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Effect of dietary inclusion of goat milk on the bioavailability of zinc and selenium in rats

M José M Alférez[1,2], Inmaculada López Aliaga[1,2], Mercedes Barrionuevo[1,2] and Margarita S Campos[1,2]*

[1]Departamento de Fisiología, Facultad de Farmacia, Campus Universitario de Cartuja, Universidad de Granada, 18071 Granada, Spain
[2]Institute of Nutrition and Food Technology, C/Ramón y Cajal 4, Edificio Fray Luis de Granada, 18071 Granada, Spain

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The effects of dietary inclusion of freeze-dried goat and cow milk on the utilization of zinc and selenium, and on the metabolic fate of zinc, were studied in transected (control) and resected rats (resection of 50% of the distal small intestine). Intestinal resection reduced the apparent digestibility coefficient and zinc retention in the cow milk diet, whereas these biological indices were similar in transected (control) and resected rats with standard (without milk) and goat milk diets. The apparent digestibility coefficient and retention of selenium were not affected by intestinal resection in the animals fed with the three diets studied. In transected (control) and resected rats, the apparent digestibility coefficient and retention of zinc and selenium were higher for the goat milk diet than for the other two diets. Zinc deposits in the organs, expressed as μg/g dry weight were in order of decreasing concentrations: femur, testes, sternum, liver, kidney, heart, spleen, longissimus dorsi muscle and brain. Deposits were greatest with the goat milk diet, followed by the standard diet and were lowest for the rats given the cow milk diet, both for transected (control) and resected animals.

We conclude that consumption of the goat milk diet produces a greater bioavailability of zinc and selenium and a greater deposit of zinc in key organs, for both the transected (control) and the resected rats, with respect to the standard diet and the cow milk diet.

Keywords: Zn and Se, goat and cow milk, bioavailability.

Zinc is an essential mineral found in abundance in the human body, being the second most common trace element in cells and tissues (Adams, 2002). In metalloenzymes, zinc can have a catalytic, structural, or regulatory functions; examples are carbonic anhydrase, Cu, Zn-superoxide dismutase and fructose bisphosphatase, respectively. Between 200 and 300 different zinc-containing enzymes have been found in biological systems. Zinc is thought to be necessary for RNA, DNA and ribosome stabilization, and is involved in the binding of a number of transcription factors (King & Keen, 1999).

Selenium is an essential nutrient of fundamental importance to human biology (Rayman, 2000). As selenocysteine, the 21st amino acid, selenium is a component of selenoproteins, some of which have important enzymic functions (Sunde, 1997). It is now recognized that all these enzymes are selenium-dependent, generally with selenocysteine at the active site (Sunde, 1997). Here selenium functions as a redox centre for instance when the selenium-dependent iodothyronine deiodinases produce active thyroid hormone from inactive precursor (Sunde, 1997). The best-known example of this redox function is the reduction of hydrogen peroxide and damaging lipid and phospholipid hydroperoxides to harmless products by the family of selenium-dependent glutathione peroxidases (Diplock, 1994; Sunde, 1997). About 35 selenoproteins have been identified, though many have roles that have not yet been fully elucidated (Behne et al. 2000).

The object of this study was to determine whether goat milk, with its special nutritional characteristics (Haenlein, 1996), including high levels of zinc and selenium (Jandal, 1996; Boza & Sanz-Sampelayo, 1997), affects the bioavailability of these two minerals in control rats and with intestinal resection (50% distal small intestine), and to carry out a comparative study with a diet based on cow milk (as the milk most commonly consumed) and the standard diet recommended by the AIN (1977).

*For correspondence; e-mail: marga@goliat.ugr.es

Materials and Methods

Animals

The study used 69 animals (white male rats, *Rattus norvegicus*, Wistar albino breed), with an initial body weight of 177 ± 3 g, obtained from the University of Granada Laboratory Animal Service. All experiments and surgical procedures with rats conformed to the guidelines established by legal requirements in the UK for the proper care and use of laboratory animals. After surgery both the transected (control) and resected animals were housed in individual, ventilated, thermoregulated cages (22 ± 2 °C) with a 12 h : 12 h light-dark period. Food and mineral-free water were available *ad libitum* to all rats.

Diets

The diets and mineral and vitamin supplements were prepared according to the recommendations of the American Institute of Nutrition (AIN, 1977) except that the level of fat in the diets was 10% rather than 5%. The standard diet (Diet S) was prepared using olive oil as the source of fat (10%) and casein as the protein source (20%). The milk-based diets (Diet C and Diet G) were formulated with lyophilized cow or goat milk respectively. These were analysed to determine the fat content (cow milk: 35·23%; goat milk: 43·63%), protein content (cow milk 23·92%; goat milk: 25·27%), lactose content (cow milk: 37·55%; goat milk: 31·10%) and mineral composition (mg/100 g of lyophilate) (cow milk: Ca: 1031·5, P: 731·3, Mg: 76·3; Fe: 0·61; Cu: 0·11; Zn: 3·72 and Se: 0·068; goat milk: Ca: 1215·2, P: 843·3, Mg: 82·5, Fe: 1·13, Cu: 0·42; Zn: 4·15 and Se: 0·091). The necessary quantities of lyophilized goat or cow milk were used to obtain a diet with a 10% fat content. To obtain the 20% protein content (as recommended by the AIN, 1977) the diet was supplemented with casein (12·53 g casein/100 g of cow milk and 14·05 g casein/100 g diet of goat milk), as the protein provided by the lyophilate used for the milk-based diets was insufficient.

Mineral supplements were prepared according to AIN (1977) recommendations for the standard diet and to our own specifications for the milk-based diets. These specific supplements were formulated taking into account the mineral content of the lyophilized milks supplied to the rats in order to meet the mineral-content recommendations of the AIN (1977): 30 mg Zn/kg of diet and 0·1 mg Se/kg of diet. The zinc and selenium contents in the diets (mg/kg diet) after analysis were as follows: standard diet: Zn: 34·41; Se: 0·087; cow milk diet: Zn: 30·96; Se: 0·088; and goat milk diet: Zn: 31·52; Se: 0·103. The zinc was added as zinc carbonate and the selenium as sodium selenite, pentahydrate.

The lactose content of the milk diets was subtracted from the total carbohydrate content of the standard diet and the difference made up with wheat starch and sucrose (Table 1).

Table 1. Composition of the experimental diets

Component	g/kg diet (dry weight)
Diet S (non-milk standard)	
Protein (casein)	209
DL-methionine	3
Fat (olive oil). MCT*: 0 g	112
Fibre (micronized cellulose)	50
Mineral supplement†	36
Vitamin supplement†	10
Choline chloride	2
Wheat starch	156
Sucrose	450
Lactose	0
kcal/kg diet	4280
Diet C (cow milk)	
Protein (casein+protein cow milk)	190
DL-methionine	3
Fat (cow milk). MCT*: 20·6 g	98
Fibre (micronized cellulose)	40
Mineral supplement‡	35
Vitamin supplement†	10
Choline chloride	2
Wheat starch	121
Sucrose	387
Lactose (cow milk)	131
kcal/kg diet	4210
Diet G (goat milk)	
Protein (casein+protein goat milk)	194
DL-methionine	3
Fat (goat milk). MCT*: 33·2 g	92
Fibre (micronized cellulose)	46
Mineral supplement‡	36
Vitamin supplement†	10
Choline chloride	2
Wheat starch	148
Sucrose	405
Lactose (goat milk)	85
kcal/kg diet	4168

* Medium-Chain Triglycerides
† Mineral and vitamin supplements were prepared according to the recommendations of the American Institute of Nutrition
‡ Specific mineral supplements according to description in Materials and Methods

Resection and transection procedures

The method described by Hartiti et al. (1994a) was used to carry out the resection of 50% of the distal small intestine. Animals in which the intestine was transected were treated identically except that the small intestine was only divided and reanastomosed at the mid-small intestine, without exclusion of any part of intestine. These transected rats were the control groups, because they maintain the whole intestine and all the blood supply.

Experimental design

Six experimental groups were formed: (1) group T-S, transected rats, standard diet (n=11); (2) group R-S,

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resected rats, standard diet (n=13); (3) group T-C, transected rats, cow milk diet (n=10); (4) group R-C, resected rats, cow milk diet (n=11); (5) group T-G, transected rats, goat milk diet (n=14); (6) group R-G, resected rats, goat milk diet (n=10).

All animals were fed up to the time of surgery, and were given access to water containing 50 g glucose/l for 24 h after surgery. Thereafter, a period of 30 d was allowed for adaptation to the diet, during which feed and mineral-free water were available *ad libitum* to all animals. Beginning 30 d after surgery, food intake (the amount of food consumed daily by each rat determined by weighing the amounts of diet given less that refused and spilled) was measured and urine and faeces were collected daily for 7 d (Thomas & Mitchell, 1923). Body weight was recorded at the beginning and end of the experimental period. Throughout the experimental period all rats had access to mineral-free water. At the end of this period all animals were fasted for 24 h and killed with sodium pentobarbital (5 mg/100 g body weight) after intraperitoneal anaesthesia and totally bled by cannulation of the abdominal aorta, after which all the organs to be studied were removed.

Analytical methods

Dry Matter. Water content in the diet, faeces, femur, sternum, *longissimus dorsi* (*L.D.*) muscle, liver, spleen, kidney, heart, brain and testes was determined by drying the material at 105±2 °C until the weight remained constant (~48 h).

Zinc determination. Samples (1–2 g) of the resulting sample (diet, faeces and liver) or the entire sample (femur, sternum, *L.D.* muscle, spleen, kidney, heart, brain, testes) was ashed at 450 °C. The residue was weighed and then diluted in 5 M-HCl to which mineral-free water was added to a predetermined volume for subsequent analysis.

The concentrations of zinc in the diet, faeces, urine, and the different organs were determined by flame atomic absorption spectrophotometry (FAAS) (Perkin-Elmer 1100 B) and compared with a series of standard values.

Selenium determination. Selenium was determined by FAAS with hydride generation (Perkin-Elmer 1100B spectrometer, Shelton, CT) of a sample that had been wet-ashed with nitric acid (Merck) and perchloric acid (Merck), according to the technique of Palacios et al. (1985).

Lyophilized bovine liver (Certified Reference Material BCR No. 185, Community Bureau of Reference, Brussels, Belgium) had a Zn content of 140±2 μg/g and a Se content of 438±12 ng/g (mean±SEM of five determinations); certified value: Zn, 142±3 μg/g; and Se, 446±13 ng/g. This material was used for quality control assays.

Biological indices

The apparent digestibility coefficient (ADC) and retention (R) of Zn and Se were calculated according to the following:

$$\text{Percentage ADC} = (\text{absorbed}/\text{intake}) \times 100$$

where nutrient absorption = intake − faecal excretion

Balance (R, retention) = intake − (faecal + urinary excretion).

Statistical analysis

We calculated the mean and SE of the mean for each parameter studied. Variance analysis (the ONEWAY method of the SPSSPC) (SPSS®, 2001) and the Bonferroni post hoc test were used to compare the different diets supplied to the two groups of animals (transected and resected rats). To compare the two groups given the same diet, we used Student's t test for independent samples (the SPSSPC TTEST procedure). Values of $P<0{\cdot}05$ were considered significant.

Results

ADC and zinc retention

The digestive utilization of zinc and the zinc balance were affected by intestinal resection (50% DSI) in the rats given the cow milk diet ($P<0{\cdot}05$) (Table 2). This was not the case, however, when the animals were given the standard or the goat milk diets, for which the ADC of zinc was similar for resected and controls (transected) rats. The highest absorption and ADC of zinc was found for rats given the goat milk diet; levels were almost 50% higher than for the control animals ($P<0{\cdot}001$) (goat milk diet *v.* the other two diets) and twice as high for the resected animals ($P<0{\cdot}001$) (ADC-Zn: G>S=C) (Table 2).

Zinc retention was higher for both groups of animals given the goat milk diet than for those consuming the other two diets; although this was not significant in the case of the control animals, it was so for the resected rats ($P<0{\cdot}001$) (Retention-Zn: RG>RS=RC) (Table 2).

ADC and selenium retention

For the ADC and retention of selenium, no differences were observed between the resected and the control (transected) animals, for any of the three diets studied. Nevertheless, the ADC of selenium was higher for the two groups of rats given goat milk than for the other two diets ($P<0{\cdot}001$), except for transected rats fed standard and goat milk diets ($P<0{\cdot}05$). Furthermore, the ADC of selenium in resected and transected rats was higher for the animals that consumed the standard diet than for those given cow milk ($P<0{\cdot}001$) (ADC-Se: G>S>C). For both groups of animals,

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Table 2. Digestive and metabolic utilization of zinc in transected and resected rats consuming standard or milk diets (cow or goat)

		Zn intake (μg/rat per d)		Faecal Zn (μg/rat per d)		Absorbed Zn (μg/rat per d)		ADC (%)		Urinary Zn (μg/rat per d)		Zn retention (μg/rat per d)	
Group	*n*	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
T-S	11	640·6	20·5	526·9	17·1	113·7	4·6	17·8	0·5	2·8	0·5	111·0	4·8
R-S	13	660·0	22·2	554·6	22·1	105·4	8·4	16·1	1·2	5·1§	0·6	100·3	8·4
T-C	10	640·7	15·4	529·3	13·4	111·7	4·3	17·4	0·6	4·3	0·3	107·5	4·3
R-C	11	685·9	18·0	587·7‡	18·1	98·3†	5·0	14·4§	0·8	7·0‡	0·9	91·3†	5·6
T-G	14	511·9‡§	19·4	375·0‡§	14·2	137·0‡§	11·2	26·8‡§	2·2	6·0‡	0·9	131·0	11·4
R-G	10	531·0‡§	19·4	356·3‡§	24·9	174·7‡§	10·3	33·6‡§	2·6	5·3	0·8	169·4‡§	10·4

T-S, transected rats fed on the standard diet; R-S, resected rats fed on the standard diet
T-C, transected rats fed on the cow milk diet; R-C, resected rats fed on the cow milk diet
T-G, transected rats fed on the goat milk diet; R-G, resected rats fed on the goat milk diet
† Significantly different ($P<0·05$) from transected group
‡ Significantly different ($P<0·05$) from corresponding standard group
§ Significantly different ($P<0·05$) from cow-milk group

Table 3. Digestive and metabolic utilization of selenium in transected and resected rats consuming standard or milk diets (cow or goat)

		Se intake (μg/rat per d)		Faecal Se (μg/rat per d)		Absorbed Se (μg/rat per d)		ADC (%)		Urinary Se (μg/rat per d)		Se retention (μg/rat per d)	
Group	*n*	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
T-S	11	1·620	0·052	0·175	0·019	1·445	0·039	89·36	0·89	0·493	0·019	0·953	0·027
R-S	13	1·669	0·056	0·172	0·010	1·497	0·048	89·75	0·34	0·499	0·023	0·996	0·029
T-C	10	1·821‡	0·045	0·232‡	0·016	1·589	0·032	87·34‡	0·57	0·643‡	0·018	0·94	0·033
R-C	11	1·950‡	0·051	0·246‡	0·013	1·704†‡	0·046	87·38‡	0·58	0·718‡	0·025	0·986	0·039
T-G	14	1·673§	0·035	0·143§	0·007	1·530	0·031	91·49‡§	0·32	0·413§	0·021	1·117‡§	0·031
R-G	10	1·735§	0·064	0·124‡§	0·007	1·611‡	0·058	92·88‡§	0·29	0·510§	0·023	1·101‡§	0·033

T-S, transected rats fed on the standard diet; R-S, resected rats fed on the standard diet
T-C, transected rats fed on the cow milk diet; R-C, resected rats fed on the cow milk diet
T-G, transected rats fed on the goat milk diet; R-G, resected rats fed on the goat milk diet
† Significantly different ($P<0·05$) from transected group
‡ Significantly different ($P<0·05$) from corresponding standard group
§ Significantly different ($P<0·05$) from cow-milk group

selenium retention was higher for the rats given goat milk than for rats given the other two diets ($P<0·001$), which showed similar values (Retention-Se: G>S=C) (Table 3).

Zinc concentrations in different organs

Intestinal resection did not affect the distribution of zinc throughout the body of the animals given the standard or cow-milk diets, except in the testicles and spleen of rats given the standard diet ($P<0·005$) and the heart for those given the cow-milk diet ($P<0·025$), where zinc deposits were lower than in control (transected) animals. For the rats fed the goat milk diet, there were no differences between the resected and control animals in the zinc content of the femur, testes, kidneys, spleen or brain. Differences were found, however, in the other organs examined sternum ($P<0·001$) and liver, heart and *L.D.* muscle ($P<0·005$) where, surprisingly, zinc retention was higher in the rats with intestinal resection than in the control (transected) animals (Table 4). In general, the goat milk diet produced the highest deposits of zinc in the different organs studied, followed by the standard diet and then by the cow-milk diet (Table 4).

Discussion

Resection of 50% of the DSI severely affects the digestive and metabolic utilization of zinc (ADC of zinc and zinc retention) which are reduced almost by half (Hartiti et al. 1994a, b). Nevertheless, in the present study, when the resected animals were given the three diets (the standard and the cow and goat milk diets), the ADC of zinc was similar to that of the control animals. This lack of effect of intestinal resection on the digestive utilization of zinc could be due to the higher protein content (20%) and fat content (10%) than in the diets supplied by Hartiti et al. (1994a, b), for which the corresponding values were 12% and 5% respectively. Sandström & Lönnerdal, (1989)

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Table 4. Zinc concentration in several organs (μg/g dry weight) in transected and resected rats consuming standard or milk diets (cow or goat)

	T-S (n=11)		R-S (n=13)		T-C (n=10)		R-C (n=11)		T-G (n=14)		R-G (n=10)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Femur	183·4	2·9	177·7	5·2	179·1‡	3·6	175·8	2·5	193·0‡§	2·9	192·4‡§	3·9
Testes	178·7	2·2	163·4†	3·9	165·2‡	3·5	165·7	3·7	183·3§	3·1	186·0‡§	3·5
Sternum	123·1	1·8	126·2	2·6	132·4‡	1·1	128·2	2·6	134·6‡	0·7	153·9†‡§	4·9
Liver	110·7	2·3	113·3	1·3	100·1‡	1·3	102·1	1·7	116·0‡§	1·6	125·1†§	3·0
Kidney	92·0	2·0	92·4	1·7	88·8	2·3	90·8	2·0	96·4§	1·9	105·6‡§	5·7
Heart	76·2	1·1	74·0	1·4	67·1‡	0·9	62·7§	1·4	78·4§	2·3	95·1‡§	4·9
Spleen	78·5	1·2	71·2†	1·9	70·5	3·0	63·8	2·5	77·5§	1·8	77·3§	2·1
L.D. muscle	59·9	2·2	64·9	2·4	55·1‡	1·9	62·1	3·8	63·2§	1·4	70·4†§	1·8
Brain	51·7	0·4	51·7	2·0	37·2‡	1·0	42·0†‡	0·8	50·6§	1·6	55·8‡§	2·0

T-S, transected rats fed on the standard diet; R-S, resected rats fed on the standard diet
T-C, transected rats fed on the cow milk diet; R-C, resected rats fed on the cow milk diet
T-G, transected rats fed on the goat milk diet; R-G, resected rats fed on the goat milk diet
† Significantly different (P<0·05) from transected group
‡ Significantly different (P<0·05) from corresponding standard group
§ Significantly different (P<0·05) from cow-milk group

showed that there is a strong correlation between the nitrogen content of the diet and zinc absorption. Moreover, proteins of animal origin (such as those provided by milk) have a greater positive effect on zinc absorption than vegetable proteins.

Zinc is absorbed in the small intestine, and especially in the duodenum and the jejunum (Cousins, 1989; Lee et al. 1989) in the rat, it is also absorbed in the colon (Naveh et al. 1993). These segments, except part of the jejunum, were preserved in the resection performed in the present study. In previous studies (Lisbona et al. 1994; López Aliaga et al. 1994; Alférez et al. 1996), we have shown that 40 d after removal of the distal small intestine, the remaining segments (duodenum, part of the jejunum and the proximal colon) undergo an adaptation, there being an increase in the absorption capacity, per unit of length and weight of intestinal mucosa, for calcium, phosphorus and magnesium. This increase is particularly evident when the animals are fed a diet in which the fat contains almost 35% medium chain triglycerides and a supplement of vitamin D_3 (Lisbona et al. 1994; López Aliaga et al. 1994; Alférez et al. 1996). It is possible that such adaptation could also increase its capacity to absorb other micronutrients, such as zinc and selenium. Furthermore, if there is a high proportion of protein in the diet (20%), a factor that favours the absorption of these two minerals (Sandström & Lönnerdal, 1989), this might also contribute to improving the digestive utilization of zinc and selenium in rats with intestinal resection.

Selenium is absorbed mainly in the form of selenoamino acids (selenomethionine or selenocysteine) although it may also be absorbed in an inorganic form as selenate or selenite (Wapnir, 1990). Absorption is favoured when selenium is supplied in organic form, as selenoaminoacids, while the inorganic form produces large variations in absorption efficiency (Levander & Burk, 1997). Therefore, the increase in dietary levels of animal proteins (rich in cysteine) would favour the absorption of selenium.

The fat content in the diets (10%) is almost double that recommended by the AIN (1977). A recent study (Alférez et al. 2001) found that an increase in the lipid content of the diet improves digestive utilization of fats in animals with resection of 50% of the DSI, and that ADC values approach those of the control animals. These results suggest that the resected rats have a greater energy supply for ATP consumption in active transport absorption mechanisms for zinc and selenium, which might lead to an increase in the digestive utilization of these two minerals. With regard to the type of diet supplied, the goat milk diet produced the best results for the ADC and retention of zinc and selenium, both for the transected (control) and resected animals.

The zinc and selenium content of goat milk is higher (4·8 mg/l and 13·3 μg/l respectively) than that of cow milk (4·2 mg/l and 9·6 μg/l, respectively) (Boza & Sanz Sampelayo, 1997). Moreover, the bioavailability of zinc and selenium in goat milk could be higher than in cow milk, for various reasons. Firstly, goat milk contains a greater amount of vitamins C and D (Jandal, 1996; Souci, 1989) and according to Hartiti et al. (1994b), this could contribute to the higher ADC of zinc in animals fed a goat milk diet. Furthermore, goat milk is richer in cysteine (830 mg/l) than cow milk (280 mg/l) (Souci et al. 1989). This amino acid is active in the absorption and metabolism of zinc and selenium. The passage of zinc through the brush-border membrane vesicle is achieved by means of a peptide transport system (Tacnet et al. 1993). The intracellular phase of zinc absorption (transcellular movement) has been extensively studied. Zinc newly acquired from the intestinal lumen is bound to many different molecular

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species. Two have been identified: metallothionein (MT) and cysteine-rich intestinal protein (CRIP) (Richards & Cousins, 1977; Hempe & Cousins, 1991). The association of zinc with CRIP is correlated to absorption; it is not likely to act in transcellular movement. In contrast, MT gene expression in intestine is directly correlated to dietary zinc intake (Cousins & Lee-Ambrose, 1992). Zinc absorption declines as MT synthesis is elevated in response to dietary zinc (Hoadley et al. 1988).

For selenium, almost all that found in animal tissues is in two forms or compartments: selenomethionine and selenocysteine, which is present in selenoproteins such as glutathione-peroxidase. Selenocysteine is the form of selenium that is biologically active (Levander & Burk, 1997). On the basis of the above, we believe the greater supply of cysteine in the goat milk diet to favour the digestive and metabolic utilization of zinc and selenium. Moreover, goat milk has a higher MCT (medium-chain triglycerides) content than cow milk (Haenlein, 1996). According to Tappenden et al. (1997), short-chain fatty acids favour intestinal adaptation after resection, probably owing to the increased quantity of the other nutrients transported through the basolateral membrane of the enterocyte. It is possible that medium-chain fatty acids, which are absorbed within the intestinal cells without re-esterification and directly enter the portal circulation, have a similar effect on intestinal adaptation. Thus, not only is energy retention favoured directly by the presence of MCT in the diet, but it could also increase as a consequence of the greater absorption of the other nutrients in the diet, such as zinc and selenium.

In general, zinc deposits in the organs did not differ between the resected and transected (control) animals, which agrees with the findings of Hartiti et al. (1994a, b), but deposits are greater in the animals fed the goat milk diet than in those given the other two diets. Zinc deposits in the bone (femur) were higher than in the other organs studied. According to Bobilya et al. (1994), bone reserves provide a utilizable source of zinc that varies according to consumption of the mineral. After the femur, highest zinc content was found in the testicles (in the prostate, prostatic secretions and in spermatozoa) (King & Keen, 1999). In descending order of zinc content, these were followed by the sternum, liver, heart, spleen, muscle and brain. Foster et al. (1979) and Wastney et al. (1986) performed studies with kinetic models of man and animals, using ^{65}Zn as a tracer. They found hepatic tissue to be the most reactive to zinc, followed by pancreatic, renal and spleen tissues; in all of these, exchange was rapid, while it was slow in the central nervous system and in the bone. These reactions are subject to hormonal regulation (Henkin et al. 1984; Dunn & Cousins, 1989). According to Miller et al. (1994), the exchangeable reserve of zinc is very small, and so a deficiency occurs rapidly when there is a failure to adapt to consumption (Golden, 1989).

The bioavailability of zinc and selenium is greater in the diet based on goat milk than in the cow milk diet. Taking into account the important role played by these minerals in the organism, this line of research could be of considerable importance, with repercussions on the consumption patterns of goat milk.

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