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Food Chemistry 69 (2000) 259–265

Food Chemistry

www.elsevier.com/locate/foodchem

Relationships of the minerals and fatty acid contents in processed turkey meat products

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Received 25 March 1999; accepted 15 October 1999

Abstract

In this paper, the chemical composition of a set of processed foods made of turkey meat, including meatball, blanquet, hamburger, smoked chest, ham, smoked ham, roule and frankfurter, are reported. Each product was analyzed for content of saturated fats, mono- and polyunsaturated fats, non-identified fats, calcium, iron, phosphorus, magnesium, potassium, sodium and zinc. In average, fatty acids are present in approximately equivalent percent concentrations, i.e. saturated:monounsaturated: polyunsaturated ≅1:1:1. Sodium, the major mineral ranged from 681 to 1327 mg per 100 g of processed meat. Iron and calcium concentration ranges were 0.4–2.2 and 3.0–43.6 mg/100 g, respectively. The results were analyzed by the multivariate techniques, hierarchical cluster analysis (HCA) and principal component analysis (PCA). It was shown that HCA can group all the samples, according to their types, and into some extent also according their basic composition (only dark meat, white meat, meat with shortening added and frankfurter as single cluster). On the other hand PCA could better expose the relationship between the products according to their fatty acids and mineral composition. PC_1 discriminates fatty/lean products, while PC_2 discriminates the frankfurters by its content of salts added, Ca and Fe from milk and soy, all added during processing, and finally PC_4 which discriminates the white/dark meat products through Zn concentration from dark meat.

Keywords: Minerals; Fatty acids; Turkey meat; ICP–OES; Chemometrics; Principal component analysis

1. Introduction

It is fairly well established that there is a close relationship between diet and health. More and more people are aware that a balanced diet can benefit their health and are becoming very concerned about the chemistry of what they eat. Consequently, the food industry is interested in maintaining a high standard of quality of their manufactured products which could meet the demands of an increasing sophisticated consumer. An important issue thereof is the determination of food composition and the establishment of analytical controls.

In his book, Margen (1992) pointed out that an estimated 40% of all cancer incidences in men and 60% in women are related to diet. For many years, a fat-rich diet has been considered a major cause of atherosclerosis and cardiovascular diseases. In order to lower the rates of heart diseases, cardiologists and nutritionists advise consumers to reduce the overall intake of saturated fatty acids which is thought to stimulate the production of low density lipoproteins (LDL, also known as bad cholesterol). Additionally, consumers are advised to increase the overall intake of monounsaturated and polyunsaturated fats which help to lower the amount of LDL cholesterol (Gotto, LaRosa, & Hunninghake, 1990; Kannel, Doyle, Osfeld et al., 1984; National Research Council, 1989)

The minerals that act as nutrients in the body are absolutely essential to a host of vital processes, from bone and tooth formation to the functioning of neurological and digestive systems and the heart (Coutinho, 1981; Crosby, 1977). In recent years, scientists have been paying a great attention to minerals and are looking for links between them and major chronic diseases. As

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0308-8146/00/$ - see front matter
PII: S0308-8146(99)00259-9

Margen (1992) pointed out, there are more than 60 minerals in the body, but only a few are considered to be essential, among them, iron, calcium, zinc, magnesium, phosphorus, sodium, potassium, manganese, selenium, copper, etc.

In the past, turkey was regarded as a once a year treat but nowadays more and more people are aware of turkey's low cost and low fat compared to "red meat" and are making it a part of their regular diet. Turkey is one of the leanest types of poultry (10% fat), and a good source of protein and of minerals such as sodium, potassium and iron.

We conducted an experiment in which, a set of 40 samples consisting of eight different types of processed turkey meat was analyzed according to two different experimental methods. Fatty acids (saturated, mono-, polyunsaturated and nonidentified) and seven different minerals were quantified by chromatography and inductively coupled plasma optical emission spectrometry (ICP–OES), respectively. Principal component analysis (PCA) and hierarchical cluster analysis (HCA) are multivariate statistical methods, which are becoming very popular and used mainly to examine data structure and interpret patterns of influence (Morgano, Ferreira, Serafim, Silva & Mantovani, submitted; Morgano, Queiroz & Ferreira, in press) In this work, PCA and HCA were performed aiming to explore the relationships between the basic composition of the various processed products and their chemical composition.

2. Materials and experimental methods

Eight types of processed turkey products were analyzed: meatball (M), blanquet (B), hamburger (Hb), smoked chest (SC), ham (H), smoked ham (SH), roule (R) and frankfurter (F). The basic composition of each product is listed in Table 1. Each of them was analyzed for saturated fatty acids (Saturated), monounsaturated (Mono-unsat), polyunsaturated (Poly-unsat) and non-identified (N-ident) fatty acids, calcium (Ca), iron (Fe), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na) and zinc (Zn).

Five different samples of each commercial product (same manufacturer) were analyzed in three replications of the same manufacturing date, except the frankfurter, which was produced on consecutive days. For statistical analysis, 15 tests were performed for each product.

2.1. Chemicals

All chemical products were purchased from Merck KGaA (64271 Darmstadt, Germany). Calibration standards of mineral elements were obtained from Titrisol Merck, 1 g/L of Ca, Fe, P, Mg, K, Na and Zn. The deionized water from Milli Q Plus System, Millipore.

Nitric acid 65% was reagent grade. The following solutions were prepared using reagent grade substances: chloroform/methanol 2:1 (v/v); aqueous solution 0.72% (w/v) of sodium chloride; saturated solution of sodium chloride in water. Saponification reagent was sodium hydroxide/methanol 2:98 (w/v) and the reagent for esterification ammonium chlorine/sulfuric acid/methanol 2:60:3 (w/v/v). Petroleum ether was also a reagent grade.

2.2. Determination of fatty acids

Fatty acids extraction was done according to the method of Bligh and Dyer (1959). Ten g sample was extracted using 200 ml chloroform/methanol 2:1 (v/v) solution, by blending in Waring blender for 2 min, then filtered and transferred to a 500 ml separatory funnel. The extract was washed with 50 ml chloroform and 40 ml potassium chloride solution 0.72%. The phases were separated and the process repeated. The organic phase was concentrated in a rotatory evaporator and followed by esterification.

Table 1
Basic composition of eight kinds of processed turkey products

Product	Protein	Fat	Carbohydrate/seasoning
Meatball (M)	White meat from breast Dark meat from drumstick	Shortening	Breadcrumb
Blanquet (B)	White meat from breast	Turkey fat	Starch (max. 2%), salt, sugar, natural spices
Hamburger (Hb)	White meat from breast, vegetable protein Dark meat from drumstick	Shortening	Natural spices, salt and powder milk
Smoked chest (SC)	White meat from breast		Sugar and salt
Ham (H)	Dark meat from drumstick		Salt and corn syrup
Smoked ham (SH)	Dark meat from drumstick		Salt and corn syrup
Roule (R)	Dark meat from drumstick		Salt, starch (max. 2%), and natural spices
Frankfurter (F)	Turkey meat, mechanically separated poultry meat, soy protein		Milk serum, starch, corn syrup and natural spices

Esterification was done according to the method of Hartman and Lago (1973). Saponification reagent (5 ml) was added to 0.50 g fatty acid in a 50 ml volumetric flask and this mixture heated at 65–75°C for 15 min. After the addition of esterification reagent, the solution was heated for additional 10 min. The extract was frozen, 2 ml of petroleum ether was added, the volume completed with a saturated solution of sodium chloride and mixed in a shaker. The fatty acids were identified and quantified by gas chromatography using normalization areas.

2.3. GC system

The chromatographic system consisted of a FID (Pye Unicam PU 4550 Philips) and a separation column Chrompack WCOT fused silica column 50 m × 0.250 mm, CP-Sill 88 stationary phase, i.d. 0.2 μm (Chrompack, The Netherlands). The chromatographic conditions were: carrier gas/make up: hydrogen WM 4.4 FID and synthetic air WM 4.7 FID; amplificator: range = 102, and attenuation = 16; integrator: Pye Unicam 4811 (Philips); chart speed: 0.5 cm/min and attenuation: 1. Pressure and flow used were, respectively: hydrogen inside the column: 17 psi, 2.5 ml/min; hydrogen in the flame: 4 bars, 23 ml/min; synthetic air: 4 bars, 280 ml/min; splitter: 240 ml/min. Temperatures used were 270°C for the injector; 300°C at the detector; with the column maintained at 180°C.

2.4. Determination of mineral elements calcium, iron, phosphorus, magnesium, potassium, sodium and zinc

Samples of mineral elements (2.0000 g) were ashed in furnace at 450°C for 12 h, using the method of AOAC (1980). The ash was dissolved in 2.5 ml concentrated nitric acid and diluted to 50 ml with deionized water. The analytical curve was plotted for each element: calcium, phosphorus and sodium (from 1 to 30 mg/100 g), magnesium (from 1 to 20 mg/100 g), potassium (from 5 to 50 mg/100 g), iron and zinc (from 0.05 to 0.5 mg/ 100 g).

The mineral elements were quantified by ICP–OES.

2.5. ICP–OES system

The 2.000 BAIRD model, simultaneous version, was the ICP–OES system used. The ICP conditions were: radio frequency generator 40 MHz; power 1000 W; nebulizator pneumatic concentric; torch conventional (low flow); flow rate gas in the plasma 14 l/min, flow rate argon auxiliary 0.7 l/min; flow rate argon of refrigeration 0.7 l/min; flow rate sample 2.0 mL/min. Lines of emission were: calcium 317.92 nm; iron 259.94 nm; phosphorus 178.28 nm; magnesium 279.08 nm; potassium 766.49 nm; sodium 579.59 nm; zinc 213.86 nm.

3. Data analysis methods

In this work, data analysis were performed using the software PIROUETTI 2.2 (Infometrix, Seattle, WA).

Most chemical applications of data analysis are by nature multivariate and the most suitable methods for such cases are PCA (Malinowski, 1991; Sharaf, Illman & Kowalski, 1986) and HCA (Hartigan, 1975; Sharaf et al., 1986).

The hierarchical cluster analysis (HCA)'s primary goal is to display the data in such a way as to emphasize their natural clusters and patterns in a two dimensional space. The results, qualitative in nature, are usually presented in a form of a dendogram, allowing the visualization of clusters and correlations among samples or variables. In HCA, the Euclidean distances between samples or variables are calculated and transformed into a similarity matrix whose elements are similarity indexes ranging from 0 to 1; a smaller distance means a larger index and therefore, a larger similarity.

PCA, on the other hand, is based on the correlation among variables. It maps samples through scores and variables by the loadings in a new space defined by the principal components. The PCs are simple linear combination of original variables. Scores plots allow sample identification, checking if they are similar or dissimilar, typical or outlier. The most important variables are identified from the loadings. An important point here is that maximum variability in the data set can be explained in a reduced variable set. The first principal component, PC_1, is defined in the direction of maximum variance in the data set, and the subsequent components are orthogonal (uncorrelated) to one another and maximize the remaining variance. Once the redundancy is removed, only the first few principal components are required to describe most of the information contained in the original data.

Interpretation of the loadings vectors (PCs) obtained through PCA become often easier when they are rotated to better match with the original variable's directions. This procedure, called Varimax Rotation (Sharaf et al., 1986) maximizes the variance in each PC. The final effect of this rotation is to decrease the effect of those variables with intermediate loadings and increase the effect of those with large (positive and negative) loadings in each factor.

4. Results and discussion

From the experimental results (Table 2), it can be seen that the fatty acids are present in equivalent concentrations for some products such as ham, smoked ham and smoked chest. However, in general, the polyunsaturated fats appear in lower levels when compared to other fatty acids. Monounsaturated and saturated fat concentrations

Table 2
Mean values and standard deviations of chemical analysis in the turkey products

	Frankfurter	Roule	Ham	Smoked ham	Blanquet	Smoked chest	Hamburger	Meatball	Mean	%RDA[a]
Saturated fat (%)	31.8 ± 0.65	34.13 ± 0.82	33.94 ± 0.54	33.61 ± 0.41	32.49 ± 0.29	32.08 ± 0.10	38.34 ± 0.43	41.07 ± 1.06	34.7	
Mononunsaturated fat (%)	46.10 ± 1.18	35.54 ± 0.71	35.55 ± 0.73	32.99 ± 0.72	43.72 ± 0.47	32.08 ± 0.74	38.85 ± 0.35	40.92 ± 0.48	38.2	
Polyunsaturated fat (%)	21.78 ± 1.31	26.93 ± 3.98	29.23 ± 1.13	32.22 ± 0.73	22.45 ± 0.50	32.17 ± 0.42	22.21 ± 0.33	17.65 ± 1.33	25.6	
Non-identified (%)	0.37 ± 0.05	1.33 ± 0.17	1.04 ± 0.03	1.17 ± 0.15	0.70 ± 0.02	2.44 ± 0.03	0.42 ± 0.10	0.27 ± 0.06	1.0	
Calcium (mg/100 g)	43.59 ± 0.05	6.44 ± 0.17	4.02 ± 0.03	2.96 ± 0.15	3.53 ± 0.10	4.12 ± 0.03	16.55 ± 0.10	7.57 ± 0.70	11.1	1.4
Magnesium (mg/100 g)	20.31 ± 0.74	17.82 ± 0.59	18.57 ± 0.28	17.16 ± 0.60	19.03 ± 0.28	25.22 ± 0.37	25.38 ± 0.47	18.94 ± 0.656	20.3	6.8
Iron (mg/100 g)	2.24 ± 0.09	0.86 ± 0.09	1.14 ± 0.05	0.95 ± 0.06	0.49 ± 0.02	0.70 ± 0.06	1.12 ± 0.03	0.88 ± 0.04	1.1	7.8
Phosphorus (mg/100 g)	207.56 ± 6.64	396.96 ± 21.08	329.67 ± 12.69	310.97 ± 5.37	337.95 ± 15.27	361.32 ± 15.08	208.21 ± 4.73	123.56 ± 7.07	284.5	35.6
Sodium (mg/100 g)	1327.11 ± 33.09	935.39 ± 16.52	934.56 ± 39.33	714.51 ± 50.00	995.12 ± 43.58	788.10 ± 8.17	680.97 ± 21.57	688.34 ± 23.78	883.0	[b]
Potassium (mg/100 g)	210.62 ± 0.08	225.57 ± 0.08	250.42 ± 0.05	219.83 ± 0.06	225.41 ± 0.02	299.37 ± 0.06	309.87 ± 0.03	237.80 ± 0.04	246.2	[c]
Zinc (mg/100 g)	1.28 ± 0.12	2.32 ± 0.19	3.63 ± 0.04	2.51 ± 0.09	0.85 ± 0.08	1.37 ± 0.22	1.52 ± 0.06	1.31 ± 0.05	1.8	12

[a] RDA: Ca = 800 mg; Mg = 300 mg; Fe = 14 mg; P = 800 mg; Zn = 15 mg.
[b] Recommended: minimum 500 mg/day; maximum 2400 mg/day.
[c] Recommended: minimum 1600 — 2000 mg/day; maximum 3500 mg/day.

appear with approximately the same range of concentrations (32–46%). The last two columns in Table 2 contain the average values for all products and the daily-recommended values (% RDA) based on a 2000-calorie diet. The average percent values for the fatty acids are 34.7, 38.2 and 25.6% for saturated, monounsaturated and polyunsaturated, respectively. It can be said that in general these turkey products are in agreement with the recommended of 1:1:1 ratios. Sodium is the major mineral, with average concentration ranging from 681 to 1327 mg/100 g, being especially high for the frankfurter, probably due to salt addition during the processing. It is well known that nitrite and nitrate salts are commonly added in curing mixtures for meats to develop and fix color, to inhibit microorganisms and to develop characteristic flavors (Lindsay, 1996). Calcium is still another mineral, which varied from one product to the other and ranged from 3 mg/100 g for blanquet to 44 mg/100 g for frankfurters. These are very low values, compared to the recommended dietary allowances (RDA) of 800 mg proposed by the Committee on Dietary Allowance Food and Nutrition Board (1989); hence, these meat products are not good sources of dietary calcium. Iron and zinc, which have RDA of 14 and 15 mg, respectively, are present in low and similar concentrations, at the order of approximately 1 mg/100 g. Magnesium is another mineral with uniform concentration in all products, but in the range of 20 mg/100 g. Note that the average value of sodium concentration (883.0 mg/100 g) is much higher than that of potassium (246.0 mg/100 g) leading to a Na:K ratio of 3.6:1. The recommended Na:K ratio is 1:1. Also, the % RDA proportion of phosphorous to calcium (35.6:1.4) greatly exceeds the 2:1 recommended ratio. From the % RDA values obtained it can be concluded that the processed turkey products studied here are not good sources of those minerals analyzed and should not be considered as a significant daily source of them.

To better understand the relationships among the basic composition of each trait based in their mineral and fatty acids content, the experimental results are analyzed using the multivariate methods HCA and PCA described above.

The original data set to be analyzed, [X = (40,11)], consists of 11 variables measured in 40 samples, (eight products, five each), where each matrix entry is an average value of three replications. The data were autoscaled prior the analysis.

HCA results are shown in Fig. 1. In this dendogram there are mainly six groups for similarity 0.7 approximately. All samples from each product are grouped showing no mixing in different types of meat. The frankfurters (F) make a unique cluster, indicating that their chemical composition is quite different from the other meats, which might be expected since it has a distinct basic composition (Table 1) among them. The

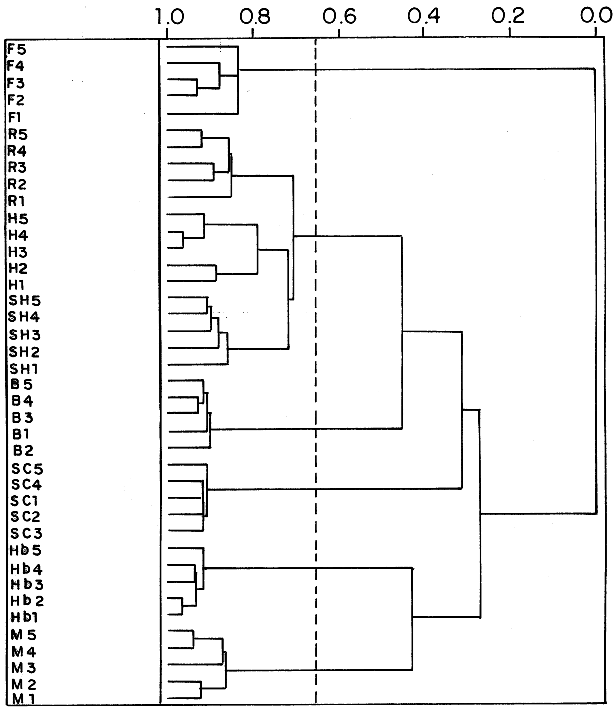

Fig. 1. Results of HCA on eight different kinds of turkey processed meats: (M) meatball, (B) blanquet, (H) hamburger, (SC) smoked chest, (H) ham, (SH) smoked ham, (R) roule and (F) frankfurter.

main group consists of one cluster with very similar samples including the smoked ham (SH), ham (H) and roule (R) products. These are products that have only dark meat from drumstick and basically the same basic composition (Table 1). Meatballs (M) and hamburgers (Hb) are spatially apart from the main group and form one cluster for similarity index of 0.45. They have in their composition white and dark meat, the main difference being in the vegetable protein added to H and their carbohydrate composition (Table 1). The blanquet (B) and the smoked chest (SC) form two other groups of processed white meat where B is a subgroup of the main one. That could be explained by the fat and starch added during the processing.

Analysis of the varimax-rotated PCA yielded similar trends and characteristics shown in HCA but with the advantage that the correlation between variables and samples becomes clearer. Table 3 contains the rotated loadings for the first principal components with their variances. PC_1 includes 30.58% of the variance in the data set and the loadings indicate that it has significant contribution from fatty acids (except monounsaturated), and phosphorus. The second PC, describes 28.98% of the total variance and has high positive loadings for the minerals Ca, Fe and Na. These correlations are confirmed through HCA of variables, which are shown in Fig. 2. The third principal component (20.22% of total variance) is described by Mg and K, which are also correlated (Fig. 2). The fourth PC spanning 18.10%

Table 3
Loadings for the first four varimax rotated PCs

Components	PC_1	PC_2	PC_3	PC_4
Saturated	**−0.48**	±0.18	0.12	0.01
Mono-unsat	−0.26	0.30	−0.22	**−0.47**
Poly-unsat	**0.44**	−0.13	0.66	**0.42**
Non-identified	**0.46**	−0.19	0.22	0.16
Ca	−0.12	**0.53**	0.02	−0.17
Mg	0.02	0.06	**0.64**	−0.19
Fe	−0.11	**0.54**	−0.02	0.08
P	**0.49**	−0.17	−0.09	0.15
Na	0.15	**0.43**	−0.26	−0.18
K	0.00	−0.16	**0.62**	0.03
Zn	0.09	−0.03	−0.12	**0.67**
Variance explained	131.17	124.32	86.76	77.66
% of total variance	30.58	28.98	20.22	18.10
Cumulative variance	30.58	59.56	79.78	97.88

The most significant loadings are highlighted in bold face.

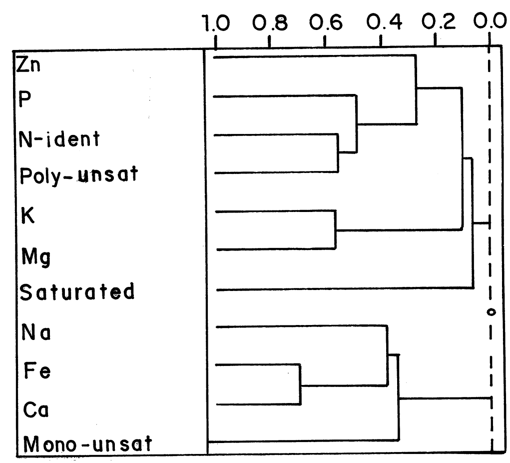

Fig. 2. Dendogram (HCA) for variables. (Saturated) saturated, (Mono-unsat) polyunsaturated and (N-ident) non-identified fatty acids; (Ca) calcium, (Fe) iron, (P) phosphorus, (Mg) magnesium, (K) potassium, (Na) sodium and (Zn) zinc.

contains significant contribution of unsaturated fats and zinc. Together, these four PCs account for almost 98% of the total variance in the data.

Figs. 3 and 4 display the varimax rotated scores and loadings. The first two rotated PCs (Fig. 3) show definite clusters for M, Hb and SC (fatty/lean products) and F products respectively, while PC_4 (Fig. 4) separates the B, R, SH and H products. PC_1 loadings (Fig. 3) which is mainly of fatty acids and P, discriminates the meatballs and hamburgers with negative scores, characterized for having a higher content of saturated fats, but lower polyunsaturated and non-identified fatty acid and SC in the other side with positive scores. That can be expected since SC has only white (the leanest) meat in its basic composition while M and Hb have white/dark meat besides the added shortening (Table 1). The PC_2 scores and loadings in Fig. 3 show that F (positive scores in PC_2) forms a unique group for its high concentration in

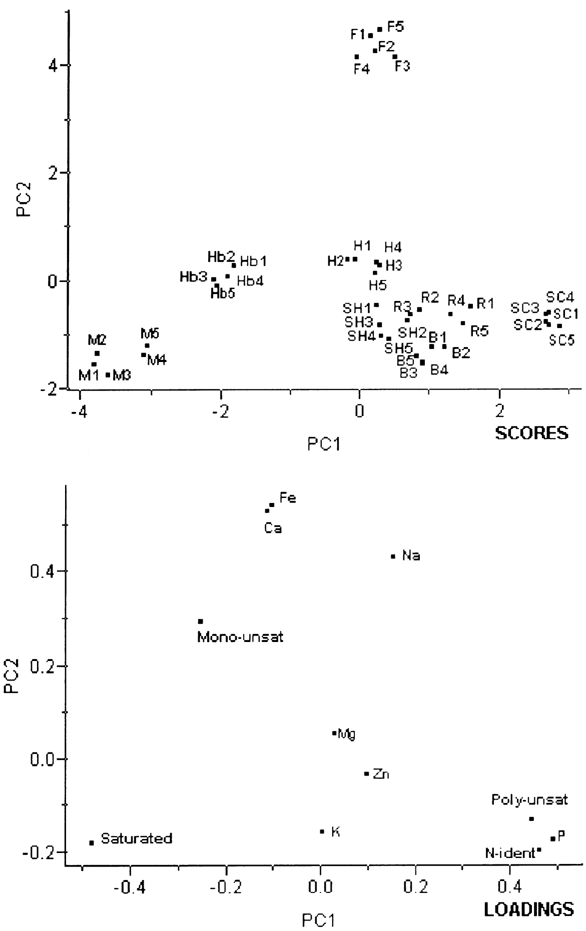

Fig. 3. Varimax rotated scores and loadings plots for the first two PCs.

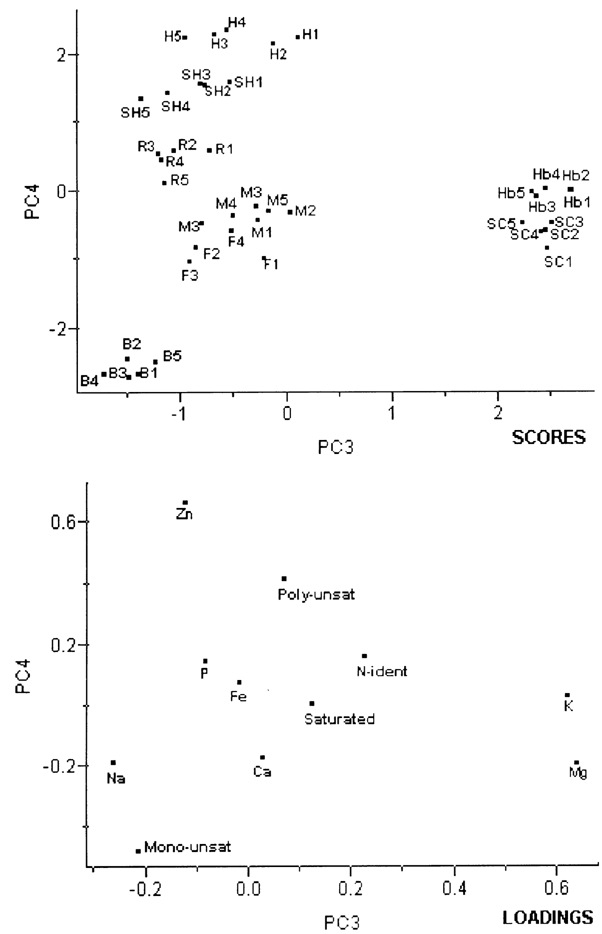

Fig. 4. Varimax rotated scores and loadings plots for PC_3 and PC_4.

Fe (probably due to soy addition in its composition), while Ca (probably resulting from addition of serum milk and soy products) (Table 1) and Na, due to addition of nitrites and nitrates as previously mentioned. F has also low concentration on saturated, polyunsaturated and non-identified fatty acids when compared to the other products (no fat has been added during the processing).

In the PC_3 and PC_4 scores plot (Fig 4), a nice discrimination of white/dark meat products is obtained in PC_4. Blanquet that contains only white meat has negative scores, while products R, SH and H made only of dark meat, has positive scores. Higher concentration of Zn in the dark meats is one of the main reason for this discrimination. It can be seen from Fig. 4 that monounsaturated fats have also high negative loadings in PC_4 indicating a higher content of monounsaturated fats in blanquet due to addition of turkey fat in its composition. The Hb and SC groups have high positive scores on PC_3 due to the influence of K and Mg. These higher contents of K found in Hb and Sc are probably related with additives such as potassium thiosulphate and soy protein hydrolysate, intended to improve water absorption. The high level of Mg in Hb is probably associated with addition of soy protein and or seasonings.

In summary, this work presents the chemical composition of different processed turkey meats according to their composition on fatty acids and seven different minerals. In average, the fatty acids follow the recommended percent ratio of saturated:monounsaturated: polyunsaturated $\cong$ 1:1:1. The seven minerals analyzed are present in low RDA%, showing that the turkey products studied should not be considered as significant daily sources of such minerals.

The variations of their minerals and fatty acids composition were analyzed as a whole using multivariate methods HCA and PCA. The first principal component is related to fatty acids, and discriminates products that have shortening added (M and Hb), from smoked ham which is the leanest and has only white meat in its composition. The second PC describes the frankfurter with high content of Fe, Na and Ca due to milk, soy and salts added. PC_3 describes two more minerals, Mg and K, found probably as a result of additives added during the processing, and the fourth principal component discriminates white/dark meats through Zn concentration and monounsaturated fats. All these results are not easily seen by examining each variable individually especially when the range of values is narrow; PCA analysis has been shown to be an essential tool for this purpose.

Acknowledgements

The authors acknowledge the financial support from CNPQ and FAPESP for this work.

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