

Utilization of nitrogen and energy from diets containing protein and fat derived from either goat milk or cow milk

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Consumption of whole milk and related dairy products has decreased considerably as a result of negative aspects associated with the consumption of saturated fats. The main difference between the composition of goat milk and cow milk concerns the composition of the fat, that of goat milk containing a larger proportion of medium-chain triglycerides. The metabolic utilization of these compounds is fundamentally oriented towards their use as sources of energy, and they may even contribute to the synthesis of proteins. This study was carried out, using 40 rats at weaning, in order to determine whether, on the basis of their fat and protein composition, there is any difference between the nutritional utilization of the N and the energy from goat and cow milk. Eight animals were killed on arrival at the laboratory, and the rest were divided into four groups of eight animals and killed at the end of the experiment. Each group was given a different diet: diet 1 contained fat and protein from goat milk; diet 2 had fat from cow milk and protein from goat milk; diet 3 had fat from goat milk and protein from cow milk; diet 4 had fat and protein from cow milk. The animals were allowed to feed *ad libitum* for 30 d and a balance assay was performed during the final 7 d to determine N and energy utilization. At the same time and by the comparative slaughter method, the protein and fat deposition for each group was established. It was concluded that goat milk protein is more digestible than that of cow milk. Moreover, the metabolic utilization of digestible N was found to be dependent on the sources of both the protein and the fat in the diet; a higher degree of utilization was recorded for the digestible N obtained using diets with protein or fat from goat milk. Consumption of diets with goat milk fat led to a lower level of thermogenesis associated with protein oxidation and a higher one for that associated with fat oxidation, which in turn implied a protein-sparing effect of the goat milk fat. These results should be taken into account when deciding upon the type of goat milk to be used (whole, skim or semi-skim), in accordance with the dairy product to be produced from this milk.

Keywords: Nitrogen utilization, energy utilization, body weight composition, goat milk, cow milk.

The abundant bibliography on the possible association between the consumption of saturated fat and the incidence of cardiovascular disease, as well as various types of cancer (Lewis, 1988; Sofos et al. 1995) has provoked great concern among consumers and led to changes in their dietary habits, with a shift towards 'light' foods, in which the fat content is reduced or even completely eliminated. Many people have gone so far as to exclude traditional foods such as whole milk or other dairy products from

their diet. These changes in dietary habits can cause deficiency-related problems, due to the absence of certain nutrients, such as amino acids, essential fatty acids, minerals or vitamins (Blaxter & Webster, 1991).

In view of the properties attributed to it, goat milk is currently employed for various types of foods intended both for the young and for other population groups, depending on their specific requirements (Haenlein, 2004; Park, 2006; Park & Haenlein, 2006). From a nutritional standpoint, this is justified on the basis of the specific composition presented by the different nutrients within goat milk, especially its protein and fat, which are aspects

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of its composition that differentiate it clearly from cow milk (Haenlein, 2004; Park, 2006). For some time, it has been suggested that goat milk protein could be more valuable than that of cow milk, in the light of its digestive and metabolic utilization. These considerations are explained by reference to the different fractional composition of the protein in the two types of milk, as well as the different levels of energy availability for protein utilization that are produced depending on the fat composition of each type of milk. With respect to the different classes of casein, goat milk contains lower levels of α_{s1} -casein and so the coagulate formed in the stomach is softer and more easily broken down, which facilitates the action of proteinases both in the stomach and subsequently in the intestine, which may give rise to faster and more efficient digestion (Park, 1994, 2006; López-Aliaga et al. 2003). The main difference between the composition of goat and cow milk concerns their fat content. Goat milk fat contains medium-chain triglycerides (MCT), made up of fatty acids whose carbon chain has 6–14 atoms of carbon; the MCT content in the goat milk fat normally approaches 30%, in contrast to cow milk fat, where these compounds do not exceed 20% (Haenlein, 2004). MCT are characterized by the fact that they employ a different utilization route from that of long-chain triglycerides (Matsuo & Takeuchi, 2004). With respect to their digestibility, the fatty acids originating from MCT hydrolysis can be absorbed without re-esterification within the intestinal cells, entering the bloodstream directly, and transferred by the portal system to the liver and other peripheral tissues. They then penetrate the cell mitochondria where, with no need of acyl-CoA carnitine transferase, they are oxidized to produce a rapid discharge of energy that can be used by the organism in diverse metabolic processes, including protein synthesis (Velázquez et al. 1996; Matsuo & Takeuchi, 2004; Sanz Sampelayo et al. 2006).

Taking these considerations into account, the objective of the present study was to investigate the N and the energy utilization of diets whose protein and fat content was derived entirely from goat milk or from cow milk. To the best of our knowledge, this is the first published research on this subject.

Materials and Methods

Animals and diets

The study was carried out with 40 weaned male Wistar rats (Harlan Interfauna Ibérica, Barcelona, Spain) of initial weight 40 ± 2 g. Eight of these animals were killed immediately upon arrival at the laboratory and the rest were divided into four groups of eight animals. They were kept in individual metabolism cages, inside an ecologic chamber (21–24 °C, 50–60% relative humidity, diurnal light cycle of 12 h) for 4 weeks, and then killed on the last day of this period. Each of the four groups of animals was fed a different diet, varying in its protein and fat content, as

Table 1. Ingredient composition (g/kg diet), chemical composition and gross energy content of experimental diets

Ingredient	Diet†			
	D1	D2	D3	D4
Skim milk powder	310.0	310.0	286.2	286.2
Fat	97.2	97.2	98.3	98.3
Purified cellulose	50.0	50.0	50.0	50.0
Wheat starch	390.8	390.8	408.5	408.5
Sucrose	107.0	107.0	112.0	112.0
Mineral mix‡	35.0	35.0	35.0	35.0
Vitamin mix‡	10.0	10.0	10.0	10.0
Chemical composition				
Dry matter (DM), %	93.82	93.86	93.69	93.54
Organic matter, % of DM	93.64	96.54	96.99	96.96
Crude protein, % of DM	10.03	10.07	10.03	10.09
Fat, % of DM	10.00	10.00	10.00	10.00
Gross energy, MJ/kg DM	18.59	18.73	18.64	18.21

†Diet: D1=protein and fat from goat milk, D2=protein from goat milk and fat from cow milk, D3=protein from cow milk and fat from goat milk, D4=protein and fat from cow milk

‡Mineral and vitamin mixed were prepared according to the recommendations of the American Institute of Nutrition (Reeves et al. 1993)

follows: diet 1 (D1) contained fat and protein from goat milk; diet 2 (D2) had fat from cow milk and protein from goat milk; diet 3 (D3) had fat from goat milk and protein from cow milk; diet 4 (D4) had fat and protein from cow milk. The protein in the diets was obtained from powdered skim goat milk (Lácteos Cobreros, Zamora, Spain) or skim cow milk (Puleva S.A., Granada, Spain). The fat source was goat milk cream (Lácteos Cobreros, Zamora, Spain) or cow milk butter (Puleva S.A., Granada, Spain). The diets were prepared in such a way that they contained 10% protein (UNU, 1980) and 10% fat (Alfárez et al. 2001). Table 1 shows the ingredients and chemical composition of the four experimental diets.

In accordance with the protein content of the goat skim milk powder and cow skim milk powder, the necessary quantity was taken to provide the total amount of protein required for each diet. As in each case skim milk contains a small amount of fat, the amount needed for each diet was obtained from goat milk cream or cow milk butter. To do so, the necessary quantities of these materials were melted in a bain-marie and then centrifuged (Hetticj; Universal 30 RF, Germany) at 4 °C and at 4000 rpm for 15 min, to separate out the supernatant fraction, which was composed entirely of fat. Each diet contained 5% purified cellulose as well as 3.5% mineral mix and 1% vitamin mix, as recommended by the American Institute of Nutrition (Reeves et al. 1993). In each case, the mineral mix was prepared taking into account the mineral composition of the corresponding skim milk powder. To complete the composition of each diet, wheat starch and saccharose were added, in proportions similar to those

recommended by the American Institute of Nutrition (Reeves et al. 1993).

Experimental procedure

The animals consumed the diets *ad libitum* and had free access to water throughout the assay period. During the first 3 weeks, the individual food intake and the body weight (BW) were recorded twice weekly. During the final week of the experimental period, a balance assay was performed and the food intake was quantified daily, and the faeces and urine produced by each animal were collected. Urine was collected in 0.5% HCl (v/v). Following the balance assay, all the animals were killed by an intraperitoneal injection of sodium pentobarbital (Pentothal; Abbot, Madrid, Spain). Then the stomach and intestines of each animal were emptied and cleaned and the bodies stored at -20°C until required for analysis. The animals that had been killed on arrival at the laboratory were dealt with in the same way. All management and experimental procedures conducted in this study were carried out in strict accordance with the requirements of the EU and Spanish rules and guidelines regarding the ethical treatment of laboratory animals (Jefatura del Estado, 2007). While still frozen, the animal bodies were minced in a Retsch ZM1 mill (Retsch, Haan, Germany), using liquid nitrogen and a 1-mm matrix size. After mincing, samples were stored at -20°C until required for analysis.

Measurements and analysis

Dry matter (DM) was determined by oven-drying at $100\pm 2^{\circ}\text{C}$ for 24 h. Nitrogen was measured using a Kjeldahl method (AOAC, 2005). Protein-N was calculated as the difference between total N and non-protein N (NPN). Total N was determined from whole skim milk powder samples. After preparing a solution of each type of skim milk powder, the NPN content was determined on a filtrate of the solutions after precipitation with 12% (w/v) trichloroacetic acid. Protein-N values were converted to protein by multiplying by a factor of 6.38. The fat content of the skim milk powders was measured by the Gerber method (AOAC, 2005) after preparing a solution of each one. Concentrations of Ca, Mg, Fe, Cu and Zn were determined by atomic absorption spectrophotometry (Perkin-Elmer 1100 B1; Perkin-Elmer, Shelton CT, USA) by a wet ashing method (Alferez et al. 2006). The concentration of P was determined by visible spectrophotometry (Perkin-Elmer UV/vis spectrometer Lambda 16) using the Fiske-Subbarow technique (Fiske & Subbarow, 1925).

The protein-fraction composition was established by the NIRS methodology (Burns & Ciurzak, 2001; Gómez-Ruiz et al. 2004). A continuous-spectrum monochromator spectrophotometer (Foss-NIRSystem 6500, Foss Inc., Silver Spring MD, USA) fitted with a gyro mechanism, scanning from 400 to 2500 nm, was used to obtain the spectra of the

milk samples. Spectra were compiled using ISI NIR53 version 2.05 (Infrasoft International, Port Matilda PA, USA). Chemometric processing of the spectroscopic data was performed using the program Winisi II, version 1.04 Foss-NIRSystem/Tecator (Infrasoft International). Preparation of the skim milk powder samples for analysis consisted of obtaining a solution of each skim milk powder, heating to 40°C , and then introducing a fibreglass filter (Millipore AP40, Millipore, Billerica MA, USA) soaked in the milk solutions.

To determine the fatty acid composition of the goat and cow milk fat, fatty acid methyl esters were prepared (Lepage & Roy, 1986). These were separated in an Autosystem GC (Perkin-Elmer, Norfolk CT, USA) fitted with an SP-2560 fused silica capillary column [100 m long, 0.25 mm (i.d.), 0.20 μm film; Supelco Bellefonte PA, USA] equipped with a flame ionization detector. The temperature was programmed from 150°C to 185°C at 5 deg C/min held for 30 min and then to 230°C at 5 deg C/min held for 26 min. The carrier gas was N_2 . Injector and detector temperatures were 250°C and 300°C , respectively. Peaks for individual fatty acids were identified using pure methyl ester standards (Supelco, Bellefonte PA). Standards for CLA isomers (*cis*-9, *trans*-11, CLA and *trans*-10, *cis*-12 CLA) were obtained from Matreya Inc. (Pleasant Gap PA, USA). Peak areas for individual fatty acids were corrected for recovery using a butter-oil reference standard (CRM 164, Commission of the European Community Bureau of References, Brussels, Belgium).

Samples of faeces, urine and body mass were analysed for DM, N and energy content. Fat content of body mass was also determined. DM was determined by lyophilization and N content using a Kjeldahl method (AOAC, 2005). The energy content of the samples was determined by adiabatic bomb calorimeter (CBA-305; Gallenkamp, London, UK). The fat content (neutral lipid fraction plus phospholipid fraction) of body mass was determined by extraction with a chloroform-methanol mixture (2:1, v/v; Folch et al. 1957). The weights of protein and fat deposited were measured by the comparative slaughter method, i.e. the body composition of animals killed at the beginning and 30 d after starting the experiment. Energy retained as protein and as fat were calculated by multiplying the weight of protein deposited by 23.8 (kJ/g protein) and the weight of fat deposited by 39.8 (kJ/g fat) (Brouwer, 1965; Van Assendelft et al. 1973). As energy retained is primarily protein and fat, this was calculated as the sum of energy retained as protein and energy retained as fat. Heat production was calculated as the difference between metabolizable energy (ME) intake and total energy retained. Values for each individual animal were calculated from its mean body weight over the experimental period, between days 0 and 30 after starting the experiment. Finally, heat loss associated with protein oxidation was calculated as the difference between the corresponding ME intake and energy retention. In the same way, heat loss associated with fat oxidation was calculated with the assumption that

Table 2. Composition of goat skim milk powder and cow skim milk powder

	Goat skim milk powder	Cow skim milk powder
Dry matter (DM), %	94.24	94.17
Protein, % of DM	32.26	34.94
Fat, % of DM	0.92	0.59
Mineral composition, mg/100 g DM		
Ca	971.30	937.90
P	974.30	785.10
Mg	113.60	86.60
Fe	1.02	0.97
Cu	0.25	0.13
Zn	3.42	5.01

Table 3. Protein fraction composition (g/100 g total protein) of goat milk protein and cow milk protein

Fraction	Goat milk protein	Cow milk protein	Difference, %†
Total casein	83.02	83.31	-0.35
α_{s1} -casein	18.50	29.02	-56.86
α_{s2} -casein	10.83	6.51	+39.89
β -+ κ -casein	53.73	47.78	+11.07
Whey protein	16.98	16.69	+1.71

† Differences between goat milk protein value and cow milk protein value [(goat milk protein value-cow milk protein value)/goat milk protein value \times 100]

fat deposition was entirely of dietary origin (Astrup et al. 2002; Sanz Sampelayo et al. 2006).

Statistical analysis

N intake, N balance, energy intake and energy balance data were analysed using Statgraphics statistical software (Statgraphics, 2001). The model took into account the two factors involved (protein and fat source in the diet) and the interaction between them. When the interaction term was not statistically significant ($P > 0.05$), the least-squares means were calculated from the model omitting this term. Duncan's multiple range test was used to determine the differences among means. Tables describe the mean values, RSD (square root of the error mean square) and the level of significance of the effects.

Results

Table 2 shows the composition of goat skim milk powder and cow skim milk powder. Differences in the mineral content reveal that goat skim milk powder contained a greater concentration of Ca, P, Mg and Cu. On the other hand, there were no differences regarding Fe, and only

Table 4. Fatty acid composition (g/100 g fatty acids) of goat milk fat and cow milk fat

Item†	Goat milk fat	Cow milk fat	Difference, %‡
C4:0	2.28	5.68	
C6:0	2.67	2.38	+12.61
C8:0	3.14	1.87	+67.91
C10:0	10.96	3.88	+182.47
C11:0	0.12	0.07	+41.67
C12:0	5.44	3.93	+38.42
C14:0	11.43	11.31	+1.05
C14:1	0.18	0.25	-38.89
C15:0	0.83	1.11	-33.73
C15:1	0.23	0.24	-4.35
C16:0	27.37	30.83	-12.64
C16:1	0.78	1.47	-88.46
C16:2 n-4	0.12	0.05	+58.33
C17:0	0.53	0.55	-3.77
C17:1	0.28	0.25	+10.71
C18:0	7.89	9.84	-24.71
C18:1 n-9, <i>trans</i>	-	1.59	-
C18:1 n-9, <i>cis</i>	21.23	20.75	+2.26
C18:2 n-6	2.78	2.50	+10.97
CLA n-7, <i>cis</i> -9, <i>trans</i> -11	0.29	0.51	-75.86
CLA n-6, <i>trans</i> -10, <i>cis</i> -12	0.07	0.04	+42.86
CLA n-7, <i>cis</i> -9, <i>cis</i> -11	0.02	-	-
CLA n-5, <i>cis</i> -11, <i>trans</i> -13	0.33	-	-
CLA total	0.71	0.55	+22.54
C18:3 n-3	0.52	0.33	+36.54
C20:0	0.19	0.13	+31.58
C20:1 n-9	-	0.09	-
C20:2 n-6	0.03	0.11	-266.67
C20:3 n-6	-	0.05	-
C21:0	0.05	0.02	+60.00
C22:0	0.18	0.15	+16.67
C23:0	0.02	0.02	-
C24:0	0.02	0.02	-
C24:1 n-9	0.02	-	-
MCFA	33.94	23.69	+43.27
SFA	73.12	71.77	+1.85
MUFA	22.72	24.64	-8.45
PUFA	4.16	3.59	+13.70
PUFA n-6	2.88	2.70	+6.25
PUFA n-3	0.52	0.33	+36.54

† MCFA=medium chain fatty acids, SFA=saturated fatty acids, MUFA=monounsaturated fatty acids, PUFA=polyunsaturated fatty acids

‡ Differences between goat milk fat value and cow milk fat value [(goat milk fat value-cow milk fat value)/goat milk fat value \times 100]

minor ones in the case of Zn. Table 3 shows the protein fraction composition of the protein in the goat and cow skim milk powder, and Table 4 shows the fatty acid profile of the goat milk cream and the cow milk butter. In both cases, the differences are conspicuous, reflecting the different composition of the protein and fat in these two types of milk.

Table 5 shows the results for utilization of N by diet consumed as well as the results of the statistical analysis.

Table 5. Effect of protein and fat source in the diet on nitrogen intake and excretion

Fat source	Protein source					Level of significance†		
	Goat milk		Cow milk		RSD‡	Protein source, P	Fat source, F	P × F
	Goat milk	Cow milk	Goat milk	Cow milk				
	g N/metabolic body weight							
Intake N	1.119	1.120	1.120	1.130	0.045	NS§	NS	NS
Faecal N	0.033 ^a	0.036 ^a	0.066 ^b	0.067 ^b	0.010	***	NS	NS
Urine N	0.415 ^a	0.433 ^a	0.420 ^a	0.478 ^b	0.024	NS	***	*
Digestible N	1.086	1.084	1.054	1.063	0.007	***	NS	NS
Retained N	0.670 ^a	0.651 ^b	0.634 ^b	0.585 ^c	0.024	***	**	NS
	%							
Digestible N/intake N	97.05 ^a	96.79 ^a	94.11 ^b	94.07 ^b	0.70	***	NS	NS
Retained N/intake N	59.87 ^a	58.13 ^b	56.61 ^b	51.77 ^c	2.01	***	***	NS
Retained N/digestible N	61.69 ^a	60.05 ^b	60.15 ^b	55.03 ^c	2.12	*	***	NS

† Protein source=main effect of protein source; fat source=main effect of fat source; P × F=protein source × fat source interaction

‡ RSD=residual standard deviation

§ $P > 0.05$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; ^{a, b, c} values with different superscript letters are different

The dependent variables measured included N intake, faecal and urinary N excretion, digestible N (N intake less faecal excretion) and N retained (digestible N less urinary excretion). All values are expressed as g per unit of metabolic body weight per day ($\text{g}/\text{kg}^{0.75}$ per d). In order to analyse the efficiencies with which N intake was utilized for digestion and metabolism, the ratios indicative of such efficiencies were calculated. The protein source affected ($P < 0.05$) values of faecal N excretion, digestible N, retained N, digestible N/intake N, retained N/intake N and retained N/digestible N. Except in the case of faecal N excretion, all these values were higher in the animals fed diets with goat milk protein. The fat source affected ($P < 0.05$) urinary N excretion, retained N, retained N/intake N and retained N/digestible N. Except in the case of urinary N excretion, all these values were higher in the animals fed diets with goat milk fat. The interaction between factors for urinary N excretion was significant ($P < 0.05$); the mean value for the diet with goat milk protein and fat was lower than that corresponding to the one with cow milk protein and fat.

Table 6 shows the results for energy utilization by diet consumed, together with the results of the corresponding statistical analysis. The parameters measured included gross energy intake, faecal and urine energy excretion, digestible energy intake (gross energy intake less faecal energy excretion), ME intake (digestible energy intake less urine energy excretion), energy retained as protein, energy retained as fat, total energy retention, total heat loss (ME intake less total energy retention), heat loss associated with protein oxidation and heat loss associated with fat oxidation, all expressed as $\text{kJ}/\text{kg}^{0.75}$ per d, as well as the energy efficiencies. Protein source influenced the digestible energy intake/gross energy intake ($P < 0.05$) with higher values being recorded in the animals fed diets with goat milk

protein. Fat source influenced faecal energy excretion, total energy retained, energy retained as fat, digestible energy intake/gross energy intake, total energy retained/ME intake, and heat loss associated with fat oxidation/total heat loss ($P < 0.05$). Except in the case of digestible energy intake/gross energy intake and heat loss associated with fat oxidation/total heat loss, all these values were lower in the animals fed diets with goat milk fat. Together with this, heat loss associated with protein oxidation/total heat loss tended ($P = 0.13$) to be also lower in the animals fed diets with goat milk fat. The interaction between factors for digestible energy intake/gross energy intake was significant ($P < 0.05$); the mean value for the diets with goat milk protein was higher but only when the fat was also from goat milk.

Discussion

Utilization of protein

Children with intolerance to the protein in cow milk show that when the latter is replaced by goat milk, it is better tolerated and its digestive utilization is higher (Fabre, 1997; Grzesiak, 1997; Reinert & Fabre, 1997). López-Aliaga et al. (2003), in a study in which rats were fed diets in which only part of the protein was derived from cow milk or goat milk, reported better digestibility and N balances when the diet utilized was the one containing protein from goat milk. The better digestive utilization of goat milk protein compared with the cow counterpart is probably due to its softer curd formation, which is more easily broken down by the action of the stomach proteinases, resulting in higher digestibility (Park, 1994, 2006). This different behaviour results from the differences in composition, especially with

Table 6. Effect of protein and fat source in the diet on energy intake and excretion

Fat source	Protein source					Level of significance†		
	Goat milk		Cow milk		RSD‡	Protein source, P	Fat source, F	P × F
	Goat milk	Cow milk	Goat milk	Cow milk				
	kJ/kg ^{0.75} per d							
Gross energy intake	1304.8	1320.4	1287.2	1366.2	77.1	NS‡‡	NS	NS
Faecal energy	39.5 ^a	95.3 ^b	59.2 ^a	91.1 ^b	19.0	NS	***	NS
Urine energy	39.3	37.7	38.3	39.7	4.8	NS	NS	NS
Digestible energy intake	1265.3	1225.1	1228.0	1275.1	71.0	NS	NS	NS
Metabolizable energy intake	1226.1	1187.5	1189.6	1235.4	69.0	NS	NS	NS
Energy retained	254.4 ^a	275.8 ^b	252.4 ^a	281.6 ^b	18.1	NS	**	NS
Energy retained as protein	99.8	96.9	95.5	93.3	5.3	NS	NS	NS
Energy retained as fat	155.6 ^a	178.9 ^b	156.9 ^a	188.3 ^b	16.6	NS	***	NS
	%							
Digestible energy/gross energy	96.97 ^a	92.78 ^c	95.40 ^b	93.33 ^c	0.51	**	***	***
Energy retained/metabolizable energy	20.75 ^a	23.23 ^b	21.22 ^a	22.79 ^b	1.75	NS	*	NS
HLp/HL§	2.34	2.90	2.55	3.14	0.91	NS	NS	NS
HLf/HL¶	10.76 ^a	7.41 ^b	10.04 ^a	7.53 ^b	1.56	NS	***	NS

† Protein source=main effect of protein source; fat source=main effect of fat source; P × F=protein source × fat source interaction

‡ RSD=residual standard deviation

§ HLp/HL=heat loss associated with protein oxidation/total heat loss

¶ HLf/HL=heat loss associated with fat oxidation/total heat loss

‡‡ P>0.05; ** P<0.01; *** P<0.001; ^{a, b, c} values with different superscript letters are different

respect to the casein fractions. As shown in the present study, the protein in cow milk has a higher proportion of α_{s1} -casein (Haenlein, 2004). The high degree of genetic polymorphism among goats, related to the levels of α_{s1} -casein in their milk, would account for the different behaviour of the casein fractions in the stomach (Ambrosoli et al. 1988; Haenlein, 2004). As for the possible effect of the nature of the fat in the two types of milk on the digestive utilization of protein, Aurousseau et al. (1989) commented that MCT could give rise to higher levels of protein digestibility, as the easy hydrolysis of these compounds in the stomach facilitates the degradability of the protein content of the coagulate that contains both nutrients. From the results of the present study we may conclude that the digestive utilization of the protein in the different diets was determined by its origin, and that there was no influence of the nature of the fat; better results were obtained when the protein was derived from goat milk.

With respect to the metabolic utilization of the digestible protein of goat or cow milk, as determined by the nature of the fat it contains, goat milk fat might be expected to have a greater effect due to its higher content of MCT. These compounds not only result in faster, more efficient digestion than is achieved by long-chain triglycerides (García Unciti, 1996; Alférez et al. 2001), but they also give rise to powerful, fast oxidative metabolism, thus showing themselves to be excellent sources of energy that could be made use of in various metabolic processes,

including protein synthesis (Velázquez et al. 1996; Matsuo & Tekeuchi, 2004). The results obtained in the present study suggest that the metabolic utilization of N is dependent on the protein source and on dietary fat, with that obtained from goat milk exercising a positive effect. This protein-sparing effect of the goat milk fat would be a consequence of its particular nature, an aspect that is highlighted in this study by the fatty acid profile of the two types of milk fat.

Utilization of energy

Diet-induced thermogenesis plays an important role in regulating energy balance and, consequently, body composition (Trayhurn et al. 1982). The macronutrient composition of the diet influences this thermogenesis, and therefore the total flow of energy lost as heat by the organism (Rothwell, 1979). The nature of dietary fat, with respect to its fatty acid composition, can influence diet-induced thermogenesis and, hence, fat deposits in the body (Shimomura et al. 1990). Various experimental results have suggested that MCT are oxidized as an energy source faster and more intensely than are long-chain triglycerides; therefore, they are deposited in the body in smaller quantities, which gives rise to an increase in diet-induced thermogenesis (Su & Jones, 1993; Matsuo & Takeuchi, 2004). In rats fed the same diet, in terms of energy, containing MCT or saturated fatty acids, both the weight gain and the quantity of fat deposits were lower

when the diet contained MCT; moreover, the rate of basal metabolism was higher (Senior, 1990). Matsuo & Takeuchi (2004) report that MCT have a particular metabolic destination, which accounts for the difference observed with these compounds concerning postprandial thermogenesis. The fatty acids in these compounds penetrate the mitochondria of the liver cells, independently of acyl-CoA carnitine transferase. The acyl-CoA formed during β -oxidation may subsequently be oxidized via the Krebs cycle, to form CO₂ and water (Velázquez et al. 1996). The level of enzymes in the Krebs cycle, considered to be an indicator of oxidative capacity in the mitochondria, is lower when MCT are consumed. Matsuo & Takeuchi (2004) report that this greater oxidative capacity is related to the mechanisms that determine the lower level of fat deposited when MCT are consumed, a consequence of the greater thermogenesis produced with consumption of a diet including these compounds. The latter authors remark that this particular metabolism is indicative of the possible utility of MCT for certain treatments for obesity.

The present results may be attributed to the differences in composition of cow and goat milk fats. The particular metabolism of MCT would mean that consumption of diets containing fat from goat milk would produce lower levels of retained energy, in the form of fat, as a consequence of the greater heat loss associated with their oxidation. Accordingly, there would also be a lower overall efficiency of utilization of ME consumed. Moreover, if the energy derived from the oxidation of fat can be used for protein synthesis such as is deduced from the present study, then a logical consequence would be a greater deposition of protein. From the above results, it might also be possible to calculate the final composition of the animals' live body weight. In the present experimental case, the BW of the animals did not differ (mean value=154.4±0.3 g) which reflects the absence of effects on growth. Other than this, the most important aspect of interest is that the fat in goat milk produces a lower level of fat retention, and thus the BW would tend to contain a lower proportion of fat.

Conclusions

The protein of goat milk is more digestible than that of cow milk. The digestible protein in both types of milk produces a metabolic utilization that depends both on its own nature and on that of dietary fat.

Goat milk fat, owing to its high content of MCT, intervenes more actively in diet-induced thermogenesis than does cow milk fat, producing lower levels of fat deposition and greater amounts of protein in the body. This leads us to deduce the existence of a protein-sparing effect of goat milk fat.

Since goat milk has certain advantages over cow milk (i.e., its hypoallergenicity and less problematic in terms of lactose intolerance) these properties should be sought in

the raw materials used for various dairy foods for the young and the elderly. The results of the present study should be considered in deciding which type of milk should be used.

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References

- Alferez MJM, Barrionuevo M, López-Aliaga I, Sanz Sampelayo MR, Lisbona F, Robles JC & Campos MS 2001 Digestive utilization of goat and cow milk fat in malabsorption syndrome. *Journal of Dairy Science* **64** 451–461
- Alferez MJM, López Aliaga I, Nestares T, Díaz-Castro J, Barrionuevo M, Ros PB & Campos MS 2006 Dietary goat milk improves iron bio-availability in rats with induced ferropenic anaemia in comparison with cow milk. *International Dairy Journal* **16** 813–821
- Ambrosoli R, Di Stasio L & Mazzoco P 1988 Content of α_{s1} -casein and coagulation properties in goat milk. *Journal of Dairy Science* **71** 24–28
- AOAC 2005 *Official Methods of Analysis*. 18th Edn. Gaithersburg, Maryland, USA: Association of Official Analytical Chemists
- Astrup A, Buemann B, Flint A & Raben A 2002 Low-fat diets and energy balance: how does the evidence stand in 2002? *Proceedings of the Nutrition Society* **61** 299–309
- Arousseau B, Vermorel M, Theriez M & Veinhet A 1989 Effects of substitution of tricaprilyng or coconut oil for tallow in milk replacers offered to pre-ruminant lambs. *Annales de Zootechnie* **38** 49–59
- Blaxter KL & Webster AJF 1991 Animal production and food: real problems and paranoia. *Animal Production* **53** 261–269
- Brouwer E 1965 Report of sub-committee on constants and factors. In *Energy Metabolism of Farm Animals*, pp. 441–442 (Ed. KL Blaxter). London, UK: Academic Press
- Fabre A 1997 Aspects of the utilization of goat milk in infant nutrition. In *Intérêts nutritionnel et diététique du lait chèvre*, pp. 123–126 (Ed. G Freund). Les Colloques N° 81, Paris, France: INRA Editions
- Fiske CH & Subbarow Y 1925 The colorimetric determination of phosphorus. *Journal Biological Chemistry* **66** 375–400
- Folch J, Less M & Stanley GHS 1957 A simple method for the isolation and purification of lipids from animal tissues. *Journal of Biological Chemistry* **226** 497–509
- Frankhuizen R 2001 NIR analysis of dairy products. In *Handbook of Near-Infrared Analysis. Practical Spectroscopy Series*. Vol. 27 (Eds D A Burns & E W Ciurczak) pp. 499–534. New York, USA: Marcel Dekker, Inc.
- García Unciti MS 1996 Therapeutic use of medium-chain triglyceride (MCT). Ketogenic diet during childhood epilepsy. *Nutrición Clínica* **16** 7–35
- Gómez Ruiz JA, Miralles B, Agüera P & Amigo L 2004 Quantitative determination of α_{s2} - and α_{s1} -casein in goats' milk with different genotypes by capillary electrophoresis. *Journal of Chromatography A* **1054** 279–284
- Grzesiak T 1997 Goat milk, the milk to have for nourishment. N° 81. In *Intérêts nutritionnel et diététique du lait chèvre*, pp. 127–148 (Ed. G Freund). Les Colloques N° 81, Paris, France: INRA Editions
- Haenlein GFW 2004 Goat milk in human nutrition. *Small Ruminant Research* **51** 155–163
- Jefatura del Estado 2007 Act of November 7, for the care of the animals on farm, transport, slaughter and experimentation. *Boletín Oficial del Estado 8 noviembre 2007* **268** 45914–45920
- Lepage G & Roy CC 1986 Direct trans-esterification of all classes of lipids in one step reaction. *Journal of Lipid Research* **27** 114–120
- Lewis B 1988 Nutrition, coronary heart disease and preventive medicine. *Proceedings of the Nutrition Society* **47** 269–295

- López-Aliaga I, Alférez MJM, Barrionuevo M, Nestares T, Sanz Sampelayo MS & Campos MS** 2003 Study of nutritive utilization of protein and magnesium in rats with resection on the distal small intestine. Beneficial effect of goat milk. *Journal of Dairy Science* **86** 2958–2966
- Matsuo T & Takeuchi H** 2004 Effects of structural medium- and long-chain triglycerides in diets with various levels of fat on body fat accumulation in rats. *British Journal of Nutrition* **91** 219–225
- Park YW** 1994 Hypo-allergenic and therapeutic significance of goat milk. *Small Ruminant Research* **14** 151–159
- Park YW** 2006 Goat milk. Chemistry and nutrition. In *Handbook of Milk of Non-Bovine Mammals*, pp. 34–58 (Eds Y W Park & G F W Haenlein) Oxford, UK: Blackwell Publishing
- Park YW & Haenlein GFW** 2006 Therapeutic and hypoallergenic values of goat milk and implication of food allergy. In *Handbook of Milk of Non-Bovine Mammals*, pp. 121–135 (Eds Y W Park & G F W Haenlein) Oxford, UK: Blackwell Publishing
- Reeves PG, Nielsen FH & Fahey JrGG** 1993 AIN-93. Purified diets for laboratory rodents: Final report of the American Institute of Nutrition ad hoc Writing Committee on the reformulation of the AIN-76A rodent diet. *Journal of Nutrition* **123** 1939–1951
- Reinert P & Fabre A** 1997 Use of goat milk for infants. Experience of Creteil N° 81. In *Intérêts nutritionnel et diététique du lait chèvre*, pp. 119–121 (Ed. G Freund). Les Colloques N° 81, Paris, France: INRA Editions
- Rothwell NJ** 1979 A role for brown adipose tissue in diet-induced thermogenesis. *Nature* **281** 31–35
- Sanz Sampelayo MR, Fernández JR, Ramos E, Hermoso R, Gil Extremera F & Boza J** 2006 Effect of providing a polyunsaturated fatty acid-rich protected fat to lactating goats on growth and body composition of suckling goat kids. *Animal Science* **82** 337–344
- Senior JR** 1990 *Medium Chain Tryglicerides*. pp. 3–6. Philadelphia PA, USA: University of Pennsylvania Press
- Shimomura Y, Tamura T & Suzuki M** 1990 Less body fat accumulation in rats fed a safflower oil diet than in rats fed a beef tallow diet. *Journal of Nutrition* **120** 1291–1296
- Sofos JN, Harmayani E & Smith GC** 1995 Cholesterol: health effects and potential for reduction. *Nutrition Abstract Review A* **65** 1–7
- Statgraphics** 2001 User manual: Statistical Graphics Systems by Statistical Graphics Corporation. Statgraphics, Herndon VA, USA
- Su W & Jones PJH** 1993 Dietary fatty acid composition influences energy accretion in rats. *Journal of Nutrition* **123** 2109–2114
- Trayhurn P, Goodbody AE & James WPT** 1982 A role for brown adipose tissue in the genesis of obesity? Studies on experimental animals. *Proceedings of the Nutrition Society* **41** 127–131
- UNU** 1980 Evaluation of protein quality in experimental animals. In *Nutritional Evaluation of Protein Feeds*, pp. 41–56 (Eds P L Pellet & V R Young). Tokyo, Japan: The United Nations University
- Van Assendelft OW, Mook GA & Zijlstra WG** 1973 International System of units (SI) in physiology. *Pflügers Archiv European Journal of Physiology* **339** 265–272
- Velázquez OC, Seto RW & Rombeau JL** 1996 The scientific rationale and clinical application of short-chain fatty acids and medium-chain triglycerides. *Proceedings of the Nutrition Society* **55** 49–78