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Comparative Assessment of the Mineral Content of a Latin American Raw Sausage Made by Traditional or Non-Traditional Processes

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1. Introduction

Mineral content of food in general, and of meat and meat products in particular, has been widely studied mainly due to its essential role in human nutrition and implication on safeness issues, i.e., mineral toxicity and deficiencies. Furthermore, since a few decades ago, instrumental analytical techniques based on atomic absorption or emission spectrometry applied to the determination of the mineral content coupled to multivariate statistical analysis have been proved to produce suitable methods to characterise food products, discriminate between food quality categories and control food authenticity, i.e., determination of the geographical origin of food, discrimination between cultivation methods (e.g. organic vs convenience crops), varieties of fruits and vegetables, or food processing practices (Grembecka et al., 2007; Kelly & Bateman, 2010; Luykx & van Ruth, 2008; Sun et al., 2011).

Inductively coupled plasma-atomic emission spectroscopy (ICP-AES) is a prevailing instrumental technique utilised for the simultaneous determination of a considerably high number of metals and some non-metals in biological samples at ppm or ppb levels. As well as in AES conventional techniques, in ICP-AES technique, analyte atoms in solution are aspirated into the excitation region where they are desolvated, vaporised, and atomised, and finally the optical emission measurement from excited atoms is used to determine analyte concentration. However, ICP-AES provides higher reproducibility and quantitative linear range compared to conventional AES, and reduces molecular interferences due to a higher temperature (7000–8000 K) in the excitation source (plasma). On the other hand, ICP-AES is more expensive than conventional AES, and in complex samples emission patters can be of difficult interpretation (Ibáñez & Cifuentes, 2001; Luykx & van Ruth, 2008).

There is a wide variety of meat products all over the world and, among them, fresh sausages represent an important part. Two types of fresh sausages can be found in shops or markets: emulsion-type and minced comminuted meat products. Fresh sausages are sold without having suffered any heat treatment, and they are generally stored and commercialised chilled or frozen (Feiner, 2006). However, many times, in Latin America fresh sausages are slightly dried at room temperature during some hours as part of the making-process and afterwards the sausages are stored and commercialised for short periods (few days) at room temperature, without the use of the cool chain. During those periods additional drying and lactic acid fermentation can take place (Kuri et al., 1995). In this case, sausages can be considered to be raw-semidry sausages instead of fresh sausages.

Meat products are generally made from various meat and non-meat matters (from different origins and suppliers), which are combined at the formulation stage in obedience to criteria of composition, technological factors, sensory characteristics, legal regulations, functionality and also production cost (Jiménez-Colmenero et al., 2010). In view of that, fresh sausages (and eventually the raw-semidry sausages derived from them) are made from different types of meat such as beef, pork, mutton, chicken, turkey, etc. and usually pork fat or fatty tissues. Moreover, numerous non-meat ingredients (salt, herbs, spices, juices, vinegar, etc.) and additives (nitrites, phosphates, sorbates, etc.) can be added depending on each sausage type, geographical traditions or manufacturing practices (Feiner, 2006).

Current fresh sausage making process includes both traditional and non-traditional methods. On the one hand, there is an increasing attention in natural products, sometimes proceeding from a particular region, elaborated according to traditional methods. On the other hand, the demand for non-traditional commercial food products is steadily increasing due to different factors, namely, cheapness, extended-shelf life or convenience. Variations in meat and non-meat ingredients and the processing conditions, with respect to traditional methods, can result in changes in nutritional composition. In order to avoid drastic and negative impact on consumers, those changes are controlled or limited by regulations. As common examples, the fat (maximum) and lean meat (minimum) content is generally legally established in most countries. Furthermore, usually it is required a minimun protein content; however, proteins could originate from meat or cheaper sources such as wheat gluten or soy protein (Feiner, 2006). In this way, low cost sausages are largely sold in many countries.

Chorizos are sausages extremely popular in Latin American countries. These sausages can be considered as variations of those that were brought to America by colonizers, usually Iberians (Mateo et al., 2008). In fact, at present there are sausages in Spain (chorizo) or Portugal (Chouriço) that resemble those from Latin America and vice versa. Chorizos are usually made from pork meat and fat. Grounded meat and fat are normally added and mixed with salt, herbs and spices and, optionally, vinegar or lemon juice, sugar and suitable additives (curing agents, phosphates, etc.). Finally, the mixture is stuffed into casings, commonly natural casings. Chorizos are made with different herbs and spices in different Latin American regions, with garlic, clove, cumin and dry *Capsicum spp*. fruits (named as chile) being typically used in Mexican chorizo. Once stuffed, these sausages are dried for a short period of time (from fours to few days) at room temperature before selling or consuming.

The mineral content of fresh or raw-semidry chorizo is the result of the sum of the contributions from all the ingredients, i.e., lean meat, fatty tissues, common salt, dry *Capsicum* spp. fruits, textured soy flour, etc., and additives included in their formulations. In order to better ascertain the eventual contribution of ingredients to the mineral content of chorizo, the mineral composition of the main ingredients used in chorizo making process is shown in Table 1. Moreover, mineral content can be further increased due to the solute concentration by evaporation which takes place during an eventual drying.

Lean meat is the main ingredient of a sausage and therefore the mineral composition of a raw sausage it is closely related to the meat content. Meat is considered as a significant dietary source of several minerals, specifically highly-available Fe and Zn (Hazell, 1982; McAfee et al., 2010). The mineral content of meat is rather stable under conditions of normal supply (average mineral composition of raw lean pork is shown in Table 1); however, this depends on pre-mortem factors such as animal genetic, physiological and environmental, e.g., age and feeding (Jiménez-Colmenero et al., 2006), and post-mortem factors such as meat cuts, meat processing and preparation (Jiménez-Colmenero et al., 2010; Lombardi-Boccia et al., 2005). Fat is the second ingredient in importance of sausages. Conversely, compared to meat, the contribution of fat to the mineral content of a sausage is poor due to the relatively low mineral content in fat or fatty tissues (Table 1).

Regarding the non-meat ingredients, common salt is the major source of Na in sausages. Apart from Na, common salt contains other minerals but at trace levels (Table 1). Nevertheless, common salt can be a notorious source of Mg or Ca because these mineral salts are on occasion added to common salt as anti-caking agents at the food industry level. Dry *Capsicum* spp. fruits (in paste or powdered form) are extensively used in Latin American and also Iberian raw sausages. The amount usually added in chorizos is approximately 2-3% of the weight of the initial mixture of sausage. An addition of dry capsicum fruits at that amount represents an appreciable source of some mineral elements, i.e., Mg, Ca, Fe and Mn, in sausage mixtures (Aguirrezábal et al., 1998; Fonseca et al., 2011).

Textured soy flour is used as filler or meat extender in a large variety of commercially prepared meat products. The use of soy-derived ingredients results in increased yields and lower cost of production (Hoogenkamp, 2008). The amount of soy flour added to those meat products range from 2 to 10% (Rocha McGuire, 2008). In Mexico, the use of textured soy flour in raw sausages is common, particularly in low-cost sausages commercialized in wholesale markets (Personal communication: technical personnel, Fabpsa Corporation, www.fabpsa.com.mx). In accordance with the mineral content of textured soy flour (Table 1) and the amount used, the contribution of this ingredient to the levels of some minerals, i.e., Ca, Mg, Cu and Mn, in raw sausages appears to be relevant. Finally, the additives commonly used for commercial fresh sausages (Feiner, 2006), such as antioxidants (erythorbate or ascorbate), preservatives (nitrite, sorbate) or others (phosphates, etc.) provide Na, P and K to the raw sausages.

	Pork Lean	Pork Backfat	Salt	Paprika, Dry *Capsicum annuum*	Defatted soy flour
Sodium	59	11	38758	68	20
Potassium	364	65	8	2280	2384
Phosphorus	217	38	0	314	674
Calcium	13	2	24	229	241
Magnesium	24	2	1	178	290
Zinc	2.2	0.4	0.1	4.3	2.5
Iron	0.8	0.2	0.3	21.1	9.2
Copper	0.1	0.0	0.0	0.7	4.0
Manganese	0.0	0.0	0.1	1.6	3.0

Table 1. Mineral composition of main ingredients used in Mexican chorizo (mg/100 g; Source: USDA, 2010)

As far as the authors are aware, there is great interest about the usefulness of mineral content analysis in meat industry. Apart from nutritive and safety issues, to assessing the differences in minerals between sausages from different qualities could reflect fraudulent manufacturing practices. The aim of the present study is therefore to determine the mineral composition of a popular Latin American raw sausage (Mexican chorizo) using ICP-AES, and to compare the mineral contents between sausages made using traditional and those made using non-traditional making processes in order to explore differences between both groups regarding nutritive value and discrimination purposes.

2. Material and methods

2.1 Samples and sampling procedure

Forty sausages belonging to two different groups (twenty per group) were used in the present study. One group consisted of Mexican chorizos elaborated in a traditional manner by small-sized producers (traditional sausages) and the other was comprised of mass-produced commercial Mexican chorizos (non-traditional sausages).

Ten samples of sausages from the first group were purchased from randomly-chosen butcheries in the Hidalgo State largest cities: Tulancingo and Pachuca (approximately 150 and 300 thousands inhabitants, respectively). The sausages from this type were locally produced by the butchers. The other ten traditional sausages sampled were purchased from rural street markets in ten randomly-chosen small villages (5 to 20 thousands inhabitants) in Hidalgo State (one sample per village). These were homemade sausages which were produced by local small-sized farmers.

On the other hand, ten out of the twenty samples of the non-traditional sausages were purchased from supermarkets at Tulancingo and Pachuca cities. These sausages were manufactured by nationwide companies and were characterised by their long shelf life. The other ten samples were purchased from wholesale large-city markets in Tulancingo, Pachuca and Mexico City. The sausages were manufactured by ten different medium-sized companies to be sold at low price. All sausage samples weighted about 1 kg each. Once taken, samples were immediately transported to the laboratory in Tulancingo, where they were first blended in a domestic food processor and then frozen and stored at -18 ºC until further analysis.

2.2 Chemical analysis

Determinations of moisture, fat, protein and ash contents in the sausage samples were performed in duplicate according to methods recommended by the AOAC International {AOAC} (AOAC, 1999) – Official Methods nos. 950.46, 991.36, 981.10 and 920.153, respectively.

The analysis of mineral composition of sausages was performed by ICP-AES on wet digested samples. Duplicate aliquots of approximately 1 g (±0.01) of the previously homogenised samples were digested with 10 ml of concentrated HNO_3 in tightly closed screw cap glass tubes for 16 h at room temperature, and then for a further 4 h at 90 ◦C. For the analysis of sodium, potassium and phosphorus, 1 ml of the mineralised solution was added with 8 ml of deionised water and 1 ml of scandium solution as internal standard. In order to determine the levels of calcium, copper, iron, magnesium, and zinc, 3 ml of the digested solution was added with 6 ml of deionised water and 1 ml of Sc solution.

The instrumental analysis was performed with a Optima 2000 DV ICP optical emission spectrometer (PerkinElmer, Waltham, MA, USA). Instrument operating conditions were: radiofrequency power, 1400 W; plasma gas flow, 15.0 l/min; auxiliary gas flow, 0.2 l/min; nebulizer gas flow 0.75 l/min, crossed flow; standard axial torch with 2.0 mm i.d. injector of silica; peristaltic pump flow, 1 ml/min; no. of replicates, 2. The spectrometer was calibrated for Cu, Mn, Zn, Fe, Ca and Mg determinations (at 224.7, 257.61, 213.9, 238.2, 393.4 and 279.6 nm, respectively) with nitric acid/water (1:1, v/v) standard solutions of 2, 5 and 10 ppm of each element, and for Na, P and K (at 589.6, 213.6 and 766.5, respectively) with nitric acid/water (1:9, v/v) standard solutions of 30, 50 and 100 ppm, respectively.

2.3 Statistical analysis

A one-way analysis of variance was performed; the values obtained for each variable (moisture, fat, protein, ash or mineral elements) on all fresh weight (FW), dry matter (DM) and nonfat dry matter (NFDM) basis were compared between groups (traditional and non-traditional) and types (as function of the place where the sausages were purchased from) of sausages. Moreover, linear correlation coefficients were calculated to describe the degree of correlation between each variable (only values expressed on DM basis were considered). A principal component (PC) analysis, unrotated method, was also performed to obtain a better perception of differences in mineral composition between the groups and types of sausages. In the PC-analysis model the contents of the mineral elements determined, except for Cu, were included. The software STATISTICA for Windows (StatSoft Inc., 2001) was used for the statistical treatment of data.

3. Results and discussion

3.1 Proximate composition

The proximate composition of the sausages studied on all FW, DM, and NFDM basis is shown in Table 2. Mean values are given for the traditional (Trad) and non-traditional (Non-Trad) sausages and for the individual types of sausages samples: Btch, traditional sausages from butcheries; RuSM, traditional sausages from rural street markets; Smkt, non-traditional sausages from supermarkets; WhCM, non-traditional sausages from wholesale city markets. The Table also shows the level of significance (*P*-level: NS, not significant; *, $P<0.05$; **, $P<0.01$ and ***, $P<0.001$) of the analysis of variance, and the standard error of the mean (SEM). Significant differences between types of sausages (Duncan-test, $P<0.05$) are marked with different superscripts. Carbohydrate content was calculated by difference.
Most of the sausages can be assigned to the category of semidry sausages according to the scheme proposed by Adams (1986), because their humidity content was inside or near the range of 40 to 50%. According to that author, weight (drying) losses for this type of sausages are estimated to be between 10 and 20%.
The variability observed within each group of sausage (as assessed by standard deviations) was high. This could be mainly attributed to large variations among samples in the amount of fat used in the sausage making process and the degree of sausage drying. In spite of the variability, statistical differences ($P<0.05$) in the proximate composition between sausage groups were observed. Traditional sausages had lower ash and carbohydrate (calculated by difference) contents than the non-traditional ones. Furthermore, protein content on DM and NFDM basis were higher in traditional than in non-traditional sausages.

	Trad n=20	Non-Trad n=20	*P*-level	Btch n=10	RuSM n=10	Smkt n=10	WhCM n=10	SEM n=40
Fresh weight								
Moisture	42.8±11.4	37.6±7.6	NS	42.9	42.7	36.5	38.7	1.6
Fat	33.4±12.0	36.7±9.0	NS	34.9	31.9	33.3	40.2	1.7
Protein	18.2±3.8	16.3±4.1	NS	16.3^{b}	20.2^{a}	19.5^{a}	13.1^{c}	0.6
Ash	2.9±0.8	3.9±1.1	**	2.8^{b}	2.9^{b}	4.6^{a}	3.2^{b}	0.2
Carbohydrate	2.7±1.8	5.4±2.6	***	3.2^{bc}	2.3^{b}	6.1^{a}	4.7^{c}	0.4
Dry matter								
Fat	57.6±11.5	58.5±10.4	NS	60.1^{ab}	53.2^{b}	52.2^{b}	64.8^{a}	1.7
Protein	33.7±12.4	26.4±6.6	*	29.6^{ab}	37.8^{a}	30.9^{ab}	21.9^{b}	1.7
Ash	5.1±1.4	6.3±1.7	*	5.0^{b}	5.2^{b}	7.3^{a}	5.3^{b}	0.3
Carbohydrate	4.5±3.1	8.8±4.4	**	5.3^{bc}	3.7^{b}	9.6^{a}	7.9^{ab}	0.7
Nonfat dry matter								
Protein	76.2±9.4	63.9±7.4	***	73.0^{ab}	79.5^{a}	65.6^{bc}	62.3^{c}	1.7
Ash	12.1±2.6	15.3±1.9	***	12.7^{b}	11.5^{b}	15.4^{a}	15.3^{a}	0.4
Carbohydrate	11.6±8.3	20.8±7.5	***	14.3^{bc}	9.0^{b}	19.0^{ab}	22.4^{a}	1.4

Table 2. Proximate composition (g/100 g) of traditional and non-traditional sausages, and of types of sausages as a function of the places where they were purchased from

Differences in ash content, assuming that common salt is the principal source of ash in sausages, are indicative of higher amounts of common salt being used in non-traditional than in traditional sausages. The amount of carbohydrate (which include lactate formed by lactic acid fermentation) found in traditional sausages (around 2-3% on FW basis) was the expected for a conventional fermented sausage, i.e., Polish sausage or summer sausage (USDA, 2010). However, the amount found in non-traditional sausages (6% on FW basis) was higher. This increase must be the result of the inclusion of hydrocolloids (gums, starches, dextrins) or other fillers in the formulations of this group of sausages (Personal communication: technical personnel, Fabpsa Corporation). Finally, the higher proportion of protein found in traditional sausages on both DM and NFDM basis is related to a higher proportion of lean meat used in this group compared to the non-traditional sausages. Lean meat is the main ingredient in sausage formulations and has a protein content relatively high, of approximately 65% of DM (USDA, 2010).

3.2 Mineral composition

Mineral composition, expressed as mg per 100 g on all FW, DM and NFDM basis is reported in Table 3. This Table shows the results found for the two groups of sausages: Traditional (Trad) and non-traditional (Non-Trad); and for the four types of sausages: Btch, traditional sausages from butcheries; RuSM, traditional sausages from rural street markets; Smkt, non-traditional sausages from supermarkets; WhCM, non-traditional sausages from wholesale city markets. The Table also shows the level of significance (*P*-level: NS, not significant; *, $P<0.05$; **, $P<0.01$ and ***, $P<0.001$) of the analysis of variance, and the standard error of the mean (SEM). Significant differences between types of sausages (Duncan-test, $P<0.05$) are marked with different superscripts.

There were statistically significant differences between both groups of sausages for practically all the minerals studied (all except for K). These differences could be attributed to variations in the ingredients and additives used, and in the dryness level of sausage samples. From the nutritional value point of view – minerals are essential nutrients –, FW-basis data provide useful information to what consumers are eating. On the other hand, DM- and NFDM-basis results could be related to type and amount of meat and non-meat ingredients and additives used in the making process and hence could be useful for sausage characterization and discrimination purposes.

	Trad n=20	Non-Trad n=20	*P*-level	Btch n=10	RuSM n=10	Smkt n=10	WhCM n=10	SEM n=40
Fresh weight								
Sodium	856±279	1287±453	***	845^{b}	867^{b}	1528^{a}	1047^{b}	68
Potassium	395±117	440±119	NS	376^{b}	414^{b}	519^{a}	361^{b}	19
Phosphorus	188±64	268±110	**	185^{b}	191^{b}	319^{a}	217^{b}	15
Calcium	36.8±22.2	60.5±34.8	*	40.5^{ab}	33.1^{b}	62.5^{a}	58.6^{ab}	4.9
Magnesium	32.2±12.9	43.0±11.4	**	28.0^{b}	36.7^{ab}	40.9^{a}	45.1^{a}	2.1
Zinc	3.32±0.81	2.64±0.71	**	3.19^{ab}	5.41^{a}	2.95^{ab}	2.33^{b}	0.83
Iron	3.05±1.14	2.47±0.45	*	2.55^{b}	3.55^{a}	2.34^{b}	2.60^{b}	0.14
Copper	-	-	-	-	-	-	0.10	-
Dry matter								
Sodium	1482±396	2063±669	**	1448^{b}	1476^{b}	2399^{a}	1727^{a}	97.6
Potassium	720±291	710±181	NS	685	755	817	602	37.8
Phosphorus	344±148	432±175	NS	336^{b}	352^{ab}	501^{a}	362^{ab}	26.3
Calcium	63.2±34.3	100±66.6	*	71.4	55.0	103.0	97.0	8.8
Magnesium	57.1±20.6	69.7±21.1	NS	49.4^{b}	64.9^{ab}	64.4^{ab}	75.0^{a}	3.4
Zinc	6.05±2.06	4.27±1.17	**	5.83^{a}	6.26^{a}	4.65^{b}	3.88^{b}	0.30
Iron	5.50±2.29	4.01±0.91	*	4.52^{a}	6.47^{a}	3.70^{b}	4.32^{a}	0.30
Copper	-	-	-	-	-	-	0.17	-
Nonfat dry matter								
Sodium	3632±1166	4997±1069	***	3839^{b}	3424^{b}	5017^{a}	4976^{a}	206
Potassium	1666±460	1717±188	NS	1668	1663	1716	1718	55
Phosphorus	787±234	1026±312	**	815^{ab}	759^{b}	1051^{a}	1003^{ab}	47
Calcium	159±101	243±131	*	180^{ab}	138^{b}	208^{ab}	278^{a}	19
Magnesium	137±54	175±55	*	126^{b}	148^{b}	136^{b}	214^{a}	9
Zinc	14.0±3.0	10.6±2.4	***	14.3^{a}	13.7^{a}	10.1^{b}	11.0^{b}	0.5
Iron	12.7±3.6	10.1±2.8	*	11.5^{a}	13.9^{a}	7.9^{b}	12.4^{a}	0.5
Copper	-	-	-	-	-	-	0.42	-

Table 3. Mineral content (mg/100 g) of traditional (Trad) and non-traditional (Non-Trad) sausages, and of types of sausages as a function of the places where they were purchased from (-: value under the detection limit; 0.1 mg/100 g)

In the sausages studied, considering the results expressed on FW basis, traditional sausages contained higher amounts of Fe and Zn, which are the mineral micronutrients most significantly related to the benefits to health of meat consumption (McAfee et al., 2010). On the contrary, non-traditional sausages presented higher Na, P, Ca and Mg levels than traditional ones. The increased levels of Na and P in the non-traditional sausages are not considered as advantageous. Excessive intake of Na derived from meat products consumption, and of P from the consumption of phosphate-added meat products have been linked to health risks: hypertension-derived pathologies and anomalous bone metabolism, respectively (Calvo & Park, 1996; Ruusunen and Poulanne, 2005).

Having into account the results expressed on DM basis, the concentrations of the mineral elements detected in the Mexican sausages (Mexican chorizos) were generally into de range of values reported for other chorizos from Latin America and Spain (Table 4): Traditional Peruvian fresh chorizo (Reyes-García et al., 2009), Spanish fresh and dry-ripened chorizo (Jiménez-Colmenero et al., 2010), and traditional Spanish dry-ripened chorizo (Fonseca et al., 2011) – all of them including dry capsicum fruits as characteristic ingredient. Furthermore, in general, chorizos had notable higher levels of Na, K, Mg and Fe than those reported for a mixture of ground pork, lean and fat (USDA, 2010; Table 4), at a similar percentages than that used in sausage making (72% to 28%, respectively). This could be explained by the presence, apart from lean and fat, of non-meat ingredients, i.e., salt and spices, and additives, in the sausage mixtures. Moreover, comparing the mineral content of ground pork, lean and fat (Table 4), with that of the traditional and non-traditional Mexican sausages (DM basis; Table 3), it can be noted that the composition of non-traditional sausages was more distant from ground pork than that of traditional sausages. This leads to the suggestion that the first type of chorizo would include larger proportions of non-meat ingredients and additives than the second group.

	Traditional Peruvian fresh chorizo	Spanish fresh chorizo	Spanish dry-ripened chorizo	Traditional Spanish dry-ripened chorizo	Ground pork, raw (72% lean/28% fat)
Sodium	1401	2364	1675	2504	157
Potassium	Nd	842	593	1106	404
Phosphorus	311	Nd	Nd	431	300
Calcium	117.4	19.7	22.7	27.4	36.4
Magnesium	Nd	50.6	32.3	58.2	29.5
Zinc	Nd	5.5	3.0	7.4	4.3
Iron	8.4	2.5	2.1	3.5	2.0

Table 4. Mineral composition (mg/100 g of dry matter) of several Latino American and Iberian sausages (chorizos) which include dry capsicum fruits as characteristic ingredient, and of ground pork (Nd: Not determined)

As shown in Table 3, non-traditional sausages had higher levels (on DM basis) of Na and Ca and lower of Zn and Fe than the traditional counterparts. When results were expressed on a NFDM basis, the differences between both groups were more pronounced than when results were expressed on DM. This is because there was considerable variation in the fat content of sausages, and mathematically removing the fat from the dry sausage eliminates the fat dilution effect on mineral contents – fat is the ingredient with lower mineral content. Thus, differences between traditional and non-traditional sausages when results being expressed as NFDM, were detected for all the mineral elements except for K. Non-traditional sausages had higher amounts of Na, P, Ca and Mg and lower of Zn and Fe than traditional sausages – differences in Na and Zn being the more statistically significant (*P*<0.001; Table 3).

Differences between the two groups of sausages regarding Na content can be explained considering that higher salt amounts are usually used in non-traditional making processes. A similar trend to that of Na was observed for P concentrations. Physiological P of animal tissues is a constituent of protein structures, and its concentration in meat products may be estimated from the concentration of protein. P to protein content ratio has been estimated as approximately 0.01 for pork (Tyszkiewicz et al., 2001). Consequently, the ratio found in traditional sausages was 0.010 (0.011 in sausages purchased from butcheries and 0.009 in those purchased from rural street markets; data not shown in Tables). However, the mean ratio in non-traditional sausages was 0.016 in the sausages from supermarkets and 0.017 in those from wholesale city markets. The addition of phosphates and textured soy flour (a non-meat proteinaceous ingredient with high P content), that are frequently used in commercial sausage making (Feiner, 2006; Personal communication: technical personnel, Fabpsa Corporation), could be responsible for the higher P concentrations in non-traditional sausages. The phosphate addition to meat products is regulated by national and international standards, for example, USDA-FSIS (2007), EC (1995), or the Codex Alimentarius (2009). As an illustration, the maximum level of addition of phosphates, as established by the European Union (EC, 1995), is 5 g/kg (expressed as P_2O_5). With respect to the textured soy flour, its P to protein ratio is higher than that of meat and has been calculated to be 0.015 (USDA, 2010).

The concentrations of Ca and Mg were also higher in non-traditional sausages and among them those from wholesale city markets (sausages commercialized at the lowest cost) contained the higher amounts. Those increased concentrations could be related to the use of the following ingredients: mechanically recovered meat (residual meat recovered using mechanical equipment from animal bones), texture soy flour and/or mineral fillers. Mechanical recovered meat is cheaper than convectional meat and, thus, its use in sausages is aimed to decrease production costs. Mechanically recovered meat has higher Ca content than the conventional manually deboned meat, from 40 to 500 mg depending on the raw matter and equipment used (Newman, 1981; USDA, 2010). Texture soy flour (compared to meat) can be considered as a relatively Ca- and Mg-rich ingredient (Table 3). Finally, mineral fillers such as Hubersorb (Akrochem, Akron, OH, USA) are included in some of the formulations commercialised for sausages (Personal communication: technical personnel, Fabpsa Corporation). That filler (Hubersorb) contains Ca silicate at a large proportion and it is used in sausages for its high absorbency properties.

On the contrary, levels of Zn and Fe were higher in traditional sausages than in non-traditional ones. This could be the result of a higher proportion of lean used and additionally the use of meat from older animals (with higher Fe content) for the first group of sausages. Fe content was especially high in sausages from rural street markets. This finding can be related not only to the age of animals but also to the feasible migration of Fe ions to meat and sausage mixture from the surfaces of cast iron equipment, i.e., pans, mincers (Quintaes et al., 2004), which are frequently present at small homemade sausage producing facilities in small villages. In spite of the lower amounts of Fe found in non-traditional sausages, the Fe concentration in sausages from wholesale city markets was comparable to that of traditional sausages. This could be indicative of the use of mechanically recovered meat, which contains higher amounts of Fe, approximately twice higher, than manually deboned meat (Newman, 1981).

3.3 Correlations and principal component analysis

Table 5 shows the correlation coefficients between the composition variables studied considering the values expressed on DM basis, for traditional and non-traditional sausages separately. Regardless the sausage group, significant correlations (*P*<0.05) detected for the

	Protein	Ash	Na	K	P	Ca	Mg	Zn	Fe
Fat									
Traditional	-0.96*	-0.57*	0.01	-0.70*	-0.70*	0.14	-0.43	-0.68*	-0.61*
Non-traditional	-0.88*	-0.90*	-0.75*	-0.92*	-0.70*	-0.38	-0.30	-0.39	-0.24
Protein									
Traditional	1.00	0,42	-0.19	0.73*	0.64*	-0.13	0.46*	0.68*	0.59*
Non-traditional	1.00	0.75*	0.58*	0.83*	0.56*	0.13	0.19	0.47*	0.12
Ash									
Traditional		1.00	0.61*	0.22	0.52*	-0.09	-0.04	0.52*	0.17
Non-traditional		1.00	0.92*	0.87*	0.74*	0.45*	0.29	0.19	0.22
Na									
Traditional			1.00	-0.13	0.20	0.03	-0.11	0.17	-0.07
Non-traditional			1.00	0.76*	0.75*	0.29	0.20	0.05	0.12
K									
Traditional				1.00	0.69*	0.48*	0.74*	0.70*	0.48*
Non-traditional				1.00	0.64*	0.39	0.42	0.28	0.26
P									
Traditional					1.00	0.17	0.54*	0.43	0.41
Non-traditional					1.00	0.40	0.16	0.41	0.20
Ca									
Traditional						1.00	0.48*	0.25	-0.14
Non-traditional						1.00	0.48*	0.23	0.51
Mg									
Traditional							1.00	0.25	0.42
Non-traditional							1.00	0.11	0.87*
Zn									
Traditional								1.00	0.49*
Non-traditional								1.00	0.30

Table 5. Simple linear correlation coefficients between the composition variables studied considering the values expressed in dry matter basis for the two groups sausages (n=20 for each group; *: *P*<0.05)

two groups of sausages were as follows: fat content was inversely correlated with protein and ash contents and with some of the mineral elements studied, namely K and P. As said before, fat has relatively low mineral content, therefore, the more the fat proportion is, the lower the mineral content will be. Conversely, protein was positively correlated with ash and with K, P and Zn; and ash was positively correlated with several minerals but mainly with Na. Furthermore, K was positively correlated with P, and Ca with Mg.

The comparison of coefficients between each group of sausages can be useful for a better understanding of the group-related differences found as described above. The correlation coefficient between protein and fat in non-traditional sausages was lower than that in traditional sausages. This denotes that in some of non-traditional sausages carbohydrate sources or mineral fillers were used. Moreover, lower correlation coefficients were detected between protein and both Zn and Fe (which appeared to be mineral elements mainly provided by meat to sausages) and between K and all P, Ca, Mg, Zn and Fe in non-traditional sausages, with respect to the traditional sausages. This leads to the suggestion that proteinaceous non-meat ingredients were used in a number of non-traditional sausages. The really high coefficient (0.92) between Na and ash observed in non-traditional sausages indicates that Na exerted a heavy significant weight on ash content for sausages of this group, and that ash explained a great part of ash-content variance. Finally, the higher correlations found between Na and P in non-traditional sausages could be partially explained by the use of phosphates as additives, which contain it their molecules not only of P but also of Na (Fonseca et al., 2011).

Results of PC analysis are shown in Table 6 and Figs. 1 to 3. PC analysis was carried out for all FW-, DM- and NFDM-basis data. Table 6 shows the factor loadings and cumulative variance explained by PC1 and PC2. The first PC accounted for a variance from 36 to 43% and the sum of both PCs from 61 to 66%. In absolute values, the elements with higher loading scores (>0.7) for PC1 were Na, K, P and Mg using data on FW basis; K, P, Mg using data on DM basis; and Ca and Mg using data on NFDM. For PC2, Zn and Fe were the elements showing higher loading scores using all FW, DM and NFDM basis data.

	Fresh weight		Dry matter		Nonfat dry matter	
	PC1	PC2	PC1	PC2	PC1	PC2
Sodium	0.792	-0.187	-0.480	0.654	-0.601	0.472
Potassium	0.845	0.263	-0.867	-0.221	-0.681	-0.382
Phosphorus	0.805	-0.031	-0.791	0.246	-0.551	0.442
Calcium	0.679	-0.257	-0.598	0.419	-0.818	-0.092
Magnesium	0.750	-0.036	-0.721	0.098	-0.827	-0.294
Zinc	0.050	0.834	-0.435	-0.727	0.128	-0.723
Iron	0.051	0.835	-0.445	-0.722	-0.052	-0.780
Cumulative variance	43.37	64.88	41.04	66.38	35.75	61.30

Table 6. Loading scores and cumulative variance explained for the two principal components (PC1 and PC2)

Figs. 1, 2 and 3, obtained from FW, DM and NFDM results, respectively, show that samples from each group of sausage are located in two defined sets of results. Among them, the neatest separation between traditional and non-traditional samples can be observed in the plot of NFDM results (Fig. 3), where moisture and fat effect in mineral concentrations were avoided by mathematically removing those components. Thus, following the NFDM results, PC1 seemed to relate to the use of ingredients comparatively rich (with respect to meat) in

Ca and Mg such as textured soy, mechanically recovered meat and PC2 with the proportion of lean meat, which is relatively rich in Zn and Fe.

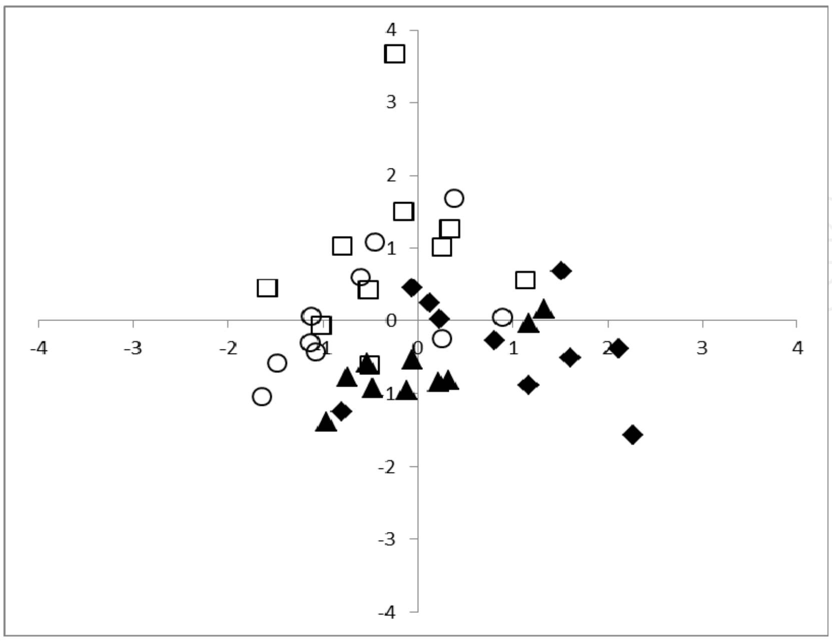

Fig. 1. Principal component (PC) score plot (PC 1 and PC 2, horizontal and vertical axis, respectively), considering mineral composition on fresh weight basis, and showing samples according to sausage types: (○) Traditional, from butcheries; (□) traditional, from rural street markets; (♦) non-traditional, from supermarkets; (▲) non-traditional, from wholesale city markets

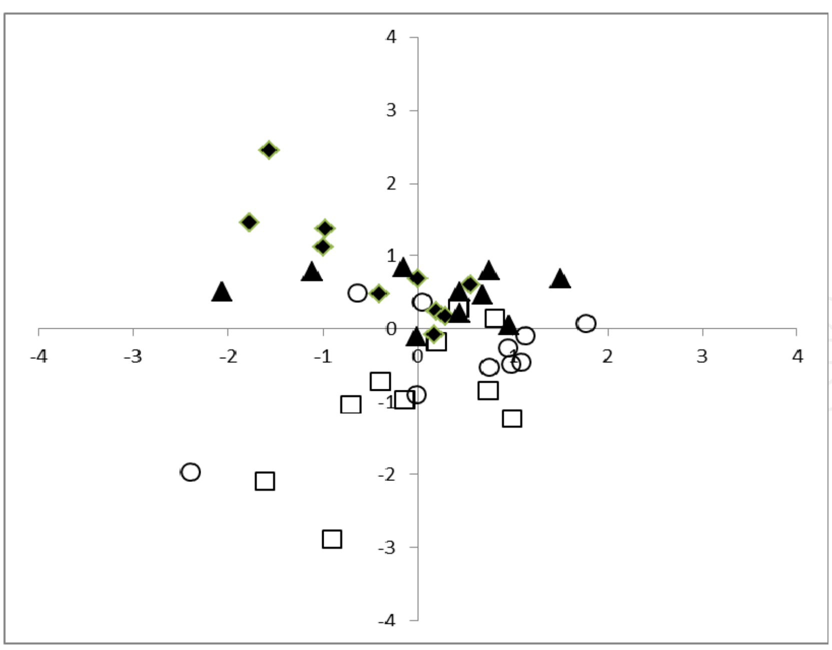

Fig. 2. Principal component score plot (PC 1 and PC 2, horizontal and vertical axis, respectively) considering mineral composition on dry matter basis, and showing samples according to sausage types: (○) Traditional, from butcheries; (□) traditional, from rural street markets; (♦) non-traditional, from supermarkets; (▲) non-traditional, from wholesale city markets

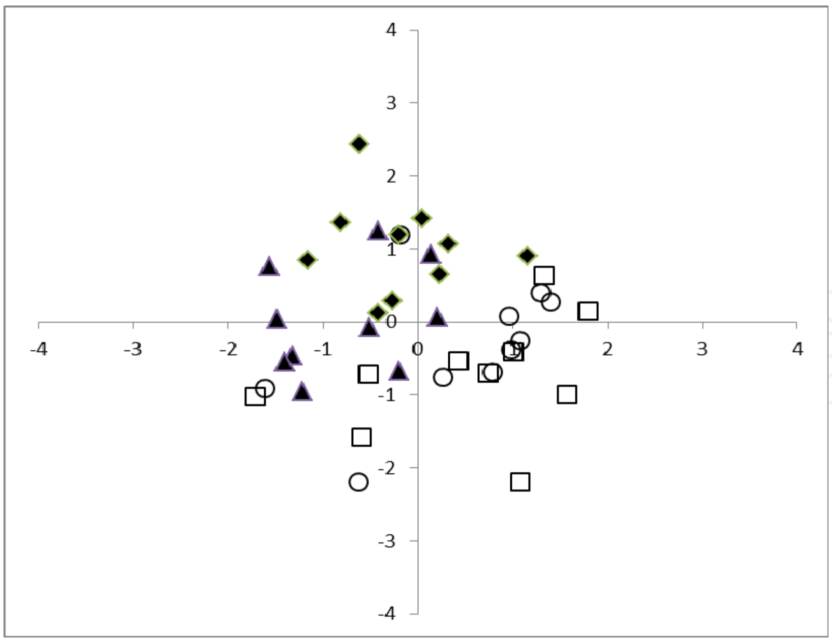

Fig. 3. Principal component score plot (PC 1 and PC 2, horizontal and vertical axis) considering mineral composition on nonfat dry matter basis, and showing samples according to sausage types: (○) Traditional, from butcheries; (□) traditional, from rural street markets; (♦) non-traditional, from supermarkets; (▲) non-traditional, from wholesale city markets

4. Conclusion

The nutritional composition (the proximate composition and mineral content, in the case of this study) of mass-produced commercial raw sausages (non-traditional) undertakes changes by reason of variations in meat and non-meat ingredients and additives used with respect to the traditional production manners. Differences in ash content and in the concentrations of most of the mineral elements studied were found between traditional and non-traditional sausages. Among those, Na and Zn had the highest statistical significance. Those changes in mineral composition can represent a disadvantage regarding nutritive value of sausages associated with lower Zn and Fe contents and higher Na and P higher in non-traditional than in mass-produced commercial sausages. Differences between traditional and non-traditional sausages are presumably due to the use of textured soy flour, mechanically recovered meat, and higher amounts of common salt in non-traditional sausages, and, conversely, higher proportion of lean meat in traditional sausages.

Determination of mineral content of raw-semidry or fresh sausages could be useful for sausage characterization purposes. Moreover, mineral content analysis performed by inductively coupled plasma atomic emission spectroscopy together with multivariate statistical analysis (chemometrics) seems to be a useful tool for discrimination purposes regarding the control of sausage authenticity (traditional vs non-traditional sausages) – with the term traditional being used for sausages made with lean and fat, salt and spices and eventually sodium nitrite, if appropriate. It seems more appreciate to conduct the multivariate analysis with the data expressed on nonfat dry matter.

In order to complete this study, further research would be needed to a) determine the mineral composition of raw-semidry or fresh sausages from other regions and countries and

b) to determine mineral elements not included in this study such as manganese, selenium, sulphur, iodine, chlorine and heavy metals (arsenic, lead, mercury, and cadmium).

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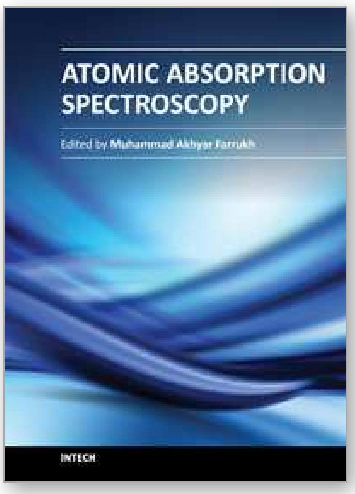

Atomic Absorption Spectroscopy
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Atomic Absorption Spectroscopy is an analytical technique used for the qualitative and quantitative determination of the elements present in different samples like food, nanomaterials, biomaterials, forensics, and industrial wastes. The main aim of this book is to cover all major topics which are required to equip scholars with the recent advancement in this field. The book is divided into 12 chapters with an emphasis on specific topics. The first two chapters introduce the reader to the subject, it's history, basic principles, instrumentation and sample preparation. Chapter 3 deals with the elemental profiling, functions, biochemistry and potential toxicity of metals, along with comparative techniques. Chapter 4 discusses the importance of sample preparation techniques with the focus on microextraction techniques. Keeping in view the importance of nanomaterials and refractory materials, chapters 5 and 6 highlight the ways to characterize these materials by using AAS. The interference effects between elements are explained in chapter 7. The characterizations of metals in food and biological samples have been given in chapters 8-11. Chapter 12 examines carbon capture and mineral storage with the analysis of metal contents.