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Fatty Acid Compositions of Selected Polish Pork Hams and Sausages as Influenced by Their Traditionality

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Abstract: Sausages and hams are perceived as important components of culinary heritage for many regions all over the world. Consumers believe that traditional foods are characterized by unique sensory properties and high quality. However, the fats found in all pork meat products are generally not associated with favorable dietary patterns. The aim of this study was to verify the possible differences regarding the composition of fatty acids between traditional Polish pork hams and *wiejska* sausages, and their conventional equivalents. For this purpose, the fat content and fatty acid profiles were determined. The research material consisted of 2 varieties of traditional hams and 5 varieties of sausages, as well as 4 varieties of both conventional hams and sausages. The results of this study demonstrated that traditional hams contained significantly higher percentage of C 20:3 (*cis*-11,14,17) acid than their conventional equivalents. Traditional sausages were characterized by lower shares of C 18:2 (*cis*-9,12) and Polyunsaturated Fatty Acids (PUFA), whereas higher content of C 18:1 (*cis*-9), C 18:3 (*cis*-9,12,15), C 20:0 and Monounsaturated Fatty Acids (MUFA). This resulted in significantly higher amounts of *n*-3 and lower of *n*-6 acids than in conventional sausages. All of the tested meat products were also characterized by an unfavorable *n*-6/*n*-3 ratio.

Keywords: traditional sausages; conventional sausages; traditional hams; conventional hams; traditional meat products; pork; fatty acids

1. Introduction

Consumers today look for foods characterized not only by health safety and proper nutritional value but also by unique sensory properties, high quality and natural composition. Therefore, an increased interest in traditional and regional food products can be noticed. Such foods, thanks to the usage of characteristic methods of growing plants, breeding animals and essentially traditional processing technologies, are characterized by a unique appearance, smell and taste [1–3]. Moreover, they are associated with the local culture and identity of people in various parts of the world, thus contributing to the folklore and traditions of specific communities and, at the same time, becoming an emblem or a flagship product of a certain region. Traditional foods have a representational value and can contribute to the development and sustainability of the countryside. They also ensure greater diversity of food choice for customers [4]. Consumers are generally convinced that traditional foods have a positive impact on health characteristics [5] that has been proved over time, and unique sensory properties [6].

The Polish market of traditional foods has been developing dynamically. Since 2005, the food producers have a possibility to register their products on the List of Traditional Products of Polish Ministry of Agriculture and Rural Development. Only highest quality products whose uniqueness results from traditional method of production (successfully used for over 25 years) can be listed. In addition, they tend to be a part of the identity of the local community and an element of the cultural heritage of the region of origin. The production methods and product features do not have to be inevitably linked to the specific place. The List is aimed to promote the unique products and facilitate the acquisition of the well-known European Union mark Traditional Specialty Guaranteed [7].

Sausages and hams are an important aspect of culinary heritage of many regions all over the world and have been consumed for centuries [8]. In Poland, smoked hams and sausages of world-renowned quality have been produced for centuries [9]. They are characterized by their incomparable sensory features. The manufacturers use only natural ingredients such as meat and natural spices in the production process. The meat comes from animals that are reared using traditional feeds (e.g., potatoes and green fodder) what positively affects its sensory characteristics and nutritional value. Substances such as artificial additives, fillers, improvers or preservatives are not permitted, except for a mixture of salt and nitrite. To extend the shelf life, hams and sausages are dried and/or smoked with the use of carefully chosen wood [10].

Beside traditional meat products, a large selection of high-performance products is available on the market. These products have lower prices but are produced by means of the technology that involves the use of various food additives which substitute high-priced raw materials [11]. As a consequence, such meat products notably differ in the sensory characteristics and partly in nutritional value [12–14].

Meat-based products contain a lot of fat whose physiological role is not only to provide energy but also to carry various substances such as hormones or vitamins. It also positively influences the sensory characteristics of meat products, mostly the juiciness and smell [15,16]. However, due to the presence of cholesterol and relatively large amounts of saturated fatty acids, as well as very low levels of *n*-3 polyunsaturated fatty acids (PUFA), the fats found in meat products are not regarded as a positive content from a nutritional point of view [17,18]. Since the current human diet is usually already rich in fats, especially saturated and *n*-6 polyunsaturated, and there is also a need to balance the *n*-6/*n*-3 fatty acid intake for prevention of chronic diseases, it is particularly essential to evaluate the fatty acid profile in daily eaten foods, such as meat products [17,19]. Yet, the composition of meat fat depends on various factors, such as the individual characteristics of the animal (age, sex, species, breed) and its diet [17,20,21]. Proper selection of raw materials can therefore have a positive effect on the fatty acid profile. The aim of this study was then to investigate the possible differences regarding the composition of various fatty acids between traditional Polish smoked hams and *wiejska* sausages, and their conventional (mass produced) equivalents.

2. Materials and Methods

2.1. Product Samples

The research material can be divided into two groups: Meat-based products that are registered on the List of Traditional Products of Polish Ministry of Agriculture and Rural Development and conventional ones. Among those listed, there were 2 varieties of smoked hams (letter codes A-B) and 5 varieties of traditional *wiejska* sausages (G-K). The conventional products tested consisted of 4 varieties of smoked hams (letter codes C-F) and 4 varieties of sausages (L-O).

The sausage samples were uniform in terms of their diameter, they were all made of pork and were semi-coarsely ground. In the initial phase of the manufacturing process of all varieties of *wiejska* sausages, firstly the raw materials are prepared and then the meat is comminuted. Subsequently, the ingredients (meat and seasoning) are mixed, natural casings are filled and left to settle (which usually takes a few hours). In the next step, the sausages are wood hot-smoked and then they are baked. The production processes mostly differ in terms of the raw materials or the type of wood used, as well as in terms of smoking or baking parameters applied. Traditional recipes allow the use of curing salts.

The hams examined were also made of pork meat. The production process of traditional hams involves the use of herbs and spices in which the meat is marinated. Then the product is tied with string or put in a special mesh and wood hot-smoked. Afterwards, the ham is scalded in hot water. As in the case of sausages, the differences in the manufacturing process include the use of different raw materials and wood, as well as smoking parameters.

The production of conventional meat products is aimed at receiving high yields in a relatively short time. Such mass-products are manufactured with the use of various types of food additives and modern-day production technologies. Detailed ingredient lists are presented in Table 1.

The main selection criterion for conventional products was their similar appearance to the traditional counterparts. The tests included six products of each variety but produced by different manufacturers and were repeated three times. The meat products were bought in various marketplaces: The manufacturer owned shops, delicatessens and supermarkets, between 3 and 7 days after their production. All of the analyses were performed and completed within 4 days after the acquisition.

Table 1. The ingredient lists of the product varieties tested (compiled on the basis of manufacturers' declarations).

Product	Ingredient List
A [a]	pork meat, salt, natural spices, preservative: sodium nitrite
B [a]	pork meat, salt, natural spices: allspice, bay leaf, pickling salt
C [b]	pork meat, salt, milk protein, pork collagen protein, lactose, glucose, stabilizers: triphosphates E451, sodium citrate E331, antioxidants: sodium ascorbate E301, sodium isoascorbate E316, flavor enhancer: monosodium glutamate E621, natural spices and their extracts, yeast extracts, aromatic preparations, acidity regulator: citric acid E330, preservative: sodium nitrite E250.
D [b]	pork meat, water, soy protein, stabilizers: E451, E452, E262, thickener E407, animal protein, sugars, antioxidants: E316, E301, flavor enhancer: E621, salt, vegetable fiber, aromas, spice extracts, acidity regulators: E331, preservative: E250.
E [b]	pork meat, water, stabilizer: E451, thickener E407, soy protein, wheat fiber, maltodextrins, animal protein, glucose, E621, E316, salt, E261, E326, natural spice extracts, aromas, E250.
F [b]	pork meat, water, salt, soy protein, stabilizers: E451, E508, E331, gelling agents: E407, E415, E425i, flavor enhancer: E621, antioxidant: E316, glucose, soy protein hydrolyzate, spice extracts, aromas, smoke flavor, preservative: E250.
G [c]	pork meat, salt, natural spices, sugar
H [c]	pork meat, salt, black pepper, natural garlic
I [c]	pork meat, salt, spices (garlic, pepper), sugar
J [c]	pork meat, garlic, salt, pickling salt
K [c]	pork meat, pork fat, salt, garlic, spices in various proportions
L [d]	pork meat, water, mechanically separated pork, potato starch, pork fat, stabilizers: E450, E451, soy protein, gelling agent (E407), pork collagen protein, antioxidant: sodium ascorbate, salt, flavor enhancer: monosodium glutamate, seasoning, aromas, plant protein hydrolysate, glucose, antioxidant: ascorbic acid, paprika extract, acidity regulator: sodium acetate, sodium citrate, hemoglobin, preservative: sodium nitrite
M [d]	pork meat, water, pork connective tissue, pork fat, potato starch, salt, aroma, dextrose, glucose syrup, taste enhancer (E621), antioxidants: E300, E301, E316, E315, stabilizers: E262, E331, modified cellulose (E461), plasma protein, preservative: E250
N [d]	pork meat, potato starch, salt, soy protein, stabilizer (E450), E451, E262, flavor enhancer (E621)
O [d]	pork meat, water, pork fat, potato starch, wheat fiber, salt, soy protein, dextrose, stabilizer: triphosphate (E407a), thickeners: xanthan gum, tare gum, acidity regulator: potassium chloride, antioxidants: isoascorbic acid, sodium isoascorbate, pork protein, grape sugar, flavor enhancers: disodium inosinate, monosodium glutamate, seasonings and extracts of spices, aroma, aroma of smoke, maltodextrin, dye: cochineal, preservative: sodium nitrite

Note: [a]—traditional hams; [b]—conventional hams; [c]—traditional sausages; [d]—conventional sausages.

2.2. Fat

The soxhlet method was used to determine the fat content. The procedure was as follows: Minced samples (5 g each) were dried (oven-drying method), then transferred to thimbles and extracted for three hours with the use of petroleum ether in the Büchi Extraction System B-811. After extraction, the thimbles were dried at 103 ± 2 °C for one hour, then they were cooled down to room temperature in a desiccator and afterwards they were weighted. Drying, cooling and weighing was repeated until the results of two successive weightings did not vary by more than 0.1% by weight of the sample [22].

2.3. Fatty Acids

In order to determine the fatty acid profile, samples of hams and sausages were subjected to extraction according to Soxhlet method. The extracts were esterified according to ISO 12966-2:2017 standard [23]. The analysis of the esterified samples was carried out in accordance with ISO 12966-1:2014 standard [24] on the SRI 8610C gas chromatograph with Restek RTX-2330 column length l = 105 m, Ø = 0.25 mm with FID detector, using hydrogen as a carrier gas. The Food Industry FAME Mix from Restek was used as a reference material.

2.4. Statistical Analysis

The measurement of the fat concentration and fatty acid profiles were analyzed with the use of statistical methods and the R 3.5.0 software. The required value for statistical significance was set at 0.05. The Shapiro-Wilk test was used to verify the normality of variable distribution. The test showed that the distributions were not normal. That is why, the differences between product varieties were analyzed using the Kruskal-Wallis test with post-hoc Dunn's test. The differences between product groups (traditional and conventional) were analyzed with the use of linear mixed models with product group as fixed effect and product source as random effect, mostly in order to account for the variance resulting from the purchase sites.

As a result of dimension reduction, performed by the means of principal component analysis (PCA), a 2-dimensional sample map was developed. It was used to identify the most similar and dissimilar samples.

3. Results and Discussion

3.1. Fat Contents and Fatty Acid Profiles of Tested Traditional and Conventional Hams and Sausages

The results of the fat content and fatty acid profiles for the tested hams are presented in Tables 2 and 3, whereas the results for the tested sausages are presented in Tables 4 and 5.

Table 2. Fat content (g/100 g) and saturated fatty acid profiles (% of total fatty acids) of selected Polish pork hams.

Parameter	Product Group	$\bar{x}$ (sd)	*p*
Fat	I (N = 2) II (N = 4)	8.56 (5.53) 5.81 (3.68)	0.329
C 12:0	I (N = 2) II (N = 4)	0.01 (0.03) 0.43 (1.04)	0.332
C 13:0	I (N = 2) II(N = 4)	0.00 (0.00) 0.05 (0.18)	0.505
C 14:0	I (N = 2) II (N = 4)	1.60 (0.24) 1.76 (0.25)	0.182
C 15:0	I (N = 2) II (N = 4)	0.00 (0.00) 0.03 (0.09)	0.505

Table 2. *Cont.*

Parameter	Product Group	x̄ (sd)	*p*
C 16:0	I (N = 2) II (N = 4)	25.9 (1.79) 26.35 (1.60)	0.664
C 17:0	I (N = 2) II (N = 4)	0.27 (0.24) 0.70 (0.99)	0.298
C 18:0	I (N = 2) II (N = 4)	12.30 (1.50) 11.76 (1.02)	0.364
C 20:0	I (N = 2) II (N = 4)	0.39 (0.23) 0.41 (0.22)	0.881
C 21:0	I (N = 2) II (N = 4)	0.33 (0.22) 0.23 (0.18)	0.346
SFA	I (N = 2) II (N = 4)	40.80 (1.98) 41.71 (2.80)	0.581

Group I—traditional hams; Group II—conventional hams; *p*—indicates significant differences between groups of products; sd—standard deviation; N—number of varieties tested.

Table 3. Unsaturated fatty acid profiles (% of total fatty acids) of selected Polish pork hams.

Parameter	Product Group	x̄ (sd)	*p*
C 14:1 (*cis*-9)	I (N = 2) II (N = 4)	0.18 (0.44) 0.22 (0.52)	0.885
C 16:1 (*cis*-9)	I (N = 2) II (N = 4)	3.96 (0.47) 4.26 (0.85)	0.466
C 17:1 (*cis*-10)	I (N = 2) II (N = 4)	0.50 (0.28) 0.35 (0.39)	0.503
C 18:1 (trans-9)	I (N = 2) II (N = 4)	0.14 (0.19) 0.50 (0.45)	0.063
C 18:1 (*cis*-9)	I (N = 2) II (N = 4)	44.61 (1.73) 43.96 (3.23)	0.645
C 18:2 (*cis*-9,12)	I (N = 2) II (N = 4)	8.37 (2.24) 8.10 (2.50)	0.887
C 18:3 (*cis*-6,9,12)	I (N = 2) II (N = 4)	0.12 (0.14) 0.16 (0.15)	0.720
C 18:3 (*cis*-9,12,15)	I (N = 2) II (N = 4)	0.66 (0.24) 0.55 (0.14)	0.203
C 20:3 (*cis*-11,14,17)	I (N = 2) II (N = 4)	0.55 (0.23) 0.19 (0.16)	0.003
MUFA	I (N = 2) II (N = 4)	49.39 (1.78) 49.28 (2.84)	0.929
PUFA	I (N = 2) II (N = 4)	9.70 (2.52) 9.00 (2.53)	0.721
UFA	I (N = 2) II (N = 4)	59.10 (1.94) 58.28 (2.81)	0.617
n-6	I (N = 2) II (N = 4)	9.04 (2.35) 8.45 (2.57)	0.768
n-3	I (N = 2) II (N = 4)	0.66 (0.24) 0.55 (0.14)	0.203
n-6/*n*-3	I (N = 2) II (N = 4)	14.37 (3.65) 16.69 (7.76)	0.679

Group I—traditional hams; Group II—conventional hams; *p*—indicates significant differences between groups of products; sd—standard deviation; N—number of varieties tested.

Table 4. Fat content (g/100 g) and saturated fatty acid profiles (% of total fatty acids) of selected Polish pork *wiejska* sausages.

Parameter	Product Group	x̄ (sd)	*p*
Fat	I (N = 5) II (N = 4)	(26.39) 3.47 (21.80) 2.90	0.010
C 12:0	I (N = 5) II (N = 4)	0.24 (0.45) 0.34 (0.24)	0.520
C 13:0	I (N = 5) II(N = 4)	0.19 (0.53) 0.43 (0.74)	0.317
C 14:0	I (N = 5) II (N = 4)	1.93 (0.51) 1.93 (0.26)	0.980
C 15:0	I (N = 5) II (N = 4)	0.00 (0.00) 0.03 (0.10)	0.261
C 16:0	I (N = 5) II (N = 4)	27.07 (2.01) 27.00 (1.11)	0.922
C 17:0	I (N = 5) II (N = 4)	0.62 (0.43) 0.33 (0.14)	0.121
C 18:0	I (N = 5) II (N = 4)	12.64 (0.82) 11.67 (0.98)	0.083
C 20:0	I (N = 5) II (N = 4)	0.38 (0.17) 0.24 (0.73)	<0.001
C 21:0	I (N = 5) II (N = 4)	0.34 (0.13) 0.32 (0.12)	0.744
SFA	I (N = 5) II (N = 4)	43.40 (2.42) 42.74 (1.24)	0.386

Group I—traditional sausages; Group II—conventional sausages; *p*—indicates significant differences between groups of products; sd—standard deviation; N—number of varieties tested.

Table 5. Unsaturated fatty acid profiles (% of total fatty acids) of selected Polish pork *wiejska* sausages.

Parameter	Product Group	x̄ (sd)	*p*
C 14:1 (*cis*-9)	I (N = 5) II (N = 4)	0.05 (0.18) 0.12 (0.41)	0.535
C 16:1 (*cis*-9)	I (N = 5) II (N = 4)	3.92 (0.59) 3.93 (0.54)	0.964
C 17:1 (*cis*-10)	I (N = 5) II (N = 4)	0.48 (0.44) 0.75 (0.93)	0.418
C 18:1 (trans-9)	I (N = 5) II (N = 4)	0.25 (0.20) 0.30 (0.20)	0.539
C 18:1 (*cis*-9)	I (N = 5) II (N = 4)	43.54 (2.10) 40.27 (1.33)	0.001
C 18:2 (*cis*-9,12)	I (N = 5) II (N = 4)	7.18 (2.13) 10.90 (1.34)	<0.001
C 18:3 (*cis*-6,9,12)	I (N = 5) II (N = 4)	0.17 (0.13) 0.16 (0.11)	0.931
C 18:3 (*cis*-9,12,15)	I (N = 5) II (N = 4)	0.65 (0.09) 0.54 (0.11)	0.004
C 20:3 (*cis*-11,14,17)	I (N = 5) II (N = 4)	0.15 (0.26) 0.11 (0.26)	0.672
MUFA	I (N = 5) II (N = 4)	48.23 (1.97) 45.38 (1.06)	0.001

Table 5. *Cont.*

Parameter	Product Group	x̄ (sd)	*p*
PUFA	I (N = 5) II (N = 4)	8.23 (2.14) 11.81 (1.37)	<0.001
UFA	I (N = 5) II (N = 4)	56.46 (2.21) 57.19 (1.25)	0.310
n-6	I (N = 5) II (N = 4)	7.58 (2.13) 11.27 (1.40)	<0.001
n-3	I (N = 5) II (N = 4)	0.65 (0.09) 0.54 (0.11)	0.004
n-6/*n*-3	I (N = 5) II (N = 4)	11.96 (3.89) 21.98 (5.83)	<0.001

Group I—traditional sausages; Group II—conventional sausages; *p*—indicates significant differences between groups of products; sd—standard deviation; N—number of varieties tested.

3.1.1. Hams

It was shown that the average fat concentration among all tested hams did not differ significantly between the analyzed groups of products. Nevertheless, conventional product F was characterized by the lowest (2.01 g/100 g) content of this nutrient, statistically significantly lower ($p < 0.001$) than for products B (10.07 g/100 g), D (8.04 g/100 g) and E (9.57 g/100 g).

The analyzed ham varieties contained more unsaturated (with predominant share of C 18:1 (*cis*-9) acid) than saturated fatty acids, what is in accordance with the results received by Kasprzyk, Tyra and Babicz [21]. They were characterized by high concentrations of C 16:0 and C 18:1 (*cis*-9), as well as a moderate content of C 16:1 (*cis*-9), C 18:0 and C 18:2 (*cis*-9,12). However, although stearic acid (C 18:0) belongs to the group of saturated acids, it was shown that its consumption does not affect the HDL or LDL cholesterol or the total cholesterol/HDL ratio, which is considered the risk factor for cardiovascular diseases [25]. Nevertheless, C:14 and C:16 acids exhibit artherogenic effects [26]. Their average concentration in hams accounted for 27.50% of total fatty acids in traditional products and 28.11% in conventional ones. Similar results were obtained by Pietrzak-Fiećko and Modzelewska-Kapituła [27]—27.05%, whereas in traditional Spanish meat products they reached 25% of the total fatty acids [28]. The slight differences between Polish and Spanish products may result from the use of different breeds of pigs that are fed differently [29,30].

All of the hams, especially variety D (27.46), were characterized by an unfavorable *n*-6/*n*-3 ratio, which should preferably vary from 1/1 to 4/1 [19]. Similar results were obtained by Garbowska, Pietrzak-Fiećko and Radzymińska [31] for Polish local, traditional and conventional pork hams. The average ratio for these groups of products ranged from 14.87 to 15.33. Pietrzak-Fiećko and Modzelewska-Kapituła [27] also received the average ratio of 15.52 in Polish smoked ham. This maybe the result of similar production methods and the use of breeds characteristic for this geographical area that are fed with the use of similar forage, since these factors mainly affect the fatty acid profile [29,30]. According to Grześkowiak et al. [32], the *n*-6/*n*-3 ratio typical for raw pork is close to 14.9. It should, however, be noted that some differences in the unsaturated fatty acids content might be attributed to the amounts of spices with anti-oxidative potential (e.g., allspice, black pepper, garlic) [33] used in the traditional products as well as the levels of artificial antioxidants added to conventional hams.

The traditional ham varieties contained significantly higher amounts of C 20:3 (*cis*-11,14,17) acid (0.55%) than their conventional equivalents (0.19%) in relation to total fatty acids. Moreover, variety B (0.61%) contained significantly more of this compound than variety F (0.00%). Considering the fatty acid profiles, no other statistically significant differences both between the ham varieties tested and between traditional and conventional products were detected. Correspondingly, Garbowska, Pietrzak-Fiećko and Radzymińska [31] showed that the fatty acid profile in pork products does not depend either on the origin of raw materials, or on the production methods. In their research local meat products showed similar fatty acid profile to the mass produced counterparts.

In the discussed study it was also shown that the fatty acid profiles of Polish hams are typical of processed pork products both from Poland [31] and from other parts of the world [17,29]. As in the case of Iberian hams examined by Fernández et al. [17], dry cured hams analyzed by Žlender et al. [29] and Polish local, traditional and conventional pork meat products tested by Garbowska, Pietrzak-Fiećko and Radzymińska [31], a high MUFA concentration indicates that these products can be an element of a healthy diet. Consuming MUFAs has a favorable effect on the cardiovascular system [34]. Moreover, besides the D variety (27.46), the other samples tested in this research had a similar *n*-6/*n*-3 ratio (12.05 to 15.93) to hams examined by Garbowska, Pietrzak-Fiećko and Radzymińska [31] (from 8.26 to 16.80), Fernández et al. [17] (from 9.36 to 13.75) and Žlender et al. [29] (from 10.4 to 16.1).

3.1.2. Sausages

Sausages are produced from meat of various fat concentrations and connective tissue of different proportions that depend on the recipe. The fat content is therefore higher than in hams and may reach even 35% [27]. In the case of the sausages tested, traditional products were characterized by statistically significantly higher content of fat than their conventional equivalents (26.39 g/100 g and 21.8 g/100 g, respectively). Sausage H had the highest content of fat (28.83 g/100 g), significantly higher than for varieties L (21.23 g/100 g), M (20.9 g/100 g) and N (19.34 g/100 g), whereas sausage N—the lowest (19.34 g/100 g) and significantly lower than for varieties J (27.44 g/100 g), K (26.87 g/100 g) and O (26.54 g/100 g) ($p < 0.001$).

Considering the fatty acid profiles, the analyzed sausages contained more unsaturated than saturated fatty acids. Similarly to the hams tested, they were characterized by high concentrations of C 16:0 and C 18:1 (*cis*-9), as well as moderate content of C 16:1 (*cis*-9), C 18:0 and C 18:2 (*cis*-9,12) in total fatty acids, what seems to be typical for Polish pork sausages [31]. The average concentrations of the sum of C:14 and C:16 acids were a bit higher than those noted for hams and equaled 29.00% for traditional products and 28.93% for the conventional ones. Pietrzak-Fiećko and Modzelewska-Kapituła [27] received a bit lower average concentration in Polish pork sausages—27.5% of total fatty acids. The significant differences between the analyzed meat product varieties concerned the concentrations of C 17:0, C 18:0, C 18:1 (*cis*-9), C 18:2 (*cis*-9,12) acids as well as monounsaturated fatty acids (MUFAs) and *n*-6 acids. Statistically significant differences were found in the samples with the highest and the lowest shares of these compounds. In the case of C 17:0 acid, they were associated with samples I (1.18%) and J (0.24%), respectively ($p = 0.025$). In relation to C 18:0 acid, J (13.75%), as well as N (10.65%) and O (11.1%) ($p = 0.008$); whereas, in the case of C 18:1 (*cis*-9), H (46.53%) as well as N (39.35%) and O (39.6%), respectively ($p = 0.005$). In the case of C 18:2 (*cis*-9,12), the differences were mostly associated with samples N (12.14%) and H (5.02%) ($p = 0.008$).The sausage H contained the highest percentages of MUFAs (51.07%), which were significantly higher than in the samples with the lowest concentration of these compounds—L (45.12%) and N (44.97%) ($p = 0.01$). It also had the lowest content of *n*-6 acids (5.56%), which was significantly lower than in the sample with the highest share of these fatty acids—N (12.37%) ($p = 0.015$).

Contrary to the results of research by Garbowska, Pietrzak-Fiećko and Radzymińska [31], in this research some significant differences between the analyzed groups of products were detected. Traditional products, in comparison to their conventional equivalents, were characterized by statistically significantly C 18:2 (*cis*-9,12) acid (7.18% and 10.9%, respectively), whereas a higher share of C 18:1 (*cis*-9) acid (43.54% and 40.27%, respectively), C 18:3 (*cis*-9,12,15) acid (0.65% and 0.54%, respectively) and C 20:0 acid (0.38% and 0.24%, respectively). The differences in C 18:2 (*cis*-9,12) and C 18:1 (*cis*-9) acids may result from the pork used for production. Thus, the proportion of C 18:2 (*cis*-9,12) is higher [35] and C 18:1 (*cis*-9) acid lower [36] in fat of the lean pigs. Traditional food producers, most probably use breeds that are richer in fat as a source of pork for sausages. This is also reflected in fat content differences among two groups of the analyzed products (Table 4). Moreover, in the discussed research traditional products also contained significantly more monounsaturated fatty acids (MUFAs) (48.23% and 45.38%, respectively) but lower amounts of polyunsaturated fatty acids (PUFAs) (8.23% and 11.81%, respectively) in the total fatty acid content. These differences can also be attributed to the fatter pigs used for production of traditional sausages [36]. As previously mentioned, a regular intake of MUFAs has a positive effect on the cardiovascular system [34]. On the other hand, PUFAs have anti-atherosclerosis, anti-inflammatory and anti-aggregation properties [37]. Similarly as in the case of hams, it should be indicated that some differences in the unsaturated fatty acids content may result from the amounts of spices with antioxidative potential (e.g., allspice, black pepper, garlic) [33] used in traditional products as well as from the supplementation of conventional sausages with artificial antioxidants.

For comparison purposes, Polish sausages examined by Pietrzak-Fiećko and Modzelewska-Kapituła [27] contained on average 49.45% of MUFAs and 9.20% of PUFAs in the total fatty acid content, whereas Swiss cooked pork sausages had 46.42% of MUFAs and 8.50% of PUFAs [38]. In the fermented dry Sremska sausages made of pork meat, examined by Parunović et al. [39], the share of MUFAs ranged from 42.50% to 52.79% and of PUFAs from 8.70% to 16.79% of total fatty acids. Amaral et al. [40] showed that pork Frankfurter type sausages contained from 45.29% to 51.53% of MUFAs and from 12.21% to 16.54% of PUFAs. Similarly, the average concentration of MUFAs was 44.89% and 11.79% of PUFAs in Chorizo ahumado (smoked sausage) [41].

Nevertheless, far more important is the content of essential unsaturated fatty acids which includes two series of compounds: *n*-3 and *n*-6 [42]. Traditional sausages had significantly higher shares of *n*-3 acids (0.65% and 0.54%, respectively) and, especially due to C 18:2 (*cis*-9,12) acid, lower concentration of *n*-6 acids (7.58% and 11.27%, respectively) than conventional products. Therefore, they were characterized by better *n*-6/*n*-3 ratio (11.96 and 21.98, accordingly), yet still quite unfavorable [19]. These differences might be attributed to the source of raw meat that comes from local breeds which are reared using traditional feeds. Petrón et al. [30] showed that the genotype and feed have a strong effect on the fatty acids profile of meat. The diet is of crucial meaning as in monogastric animals, fats are absorbed unmodified [43].

Similarly, Garbowska, Pietrzak-Fiećko and Radzymińska [31] received more favorable ratio for traditional sausages (8.26) in comparison to local (16.80) and conventional (13.75) products. Pietrzak-Fiećko and Modzelewska-Kapituła [27] obtained an average ratio of 13.87 for Polish sausages, whereas Amaral et al. [40] a ratio of 9 to 13 for pork Frankfurter type sausages, and Romero et al. [41] 10.55 for Chorizo ahumado (smoked sausage). On the other hand, Parunović et al. [39] received much less favorable ratios for fermented dry pork Sremska sausages (from 17.33 to 38.94) depending on the pig breed used as a source of meat.

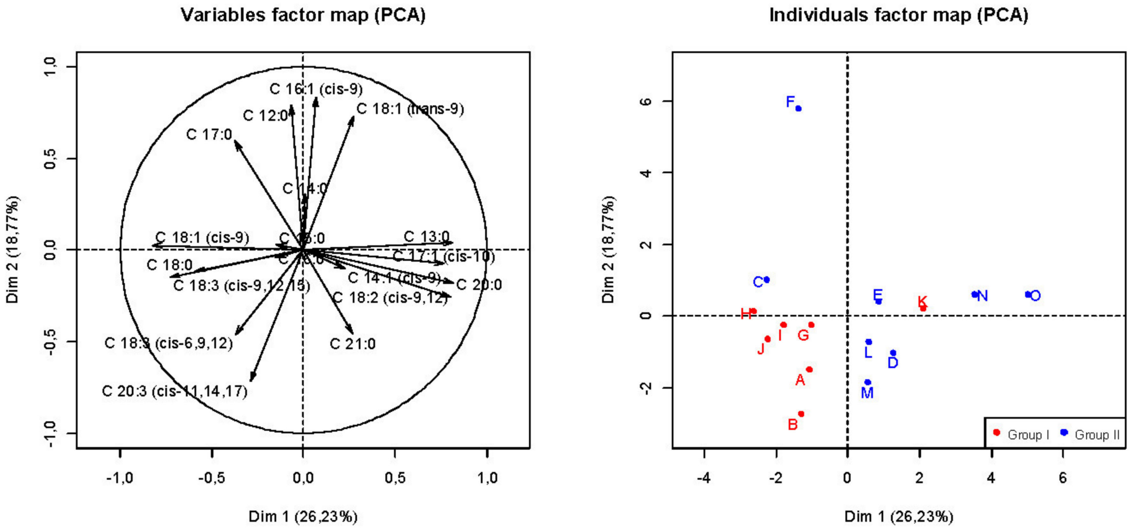
3.2. The Verification of the Differences between Traditional and Conventional Hams and Sausages with the Use of Principal Component Analysis (PCA)

With the intention of illustrating the differences between the traditional and conventional meat products tested, the PCA method was employed. The first two main components obtained explained the 45% of the total variance; the first component explained 26.23% and the second one 18.77%.

The first component indicates a high content of: C 13:0, C 17:1 (*cis*-10), C 18:2 (*cis*-9,12), C 20:0, and low concentration of C 18:0, C 18:1 (*cis*-9) fatty acids in the product.

The second component indicates a high concentration of C 12:0, C 16:1 (*cis*-9), C 18:1 (trans-9) and low content of C 20:3 (*cis*-11,14,17) fatty acids in the product.

The variables are presented as a factor map (Figure 1a). The individuals factor map (Figure 1b) shows that traditional products are mostly gathered in the bottom left corner. Although the product H has a positive value of the second component, it is very low and close to 0. The exception is, however, sausage K, which has positive values of both components and differs much from other traditional meat products tested. Therefore, on the basis of PCA, it can be stated that Polish traditional smoked hams and sausages are generally characterized by relatively higher shares of C 18:0, C 18:1 (*cis*-9), C 20:3 (*cis*-11,14,17) and lower of C 13:0, C 17:1 (*cis*-10), C 18:2 (*cis*-9,12), C 20:0, C 12:0, C 16:1 (*cis*-9), C 18:1 (trans-9) than conventional meat products.



(**a**) The variables factor map (**b**) The individuals factor map

(Group I—traditional meat products; Group II—conventional meat products; A-F—hams; G-O—sausages)

Figure 1. The results of the principal component analysis (PCA).

4. Conclusions

Traditional food products are believed to be of higher quality than their conventional counterparts. The results of this study demonstrated that the average fat content in the ham samples tested did not differ significantly between the analyzed groups of products, whereas traditional sausages had statistically significantly higher fat concentration than their conventional equivalents. Therefore, when considering fatty acid profiles traditional and conventional hams are similar. It means that the breads of pigs (and the systems of their feeding) used as raw materials were alike. Moreover, traditional production methods did not have an influence on the content of fatty acids.

It was also shown that the fatty acid profiles of the Polish pork hams and sausages tested are typical for processed pork products both from Poland and other parts of the world. In the case of hams, traditional products contained significantly higher amounts of C 20:3 (*cis*-11,14,17) acid than their conventional equivalents. More significant differences were found in sausages. Traditional products were characterized by lower concentrations of C 18:2 (*cis*-9,12) acids, whereas higher content of C 18:1 (*cis*-9), C 18:3 (*cis*-9,12,15) and C 20:0 acids. What is more, they contained significantly more MUFAs and less PUFAs. All of the tested meat products were characterized by unfavorable *n*-6/*n*-3 ratio. However, in the case of sausages, traditional ones contained significantly higher amounts of *n*-3 and lower of *n*-6 acids than their conventional equivalents. Consequently, they were characterized by a better *n*-6/*n*-3 ratio that is more favorable from a nutritional point of view. The differences between two groups of sausages tested are most probably the result of using fatter pig breeds for production of traditional products. The producers choose this type of pork because it has a positive influence on the flavor as fat is its carrier. Therefore, it can be stated that this is one of the reasons why traditional sausages represent unique sensory characteristics.

On the basis of PCA it was determined that Polish traditional smoked hams and sausages are generally characterized by relatively higher percentages of C 18:0, C 18:1 (*cis*-9), C 20:3 (*cis*-11,14,17), whereas lower shares of C 13:0, C 17:1 (*cis*-10), C 18:2 (*cis*-9,12), C 20:0, C 12:0, C 16:1 (*cis*-9), C 18:1 (trans-9) than conventional meat products. This proves that the use of traditional raw materials, and perhaps to some extent the processing methods, has an influence on the fatty acid profiles of pork meat products such as hams or sausages.

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