ELSEVIER

Food Chemistry 70 (2000) 85–89

Food Chemistry

www.elsevier.com/locate/foodchem

Influence of the addition of fruit on the mineral content of yoghurts: nutritional assessment

P.J. Sánchez-Segarra *, M. García-Martínez, M.J. Gordillo-Otero, A. Díaz-Valverde, M.A. Amaro-Lopez, R. Moreno-Rojas

Department of Food Hygiene and Technology, University of Córdoba, Campus Universitario de Rabanales, Edificio C-1, Anexo, 14014 Córdoba, Spain

Received 5 January 2000; accepted 7 April 2000

Abstract

The contents of copper, iron, zinc, manganese, calcium, magnesium, sodium and potassium were investigated in fruit-added yoghurts of seven different flavours, belonging to three commercial brands widely distributed on the international market. The analytical determinations were made by flame atomic absorption spectroscopy. The analyses of variance between flavours established statistically significant differences ($P < 0.05$) for all the minerals analyzed. Differences in the mineral content were observed with the presence of different fruit, and there were notably high concentrations of iron and manganese in the wild berry fruit and pineapple flavours. Conversely, the peach-flavoured yoghurt had the lowest concentrations of iron, manganese, magnesium, sodium and potassium. In general, it was seen that the presence of fruit pieces in yoghurt caused an increase in the contents of copper, iron and manganese. Finally, their contribution to the daily intake was calculated from the mean concentrations of each of the elements investigated so that one yoghurt (125 g) gave a mean 28.1 µg of copper, 178 µg of iron, 390 µg of zinc, 8.5 µg of manganese, 123 mg of calcium, 11.7 mg of magnesium, 45.7 of sodium and 147 mg of potassium.

1. Introduction

There are numerous bibliographic references on the mineral content of milk but few studies on other dairy products and, to be more specific, yoghurt (there is an increasing number of flavours and of yoghurts enriched with fruit pieces, cereals, jams) which is now widely consumed both by infant and adult populations. Yoghurt is a highly important food because of its source of calcium for those individuals who, for different reasons, do not consume a quantity of milk sufficient to cover the RDA (NRC, 1989) of calcium. Yoghurt, especially, shows a high bioavailability of this mineral (Moreno-Rojas, 1995), which is a sufficient reason for proposing the analysis of different types of this product.

The aim of this work was to determine the mineral composition (Cu, Fe, Zn, Mn, Ca, Mg, Na and K) of the different fruit-added yoghurts from three commercial brands with a wide international distribution and to verify whether the presence of fruit pieces modifies the final mineral composition.

2. Material and method

2.1. Samples

Yoghurt samples were taken from four production batches at three-month intervals including, in each one, seven different flavours with added fruit, from three internationally known brands (Danone, Nestlé and Yoplait), with a total of 44 samples analyzed. The flavours were: strawberry (three brands), pineapple (one brand), peach (one brand), yellow peach (one brand), red peach (one brand), mixed fruit (one brand) and wild berry fruit (two brands).

2.2. Treatment of samples

For the analysis of the mineral composition of yoghurt the dry mineralization method described by Moreno Rojas, Amaro López and Zurera Cosano (1994)

* Corresponding author. Tel.: +34-57-212009; fax: +34-57-212000.
E-mail address: bt2sasep@uco.es (P.J. Sánchez-Segarra).

0308-8146/00/$ - see front matter
PII: S0308-8146(00)00146-1

was used. Fifty g of yoghurt was weighed into porcelain crucibles, previously damaged, and dried in a furnace at 100°C to a constant weight, from which (and the initial fresh weight) the moisture content was calculated. Once dried, the samples were incinerated in a muffle furnace at 460°C for 15 h. The ash was bleached after cooling by adding 2 ml of 2 N nitric acid, drying on thermostatic hotplates and maintaining in a muffle microwave oven at 460°C for 1 h. Ash recovery was performed with 5 ml of 2 N (suprapur) nitric acid, gauging to 25 ml with 0.1 N nitric acid.

The determinations were carried out by flame atomic absorption spectroscopy, except for sodium and potassium which were analyzed by flame atomic emission. For the determination of sodium and potassium, it was necessary to dilute the samples 1/100, and, in the case of calcium and magnesium, lanthanum chloride ($LaCl_3 \cdot 7H_2O$) was added to make up a final concentration of 0.27% of the sample, in order to prevent anionic interferences, which might modify the result of the determinations.

2.3. Optimization of the analysis procedure

The optimization of the analysis procedure was performed with four parameters: sensitivity, concentration limits, precision and accuracy. The sensitivity, defined as the concentration required of an element (in mg/l) to produce a 1% absorption signal, comparable to a reading of 0.0044 absorption units, is expressed in Table 1. This table also shows the concentration limit calculated, based on criteria established by Long and Winefordner (1983) and the Analytical Methods Committee (1987), who define it as the smallest absorption signal, expressed as zero concentration, which can be distinguished, with a known probability, from a blank sample analyzed under the same conditions.

Precision was defined as the degree of variability given by the expression of results, not taking into account the influence of the sample (sample variability). Baucells, Lacort, Roura, Barberá and Farré (1988) use the variation coefficient of a homogeneous group of samples as an indicator of the precision. To calculate the precision by this method, Baldini, Bocca and Mosca (1988) indicate, as being optimal, the analysis of 10 samples. In our case, homogeneous samples of powdered milk were used and the variation coefficients obtained are shown in Table 1.

In order to check the accuracy of the method in the determination of Cu, Fe, Zn, Mn,Ca, Mg, Na, K and P, five samples of non-fat milk powder, supplied by the National Institute of Standards and Technology (NIST-1549), were analyzed. The recovery percentages are shown in Table 1 and, from the results obtained, it can be seen that the recovery value means of all the mineral elements considered are found to be within the interval of confidence ($P<0.05$) calculated for the value certified.

2.4. Statistical analysis

Data obtained from the chemical analysis of the samples were evaluated statistically using a variance analysis with a Tukey honest test (SAS, 1989).

3. Results and discussion

Table 2 shows the mean concentrations (mg/kg in fresh weight) and standard deviation of copper, iron, zinc, manganese, calcium, magnesium, sodium and potassium. Analyses of variance were carried out between flavours, establishing statistically significant differences ($P<0.001$) for zinc, manganese, iron, calcium and magnesium with the lowest significance level ($P<0.01$) for sodium and potassium and ($P<0.05$) for copper. When it was verified that there were statistically significant differences ($P<0.05$), the Tukey HSD means homogeneity a posteriori test ($P<0.05$) was applied for the formation of homogeneous groups between flavours.

The Tukey HSD test ($P<0.05$) for the copper content, per flavour, showed statistically significant differences between the extreme values, i.e. between the strawberry and the pineapple yoghurt. According to the

Table 1
Quantification limits, precision, method sensitivity and accuracy values, taken from certified reference materials

	C.L.	*Precision*	*Sensitivity*	*Certified reference material* ($mg\ kg^{-1}$)[1]			
Element	($mg\ kg^{-1}$)	(%)	($mg\ l^{-1}$)	NIST 1549	Found	% Rec.	I.C. (95%)
Cu	0.008	2.6	0.133	0.70±0.10	0.68±0.04	97	0.60–0.76
Fe	0.058	3.2	0.177	1.80±0.10	1.80±0.07	101	1.66–1.94
Zn	0.083	1.0	0.354	46.1±2.20	46.2±0.80	100	44.7–47.8
Mn	0.007	4.3	0.031	0.26±0.06	0.26±0.02	98	0.21–0.30
Ca	10.5	2.0	0.721	13,000±500	13,260±290	102	12,700–13,800
Mg	0.577	1.2	0.041	1200±30	1217±39	101	1140–1300
Na	0.355	1.1	1.90	4970±100	5174±145	104	4900–5460
K	0.148	2.0	2.55	16,900±300	16,275±414	96	15,460–17,100

Table 2
Concentrations (mean±S.S.) of metal elements (mg/kg fresh weight) in fruit-added yoghurts

Flavours	Cu	Fe	Zn	Mn	Ca	Mg	Na	K
Strawberry	0.18±0.049	1.18±0.28	3.2±0.19	0.632±0.064	990±62	94±4	385±29	1191±178
Wild berry fruit	0.27±0.054	3.46±1.87	3.2±0.30	0.887±0.309	1009±72	101±5	356±25	1209±91
Mixed fruit	0.22±0.004	1.06±0.06	3.5±0.10	0.793±0.141	1047±15	105±3	392±21	1337±29
Peach	0.21±0.090	0.45±0.01	2.8±0.09	0.082±0.006	917±19	82±4	303±4	921±19
Yellow peach	0.22±0.073	0.86±0.20	2.8±0.18	0.071±0.007	881±24	84±2	385±17	1119±69
Red peach	0.20±0.055	0.62±0.11	2.9±0.08	0.044±0.005	964±25	86±3	354±17	1135±57
Pineapple	0.32±0.024	0.78±0.08	3.4±0.10	2.209±0.187	1056±31	97±1	357±28	1285±12
Total	0.23±0.072	1.42±1.35	3.1±0.29	0.687±0.619	985±71	94±8	366±35	1179±152

literature consulted, copper content in natural yoghurt may be 0.12 mg/kg (Wong, LaCroix & Alford, 1978), 0.11 mg/kg (Comas Font, Farré Rovira, Miguel Carbó & De la Torre Boronat, 1980), 0.095 mg/kg (Varo, Nuurtamo, Saari & Koivistoinen, 1980), 0.18 mg/kg (Moreno-Rojas, Cañal Ruiz, Amaro López & Zurera Cosano, 1993), 0.04 mg/kg (Buttriss, 1997) and 0.17 mg/kg (García Martínez, Sánchez Segarra, Gordillo Otero, Amaro López & Moreno-Rojas, 1998). In this study the copper concentrations in the fruit-added yoghurt were, in all flavours, higher than those found in the literature. This was logical if it is taken into account that the copper content in fruit is higher than that of milk (Souci, Fachmann & Kraut,1994) so that the addition of fruit in the making of the yoghurt would indicate an increase in the final content of copper.

In the case of iron, the Tukey test established the formation of two homogeneous groups, one formed by the wild berry fruit flavour with the highest content of iron, and another comprising the rest of the flavours. The high concentrations in the wild berry fruit flavour were due to the addition of pieces of raspberry and blackberry, these being the fruit with the highest iron content among all the fruit used in the making of these yoghurts (McCance & Widdowson, 1993; Souci et al., 1994). In the literature consulted, it was found that iron levels in natural yoghurt are 0.4 mg/kg (Pennington & Young, 1990), 0.47 mg/kg (Moreno-Rojas et al., 1993) and 0.5 mg/kg (García Martinez et al., 1998) and yoghurt is considered as falling short, as a food, because of its low contribution of iron to the diet (Schneider, 1994). The addition of fruit pieces, especially raspberry, blackberry and strawberry (McCance & Widdowson; Souci et al.), causes an increase in the concentrations of the above mineral. In all the flavours, a positive influence of the presence of fruit pieces in the final iron content in the yoghurt was proven.

The HSD Tukey test ($P<0.05$) for zinc revealed statistically significant differences between the yoghurt with pieces of peach (normal, yellow and red) with respect to those containing pieces of pineapple and mixed fruit . This might be because the peach has low concentrations of this mineral (Mataix Verdú, 1993). It should be pointed out that the zinc levels in natural yoghurt are 3.85–5.24 mg/kg (Comas Font et al., 1980), 5.5 mg/kg (Varo et al., 1980) 4.6 mg/kg (Moreno-Rojas et al., 1993), 7 mg/kg (Buttriss, 1997) and 3.5 mg/kg (García-Martinez et al., 1998). These values are slightly higher than those found in our study and this could be explained by the diluting effect of the addition of fruit pieces on the final mineral composition of the yoghurt.

With regard to manganese, a similarity can be noted between the three types of yoghurt with peach (normal, red and yellow), which is the group with the lowest concentrations, while the yoghurts with wild berry fruit, mixed fruit and strawberry form a second group, with intermediate concentrations, and finally the pineapple yoghurts comprise another group with higher manganese concentrations. In the references consulted, the manganese concentration in natural yoghurt is reported as 0.041 mg/kg (Wong et al., 1978), 0.030 mg/kg (Pennington & Young, 1990), 0.061 mg/kg (Moreno-Rojas et al., 1993) and 0.039 mg/kg (García-Martinez et al., 1998) and it is considered as a food with a poor manganese content. The addition of pieces of strawberry, mixed fruit or wild berry fruit increases the manganese content between 10- and 20-fold and the addition of pineapple pieces between 40- and 80-fold in the final composition of the yoghurt. Thus, the addition of fruit pieces to yoghurt increases the manganese content although the great variability between flavours should be noted. The data on fruit collected in the literature confirm these results, indicating a high content of manganese in fruit such as the blackberry–raspberry (wild berry fruit) and pineapple (McCance & Widdowson, 1993; Souci et al., 1994; Tingii, Reilly & Patterson, 1997).

The HSD Tukey test ($P<0.05$) result for calcium was highly complex since the concentrations in all the flavours were fairly similar, excepting the three types of yoghurt with peach pieces which showed the lowest concentrations of the above element. The calcium concentrations in natural yoghurt are 1525 mg/kg (Wong et al., 1978), 1355 mg/kg (Moreno-Rojas et al., 1993), 2000 mg/kg (Buttriss, 1997) and 1112 mg/kg (García-Martinez et al., 1998). These data are slightly higher than those

Table 3
Mean daily intake (µg/day), percentage of contribution to the recommended daily allowance (RDA) and nutrient density for the minerals investigated

	Cu	Fe	Mn	Zn	Ca	Mg	Na	K
Mean daily intake[a]	3–5	22–32	0.68–1.5	45–70	15.1–21.2	1343–2117	5535–8266	17 725–26 637
Mean daily intake[b]	28.1	178.1	8.5	390	123	11.714	45.720	147.331
% RDA[b]	1.4	1.78	2.01	2.6	12.8	3.34	9.14	7.4
% D.N.	36.7	46.9	84.3	68	401.2	87.2	237	191

[a] Calculated from data of the INE (1985) and MAPA (1992).
[b] Calculated on the basis of the ingestion of one yoghurt (≈125 g).

found in this study. The addition of any other ingredient to yoghurt therefore causes a diminution of the concentration of this mineral.

With regard to magnesium, the Tukey HSD ($P<0.05$) again showed that the peach-added yoghurts formed an independent group with lower concentrations (Souci et al., 1994) than the rest of the yoghurts. Magnesium concentrations in natural yoghurt are 131 mg/kg (Moreno-Rojas et al., 1993), 80 mg/kg (Buttriss, 1997) and 103 mg/kg (García-Martinez et al., 1998). These data are similar to those found in our study.

The Tukey HSD test ($P<0.05$) for sodium indicated that all flavours formed a single group, except for peach which stood out as being the flavour with the lowest content of this mineral, as well as showing the lowest concentrations of iron, magnesium and potassium. Sodium concentrations in natural yoghurt are 311 mg/kg (Wong et al., 1978), 480 mg/kg (Souci et al., 1981) and 374 mg/kg (García Martinez et al., 1998). These data are similar to those found in our study.

In the case of potassium, the Tukey HSD test ($P<0.05$) showed that all the yoghurts, except for normal peach, formed a single group, although the yoghurts containing red and yellow peach, also included in the single group, belonged to the normal peach group as well. The potassium concentrations in natural yoghurt are 2174 mg/kg (Wong et al., 1978), 1843 mg/kg (Moreno-Rojas et al., 1993) and 1297 mg/kg (García-Martinez et al., 1998), these data being slightly higher than those found in our investigation. On reviewing the potassium content in fruit (McCance & Widdowson, 1993; Souci et al., 1994) and comparing it with the results obtained, it can be concluded that the addition of fruit pieces confers a dilution phenomenon of this element in the yoghurt as has already been observed in the case of zinc and calcium.

3.1. Nutritional assessment

In order to determine the nutritional value of fruit-added yoghurt in terms of its mineral composition, two types of studies were made; on the one hand, the percentage of the recommended daily amount that the consumption of one yoghurt covered for each of the mineral elements (RDA) (NRC, 1989) was calculated, and on the other, the nutrient density was calculated (Renner, Schaafsma & Scott, 1989). Prior to this nutritional valuation, the mineral contributions to the daily intake of the consumption of this type of yoghurt in the Spanish diet were found.

The daily contribution to dietary intake was calculated from the mean concentration of each of the elements investigated and, based on the consumer data on yoghurt in Spain, which were 15.6 g/day (INE, 1985) and 22.6 g/day (MAPA, 1992). Since the daily consumption data of the different fruit-added yoghurts were not found in the references consulted and, taking into account that yoghurt is a food that is usually consumed in units packed individually (≈125 g), it was decided to indicate the nutritional contribution in terms of the consumption of one yoghurt (Table 3).

The RDA percentages were calculated on the basis of the "Recommended Dietary Allowances" established by the National Research Council for an adult male whose calorie consumption is 2.900 kcal/day. The nutrient density values (Renner et al., 1989) were calculated following the same formula:

$$D.N.(\%) = \frac{N_p/E_p}{N_r/E_r} \cdot 100 \tag{1}$$

where N_p is the nutrient concentration (mineral element) studied in the food, E_p, the energy supplied by the food (yoghurt), N_r the recommended amount of the nutrient to be ingested daily and E_r the daily energy recommended (NRC, 1989), in the terms previously indicated. These are expressed as percentages and values of close to 100% are considered to be adequate.

From the values in Table 3, it is verified, both by the RDA percentage and by the nutrient density values, that yoghurt constitutes a good source of calcium and, to a lesser extent, of sodium and potassium, whilst for the rest of the minerals it is a relatively poor source. If the modifications proposed for nutritional labelling regulation (Porter, Earl & Erdman, 1991) are taken into account, whole yoghurt with fruit pieces can be considered as being "a good source of calcium" and as a food "containing sodium, potassium, magnesium, zinc and magnesium''. Conversely, it should be considered as a mediocre food on the basis of its contribution of iron and copper, although the concentrations of these minerals considerably increased with the addition of fruit pieces. This way of rating a food is done on the basis of the RDA percentage fulfilled so that a foodstuff is rated as being ''a very good source of''.. when the nutrient is over 20% of the corresponding RDA, the rating of ''a good source of ...'' is when it is 11 to 20% of the RDA, and ''contains...'' refers to when the nutrient is between 2 and 10% of the RDA.

Acknowledgements

This work has been financed by the Ministry of Education and Science CICYT AL195-0670 and by the Council of Education & Science of the Autonomous Government of Andalusia, group 2032.

References

Analytical Methods Committee (1987). Recommendations for definition, estimation and use of detection limit. *Analyst, 112*, 199–204.

Baldini, M., Bocca, A., & Mosca, M. (1988). Investigation of microelements content of bulk milk from different regions of Italy. *Food Additives Contaminants, 5*, 45–50.

Baucells, M., Lacort, G., Roura, M., Barberá, R., & Farré, R. (1988). Determination of cobalt in foods by atomic absorption and inductively coupled plasma spectrometry. *Die Nahrung, 32*, 409–411.

Buttriss, J. (1997). Nutritional properties of fermented milk products. *International Journal of Dairy Technology, 50*, 21–27.

Comas Font, M., Farré Rovira, R., Miguel Carbó, F. X., & De la Torre Boronat, M. C. (1980). Niveles de cinc y cobre en la alimentación de lactantes de Barcelona. *Alimentaria, 11*, 29–33.

García Martinez, M., Sánchez Segarra, P. J., Gordillo Otero, M. J., Amaro López, M. A., & Moreno-Rojas, R. (1998). Valoración nutricional de la composición mineral de yogures enteros aromatizados. *Alimentaria, 297*, 73–76.

INE (Instituto Nacional de Estadística) (1985). *Encuesta de Presupuestos Familiares*. *Estudio sobre Nutricion* (5) (DL, M-32466-85). Madrid, Spain: INE.

Long, G. L., & Winefordner, J. D. (1983). Limit of detection: a closer look at the IUPAC definition. *Analyst Chemistry, 55*, 712A–724A.

Mataix Verdú, J. (1993). *Tabla de composicion de alimentos Españoles*. Granada: Instituto de Nutrición y Tecnología de Alimentos, Universidad de Granada.

MAPA (Ministerio de Agricultura, Pesca y Alimentación) (1992). *La alimentación en España*. Madrid, España: Secretaría General De Alimentación (Chapter V).

McCance, Widdowson (1993). *The composition of foods* (5th revised and extended ed.). Cambridge, UK: The Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food.

Moreno Rojas, R. (1995). Lácteos como fuente ideal de calcio/fósforo en la dieta. *Alimentación, Nutrición y Salud, 2*, 52–58.

Moreno Rojas, R., Amaro López, M. A., & Zurera Cosano, G. (1994). Concentration and seasonal variatons of calcium, magnesium, sodium and potassium in raw cow, ewe and goat milk. *International Journal Food of Science Nutricional, 45*, 99–105.

Moreno Rojas, R., Cañal Ruiz, C., Amaro López, M. A., & Zurera Cosano, G. (1993). Contenido mineral del yogur natural. *Alimentaria, 239*, 81–84.

NRC (National Research Council) (1989). *Recommended dietary allowances* (RDA) (10th ed.). Washington, DC: National Academy Press.

Pennington, J. A. T., & Young, B. (1990). Iron, zinc, copper, manganese, selenium, and iodine in foods from United States total diet study. *Journal of Food Composition and Analysis, 3*, 166–184.

Porter, D., Earl, R., & Erdman, J. W. (1991). Nutrition labeling: comparison of proposals for regulatory reform. *Food Technology, 45*, 68–75.

Renner, E., Schaafsma, G., & Scott, K. J. (1989). Micronutrients in milk. In E. Renner, *Micronutrients in milk and milk-based food products* (Chapter 1, pp. 28). London: Elsevier Applied Science.

SAS (1989). General lineal model (GLM) procedures. In *SAS/STAT user's guide,* (4th ed.) (pp. 45–52) Cary, NC: SAS Institute Inc.

Schneider E. (1994). La leche y sus derivados. In *La salud por la nutrición*. (Vol. 2) (pp. 763–791). Madrid: Safeliz.

Souci, S.W., Fachmann, W. & Kraut, H. (1994) *Food composition and nutrition tables* (5th revised and completed ed.) (Deutsche Forschungsanstalt für Lebensmittelchemie, Garching b. München) (compiled by H. Scherz & F. Senser) Stuttgart: Medpharm Scientific Publ.; Boca Raton, Ann Arbor, London, Tokyo: CRC Press.

Tingii, U., Reilly, C., & Patterson, C. (1997). Determination of manganese and chromium in foods by atomic absorption spectrometry after wet digestion. *Food Chemistry, 600*(1), 123–128.

Varo, P., Nuurtamo, M., Saari, E., & Koivistoinen, P. (1980). Mineral element composition of Finnish foods. VII. Dairy products, eggs and margarine. *Acta Agriculture Scandinavica, 22*(suppl.), 115–126.

Wong, N. P., LaCroix, D. E., & Alford, J. A. (1978). Mineral content of dairy products. *Journal of the American Dietetic Association, 72*, 188–291.