

Digestive utilization of goat and cow milk fat in malabsorption syndrome

By M. J. M. ALFÉREZ^{1,2}, M. BARRIONUEVO^{1,2}, I. LÓPEZ ALIAGA^{1,2},
M. R. SANZ-SAMPELAYO³, F. LISBONA^{1,2}, J. C. ROBLES¹
AND M. S. CAMPOS^{1,2*}

¹*Departamento de Fisiología e* ²*Instituto de Nutrición y Tecnología de los Alimentos, Facultad de Farmacia, Campus Universitario de Cartuja, University of Granada, E-18071 Granada, Spain*

³*Estación Experimental del Zaidin. C.S.I.C., Departamento de Nutrición Animal, Profesor Albareda, 1, E-18008 Granada, Spain*

(Received 30 March 2000 and accepted for publication 5 February 2001)

SUMMARY. We studied the effects of goat and cow milk fat on the digestive utilization of this nutrient and on some of the biochemical parameters that are related to the metabolism of lipids, using rats with a resection of 50 % of the distal small intestine and control animals (transected). The fat content in all the diets was 10 % but the lipid quality was varied: the standard diet was based on olive oil, while the other two diets included fat obtained from lyophilized goat milk and cow milk, respectively. The digestive utilization of the fat was lower in the resected animals than in the transected ones for all three diets studied. In both resected and transected animals, the apparent digestibility coefficient (ADC) of the fat was greater with the standard diet (olive oil) than with diets whose fat content was provided by goat or cow milk. The digestive utilization of the fat was greater in the transected and resected rats receiving a diet of goat's milk (rich in medium-chain triglycerides) than those given a cow-milk-based diet, and more closely approached the values obtained for olive oil. The consumption of goat milk reduced levels of cholesterol while levels of triglycerides, HDL, GOT and GPT remained within the normal ranges, for both transected and resected animals. The advantageous effect of goat milk on the metabolism of lipids with respect to cow milk suggests that the former should be included in the diet in cases of malabsorption syndrome.

KEYWORDS: fat, goat milk, cow milk, malabsorption

Resections of the small intestine produce a great many disorders, both metabolic and endocrinal, which can lead to problems in the absorption of nutrients such as fats (Coves *et al.* 1991*a*). Although intestinal resection is associated with a compensatory response that consists of a variety of morphological and functional changes in the residual gut, the intensity of this response is dependent on factors such as the site of resection (Sarna *et al.* 1983; Wittman *et al.* 1985), the amount of bowel removed (Hanson *et al.* 1977*a*), the time elapsed after surgery (Hanson *et al.* 1977*b*) and the type of nutrition provided (Biasco *et al.* 1984).

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

The resection of 50% of the distal small intestine (DSI) produces a significant decrease in the amount of fat absorbed, which is reflected in the apparent digestibility coefficient (ADC; Barrionuevo & Campos, 1980; Coves *et al.* 1988, 1991a), due to a diminution in the absorptive surface area and to the greater intestinal transit speed, which means there is less contact time between the fat and the mucosa (Ladefoged *et al.* 1996). Moreover, as the ileum is the preferential site for the absorption of bile salts, distal resection of the small intestine creates an interruption in enterohepatic circulation which impedes the absorption of fats (Erlinger, 1987).

The search for nutrients with a lipid content that favours digestive utilization, particularly in cases of deficient absorption syndrome, led us to study goat milk, which is rich in medium-chain triglycerides (MCT). Two of the diets studied were created with lyophilized cow and goat milk, with a fat content of 10% (greater than that recommended by the American Institute of Nutrition, 1977, for the rat). The purpose of this was to study the effects of the fat in this kind of milk on digestive utilization and on some of the biochemical parameters related to lipid metabolism. We also sought to determine whether the level of fat in these diets, 10%, twice that used in studies by other authors (Coves *et al.* 1991a; Lisbona *et al.* 1999), had a positive or a negative effect on these animals' recovery. In the present study, cows' milk was used as a control because it is the milk that is usually provided in nutrition, while olive oil was used as the source of fat for the standard diet due to its well-known beneficial effects on lipid metabolism (Grundy, 1986).

MATERIALS AND METHODS

Animals

We studied a total of 69 male albino Wistar rats with an initial body weight of 177 ± 3 g, obtained from the University of Granada Laboratory Animal Service. All experiments and surgical procedures using rats conformed to the guidelines and legal requirements established in the UK for the proper care and use of laboratory animals. After surgery both the transected and resected animals were housed in individual ventilated thermoregulated cages (22 ± 2 °C) with a 12:12 h light:dark photoperiod. Food and distilled 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 created with lyophilized cow milk 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 lyophilized: cow milk: Ca: 1031.5, P: 731.3, Mg: 76.3; Fe: 0.61; Cu: 0.11 and Zn: 3.72; goat milk: Ca: 1215.2, P: 843.3, Mg: 82.5, Fe: 1.13, Cu: 0.42 and Zn: 4.15). The necessary quantities of lyophilized goat milk or cow milk were taken 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 diet cow's milk and 14.05 g casein/100 g diet goat's milk), as the protein provided by the liophylate used for the milk-based diets was insufficient.

Table 1. *Composition of the experimental diets*

	g/kg diet (dry weight)
Diet S	
Protein (casein)	209
DL-methionine	3
Fat (olive oil)	112
Fibre (micronized cellulose)	50
Mineral supplement*	36
Vitamin supplement*	10
Choline chloride	2
Wheat starch	156
Sucrose	450
Diet C	
Protein (casein + protein cow milk)	190
DL-methionine	3
Fat (cow milk)	98
Fibre (micronized cellulose)	40
Mineral supplement*	35
Vitamin supplement*	10
Choline chloride	2
Wheat starch	121
Sucrose	387
Lactose (cow milk)	131
Diet G	
Protein (casein + protein goat milk)	194
DL-methionine	3
Fat (goat milk)	92
Fibre (micronized cellulose)	46
Mineral supplement*	36
Vitamin supplement*	10
Choline chloride	2
Wheat starch	148
Sucrose	405
Lactose (goat milk)	85

* Mineral and vitamin supplements were prepared according to the recommendations of the American Institute of Nutrition (1977).

The mineral correctors were prepared according to AIN recommendations (1977) for the standard diet and to our own specifications for the milk-based diets. These specific correctors 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).

The lactose content of the milk diets was subtracted from the total carbohydrate content of the standard diet and wheat starch and sucrose were added corresponding to the difference (Table 1). The fatty acid composition of diets is shown in Table 2.

Resection and transection procedures

The method described by Hartiti *et al.* (1995) was used to carry out the resection of 50% of the distal small intestine and the transection.

Experimental design

Six experimental groups were formed: (1) group T-S, transected rats, standard diet ($n = 11$); (2) group R-S, 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/l glucose for 24 h after surgery. Thereafter, a period of 30 d was allowed for adaptation to the diet, during which feed and double-distilled 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, refused and spilled) was measured and urine and faeces were collected daily for a period of 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 double-distilled water. At the end of this period all animals were fasted for 24 h and killed after intraperitoneal anaesthesia with sodium pentobarbital (5 mg/100 g body weight) and totally bled by cannulation of the abdominal aorta. The entire volume of blood was centrifuged to separate the serum, which was frozen at -30°C until biochemical analysis.

Biological indices

The ADC was calculated according to the formula:

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

where nutrient absorption = intake – faecal excretion

Analytical methods

Water content in the diet and faeces was determined by drying the material at $105 \pm 2^{\circ}\text{C}$ until the weight remained constant. Determination of the fat content in the diet and the faeces was performed using the Stoldt method, acid hydrolysis with HCl and obtention of the dry extract by ether, using the Soxhlet method. Cholesterol was determined by the CHOD-PAD method, colorimetric enzymatic tests, Peridochrom® Cholesterol (Boehringer Mannheim GmbH Diagnostica). Triglycerides were determined by a colorimetric enzymatic test, Peridochrom® Triglycerides GPO-PAP (Boehringer Mannheim GmbH Diagnostica). Glutamate oxalacetate transaminase (GOT) was determined by an ASAT/AST/GOT Monotest®, according to IFCC/NUKC without pyridoxal phosphate and without blanks, UV test (Boehringer Mannheim GmbH Diagnostica). Glutamate piruvate transaminase (GPT) was determined by an ALAT/ALT/GPT Monotest®, according to IFCC/NUKC without pyridoxal phosphate and without blanks, UV test (Boehringer Mannheim GmbH Diagnostica). Serum cholesterol associated with HDL was determined by the CHOD-PAD method (Boehringer Mannheim GmbH Diagnostica).

Statistical analysis

We calculated the mean and the standard error of the mean for each parameter studied. Variance analysis (the oneway method of the SPSSPC) 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 a Student's *t* test for independent samples (the SPSSPC TTEST procedure). Values of $P < 0.05$ were considered significant.

RESULTS

Food intake and variations in body weight

No differences were observed between the intake of nutrients by the control (transected) animals and those with an intestinal resection, for each of the diets tested. Nevertheless, food intake was somewhat higher in resected animals than in

Table 2. Fatty acid contents of experimental diets

Fatty acids (%)	Diet S (virgin olive oil)*	Diet C (cow milk diet)	Diet G (goat milk diet)
C _{4:0}	—	3.67	2.46
C _{6:0}	—	2.89	4.11
C _{8:0}	—	1.27	4.25
C _{10:0}	—	2.55	11.37
C _{12:0}	—	2.58	4.51
C _{14:0}	—	8.73	9.34
C _{14:1}	—	0.96	0.52
C _{16:0}	11.32	28.63	24.17
C _{16:1}	0.95	1.52	0.93
C _{17:0}	—	0.64	0.81
C _{18:0}	4.34	13.79	9.56
C _{18:1}	74.12	26.99	22.10
C _{18:2}	7.64	3.36	2.08
C _{18:3}	0.61	1.42	0.78
C _{20:0}	—	0.20	0.35
C _{20:2}	—	0.22	0.16
C _{20:3}	—	0.05	0.06
C _{20:4}	—	0.23	0.15
C _{20:5}	—	0.06	0.06
C _{22:0}	—	0.09	0.13
C _{22:6}	—	0.03	0.04
Medium-chain triglycerides	—	21.70	36.04
Saturated fatty acids	16.02	65.68	71.88
Unsaturated fatty acids	83.98	34.86	26.86
Monounsaturated fatty acids	75.06	29.48	23.54
Polyunsaturated fatty acids	8.25	5.38	3.32

* Mataix *et al.* 1998.

Table 3. Changes in body weight and food intake in transected and resected rats

Group	<i>n</i>	Initial weight (g)	Final weight (g)	Weight change (g/rat per day)	Food intake (g/rat per day)
T-S	11	328.1 ± 8.2	350.5 ± 9.3	3.21 ± 0.30	18.62 ± 0.59 ^{a,b}
R-S	13	324.9 ± 6.3	344.8 ± 7.9	2.85 ± 0.48	19.18 ± 0.64 ^{c,d}
T-C	10	333.6 ± 8.9	351.2 ± 8.9	2.51 ± 0.57	20.71 ± 0.50 ^e
R-C	11	331.2 ± 6.4	350.8 ± 6.8	2.81 ± 0.22	22.16 ± 0.58 ^f
T-G	14	326.7 ± 5.8	345.7 ± 6.1	2.71 ± 0.21	16.24 ± 0.34
R-G	10	322.0 ± 6.3	344.8 ± 6.9	2.86 ± 0.32	16.85 ± 0.62

All values are expressed as mean ± SEM.

R-C, resected rats, cow-milk diet; R-G, resected rats, goat-milk diet; R-S, resected rats, standard diet; T-C, transected rats, cow-milk diet; T-G, transected rats, goat-milk diet; T-S, transected rats, standard diet.

^a Significant difference between T-S and T-C.^b Significant difference between T-S and T-G.^c Significant difference between R-S and R-C.^d Significant difference between R-S and R-G.^e Significant difference between T-C and T-G.^f Significant difference between R-C and R-G.

transected controls. On comparing the three diets, we see that consumption of the goat-milk diet was significantly lower than that of the other two diets, both for the control and for the resected animals. In turn, the intake of the standard diet was less than that of the cow-milk diet (Table 3).

Weight gain was not affected by intestinal resection nor by the type of diet supplied; the results were similar among the six groups of animals comprising the study (Table 3).

Table 4. *Digestive utilization of fat in transected and resected rats*

Group	<i>n</i>	Fat intake (mg/rat per day)	Faecal fat (mg/rat per day)	Absorbed fat (mg/rat per day)	ADC (%)
T-S	11	1902.7 ± 60.7 ^a	107.8 ± 16.0 ^{g,h}	1794.9 ± 64.9 ^{a,h}	94.2 ± 0.9 ^{a,g,h}
R-S	13	1960.2 ± 65.8 ^{b,c}	193.6 ± 17.9 ^b	1766.6 ± 59.4 ^c	90.1 ± 0.8 ^{b,c}
T-C	10	1888.3 ± 81.4 ^{d,e}	274.4 ± 28.7 ^{d,e}	1613.9 ± 69.0 ^e	85.6 ± 1.2 ^{d,e}
R-C	11	2168.8 ± 56.8 ^f	574.5 ± 33.9 ^f	1594.4 ± 41.5 ^f	73.2 ± 1.2 ^f
T-G	14	1495.8 ± 31.1	142.9 ± 7.4 ⁱ	1352.9 ± 29.4	90.4 ± 0.5 ⁱ
R-G	10	1551.6 ± 56.8	207.1 ± 24.3	1344.5 ± 47.3	86.8 ± 1.2

All values are expressed as mean ± SEM.

R-C, resected rats, cow-milk diet; R-G, resected rats, goat-milk diet; R-S, resected rats, standard diet; T-C, transected rats, cow-milk diet; T-G, transected rats, goat-milk diet; T-S, transected rats, standard diet.

^a Significant difference between T-S and T-G.

^b Significant difference between R-S and R-C.

^c Significant difference between R-S and R-G.

^d Significant difference between T-C and R-C.

^e Significant difference between T-C and T-G.

^f Significant difference between R-C and R-G.

^g Significant difference between T-S and R-S.

^h Significant difference between T-S and T-C.

ⁱ Significant difference between T-G and R-G.

ADC of fat

The digestive utilization of fat was greater among the control rats (transected) than among those subjected to intestinal resection, irrespective of the type of diet. For the animals given the standard (olive oil) diet, the ADC of the fat was greater than for the diets based on cow milk or goat milk, both transected and resected rats. The digestive utilization of the fat was higher for goat milk than for cow milk, for both groups of animals (Table 4).

Triglycerides

The serum level of triglycerides was not affected by intestinal resection for any of the diets, and was similar to that of the control (transected) animals. There were no large differences between the animals given cow-milk-based or goat-milk-based diets, but levels in both cases were significantly higher than for the rats that consumed the standard olive oil diet (Table 5).

Cholesterol

The total cholesterol level was significantly lower in the resected rats than in the transected ones when the standard olive oil diet was supplied. In contrast, for the rats given a milk-based diet (whether cow or goat milk), the quantity of cholesterol in serum was similar for the two groups of animals. In the control animals, the cholesterol level was similar for the standard and cow-milk-based diets, but significantly lower among the animals that were given goat milk. Among the rats with an intestinal resection, the lowest levels of cholesterol were found for those taking the goat milk diet, followed by those given the standard diet, whilst the highest levels corresponded to the animals given the cow-milk-based diet (Table 5).

High density lipoprotein

The HDL fraction was not affected by the intestinal resection, and was similar to that of the control animals for each of the three diets in the study. There were no differences in HDL levels among the transected animals given the three diet types.

Table 5. Lipid and hepatic metabolism in transected and resected rats

Group	<i>n</i>	Triglycerides (g/l)	Cholesterol (g/l)	HDL (g/l)	GOT/ASAT (UI/l)	GPT/ALAT (UI/l)
T-S	11	0.65 ± 0.024 ^{a,b}	0.76 ± 0.022 ^{e,b}	0.16 ± 0.029	99 ± 9.7	13 ± 1.0 ^{a,b,e}
R-S	13	0.64 ± 0.023 ^{c,d}	0.66 ± 0.022 ^c	0.20 ± 0.015 ^c	92 ± 6.6	17 ± 1.4 ^c
T-C	10	0.84 ± 0.016	0.79 ± 0.014 ^f	0.16 ± 0.009	107 ± 7.6 ^f	23 ± 1.0
R-C	11	0.82 ± 0.015	0.75 ± 0.016 ^g	0.14 ± 0.006 ^g	93 ± 5.7 ^g	24 ± 1.3 ^g
T-G	14	0.81 ± 0.016	0.67 ± 0.014	0.17 ± 0.008	91 ± 4.3 ^h	20 ± 1.5
R-G	10	0.81 ± 0.021	0.64 ± 0.017	0.19 ± 0.016	78 ± 2.6	17 ± 0.6

All values are expressed as mean ± SEM.

R-C, resected rats, cow-milk diet; R-G, resected rats, goat-milk diet; R-S, resected rats, standard diet; T-C, transected rats, cow-milk diet; T-G, transected rats, goat-milk diet; T-S, transected rats, standard diet.

^a Significant difference between T-S and T-C.

^b Significant difference between T-S and T-G.

^c Significant difference between R-S and R-C.

^d Significant difference between R-S and R-G.

^e Significant difference between T-S and R-S.

^f Significant difference between T-C and T-G.

^g Significant difference between R-C and R-G.

^h Significant difference between T-G and R-G.

Among the resected animals, however, the amount of HDL was higher among those given a goat-milk based diet, rather than the diet based on cow milk, and similar to the standard diet (Table 5).

Glutamate oxalacetate transaminase and glutamate pyruvate transaminase

The levels of GOT were found to be similar between the transected and the resected animals except in the case of the goat-milk-based diet, which produced lower levels among rats with an intestinal resection than among the respective control animals. The levels of GPT were similar between the transected and resected rats fed with milk-based diets and higher in resected rats fed with the standard diet with respect to transected rats fed the same diet. On comparing the diets, we observed that the resected animals given the cow-milk diet presented the highest quantities of GOT and GPT, followed by the standard diet and finally by the goat-milk diet (Table 5).

DISCUSSION

For the three diets studied, characterized by a 10% fat content and with differing lipid qualities, food intake is rather greater in resected rats than in transected controls; which seems to indicate that rats increase food intake to satisfy caloric needs, because after intestinal resection the absorptive surface is lower. These results coincide with those obtained by Coves *et al.* (1991a), who used a diet based on a 4% fat content (olive oil). The lipid quality does, however, seem to influence food intake, with the goat-milk diet being the least consumed. This might be due to the special organoleptic characteristics of this milk, which has an intense odour and strong flavour and a slightly salty taste (Jandal, 1996).

Due to the high MCT content of goat milk, and the fact that it is more rapidly metabolized to produce energy compared to LCT (long-chain triglycerides), the animal is able to adjust its food intake according to easier energy utilization.

With regard to weight gain, this was similar for all the groups of animals included in the study, despite the different quantities of food intake, depending on the diet type; thus the animals consuming the goat-milk diet presented a similar weight gain

to the other animals, although the quantity of food consumed was lower. This might be explained by the availability of energy provided by each diet (Alfárez *et al.* 1990). According to Tappenden *et al.* (1997), short chain fatty acids favour intestinal adaptation after intestinal resection, probably due to the increased quantity of other nutrients transported through the basolateral membrane. It is possible that medium chain fatty acids, which are absorbed within the intestinal cells without re-esterification and enter portal circulation directly, have the same effect on intestinal adaptation. Thus not only is energy obtention 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.

In order for the fatty acids to enter the mitochondria and to be oxidized, carnitine must be present, and this substance is found in goat milk in large quantities (136 $\mu\text{mol/l}$) (Sandor *et al.* 1982; Penn *et al.* 1987). Although the MCT do not need carnitine to enter the mitochondria, and thus their β -oxidation is faster than that of the LCT (Bach & Babayan, 1985), goat milk, with its high carnitine content, certainly favours the obtention of energy from the other fats present in the diet. One consequence of this is that although the three diets have the same caloric content, the lower food intake when the goat milk diet is provided nevertheless results in a weight gain similar to that of the other two diets.

The lesser absorption of fat in the rats with intestinal resection, for the three diets used in this study, is a result of the diminution in the absorptive surface area and of the increased speed of intestinal transit, which leads to a reduced contact period between the fat and the mucosa. This conclusion is in agreement with the findings of other authors (Barrionuevo & Campos, 1980; Coves *et al.* 1988; Tappenden *et al.* 1997).

The proportion of fat included in the standard olive oil diet (10%) improved the digestive utilization of this nutrient in both transected and, especially, resected rats, compared with the results obtained by Coves *et al.* (1991*a*), who used a diet based on a 4% fat content (olive oil). It is noteworthy that when half of the intestine was removed, thus reducing the absorptive surface, the increased fat content in the diet (10%) did not lead to greater faecal losses with respect to resected rats fed with olive oil diet (4%); however, absorption was clearly improved. Evidently, the intestine remaining is capable of making better use of the fat when its proportion in the diet is more than doubled. This supports the results of Alfárez *et al.* (1990), who found that an increase in the level of fat in the diet (to 14.5%) favoured its absorption. This phenomenon also occurs in resected animals, which is evidence of the rat's high degree of adaptability in situations of malabsorption (Warner *et al.* 1997).

A comparison of the digestive utilization of the fat content in olive oil (vegetable fat) with the two types of animal fat used (goat and cow milk fat) reveals that in both the transected and resected rats, utilization is greater when the lipid supply is olive oil, due to its high level of digestibility. This observation has been confirmed by other authors (Coves *et al.* 1991*b*).

On studying the digestive utilization of the fat (ADC) in the diets prepared with cow milk or goat milk, we discover that goat milk is of greater benefit for the transected animals and, especially, for those presenting malabsorption syndrome. This might be because goat milk improves digestive utilization and reduces faecal losses of this nutrient (characteristic of this type of syndrome). The fat of goat milk is more digestible than that of cow milk because the fat globules of goat milk are smaller and present a greater surface area; in consequence, lipases in the gut are able to attack the lipids more rapidly (Jandal, 1996).

The greater digestibility could also be due to the higher MCT content of the fat in goat milk with respect to that of cow milk (36% compared to 21%, respectively; Table 2). These results agree with those obtained by Coves *et al.* (1991b), who concluded that the presence of medium chain fatty acids increases digestive utilization of the fat. Therefore, we conclude that the digestive utilization of goat milk fat is not only much greater than that of cow milk fat but that it approaches the ADC of olive oil, both in transected and resected animals.

Although the ADC of fat was lower in the animals with intestinal resection for the three diets tested in this study, the level of triglycerides did not vary with respect to the control (transected) animals; this may have been due to the fact that, in absolute terms, the absorption of fat is similar in both groups of animals and thus the triglyceride levels should also be comparable. When the goat or cow milk diet was provided, both the transected and resected animals presented the same level of triglycerides in serum. These levels were higher than those obtained for the olive oil diet, which was expected as animal fat is known to raise the level of triglycerides in serum (Jacques *et al.* 1992).

The level of cholesterol in serum in transected animals given a standard diet containing 10% olive oil was the same as that found by Coves *et al.* (1991a) and by Lisbona *et al.* (1999), who used diets containing 4% and 5% olive oil, respectively. This shows that for higher levels of fat in the diet, the use of olive oil does not affect levels of cholesterol in serum in the rat.

In the animals with intestinal resection supplied with the standard diet, the cholesterol level was lower than that of the control animals; this coincides with the findings of Coves *et al.* (1991a). This fall in the level of cholesterol in serum could be a consequence of the fact that in the resected animals, the enterohepatic circulation of bile salts was largely interrupted, and so *de novo*-synthesized cholesterol was routed toward the biosynthesis of these acids (Turley & Dietschy, 1981, 1982; Gómez-Ayala *et al.* 1994).

With regard to the milk-based diets (cow or goat milk), there were no differences in levels of cholesterol in serum between transected and resected animals, which could be due to the cholesterol provided by the milk. Therefore, although among the resected animals the level of endogenous cholesterol fell because it was routed to synthesis bile salts (Turley & Dietschy, 1981, 1982; Gómez-Ayala *et al.* 1994), the diet provided an input of exogenous cholesterol which counterbalanced this effect in rats with intestinal resection.

On comparing the milk-based diets prepared for transected and resected animals, we see that the lowest level of cholesterol corresponded to the two groups of animals given goat milk; this agrees with the results obtained by Zoppi *et al.* (1995) who experimentally showed that the consumption of a diet containing goat milk reduces both total cholesterol levels and the LDL fraction. This fall in the level of cholesterol in serum among animals consuming goat milk could be a result of lower food intake and also of the higher levels of MCT (36%) compared to cow milk (21%), as the presence of MCT in the diet reduces the synthesis of endogenous cholesterol and its intestinal absorption (The American Dietetic Association, 1992). The endogenous synthesis of cholesterol from Acetyl-CoA, obtained from the β -oxidation of the MCT in the mitochondria, is slowed down as a result of the reduced activity of the enzyme that is crucial for synthesizing cholesterol. Furthermore, there is a lower absorption of sterols and thus of cholesterol when the MCT are included in the diet, due to the preferential absorption of MCT rather than LCT (García Unciti, 1996).

After the resected rats consumed goat milk fat, levels of HDL in serum were

higher than those of cow milk fat and similar to those of olive oil, and according to Thomsen *et al.* (1999), this type of vegetable fat is beneficial for humans because it increases this cholesterol fraction.

Despite the variations in the levels of GOT and GPT for the three diets tested, among both groups of animals, these enzymes were found to be within the normal limits described in the bibliography for the rat (Iffa Credo, 1988).

It is remarkable that, in relation to lipid metabolism, goat-milk-based diet (animal fat) has a beneficial effect and thus its consumption may be recommended especially in cases of malabsorption syndromes.

This study was supported by the Interministerial Commission of Science and Technology, Madrid, Spain (Project ALI96-1024-C02-02). We thank Ms Elisa Alcover for her efficient administrative support and Ms Francisca Gil Extremera and Ms Rosa Jiménez for their competent technical assistance.

REFERENCES

- Alferez, M. J. M., Campos, M. S., Barrionuevo, M. & López-Aliaga, I. 1990 Nutritive utilization of protein and digestive utilization of fat in two commercial diets designed for clinical enteral nutrition. *Die Nahrung* **34** 499–507
- American Institute of Nutrition 1977 Report of the AIN Ad Hoc Committee on standards for nutritional studies. *Journal of Nutrition* **107** 1340–1348
- Bach, A. C. & Babayan, U. K. 1985 Medium-chain triglycerides: an uptake. *American Journal of Clinical Nutrition* **4** 67–71
- Barrionuevo, M. & Campos, M. S. 1980 Resecciones intestinales en la rata. Influencia sobre la absorción lipídica. *Revista Clínica Española* **157** 187–190
- Biasco, G., Gallari, C., Lami, F., Minarini, A., Miglioni, M. & Barbara, L. 1984 Intestinal morphological changes during oral refeeding in a patient previously treated with total parenteral nutrition for small bowel resection. *American Journal of Gastroenterology* **79** 585–588
- Boza, J. & Sanz-Sampelayo, M. R. 1997 Aspectos nutricionales de la leche de cabra. *Anales de la Academia de Ciencias Veterinarias de Andalucía Oriental* **10** 109–139
- Coves, F., Lisbona, F., García, J. A. & Campos, M. S. 1988 Influence of two dietary sources of fat on lipid digestive utilization and metabolism in rats with intestinal resection. *Journal of Clinical Nutrition of Gastroenterology* **3** 37–41
- Coves, F., López-Aliaga, I., Campos, M. S., Lisbona, F. & Barrionuevo, M. 1991a Influencia de la resección intestinal y de la calidad lipídica de la dieta sobre la utilización nutritiva de la grasa. *Revista Española de Enfermedades del Aparato Digestivo* **79** 9–14
- Coves, F., Lisbona, F., Campos, M. S., García, J. A., López Aliaga, I. & Barrionuevo, M. 1991b Influence of intestinal resection, type of dietary fat and time on the digestive and metabolic utilization of fat in rats. *Biomedica Biochimica Acta* **3** 285–292
- Erlinger, S. 1987 Physiology of bile secretion and enterohepatic circulation. In *Physiology of the gastrointestinal tract*, pp. 1557–1580 (Ed. L. R. Johnson). New York: Raven
- García Unciti, M. S. 1996 Utilidad terapéutica de los triglicéridos de cadena media (MCT). Dietas cetogénicas en la epilepsia infantil. *Nutrición Clínica* **16** 7–35
- Gómez-Ayala, A. E., Lisbona, F., López-Aliaga, I., Barrionuevo, M., Pallarés, I., Alferez, M. J. M., Hartiti, S. & Campos, M. S. 1994 Effects of intestinal resection, type of dietary fat and time on biliary lipid secretion in rats. *Experimental Physiology* **79** 25–33
- Grundy, S. M. 1986 Comparison of monounsaturated fatty acids and carbohydrates for lowering cholesterol. *New England Journal Medical* **314** 745–748
- Hanson, W. R., Osborne, J. W. & Sharp, J. G. 1977a Compensation by the residual intestine after intestinal resection in the rat. I. Influence of amount of tissue removed *Gastroenterology* **72** 692–700
- Hanson, W. R., Osborne, J. W. & Sharp, J. G. 1977b Compensation by the residual intestine after intestinal resection in the rat. II. Influence of postoperative time interval. *Gastroenterology* **72** 701–705
- Hartiti, S., Barrionuevo, M., López-Aliaga, I., Lisbona, F., Pallarés, I., Alferez, M. J. M., Gómez-Ayala, A. E. & Campos, M. S. 1995 Effects of intestinal resection, cholecalciferol and ascorbic acid on iron metabolism in rats. *British Journal of Nutrition* **73** 871–880
- Iffa Credo 1988 *Données biologiques rat wistar*. Paris: Iffa Credo
- Jacques, H., Laurin, D., Moorjani, S., Steinke, F. H., Gagne, C., Brun, D. & Lupien, P. J. 1992 Influence of diets containing cow's milk or soy protein beverage on plasma lipids in children with familial hypercholesterolemia. *Journal American College of Nutrition* **11** 698–738
- Jandal, J. M. 1996 Comparative aspects of goat and sheep milk. *Small Ruminant Research* **22** 177–185

- Ladefoged, K., Hesson, I. & Jarnum, S. 1996 Nutrition in short-bowel syndrome. *Scandinavian Journal of Gastroenterology* **216** 122–131
- Lisbona, F., Reyes-Andrada, M. D., López-Aliaga, I., Barrionuevo, M., Alférez, M. J. M. & Campos, M. S. 1999 The importance of the proportion of heme/nonheme iron in the diet to minimize the interference with calcium, phosphorus, and magnesium metabolism on recovery from nutritional ferropenic anemia. *Journal of Agricultural and Food Chemistry* **47** 2026–2032
- Penn, D., Dolderer, M. & Schmidt-Sommerfeld, E. 1987 Carnitine concentrations in the milk of different species and infant formulas. *Biology of Neonate* **52** 70–79
- Sandor, A., Pecsvac, K., Kerner, J. & Alkonyi, I. 1982 On carnitine content of the human breast milk. *Pediatric Research* **16** 89–91
- Sarna, S., Conson, R. E. & Cowles, V. 1983 Enteric mechanism of initiation of migrating myoelectric complexes in dogs. *Gastroenterology* **84** 814–822
- Tappenden, K. A., Thomson, A. B., Wild, G. E. & Meburney, M. I. 1997 Short-chain fatty acid-supplemented total parenteral nutrition enhances functional adaptation to intestinal resection in rats. *Gastroenterology* **112** 792–802
- The American Dietetic Association 1992 Medium-chain-triglycerides-based ketogenic diet. In *Hand-book of clinical dietetics*, 2nd edn, pp. 392–402. New Haven & London: Yale University Press
- Thomas, K. & Mitchell, H. H. 1923 A method of determining the biological value of protein. *Journal of Biological Chemistry* **58** 873–903
- Thomsen, C., Rasmussen, O., Lousen, T., Holst, J. J., Fenselau, S., Schrezenmeir, J. & Hermansen, K. 1999 Differential effects of saturated and monounsaturated fatty acid on postprandial lipemia and incretin responses in healthy subjects. *American Journal of Clinical Nutrition* **69** 1135–1143
- Turley, S. D. & Dietschy, J. M. 1981 The contribution of newly synthesized cholesterol to biliary cholesterol in the rat. *Journal Biological Chemistry* **256** 2438–2446
- Turley, S. D. & Dietschy, J. M. 1982 Cholesterol metabolism and excretion. In *The liver. Biology and pathobiology*, pp. 467–492 (Eds I. Arias, H. Popper, D. Schaether, and D. A. Chafritz). New York: Raven
- Warner, B. W., Vander-Kolk, W. E., Can, G., Helmuth, M. A., Shin, C. E. & Erwin, C. R. 1997 Epidermal growth factor receptor expression following small bowel resection. *Journal of Surgery Research* **70** 171–177
- Wittmann, T., Crenner, F. & Pousse, A. 1985 Changes in motility after jejunal and ileal resection: electromyographic study in rats. *Digestion* **32** 114–123
- Zoppi, S. T., Berra, B & Enne, G. 1995 Goat milk products in the diet therapy of arteriopathic patients and/or in geriatric age. *Rev Ita Sostanze Grasse* **72** 67–71