans-fatty acids (TFA) between the evaluated products.

Table 5. Fatty acid profile (% fatty acids) and content (mg/100 g product) of pork pâtés (mean ± s.d.).

%Fatty Acids	Pâté CON	R	F
%fatty acids SFA	40.23 ± 0.32	39.81 ^{A} ± 0.26	40.83 ^{B} ± 0.28
BCFA	nd	0.13 ± 0.03	0.09 ± 0.02
MUFA	50.93 ^{B} ± 0.46	49.81 ^{A} ± 0.33	50.28 ^{A} ± 0.43
PUFA	8.65 ^{A} ± 0.14	9.98 ^{B} ± 0.066	8.55 ^{A} ± 0.18
SFA/PUFA	4.65 ^{B} ± 0.04	3.99 ^{A} ± 0.03	4.78 ^{C} ± 0.09
n-3	0.57 ^{A} ± 0.04	1.71 ^{C} ± 0.045	0.79 ^{B} ± 0.08
n-6	7.97 ^{B} ± 0.12	8.05 ^{B} ± 0.07	7.57 ^{A} ± 0.15
n-6/n-3	13.98^{C} ± 0.89	4.70 ^{A} ± 0.14	9.57 ^{B} ± 0.98
EPA	nd	0.29 ^{B} ± 0.02	0.08 ^{A} ± 0.02
DHA	0.03 ^{A} ± 0.01	0.73^{C} ± 0.02	0.21 ^{B} ± 0.01
TFA	0.19±0.02	0.27±0.02	0.25±0.03
mg/100 g product SFA	7517.49 ^{C} ± 60.00	5860.264 ^{B} ± 38.89	5317.20 ^{A} ± 36.81
BCFA	nd	18.75 ^{B} ± 5.12	11.63 ^{A} ± 2.37
MUFA	9516.01 ^{C} ± 85.48	7332.01 ^{B} ± 48.26	6546.82 ^{A} ± 55.44
PUFA	1616.78 ^{C} ± 25.25	1469.37 ^{B} ± 9.75	1112.88 ^{A} ± 23.79
n-3	106.89 ^{A} ± 7.23	252.21 ^{B} ± 6.56	103.76 ^{A} ± 9.88
n-6	1488.38 ^{C} ± 23.04	1184.84 ^{B} ± 10.98	985.14 ^{A} ± 19.99
EPA	nd	43.17 ^{B} ± 2.79	10.79 ^{A} ± 2.13
DHA	5.25 ^{A} ± 1.45	107.94 ^{C} ± 2.37	27.56 ^{B} ± 1.63
TFA	34.66 ^{AB} ± 2.89	39.29 ^{B} ± 2.49	33.10 ^{A} ± 4.44
Indexes S/P	0.66 ^{A} ± 0.01	0.65 ^{A} ± 0.01	0.68 ^{B} ± 0.01
TI	1.26 ^{B} ± 0.02	1.14 ^{A} ± 0.01	1.27 ^{B} ± 0.02
AI	0.51 ^{B} ± 0.01	0.49 ^{A} ± 0.04	0.52 ^{C} ± 0.01
h/H	1.98 ± 0.02	2.01 ± 0.02	1.93 ± 0.02
NV	0.52 ± 0.01	0.53 ± 0.01	0.54 ± 0.01

Mean values in rows with different letters differ statistically significantly: ^{A}, ^{B}, ^{C}—$p \leq 0.01$; SFA: total saturated fatty acids; BCFA: total branched-chain fatty acids; MUFA: total monounsaturated fatty acids; PUFA: total polyunsaturated fatty acids; total n-3 fatty acids; total n-6 fatty acids; EPA: eicosapentaenoic acid (C20:5n-3); DHA: docosahexaenoic acid (C22:6n-3); TFA: total trans fatty acids; S/P: saturation index S/P = (C14:0 + C16:0 + C18:0)/(MUFA + PUFA); TI: thrombogenic index TI = (C14:0 + C16:0 + C18:0)/(0.5 × MUFA + 0.5 × n-6 + 3 × n-3 + n-3/n-6), S/P = (C14:0 + C16:0 + C18:0)/(MUFA + PUFA); AI: atherogenic index AI = (C12:0 + 4 × C14:0 + C16:0)/(MUFA + n-6 + n-3); h/H: the ratio of hypo- and hypercholesterolemic acids h/H = (C18:1 c9 + C18:2 n-6 + C18:3 n-6 + C18:3 n-3 + C20:2 n-6 + C20:3 n-6 + C20:4 n-6 + C20:3 n-3 + C20:4 n-3 + C20:5 n-3 + C22:4 n-6 + C22:5 n-6 + C22:5 n-3 + C22:6 n-3)/(C12:0 + C14:0 + C16:0); NV: nutritional value of lipids NV = (C12:0 + C14:0 + C16:0)/(C18:1 c9 + C18:2 n-6); nd: not detected.

The presentation of the content of fatty acids (especially those with a health-promoting effect) in absolute terms seems important for consumers (Table 5). Pâtés with fish raw materials contained significantly ($p \leq 0.01$) less SFA, MUFA, PUFA, and n-6 in 100 g, which was associated with a significantly lower fat content compared to the CON pâté (Table 3). The lowest share of the above-mentioned groups of acids was found in pâté F.

Noteworthy is the pâté R, in which the highest content of n-3 fatty acids, including docosahexaenoic acid (DHA), was found. Moreover, this pâté was characterized by a significantly higher concentration of saturated branched chain fatty acids (BCFA) and eicosapentaenoic acid (EPA), as compared to F pâté. However, no BCFA and EPA were found in the CON product.

The raw material composition of pâtés had a significant influence ($p \leq 0.01$) on the saturation level of fat and the athero- and thrombogenic indices (Table 5). Pâté R was characterized by significantly the most favorable (the lowest) values of the above-mentioned indices. In product F, the highest levels of S/P and AI were marked significantly, while the value of TI index was similar to that recorded in pâté CON. The addition of fish raw materials did not significantly affect the proportions of hypo- and hypercholesterolemic acids, as well as the nutritional value of lipids.

The formula composition of the pâté significantly ($p \leq 0.01$) differentiated most of the analyzed parameters of fat oxidation and hydrolysis (Table 6). Pâté R showed significantly the highest value of acid value (AV) of all products. On the other hand, the significantly highest value of TBARS and content of conjugated dienes and trienes, as well as value of peroxide number ($p > 0.05$), were recorded in pâté F.

Table 6. Acid value (AV), peroxide value (PV), thiobarbituric acid reactive substances (TBARS), and content of conjugated dienes (CD) and trienes (CT) of pork pâtés (mean ± s.d.).

Parameter	Pâté		
	CON	**R**	**F**
AV (mg KOH/g fat)	$9.87^{A} \pm 0.20$	$14.09^{B} \pm 0.99$	$9.14^{A} \pm 0.56$
PV (mEq O_2/kg fat)	5.20 ± 0.07	5.69 ± 0.02	6.39 ± 0.02
TBARS (mg MDA/kg pâté)	$2.78^{AB} \pm 0.09$	$2.66^{A} \pm 0.22$	$2.94^{B} \pm 0.05$
CD (mmol of hydroperoxides/kg of oil)	$10.78^{A} \pm 0.82$	$10.67^{A} \pm 0.52$	$14.04^{B} \pm 1.61$
CT (mmol of hydroperoxides/kg of oil)	$2.14^{A} \pm 0.39$	$2.16^{A} \pm 0.06$	$3.15^{B} \pm 0.39$

Mean values in rows with different letters differ statistically significantly: ^{A}, ^{B}—$p \leq 0.01$.

4. Discussion

4.1. Physicochemical Properties of Pork Pâtés

In the present study, the average pH of the pâtés ranged from 6.43 to 6.67. This range was similar to the values given by other authors for this type of product [2,4]. Domínguez et al. [6] did not find significant changes in the pH of pâtés after being enriched with fish oil. Tyburcy et al. [21] indicated that the high pH of products (>5.9), together with their high water content (>55%), forces them to be eaten quickly after opening the package, due to the favorable conditions for microbial growth caused by the reinfection of the canned food.

The color of food products is one of the key parameters on the basis of which the consumer chooses a product. The color of processed meat products is the result of the chromatic effect of meat, fat, and other additives. However, the quantity, composition, and metabolism of hem pigments in muscle tissue plays a decisive role in the color forming [3].

Apart from the basic raw materials, the color of pâtés may be significantly influenced by the use of non-meat additives, spices, curing compounds, or color stabilizers [3]. However, the additives used should not cause significant changes in the color of the new product in comparison with the conventional one [22]. Mokrzycki and Tatol [23] demonstrated that a qualified observer is able to observe a color difference between two objects when the value of total color difference (ΔE) is greater than 3.5. In the present study the value of ΔE for pâtés with fish additives was 3.59 for roe and 2.22 for fish meat, respectively. Thus, the color of CON and F pâtés was similar, and in the case of R, the potential consumer would be able to distinguish it from traditional pâtés.

4.2. Proximate Composition, Calorific Value, and NQI for Protein and Fat of Pork Pâtés

The water and fat contents in the analyzed pâtés (Table 3) were within ranges reported by Makała and Tyszkiewicz [24] for market meat pâtés (56.9–70.4% and 13.4–24.7%, respectively), while the protein content was twice as high compared to the results of the quoted authors.

Fat plays a special and multifaceted role in the sensory perception of food, giving the feeling of "fullness". It is a source and precursor of many flavors, masks off-odors, shapes the palatability and texture of products, and influences the release of aromas from products [25]. Unfortunately, pâtés are characterized by a high proportion (about 30%) of animal fat, which is necessary to achieve the desired sensory characteristics [26]. The share of fat in the model pâté was about 20%, and in relation to the Estévez et al. [4], should be considered as a low-fat pâté. On the other hand, the lipid content in experimental pâtés, especially in product F, was significantly lower than in product CON, which most probably resulted from replacing the fatty pork shoulder with lean pike meat [27] and perch meat [28].

The fat content of a product is closely related to its calorific value [4]. Pâtés with the addition of roe and fish meat contained significantly less calories compared to control pâtés. According to Delgado-Pando et al. [2], the energy value of 100 g of pâtés with a fat content of 30% was 345 kcal and of pâtés with 15% lipid content was 201 kcal. The higher energy value of the tested pâtés was most probably due to a higher (>20%) share of protein than in the cited study (about 13%).

In the present study, pâtés contained the addition of fish raw materials and had a high NQI value for protein (>1). Thus, from a nutritional point of view, it indicates that they can be a good source of protein and, at the same time, make up for the deficit of animal protein in the diet. All evaluated products were also well balanced in terms of lipid content (NQI >1) in relation to energy, although the experimental pâtés were less so than the CON product.

4.3. Texture Parameters of Pork Pâtés

The product's texture is largely determined by the fat presence, which gives the right consistency and juiciness [4]. Troutt et al. [29] found that low-fat pâtés (5% and 10%) were much harder and less solid, juicy, and aromatic than pâtés that contained 20–30% of fat. In turn, Delgado-Pando et al. [2] observed that pâtés with a reduced fat content were softer and more spreadable.

Besides the content, the type of fat also seems to affect the texture of meat products. Domínguez et al. [6] reported that decreased SFA content and increased proportion of unsaturated fatty acids by replacing pork fat with fish oil has resulted in a significant decrease in the hardness and gumminess of pork pâtés. A similar decrease in hardness was observed when pork fat in pâtés was replaced by vegetable oils [7].

The hardness of the pâtés in the present study did not differ from the results obtained by other authors [4,6]. Nielsen and Jacobsen [30] investigated texture of fish pâté made from cod and enriched with different 5% oil mixtures. The fish pâtés all had similar textural parameters with no consistent differences, and the hardness of fresh products ranged from 475 to 610 g/cm. In the present study, it was found that the products containing muscle tissues (pork in CON samples and fish meat in F samples) showed a greater hardness than R samples with roe. This is probably due to the existence of a stronger network of myofibril proteins, which consequently increased the product's resistance to compression [31].

4.4. Organoleptic Assessment of Pork Pâtés

The commercial success of new food ingredients, and thus food products, depends on consumer acceptance [32]. One of the most important features influencing the consumer's buying decision is product's appearance, taste, and aroma [33]. The quantitative and qualitative chemical composition of food products plays a decisive role in forming sensory characteristics [3]. Undoubtedly, higher scores for taste and scent of fish in R and F pâtés resulted from the presence of fish components in these products. Aquerreta et al. [34] analyzed pâtés manufactured with mackerel flesh and tuna liver and reported a strong fishy taste in experimental pâtés, however, all of them were considered to be acceptable. According to Jin et al. [35], sensory evaluation scores of fried fish paste with a different share of surimi and spent laying hen meat were not as much influenced by product composition as physicochemical parameters (e.g., shear force or fatty acids composition). Our study indicated that the addition of fish raw materials was most often recognized by evaluators in the case of F pâté (the strongest fish taste and smell). However, in the overall assessment of structure, consistency, and acceptability, pâtés achieved similar marks.

4.5. Fatty Acid Profile and Content of Pork Pâtés

In the human diet, apart from the level of fat intake, its composition is important, especially the content of individual groups of fatty acids. In each of the evaluated pâtés, MUFA constituted the largest percentage of all acids, followed by SFA and PUFA. Similar results were obtained in pork pâtés by other authors [1,2,6]. Fish meat pâté had the significantly highest SFA content among all products (Table 5), which can be explained by the high SFA content in fish muscle tissue. In pike, a high seasonal effect on the variability of the fatty acid profile was observed, with SFA content ranging from 25.7% (November) to 64.7% (April) [36]. In the case of perches, the differences were smaller, i.e., from 25.5% (March/April) to 34.6% (October/November) [28].

The proportion of n-6/n-3 fatty acids is an important parameter from the point of view of human health, and its value should not exceed 4 [37]. The value of the n-6/n-3 ratio of the control pâté was 3.5 times higher than the mentioned limit, while in pâté with fish meat it was more than twice as high (Table 5). Only pâté with the addition of roe was similar to the recommended value of this ratio (4.70). Domínguez et al. [6] reported that the replacement of pork fat with fish oil reduced the level of this proportion from 13.13 to even 0.47.

The presentation of the content of fatty acids in absolute figures (mg/100 g of meat) allows for an estimate of the coverage of the recommended daily requirement for these acids [12]. For a diet providing 2000 kcal per day, a portion of 100 g of CON pâté covered on average 34.2% of the recommended intake for SFA, 24.7% for MUFA, 8.7% for PUFA, and 11.6% for n-6 acids. The same portion of experimental pâtés covered a much smaller extent the recommended intake of the above-mentioned acids (R pâtés: SFA 26.6%, MUFA 19%, PUFA 7.9%, n-6 9.3%; F pâté: SFA 24.2%, MUFA 17%, PUFA 6%, n-6 7.7%), which was related to their lower fat content. However, pâté R provided more than 9% of the daily demand for n-3 acids and as much as 60% for EPA+DHA, where, by comparison, the CON pâté only covered the demand for these acids in 3.9% and 2.1%, respectively, and the fish meat pâté in 3.7% and 15.3%.

Determined indices of fatty acids (AI, TI, S/P, NV, and h/H) may indicate the direction of influence of consumed lipids. Saturated fatty acids C12:0, C14:0, and C16:0 showed atherogenic effects (increase total cholesterol and LDL fraction), while C14:0, C16:0, and C18:0 showed thrombogenic effects (stimulate platelet aggregation). Due to their antiatherosclerotic properties, MUFA and PUFA acids (n-3 and n-6) have a positive effect on human health. Therefore, the higher values of AI, TI, S/P, NV, and lower h/H indices indicate the reduction of the product's health value [38]. Domínguez et al. [6] demonstrated that the partial replacement of pork fat by fish oil resulted in lower AI and TI values, as well as higher h/H. Replacement of pork shoulder with fish roe, in our own research, had a similar effect, however, the addition of fish meat did not have a positive effect on the values of the above parameters.

4.6. Oxidative Stability of Pork Pâtés

The AV value in products CON, R, and F were 9.87, 14.09, and 9.14 mg KOH/g fat, respectively, while PV—5.30, 5.69, and 6.39 meq active oxygen/kg fat (Table 6). In the available literature, there are no studies in which the acid and peroxide value in pates were analyzed. The internationally accepted standards and recommendations of Codex Alimentarius [39–41] allow the consumption of animal fats with AV < 4 mg KOH/g fat and fish oils with an acid value of 3 to 45 mg KOH/g fat. According to the Codex, the permitted peroxide value of animal fats is 10 mEq active oxygen/kg fat and of fish oil is 5 mEq active oxygen/kg fat.

The TBARS value is characterized by secondary lipid oxidation products. The content of these compounds in our own pâtés was similar to the level recorded by Estévez et al. [4] in lean pork pâtés (2.87 mg MDA/kg pâté). The quoted authors observed a much higher concentration of secondary fat oxidation products in pâtés with high fat content (31.2%) than in pâtés with low lipid content (20.5%), confirming the relationship between fat content and TBARS value. Delgado-Pando et al. [42] obtained the highest TBARS value in pâtés enriched with PUFA n-3 acids, which suggests that fat oxidation also accelerates the addition of fish oil. A significant increase in TBARS value was not noticed by D'Arrigo et al. [1] in pâtés with increased n-3 acid content, produced on the basis of raw materials from animals fed with vegetable oils.

The content of conjugated dienic and trienic acids is one of the indicators for assessing the oxidative stability of lipids. The presence of these compounds is primarily indicative of the initiation of the oxidation process [43]. Conjugated dienes are formed by the oxidation of polyunsaturated acids, whereas conjugated trienes are formed by the dehydration of conjugated diene-hydroxides [44]. There are no studies available on the content of these compounds in pâtés. In the results obtained, it is puzzling that TBARS, CD, and CT were significantly ($p \leq 0.01$) higher in fish meat pâté compared to other products. These differences can be explained by the presence of antioxidants in the roe, which slow down the lipid oxidation processes. Antioxidants in the animal body accumulate primarily in gonads and then in fish eggs (roe), where they have a protective function for embryos in the first stages of development [45].

5. Conclusions

Modification of pâtés by substitution of fatty pork shoulder with fish raw materials (primarily roe) has been shown to be a good strategy to improve their nutritional quality, e.g., to decrease fat content and its calorific value as well as increase omega-3 fatty acid content, including EPA and DHA. From the sensory point of view, these products could be acceptable to the consumer. Additives of fish meat may increase the lipid oxidative status, but the addition of fish eggs to the product does not deteriorate its lipid oxidation parameters.

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References

1. D'Arrigo, M.; Hoz, L.; Cambero, I.; Lopez-Bote, C.J.; Pin, C.; Ordónez, J.A. Production of n-3 fatty acid enriched pork liver pâté. *LWT-Food Sci. Technol.* **2004**, *37*, 585–591. [CrossRef]
2. Delgado-Pando, G.; Cofrades, S.; Rodríguez-Salas, L.; Jiménez-Colmenero, F. A healthier oil combination and konjac gel as functional ingredients in low-fat pork liver pâté. *Meat Sci.* **2011**, *88*, 241–248. [CrossRef]

3. Tolik, D.; Słowiński, M.; Desperak, K. Effect of using mechanically deboned and desinewed poultry meat on quality of sterilized pâtés. *Food. Sci. Technol. Qual.* **2015**, *5*, 132–141. (In Polish) [CrossRef]
4. Estévez, M.; Ventanas, S.; Cava, R. Physicochemical properties and oxidative stability of liver pâté as affected by fat content. *Food Chem.* **2005**, *92*, 449–457. [CrossRef]
5. Morales-Irigoyen, E.E.; Severiano-Pérez, P.; Rodriguez-Huezo, M.E.; Totosaus, A. Textural, physicochemical and sensory properties compensation of fat replacing in pork liver pâté incorporating emulsified canola oil. *Food Sci. Technol. Int.* **2012**, *18*, 413–421. [CrossRef]
6. Domínguez, R.; Pateiro, M.; Munekata, P.E.S.; Campagnol, P.C.B.; Lorenzo, J.M. Influence of partial pork backfat replacement by fish oil on nutritional and technological properties of liver pâté. *Eur. J. Lipid Sci. Technol.* **2017**, *119*, 1600178. [CrossRef]
7. Martin, D.; Ruiz, J.; Kivikari, R.; Puolanne, E. Partial replacement of pork fat by conjugated linoleic acid and/or olive oil in liver pâtés: Effect on physicochemical characteristics and oxidative stability. *Meat Sci.* **2008**, *80*, 496–504. [CrossRef]
8. Marciniak-Łukasiak, K. The role and significance of omega 3 fatty acids. *Food. Sci. Technol. Qual.* **2011**, *6*, 24–35. [CrossRef]
9. Bińczak, O.; Samotyja, U.; Małecka, M. Aktywność przeciwutleniająca wytłoku z orzecha włoskiego. In *Zagospodarowanie Ubocznych Produktów Przemysłu Spożywczego*; Górecka, D., Pospiech, E., Eds.; Wydział Nauk o Żywności i Żywieniu Uniwersytet Przyrodniczy w Poznaniu: Poznań, Poland, 2016; pp. 15–24. (In Polish)
10. Białek, M.; Rutkowska, J.; Bajdałów, E.; Rutkowska, E. Effects of fat type on oxidative and hydrolytic changes in stored confectionery products. *Probl. Hig. Epidemiol.* **2015**, *96*, 475–481.
11. Hansen, R.G.; Wyse, B.W.; Sorenson, A.W. *Nutrition Quality Index of Food*; AVI Publishing Co.: Westport, CI, USA, 1979.
12. Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the Provision of Food Information to Consumers. *Annex XIII Off. J. EU L* **2011**, *304*, 18–63.
13. Domaradzki, P.; Florek, M.; Skałecki, P.; Litwińczuk, A.; Kędzierska-Matysek, M.; Wolanciuk, A.; Tajchman, K. Fatty acid composition, cholesterol content and lipid oxidation indices of intramuscular fat from skeletal muscles of beaver (*Castor fiber* L.). *Meat Sci.* **2019**, *150*, 131–140. [CrossRef] [PubMed]
14. Ulbricht, T.L.V.; Southgate, D.A.T. Coronary heart disease: Seven dietary factors. *Lancet* **1991**, *338*, 985–992. [CrossRef]
15. Santos-Silva, J.; Bessa, R.J.B.; Santos-Silva, F. Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II. Fatty acid composition of meat. *Livest. Prod. Sci.* **2002**, *77*, 187–194. [CrossRef]
16. Estévez, M.; Morcuende, D.; Ramírez, R.; Ventanas, S.; Cava, R. Extensively reared Iberian pigs versus intensively reared white pigs for the manufacture of liver pâté. *Meat Sci.* **2004**, *67*, 453–461. [CrossRef] [PubMed]
17. Koniecko, E.S. *Handbook for Meat Chemists*; Avery Publishing Group Inc.: Wayne, NJ, USA, 1979.
18. Joseph, S.; Chatli, M.K.; Biswas, A.K.; Sahoo, J. Oxidative stability of pork emulsion containing tomato products and pink guava pulp during refrigerated aerobic storage. *J. Food Sci. Technol.* **2014**, *51*, 3208–3216. [CrossRef] [PubMed]
19. Witte, V.C.; Krause, G.F.; Bailey, M.E. A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. *J. Food Sci.* **1970**, *35*, 582–585. [CrossRef]
20. Pegg, R.B. Measurement of Primary Lipid Oxidation Products. *Curr. Protoc. Food Anal. Chem.* **2001**, D2.1.1–D2.1.15. [CrossRef]
21. Tyburcy, A.; Kosińska, A.; Cegiełka, A. Characteristics of sterilized liver paté manufactured from different raw materials. *Acta Sci. Pol. Technol. Aliment.* **2005**, *4*, 103–110. (In Polish)
22. Grunert, K.G. What's in a steak? A cross-cultural study on the quality perception of beef. *Food Qual. Prefer.* **1997**, *8*, 157–174. [CrossRef]
23. Mokrzycki, W.; Tatol, M. Color difference ΔE—A survey. *Mach. Graph. Vis.* **2011**, *20*, 383–411.
24. Makała, H.; Tyszkiewicz, S. Charakterystyka jakości sensorycznej i stanu mikrobiologicznego rynkowych pasztetów mięsnych. *Acta Agrophys.* **2011**, *18*, 321–334.
25. Kostyra, E. Interactions of the volatiles and non-volatiles with food components: Physicochemical aspects. *Food Sci. Technol. Qual.* **2004**, *4*, 30–43. (In Polish)
26. Latoch, A. Wpływ inuliny jako zamiennika tłuszczu na skład chemiczny, wartość kaloryczną, kwasowość oraz stopień utlenienia lipidów pasztetów z mięsa indyka. In *Rola Procesów Technologicznych w Kształtowaniu Jakości Żywności*; Duda-Chodak, A., Najgebauer-Lejko, D., Drożdż, I., Tarko, T., Eds.; Oddział Małopolski Polskiego Towarzystwa Technologów Żywności: Cracow, Poland, 2016. (In Polish)
27. Skałecki, P.; Florek, M.; Kaliniak, A.; Kędzierska-Matysek, M.; Dmoch, M. Quality in use and nutritional value of the muscle tissue of zander (*Sander lucioperca*) and pike (*Esox lucius*) reared in polyculture. *Sci. Ann. Pol. Soc. Anim. Prod.* **2016**, *12*, 33–38. [CrossRef]
28. Skałecki, P.; Florek, M.; Staszowska, A. Effect of fishing season on value in use, intrinsic properties, proximate composition and fatty acid profile of perch (*Percafluviatilis*) muscle tissue. *Arch. Pol. Fish.* **2013**, *21*, 249–257.
29. Troutt, E.S.; Hunt, M.C.; Johnson, D.E.; Claus, J.R.; Kastner, C.L.; Kropft, D.H.; Stroda, S. Chemical, physical and sensory characterisation of ground beef containing 5 to 30 percent fat. *J. Food Sci.* **1992**, *57*, 25–29. [CrossRef]
30. Nielsen, N.S.; Jacobsen, C. Retardation of lipid oxidation in fish oil-enriched fish pâté–combination effects. *J. Food Biochem.* **2013**, *37*, 88–97. [CrossRef]
31. Kamani, M.H.; Meera, M.S.; Bhaskar, N.; Modi, V.K. Partial and total replacement of meat by plant-based proteins in chicken sausage: Evaluation of mechanical, physico-chemical and sensory characteristics. *J. Food Sci. Technol.* **2019**, *56*, 2660–2669. [CrossRef]

32. Sun-Waterhouse, D.; Wadhwa, S.S. Industry-relevant approaches for minimising the bitterness of bioactive compounds in functional foods: A review. *Food Bioproc. Technol.* **2013**, *6*, 607–627. [CrossRef]
33. Smarzyński, K.; Sarbak, P.; Musiał, S.; Jeżowski, P.; Piątek, M.; Kowalczewski, P.Ł. Nutritional analysis and evaluation of the consumer acceptance of pork pâté enriched with cricket powder-preliminary study. *Open Agric.* **2019**, *4*, 159–163. [CrossRef]
34. Aquerreta, Y.; Astiasarána, I.; Mohino, A.; Bello, J. Composition of pâtés elaborated with mackerel flesh (*Scomberscombrus*) and tuna liver (*Thunnus thynnus*): Comparison with commercial fish pâtés. *Food Chem.* **2002**, *77*, 147–153. [CrossRef]
35. Jin, S.K.; Park, J.H.; Hur, S.J. Effect of Substituting Surimi with Spent Laying Hen Meat on the Physicochemical Characteristics of Fried Fish Paste. *Food Bioprocess Technol.* **2014**, *7*, 901–908. [CrossRef]
36. Zakęś, Z.; Pietrzak-Fiećko, R.; Szczepkowski, M.; Modzelewska-Kapituła, M.; Jankowska, B. Slaughter yield and fatty acid profiles of fillets of pike (*Esox lucius* L.) caught before and after spawning. *Arch. Pol. Fish.* **2015**, *23*, 231–235. [CrossRef]
37. Simopoulos, A.P. Omega-6/omega-3 essential fatty acid ratio and chronic diseases. *Food Rev. Int.* **2004**, *20*, 77–90. [CrossRef]
38. FAO (Food and Agriculture Organization of the United Nations). *Fats and Fatty Acids in Human Nutrition. Report of an Expert Consultation*; FAO Food and Nutrition Paper; FAO: Rome, Italy, 2010; p. 91.
39. CAC (Codex Alimentarius Commission). Joint FAO/WHO Food Standards Programme Codex Alimentarius Commission, Fortieth Session CICG. In Proceedings of the 25th Session of the Codex Committee on Fats and Oils, Kuala Lumpur, Malaysia, 27 February–3 March 2017.
40. *Codex-Stan 19-1981. Codex Standard for Edible Fats and Oils Not Covered by Individual Standards. Section 1. Codex General Standard for Fats and Oils. The Codex Alimentarius. Fats, Oils and Related Products*, 2nd ed.; Revised 2001; Food and Agriculture Organization of the United Nations/World Health Organization: Rome, Italy, 2001; Volume 8, pp. 1–4.
41. *Codex-Stan 211-1999. Codex Standard for Named Animal Fats. Section 3. Codex Standard for Fats and Oils from Animal Sources. The Codex Alimentarius. Fats, Oils and Related Products*, 2nd ed.; Revised 2001; Food and Agriculture Organization of the United Nations/World Health Organization: Rome, Italy, 2001; Volume 8, pp. 1–7.
42. Delgado-Pando, G.; Cofrades, S.; Ruiz-Capillas, C.; Triki, M.; Jimenez-Colmenero, F. Enriched n-3 PUFA/konjac gel low-fat pork liver pâté: Lipid oxidation, microbiological properties and biogenic amine formation during chilling storage. *Meat Sci.* **2012**, *92*, 762–767. [CrossRef]
43. Flaczyk, E.; Kobus, J.; Rudzińska, M.; Buszka, K.; Górecka, D.; Szczepaniak, B.; Korczak, J. Evaluation of quality and stability of "*extra virgin*" olive oils available in retail. *Oilseed Crops* **2005**, *26*, 621–630.
44. De, B.; Chatterjee, S. Impact of assorted spices on lipid quality alteration of refrigerated fish muscle. *Int. Food Res. J.* **2015**, *22*, 304–310.
45. Martínez-Alvarez, R.M.; Morales, A.E.; Sanz, A. Antioxidant defenses in fish: Biotic and abiotic factors. *Rev. Fish Biol. Fish.* **2005**, *15*, 75–88. [CrossRef]