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Physicochemical, microbiological and sensory attributes for the characterization of Greek traditional sausages

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Abstract

Physicochemical, microbiological and sensory analyses were performed on 67 samples of Greek traditional sausages. The following physicochemical attributes were recorded: moisture 49.17% $\pm$7.05, protein 17.62% $\pm$2.67, fat 29.74% $\pm$8.02 and ash content 2.99% $\pm$0.55, moisture/protein ratio 2.83 $\pm$0.5. pH value 5.48 $\pm$0.49, water activity (a_w) 0.959 $\pm$0.015, total grill losses 12.81% $\pm$5.27 and fat grill losses 9.64% $\pm$4.36. The microbial counts, expressed as $\log_{10}$cfu/g, were for aerobic plate count 8.22 $\pm$0.5, lactic acid bacteria 7.45 $\pm$0.66, *Brochothrix thermosphacta* 7.02 $\pm$1.21, pseudomonads 6.88 $\pm$1.33 and yeasts 5.39 $\pm$1.03. Mean sensory scores, on a five-point hedonic scale, were 4.46 $\pm$0.63 for appearance, 4.14 $\pm$0.63 for firmness, 3.80 $\pm$0.97 for flavour and 4.12 $\pm$0.52 for overall quality. The discriminant analysis have shown that, based on their pH and a_w values, 74.6% of sausages were classified as easily perishable, 19.4% as perishable and 5.9% as shelf-stable. Also, 4.4% of sausages had fat content less than 15%, 23.8% from 15 to 25%, 46.2% from 25 to 35% and 25.3% more than 35%. Principal component analysis has shown that the first two components (PC1 PC2) account for 44.1% of the total variance. PC1 was related to water activity, ash, moisture and fat content, flavour, *Br. thermosphacta* and pseudomonads count, and to a lesser extent to cross section quality. PC2 was related to aerobic plate count, lactic acid bacteria and moisture content.

Keywords: Traditional sausages; Greek sausages; Fresh sausages

1. Introduction

Traditional sausages are well-known and very popular meat products in Greece. Most Greek rural families produced them in the past on Christmas' day using pork meat and fat. The production technology was almost the same. Pork meat and fat were chopped and thoroughly mixed with salt and seasonings, which differ from region to region. In some parts of Greece onion, celery or leek were used and in others oranges, red wine, oregano and cumin. The prepared sausage mixture was stuffed in natural casings from the cleaned small intestine of pigs. After stuffing, the sausages were spiked over the entire surface to allow the entrapped air to escape and were stored in cool rooms with sufficient air circulation for drying purposes. In some regions the sausages, immediately after stuffing, were put for a few seconds in very hot water (85–90 °C) in order to improve their external colour and preservation. In other regions, an olive oil was applied externally in order to protect them from fungi development in the surface. These sausages were intended to be consumed within a few weeks. Sometimes after a long period of drying in low temperatures and having lost about 30% of their initial weight, they could be preserved and consumed over summer or later on. In some areas, after drying for 1–2 weeks, the sausages were placed in big pots, covered with melted pork fat or olive oil, stored in a cool room and consumed over summer.

Nowadays, most traditional sausages are produced throughout the year at butchers' shops and by sausage

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manufacturing companies. Lean or semi-lean pork and beef meat, pork bellies and pork back fat are used as raw materials. In some regions these products are produced only from beef meat and pork back fat. The various raw materials are more or less coarse minced and mixed with 1.6–2.5% salt, phosphates, nitrites and different seasonings, using sometimes 1–2% added water. The sausage mixture is still stuffed in natural casings as in the past, but the ready products have to be kept until consumption under cold storage. According to Greek Food Legislation (1998), they are characterised as fresh, non cooked sausages, manufactured only from lean meat and fat under the addition of salt, phosphates, nitrites, monosodium glutamate (MSG), ascorbic acid or salt, sugars and different seasonings. They may be partially dried or smoked, should not contain more than 35% fat and should be consumed only after heat processing (frying, grilling or cooking).

Papadima and Bloukas (1999) and Papadima, Arvanitoyannis, Bloukas, and Fournitzis (1999) have conducted research on the quality characteristics of Greek traditional sausages. Grigoriadis, Kabamanoli-Dimou, and Sagri (1988), Karaioannoglou (1975) and Samelis and Metaxopoulos (1998) have studied the microbiology of these products.

The object of this study was to identify and to quantify those parameters of Greek traditional sausages, which better describe and characterise them, as a first step in our research to standardise its composition and processing conditions and improve their quality and shelf life.

2. Material and methods

2.1. Samples

Physicochemical, microbiological and sensory analyses were performed on 67 samples of traditional fresh sausages from north Greece. The samples were purchased from butchers' shops and supermarkets 2–6 days after the end of their production. About 1 kg per sample of sausages was transferred under cooling to the Laboratory. All analyses were performed and completed within 5 days after purchase.

2.2. Physicochemical analysis

Moisture, *fat* (ether-extractable), *protein* and *ash* were determined according to standard AOAC procedures (1990).

pH measurement: The pH values were measured in homogenates prepared by blending 20 g of sausage with 80 ml of distilled water for 1 min. Measurements were taken with a WTW microprocessor pH-meter (WTW GmbH, Weilheim, Germany). Means of two measurements were recorded.

Water activity (a_w): It was measured with the AQUA LAB instrument, Mod. CX-2 (Decagon Devices Inc. Pullman Washington 99163) in samples, which were taken after coarse homogenisation of 100 g of the sausage. Means of two measurements were recorded.

Cooking losses: three pre-weighted sections (15 cm length, 26–30 mm calibre and about 60–75 g weight) from each sample of sausage were grilled in an electrical plate grill to a core temperature of 71° C. A thermocouple (Ellab cmc 821, Denmark) was used to monitor the temperature in the centre of sausages. After cooling for 3 min, the sections of each sausage were re-weighted and the total looses were calculated as g/100 g of their initial weight. The separated melted fat from each section of sausages during grilling was collected and weighted. It was expressed as fat loss calculated as g/100 g of the initial weight of each section. The mean value of the three sections from each sausage was recorded.

2.3. Microbiological analysis

A sample (20 g) of each sausage after peeling was aseptically transferred to a sterile plastic bag and pummelled for 2 min in a stomacher (Lab blender 400. Seward medical, London, UK), with 180 ml of sterile 0.1% peptone water (Acuff, 1992). Appropriate decimal dilutions of the samples were prepared using the same diluent and plated in duplicate on different growth media. The following media and incubation conditions were used: (1) Plate Count Agar (Oxoid) at 32 °C for 3 days, for aerobic plate count (Maturin & Peeler, 1998). (2) deMan Rogosa Sharpe (MRS) agar (Oxoid) microaerophilic incubated at 30 °C for 3 days, for lactic acid bacteria count. (3) Pseudomonads agar (Oxoid) with selective C-F-C supplement (Oxoid SR 103) at 25 °C for 48 h for *Pseudomonads spp*. count. (4) Gardner's STAA agar (Oxoid) for *Brochothrix thermosphacta* (Gardner, 1996), after 3-days incubation at 25 °C, the plates were flooded with 1% tetramethyl-*p*-phenylene diaminedihydrochloride solution and uncoloured oxidase (−)ve colonies were counted as *Br. thermosphacta* (Acuff, 1992; Sneath & Jones, 1986). (5) Potato dextrose agar (Oxoid) plus 40 mg/l chloramphenicol-HCl (Sigma) at 25 °C for 5 days, for yeasts and molds (Bandler, Stack, Koch, Tournas, & Mislivec, 1995). Results were expressed as $\log_{10}$ numbers of colony forming units/gram ($\log_{10}$ cfu/g).

2.4. Sensory evaluation

An experienced five-member panel was used to evaluate the traditional sausages. Panellists were chosen on the basis of previous experience in consuming traditional sausages. Furthermore, a preparatory session was held prior to testing so that each panel member could thoroughly discuss and clarify each attribute to be evaluated. Testing was initiated after the panellists agreed on the specifications.

Panellists were at first served with a section of fresh sausage, about 10 cm long cut across its axis, and asked to evaluate the appearance, the firmness, the fat particle size and the cross section quality according to the following scales: *Appearance*: 5 = excellent, well stuffed, casings with the same calibre, smooth and dry surface, red colour, visible fat particles, 1 = unacceptable, separated casings, wrinkled surface, brown colour, other defects. *Firmness* (determined by the force required to induce with hands any deformation to sausages): 5 = very hard, 1 = very soft. *Fat particle size*: 5 = coarse comminuted fat, fat particles bigger than 5 mm, 1 = finely comminuted fat, fat particles smaller than 1 mm. *Cross section quality*: 5 = excellent, visible meat and fat particles of similar size, clear cutting surface, red in colour, without sinews and gristles. 1 = unacceptable, no visible meat and fat particles, melting of fat during cutting, no clear cutting surface, intensive discoloration, presence of sinews and gristles.

Sausages were grilled as mentioned above and after cooling for 3 min at ambient temperature they were cut in pieces of 5 cm and served to the panellists. They were asked to evaluate the *flavour* (odour and taste) according to the following scale: 5 = excellent with good seasoning composition, not too fatty, salty, or acid, not rancid, 1 = totally unpleasant odour and taste.

Taking into account the above sensory attributes the overall quality of the sausages was evaluated using the following formula:

Overall quality = $1/10 \times (a+b+2c+6d)$, where a, b, c and d are the mean score given by the panellists for appearance, cross section quality, firmness and flavour, respectively.

2.5. Statistical analysis

Data collected for physicochemical, microbiological and sensory attributes were analysed by one way analysis of variance. Simple correlations were determined between selected response variables. Discriminant analysis was contacted for the examined samples based on pH and water activity, fat content and flavour, using the Statistical Package for Social Sciences software statistical program (SPSS, 1998). Means were separated using the $LSD_{0.05}$ test. Categorical principal component analysis (CATPCA) was carried out through SPSS software statistical program, on the basis of the 20 physicochemical, microbiological and sensory variables studied.

3. Results and discussion

3.1. Attributes of sausages; range and variability

Table 1 summarises the results as mean, minimum and maximum values, standard deviation (S.D.) and coefficient of percentage variation (CV%) of physicochemical and microbiological analyses and sensory assessments.

3.1.1. Composition

The mean value for chemical composition was for moisture 49.17% ± 7.05, for protein 17.62% ± 2.67, for fat 29.74% ± 8.02 and for ash 2.99% ± 0.55. Papadima et al. (1999) found that 31 samples of the same sausages had 43.98% ± 9.18 moisture, 19.19% ± 3.53 protein, 33.5% ± 9.16 fat and 3.3% ± 0.60 ash. Among the components of chemical composition fat content had the highest coefficient of variation (26.96%). About the same coefficient of variation (27.35%) for fat content was found by Papadima et al. (1999). This means that there is great variability in the fat content among the Greek traditional sausages. Although the sausages examined had a mean fat content lower than the upper limit (35%) put by Greek Food Legislation (1998), 25.37% of samples had higher fat content than that

Table 1
Mean, minimum, maximum, standard deviation (S.D.) and percent coefficient of variation (CV%) on physicochemical, microbiological and sensory variables evaluated on 67 Greek traditional sausages

Variables	Mean	Min	Max	S.D.	CV%
Physico-chemical					
Moisture (g/100 g)	49.17	33.73	64.40	7.05	14.33
Protein (g/100 g)	17.62	12.93	25.64	2.67	15.15
Fat (g/100 g)	29.74	10.70	46.74	8.02	26.96
Ash (g/100 g)	2.99	2.13	5.07	0.55	18.39
Moisture/protein	2.83	1.71	4.12	0.50	17.97
pH	5.48	4.67	6.09	0.29	5.32
Water activity (a_w)	0.959	0.910	0.970	0.015	1.57
Grill loss					
Fat loss (g/100 g)	9.64	1.50	20.30	4.36	45.52
Total loss (g/100 g)	12.81	0.90	30.00	5.27	41.43
Microbiological (log_{10} cfu/g)					
Aerobic Plate Count (APC)	8.22	5.14	8.96	0.59	7.29
Lactic acid bacteria (LAB)	7.45	4.27	8.79	0.66	8.92
Br. thermosphacta	7.02	3.70	8.90	1.21	16.98
Pseudomonads	6.88	3.46	8.60	1.33	18.49
Yeasts	5.39	2.41	7.71	1.03	19.30
Sensory					
Appearance	4.46	3	5	0.63	14.29
Firmness	4.14	3	5	0.63	14.93
Fat particle size	2.95	1	5	1.12	38.32
Cross section quality	3.77	1	5	1.22	32.72
Flavor	3.80	1	5	0.97	25.77
Overall quality	4.12	3	5	0.52	12.85

limit. Fat content was significantly negatively correlated to the moisture content ($Y = 82.224 - 1.067 \times$ (moisture), $r = -0.938$, $P < 0.01$).

3.1.2. Moisture/protein ratio

Traditional sausages studied had a mean moisture/protein ratio 2.83 ± 0.5, with a range from 1.71 to 4.12. Papadima et al. (1999) found for the same sausages a mean moisture/protein ratio of 2.29. According to Greek Food Legislation (1998) traditional sausages can be partially dried and/or smoked. During this process and subsequent storage, sausages are dried and the moisture/protein ratio is decreased. Papadima and Bloukas (1999) found that the mean moisture/protein ratio of traditional sausages reduced from 5.29 to 2.59 in 21 days. It is therefore concluded that traditional sausages offered in the market are consumed within 1–2 weeks from their day of preparation and some of them up to 4 weeks. Acton and Dick (1976) have suggested the moisture/protein ratio as a classification system for fermented sausages. They found that semidry sausages have a moisture/protein ratio between 2.25 and 3.0.

3.1.3. pH Value

The pH of traditional sausages, ranged from 4.67 to 6.09 had a mean value 5.48 and a very low coefficient of variation (5.32%). pH was weakly negatively correlated to aerobic plate count ($r = -0.264$, $P < 0.05$), lactic acid bacteria count ($r = -0.346$, $P < 0.01$) and positively correlated to *Br. thermosphacta* count ($r = +0.395$, $P < 0.05$) and pseudomonads count ($r = +0.245$, $P < 0.05$). Traditional sausages examined by Karaioannoglou (1975) and Papadima et al. (1999) had a mean pH value 5.79 and 5.76 and coefficients of variation 10.1 and 9.23%, respectively. The above results show that traditional sausages have low variability for the pH.

Taking into account that the pH of traditional sausages on the day of preparation ranged from 6.0 to 6.35 (Papadima & Bloukas, 1999; Samelis & Metaxopoulos, 1998) the results indicate that a limited fermentation has taken place in the sausages, resulting in the reduction of their pH to about 5.5–5.8. Because no sugars are added in the meat mixture of traditional sausages during preparation, the limited fermentation is attributed to the action of bacteria on the carbohydrates present in the leek and spices.

3.1.4. Water activity (a_w)

Water activity had a mean value 0.95 and a very low coefficient of variation. Similar results ($a_w = 0.94$) were found by Papadima et al. (1999). Water activity was significantly correlated to moisture ($r = +0.805$, $P < 0.01$) and ash content ($r = -0.738$, $P < 0.01$) and moderately to the fat content (r = –0.522, p0.01). The following regression equation was found between the water activity and the moisture, fat and ash content of traditional sausages:

$$\begin{aligned}\text{Water activity } (a_w) = {} & 0.0903 + 0.001672 \\ & \times (\text{moisture}) + 0.0003474 \\ & \times (\text{fat})\text{-}0.01241 \times (\text{ash}), \\ & \left(R^2 = 0.846, \text{adjusted} R^2 = 0.838, P < 0.01\right).\end{aligned}$$

3.1.5. Grill loss

Traditional sausages are grilled, fried or cooked before consumption. During grilling fat and moisture are lost which negatively affects the quality of these products. A good fat binding and water holding capacity improves the juiciness and the total sensory quality of the traditional sausages. The results have shown that fat loss was $9.64\% \pm 4.36$ and total loss $12.81\% \pm 5.27$. Fat loss was moderately correlated to the moisture content ($r = +0.458$, $P < 0.01$) and to moisture/protein ratio ($r = +0.480$, $P < 0.01$).

3.1.6. Microbial counts

Traditional sausages were found to have a rather high population of aerobic plate count (APC) and lactic acid bacteria (LAB) count. The mean value was 8.22 and 7.45$\log_{10}$ cfu/g, respectively. APC was significantly correlated to the LAB count ($r = +0.788$, $P < 0.01$). There was also very low variability in APC and LAB counts (7.29 and 8.92%, respectively) among the Greek traditional sausages. These results are in good agreement with those reported by Papadima et al. (1999) and Samelis and Metaxopoulos (1998). The high LAB count confirms the assumption that a limited fermentation takes place in traditional sausages during storage. Such a high population of LAB in traditional sausages inhibits the growth of pathogenic bacteria, especially that of *St. aureus* (Geisen, Luecke, & Kroeckeel, 1992) and spoilage bacteria as well. The main mechanisms by which LAB suppress their competitors are the formation of lactic acid, acetic acid and possibly bacteriocins (Luecke, 2000). In addition, it was reported that LAB taken with food have a positive effect on human health (Fernades & Shahani, 1990, Incze, 1992).

The population of *Br. thermosphacta*, pseudomonads and yeasts were also rather high, with mean counts of 7.02, 6.88 and 5.39 $\log_{10}$ cfu/g respectively and with a coefficient of variation from 16.98 to 19.30%. There was also a moderate correlation between the *Br. thermosphacta* and pseudomonad counts ($r = +0.631$, $P < 0.01$) and Br. thermosphacta and yeasts and molds count ($r = +0.582$, $P < 0.01$). Samelis and Metaxopoulos (1998) have found, that the mean pseudomonad and yeast count in Greek traditional sausages on the day of preparation were 5.79 and 4.25 $\log_{10}$ cfu/g. respectively.

During their subsequent storage at 3 and 12 °C, the pseudomonad count was slightly reduced while that of yeast significantly increased. These microorganisms are considered as spoilage microflora and their presence in such high amounts is considered undesirable. According to Samelis and Metaxopoulos (1998), yeasts appeared to be the main causative agent of spoilage in traditional Greek Sausages, which contribute to an increase in pH of the sausages.

3.2. Sensory attributes

The external appearance of traditional sausages was good to satisfactory with a mean score 4.46±0.63. The main defects in appearance were the brown colour (23.88%) and the bad quality of casings (19.40%). The mean score for firmness was 4.14±0.63, which was considered satisfactory to good. The fat particles in the sausages had a medium to large size, with a mean score 2.95±1.12. The cross section quality had a medium to good appearance with a mean score 3.77±1.22. There was a great variability among traditional sausages in fat particle size and cross section quality. The main defects in cross section quality were the easily separated particles (40.29%), the non-uniform particle size (38.8%), the case hardening at cross section 22.38%, the presence of difficulty chewed particles (20.89%), the unclear cutting surface (17.91%), and the presence of brown to green spots (13.43%). The flavour of grilled sausages was evaluated as satisfactory to good, with a mean score 3.80±0.97 and a high coefficient of variation (25.77%). The main defects in flavour were the non-acceptable seasonings (22.38%), the rancid smell and taste (16.41%) and the sour taste (14.92%). The overall quality of sausages was satisfactory to good with a mean score 4.12±0.52.

Table 2
Physicochemical, microbiological and sensory variables evaluated on 67 Greek traditional sausages classified according to pH and water activity (a_w)

	Easily perishable	Perishable	Shelf stable
Number of samples (N)	50	13	4
Moisture (g/100 g)	51.33a	44.06b	38.74b
Fat (g/100 g)	27.95b	33.26a	40.75a
Ash (g/100 g)	2.83b	3.40a	3.66a
Moisture/protein	2.98a	2.41b	2.36b
pH	5.53a	5.45a	4.88b
Water activity (a_w)	0.965a	0.945b	0.931c
Grill moisture loss (g/100 g)	14.05a	9.60b	7.90b
Aerobic plate count[a]	8.24	8.07	8.49
Lactic acid bacteria[a]	7.49	7.17	7.86
Br. thermosphacta[a]	7.34a	6.62b	4.44c
Pseudomonads[a]	7.03a	7.07a	4.20b
Yeasts[a]	5.64a	4.93b	3.71c
Flavor	3.94	3.61	3.00

Easily perishable: pH > 5.2 and a_w > 0.95; Perishable: pH = 5.2 – 5.0 (inclusive) or a_w = 0.95 – 0.91 (inclusive); Shelf-stable: pH $\leqslant$5.2 and a_w $\leqslant$0.95 or only pH < 5.0 or only a_w < 0.91 (Leistner and Roedel, 1975). Means within the same row with different letters are different (P < 0.05).

[a] Expressed as $\log_{10}$ cfu/g.

3.3. Discriminant analysis

3.3.1. pH and water activity

According to Leistner and Roedel (1975) meat products are distinguished into "easily perishable", "perishable" and "shelf-stable" based on their pH and water activity values. The "easily perishable" meat products have a pH > 5.2 and an a_w > 0.95 and must be stored at or below +5 °C. The "perishable" meat products have either a pH of 5.2–5.0 (inclusive) or an a_w of 0.95–0.91 (inclusive) and must be stored at or below +10 °C. The "shelf-stable" meat products have a pH < 5.2 and an a_w < 0.95 or only pH < 5.0 or a_w < 0.91; these products need no refrigeration and their shelf-life is often not limited by bacteria but by chemical or physical spoilage, especially rancidity and discoloration. Based on that information the examined traditional sausages were classified into "easily perishable" (74.6%), "perishable" (19.4%) and "shelf-stable" (5.9%). The results show (Table 2) that pH and a_w of each group have a significant effect (P < 0.05) on moisture, fat and ash content, on moisture/protein ratio and grill total loss, and on *Br. thermosphacta*, pseudomonads and yeasts counts. "Easily perishable" traditional sausages had the highest (P < 0.05) moisture and lowest fat and ash content as well as the highest *Br. thermosphacta*, pseudomonads and yeasts counts. No differences (P > 0.05) were found in aerobic plate count and lactic acid bacteria count. Shelf-stable sausages had lower, but not significant (P > 0.05), flavour, probably due to the rancidity developed.

3.3.2. Fat content

Health organisations all over the world are encouraging people to adopt a diet that is low in calorie intake, saturated fatty acids and cholesterol as a means of preventing cardiovascular heart disease (AHA, 1986; NCEP, 1988; Department of Health, 1994; Enser, Hallett, Hewitt, Fursey, & Wood, 1996). Papadima and Bloukas (1999) have found that the proportion of fat in traditional sausages, produced with 10, 20 and 30% fat on the day of preparation, increased during storage for 21 days to about 18, 28 and 35%, respectively. Taking into account the above information the traditional sausages examined were classified into four groups as follows: less than 15% fat, 15–25% fat, 25–35% fat and more than 35% fat. The results have shown (Table 3) that 4.4, 23.8, 46.2 and 25.3% of the samples, respectively were present in each group.

The fat content of traditional sausages significantly affected ($P<0.05$) the chemical composition, the moisture/protein ratio, the water activity and the fat loss during grilling, the *Br. thermosphacta* count and the flavour, while it had no effect ($P>0.05$) on aerobic plate count, lactic acid bacteria, pseudomonads and yeasts count. Papadima and Bloukas (1999) have also found that fat level had no effect ($P>0.05$) on lactic acid bacteria count. The higher the fat content the lower the moisture and protein content and the higher the fat loss during grilling. Traditional sausages with more than 35% fat had lower ($P<0.05$) water activity and lower *Br. thermosphacta* count than other sausages. Traditional sausages with either less than 15% fat or more than 35% fat had a lower ($P<0.05$) flavour score than sausage with 15–25% and 25–35% fat. These results are in agreement with those of Papadima and Bloukas (1999). Traditional sausages with low fat become very dry after grilling while those with very high fat taste as too fatty.

3.3.3. Flavour

Flavour is the most important sensory attribute which affects the quality of meat products. The traditional sausages examined were classified according to their flavour score during sensory evaluation into the following groups: <2, 2.1–3.0, 3.1–4 and 4.1–5.0 (Table 4). The results have shown that 7.4, 31.3, 32.8 and 28.3% of the samples respectively were present in each group.

The higher the flavour score of traditional sausages the higher the *Br. thermosphacta* and pseudomonads count and the better the external appearance. Also sausages with the highest ash content and the lowest total loss during grilling had the lowest score for flavour. The above results agree with those of Papadima and Bloukas (1999) who found that traditional sausages had higher ($P<0.05$) scores for odour and taste on the 7th day than on the 21st day. Fresh traditional sausages have high counts of *Br. thermosphacta* and pseudomonads due to the contamination of meat mixture during preparation and probably the use of meat with a high microbial count. Fresh sausages also have a higher total loss during grilling and lower ash content due to higher moisture content. On the other hand fresh sausages have an intensive flavour, which is due mainly to the presence of spices and leek. During subsequent storage the sausages are progressively dried, because they are encased in natural casings with a small diameter. A limited fermentation also takes place, which favours the increase of lactic acid bacteria and suppresses the population of *Br. thermosphacta* and pseudomonads. However, during the storage of sausages the rancidity is more pronounced resulting in the reduction of the flavour score.

3.4. Categorical principal component analysis

The goal of principal components analysis is to reduce an original set of variables into a smaller set of uncorrelated components that represent most of the information found in the original variables. By reducing the dimensionality, it is easier to interpret a few components than a large number of variables. On the other hand, while standard principal components analysis assumes linear relationships between numeric variables, in categorical principal component analysis, as a result of optimal quantification in the specified dimensionality, nonlinear relationships between variables can be modeled (Leeuw & Van Rijckevorsel, 1980; Siardos,

Table 3
Physicochemical, microbiological and sensory variables evaluated on 67 Greek traditional sausages classified according to fat content

	Fat content			
	<15%	15–25%	25–35%	>35%
Number of samples *(N)*	3	16	31	17
Moisture (g/100 g)	61.78a	55.67b	49.46c	40.30d
Protein (g/100 g)	22.78a	19.08b	17.24c	16.01c
Fat (g/100 g)	12.07d	21.72c	29.93b	40.07a
Ash (g/100 g)	3.32ab	2.92b	2.80b	3.36a
Moisture/protein	2.67b	2.99a	2.90a	2.58b
Water activity (a_w)	0.967a	0.967a	0.962a	0.942b
Grill fat loss (g/100 g)	3.46b	7.35b	10.51a	11.30a
Aerobic plate count[a]	8.70	8.09	8.32	8.17
Lactic acid bacteria[a]	8.00	7.20	7.57	7.38
Br. thermosphacta[a]	7.86a	7.51a	7.14a	6.19b
Pseudomonads[a]	7.84	7.31	6.78	6.42
Yeasts[a]	5.27	5.68	5.52	4.89
Flavor	2.66c	4.06bc	4.16ab	3.29c

Means within the same row with different letters are different ($P<0.05$).
[a] Expressed as $\log_{10}$ cfu/g.

Table 4
Effect of some physicochemical, microbiological and sensory variables on the flavor score evaluated on 67 Greek traditional sausages

	Flavor score			
	<2	2.1–3.0	3.1–4.0	4.1–5.0
Number of samples (*N*)	5	21	22	19
Ash (g/100 g)	3.71a	3.00b	2.88	2.91b
Grill moisture loss (g/100 g)	7.90b	11.91ab	14.81a	12.78ab
Aerobic plate count[a]	7.64	8.19	8,24	8.39
Lactic acid bacteria[a]	6.84	7.55	7.45	7.50
Br. thermosphacta[a]	5.66c	6.59bc	7.19ab	7.65a
Pseudomonads[a]	5.17b	6.97a	6.97a	7.06a
Yeasts[a]	4.46	5.35	5.49	5.56
Appearance	4.00b	4.23b	4.54ab	4.73a

Means within the same row with different letters are different ($P<0.05$).
[a] Expressed as $\log_{10}$ cfu/g.

1999; SPSS, 1998). Five of these variables, namely appearance, firmness, fat particle size, cross section quality and flavour, were measured in ordinal scale, while all others were numerical.

The results have shown that the first two components account for 44.1% of total variance. Table 5 shows the relative importance of each variable in the model. The loading of each variable on the first two components

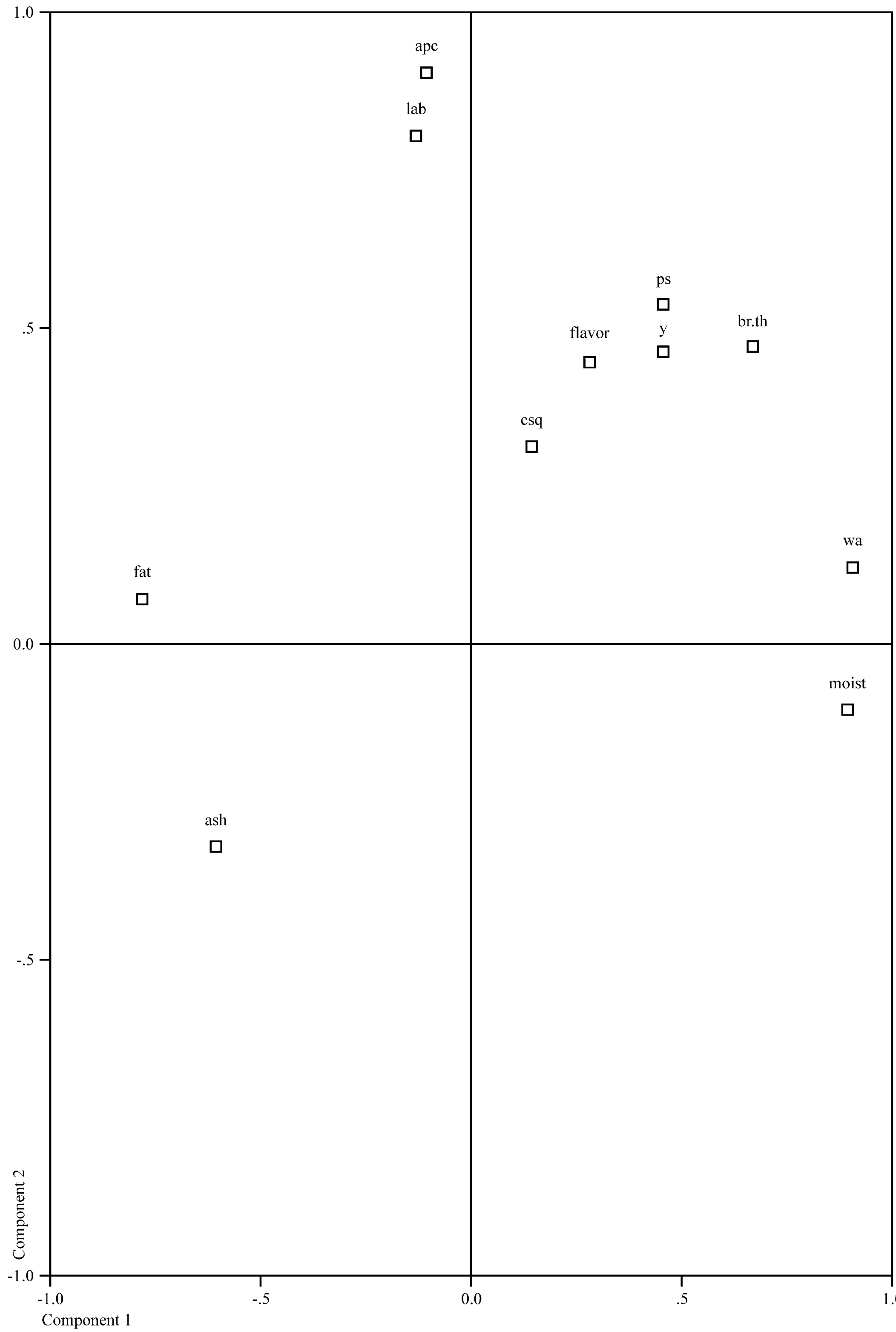

Fig. 1. Component plot in rotated space for the 11 selected variables. wa = water activity; moist. = moisture; csq = cross section quality; apc = aerobic plate count; lab = lactic acid bacteria; br.th = Br. thermosphacta; ps = pseudomonads; y = yeasts.

Table 5
Principle component analysis of physicochemical, microbiological and sensory variables loadings of the first two components and explained variance

Variable	Loadings		Explained variance (%)
	PC1 ($\alpha = 0.866$)	PC2 ($\alpha = 0.722$)	
pH	0.144	0.367	15.5
Water activity	0.828	0.403	84.7
Moisture (g/100g)	0.695	0.619	86.6
Fat (g/100 g)	−0.645	−0.512	67.8
Protein (g/100 g)	0.188	−0.036	3.7
Ash (g/100 g)	−0.703	−0.066	49.9
Moisture/protein	0.415	0.542	46.5
Fat loss (g/100 g)	0.106	−0.394	16.7
Moisture loss (g/100 g)	0.512	0.236	31.7
Fat particle size	−0.385	0.413	31.8
Fat particle quality	0.599	−0.415	53.1
External appearance	0.247	−0.230	11.4
Texture	0.367	−0.366	26.9
Flavor	0.639	−0.339	52.4
Overall acceptability	0.568	−0.349	44.5
Total plate count	0.380	−0.744	69.8
Lactic acid bacteria	0.317	−0.629	49.7
Br. thermosphacta	0.789	0.047	62.5
Pseudomonas	0.635	−0.091	41.1
Yeasts	0.596	−0.094	36.4
Active total (eigen value)	5.640	3.188	8.828
Explained variance%	28.20	15.94	44.14

and variance accounted for by each variable are reported. According to α-Cronbach reliability values only the two components, having reliability values $\alpha = 0.866$ and 0.722, respectively, are considered significant. As regards the first principal component variability it is mainly related to a number of variables such as water activity, ash, moisture and fat content, flavour, *Br. thermosphacta* and pseudomonads count, and to a lesser extent to cross section quality and yeasts count. As regards the second principal component, aerobic plate count, lactic acid bacteria, and moisture content are the most relevant.

Each of these variables accounts for more than 50% of the explained variance (Table 5). These variables are therefore considered as important parameters for the characterisation of traditional Greek sausages. All other variables either are related to them by a formula or have a contribution to the explained variance lower than 50%.

Applying the principal component analysis only to these 11 variables the first two components account for 58,32% of total variance. The position of the above 11 variables on the two dimensional space is shown in Fig. 1. Moisture and water activity as well as *Br. thermosphacta*, pseudomonads and yeasts count are considered as the ‘‘freshness index’’ for the sausages. Samples with low moisture content and low water activity have been dried during processing or have a long storage period. *Br. thermosphacta,* pseudomonads and yeasts count is high in fresh sausages mainly due to the contamination of the meat mixture. However the population of these microorganisms should be kept as low as possible by selecting good quality raw materials and applying hygienic conditions during processing. Flavour and cross section quality are considered as the ‘‘good quality index’’ of the traditional sausages. Each consumer expects to buy sausages with a good cross section quality and excellent flavour. Fat and ash content are considered as ‘‘negative quality index’’. According to discriminant analysis, sausages with less than 15% or more than 35% fat and also with a high ash content have lower flavour intensity. Total aerobic count and more especially the lactic acid bacteria count is considered as ‘‘fermentation process index’’. The higher the lactic acid bacteria count, the more intensive the fermentation process during the storage of sausages.

4. Conclusions

The majority of traditional sausages (74.6%) are easily perishable with a high pH (5.53) and moisture content (51.33%) and high *Br. thermosphacta*, pseudomonads and yeasts count. Fresh sausages as well as sausages with a medium fat content (15–35%) have higher flavour intensity. Moisture content and high water activity as well as *Br. thermosphacta*, pseudomonads and yeasts count are considered as the ‘‘freshness index’’ for traditional sausages. Flavour is the ‘‘main quality index’’ while very low (15%) and very high (35%) fat content and high ash content are considered as ‘‘negative quality index’’.

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