

## Dietary factors affecting the maximum feed intake and the body composition of pre-ruminant kid goats of the Granadina breed

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An experiment was carried out with kid goats of the Granadina breed to identify the dietary factors affecting voluntary feed intake of the kid goat and those that additively could determine its body composition. The animals used were from birth to 61 d of age, fed *ad lib.* on different milk replacers containing 200, 240 and 280 g crude protein/kg DM and 200, 240 and 280 g fat/kg DM, thus giving nine dietary treatments. The utilization of the milk replacers and the animals' body composition were determined by balance and slaughter trials. There were significant positive effects of protein concentration of the milk replacers on component digestibilities, energy metabolizability, feed intake, empty-body weights, empty-body composition and protein and fat retention. The concentration of fat in the milk replacers also had a significant positive effect on the digestible and metabolizable energy concentration of the diets and on fat retention. The relationships existing between feed intake and diet composition (concentration of digestible protein, metabolizable energy and digestible protein:metabolizable energy ratio) as well as between empty-body composition or protein and fat retention and diet composition, were examined. From these it was deduced that feed intake was significantly influenced by the digestible protein concentration of the diets. The higher the digestible protein concentration the higher the feed intake up to a maximum digestible protein concentration value. As the digestible protein concentration of the diets was the dietary factor which significantly influenced feed intake, this also significantly influenced the body composition and the protein and fat retention. The protein concentration of the feed at which metabolizable energy intake in these animals would be greatest was estimated to be 347 g/kg DM.

### Feed composition: Feed intake: Body composition: Kid goats

The low voluntary feed intake of pre-ruminant animals explains why from birth until 30–35 d of age their body composition is determined more by their weight than by their feed intake (Walker, 1986). In this context, the maximum feed intake of the kid goat has been found to be low in comparison with other pre-ruminants. Sanz Sampelayo *et al.* (1990b) reported that for the first month of life, empty-body composition of kids depended on empty-body weight, independently of intake level and even of dietary regimen. However, in older or heavier kids, which are those considered ideal for slaughter, results indicate that the dietary regimen and level of feed intake do have some effect on the body composition (Bas & Morand-Fehr, 1987; Bas *et al.* 1987, 1992; Lara, 1991). Because of this, and because the typical development of caprine species gives rise to very lean carcasses (Morand-Fehr *et al.* 1985), different studies were conducted by feeding individuals of different breeds with milk replacers differing in their fat concentrations (Bas & Morand-Fehr, 1987; Bas *et al.* 1987; Lara, 1991). In all cases the responses to the different levels of fat were very weak and much lower than expected, which in the opinion of Lara (1991) could be due to the low levels of voluntary feed intake generally recorded. With this in mind, and with the objective

of obtaining a better system for artificially milk-feeding the pre-ruminant kid to achieve a satisfactory body composition, a study was designed to analyse the dietary factors affecting voluntary feed intake of the kid goat and those that additively could determine its body composition. In the present study these aspects were analysed using milk replacers differing in their protein and fat concentrations. The effect of treatment on feed intake, digestibility of the nutrients, digestible protein and metabolizable energy concentrations and digestible protein:metabolizable energy ratio in the diets, and on body composition were analysed. The relationships between feed intake or empty-body composition and digestible protein concentration, metabolizable energy concentration and digestible protein:metabolizable energy ratio in the diets were also established.

## MATERIALS AND METHODS

### *Animals and experimental design*

Forty-two male kid goats of the Granadina breed were used. These were separated from their dams when they were 2 d old. Then an initial slaughter group of six animals was killed while the remaining thirty-six were kept individually under the experimental conditions until they were 61 d old. The experiment was designed in a completely randomized  $3 \times 3$  factorial arrangement. Treatments consisted of three concentrations of crude protein in the milk replacer (low (L): 200 g/kg DM, medium (M): 240 g/kg DM and high (H): 280 g/kg DM) and three concentrations of fat in the milk replacer (L: 200 g/kg DM, M: 240 g/kg DM and H: 280 g/kg DM). Four animals were allocated at random to each treatment.

### *Experimental procedure*

Animals were housed in individual cages in an animal house maintained at a temperature of  $24 \pm 2^\circ$  and a relative humidity of  $60 \pm 5\%$ . During the first 4 d of life all the animals consumed colostrum *ad lib.* and, thereafter, one of the nine milk replacers until they were 60 d old. In order to assess the effect of replacer composition on voluntary feed intake, animals had *ad lib.* access daily from 09.00 until 18.00 hours. The replacers were prepared at 170 g fresh powder/kg and were offered in containers fitted with teats. The containers were placed over a device designed to maintain the replacer temperature at  $39 \pm 2^\circ$  and to keep it satisfactorily mixed (Ruiz Mariscal *et al.* 1990). Because kid goats are very sensitive to cold, the milk replacer temperature was maintained at body temperature which also helped to prevent the separation of the fat. The protein component of the milk replacers was obtained from three different protein sources: spray-dried skimmed milk powder, soyabean micronized for milk replacer, and casein (50:25:25 w/w). To bring the methionine and lysine contents up to those recommended for pre-ruminants (Walker, 1973; Patureau-Mirand, 1975; Williams & Hewitt, 1979) further quantities of these two amino acids were added separately. To satisfy requirements for Ca and P (Sanz Sampelayo *et al.* 1987),  $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$  and  $\text{CaCO}_3$  were added. NaCl and a mineral-vitamin supplement (Auromix Milk, Cyanamid Iberica, Madrid, Spain) were included in all replacers. The fat component of the replacers was obtained from purified pork lard. After melting the lard in a water bath, it was incorporated into the diets by homogenization using a mechanical mixer. To stabilize the emulsion, two emulsifiers were added (Keltrol F., Vedegsa, Barcelona, Spain and Tween 80, Acofar, Barcelona, Spain). Glucose was included in the nine replacers in different quantities to balance the remaining ingredients. To reduce bacterial growth and digestive disorders the replacers were acidified to 3 ml/l with lactic acid, as proposed by Havrevoll *et al.* (1991). In relation to the nutritional utilization and the performance of animals, protein, fat and carbohydrate sources employed are considered

Table 1. *Ingredients (g/kg DM) and gross energy concentration (MJ/kg DM) of the milk replacers*

Protein concentration ...	H			M			L		
Fat concentration ...	H	M	L	H	M	L	H	M	L
<b>Ingredient</b>									
Skimmed milk	394.6	394.6	394.6	339.7	339.7	339.7	284.8	284.8	284.8
Micronized soyabean	133.8	133.8	133.8	114.8	114.8	114.8	95.8	95.8	95.8
Casein	72.7	72.7	72.7	62.3	62.3	62.3	51.9	51.9	51.9
Pork lard	275.9	238.0	196.5	276.8	238.9	197.2	277.7	239.8	198.1
Glucose	59.6	97.5	139.2	138.8	176.7	218.4	220.1	258.0	299.7
Mineral-vitamin mix	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Sodium chloride	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Dicalcium phosphate	14.5	14.5	14.5	19.4	19.4	19.4	22.2	22.2	22.2
Calcium carbonate	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Lysine	2.9	2.9	2.9	2.5	2.5	2.5	2.1	2.1	2.1
Methionine	2.5	2.5	2.5	2.2	2.2	2.2	1.9	1.9	1.9
Gross energy	23.9	23.2	22.1	23.4	22.5	21.4	23.3	22.3	21.2

H, high (280 g/kg DM); M, medium (240 g/kg DM); L, low (200 g/kg DM).

adequate for pre-ruminant milk replacers (Soliman *et al.* 1979; Ørskov, 1982; Moulin, 1983). The ingredient composition of the diets and their gross energy concentration are shown in Table 1.

All animals were weighed every 3 d. Three balance trials of 8 d duration were performed, starting when the animals were aged 23, 38 and 53 d respectively. During these trials total faeces and urine collections were made and samples were stored frozen. From the bulked samples, subsamples were taken for the determination of DM, N and energy contents of the urine, and DM, N, fat and energy contents of the faeces. The protein, fat and energy digestibilities and the energy metabolizability were calculated for each animal. The digestible protein (DP; g/kg DM), digestible energy (DE; MJ/kg DM) and metabolizable energy (ME; MJ/kg DM) concentrations of the diets as well as the corresponding DP:ME ratios (g/MJ) were also calculated, as were the DM intakes (DMI; g/kg<sup>0.75</sup> per d) and ME intakes (MEI; kJ/kg<sup>0.75</sup> per d). The day after the end of the final balance period, when the animals were aged 61 d, they were slaughtered by carotid section after anaesthetization using an intramuscular injection of Xylazine (Rompun, Bayer, Barcelona, Spain). Once the animals were dead and completely bled, the skin, limbs, internal organs and head were removed. The rumen, reticulum, omasum and abomasum were washed of their contents. The blood, skin, alimentary canal, all internal organs and the carcass were considered as distinct body parts and were minced separately. Empty-body-weight values (EBW; kg) and composition, i.e., DM, protein, fat (g/kg EBW) and energy (MJ/kg EBW) were calculated. Finally, from the body composition of animals slaughtered at birth and at 61 d of age, protein retention and fat retention rates (g/kg<sup>0.75</sup> per d) were also calculated.

DM and N analyses were performed on samples of the freshly minced parts. All other determinations were carried out on lyophilized samples. N was determined by the Kjeldahl method and energy using an adiabatic bomb calorimeter. The fat concentration of the different milk replacers was analysed by the Gerber method (Pearson, 1976), that of the faeces by extraction with petroleum ether (boiling point 40–60°) after HCl hydrolysis and that of the different body parts by extraction with chloroform-methanol (2:1, v/v).

### *Statistical analysis*

The effect of protein and fat concentrations in the milk replacers on various aspects of milk replacer intake and utilization, empty-body composition, and fat and protein deposition rates were analysed by the least squares ANOVA method (Steel & Torrie, 1984), using a model with two main effects (protein concentration and fat concentration in the milk replacer) and their interaction. The birth weight was used as covariance factor to analyse the effect of protein and fat concentrations in the milk replacer on the empty-body weights achieved by the animals at the end of the experiment. In the same way, the empty-body weight was used as covariance factor to analyse the effect of protein and fat concentrations in the milk replacer on empty-body composition. Finally, the relationships existing between feed intake, empty-body composition or protein and fat deposition rates and DP concentration, ME concentration and DP:ME ratio in the diets, were analysed by multiple regression techniques. For this, the results were analysed using the Statgraphics statistical package (Statgraphics, 1991; regression analysis, stepwise variable selection method), after examining the data for possible collinearity existing between the considered independent variables (Aziz & Sharaby, 1993).

## RESULTS

### *Effect of treatment on component digestibilities, energy metabolizability and intakes*

The effects of different concentrations of protein and fat in the milk replacers on component digestibilities, energy metabolizability, DP, DE and ME concentrations and DP:ME ratios in the diets, and on DM and ME intakes are shown in Table 2. There were no significant interactions ( $P > 0.05$ ) in any of the analyses and so only main effects are reported. As the concentration of protein increased, the values for all these variables also increased and this effect was always significant. The increasing concentration of fat significantly reduced the energy digestibility and metabolizability values but increased the DE and ME concentrations of the diets.

### *Effect of treatment on empty-body-weight values, empty-body composition and protein and fat deposition rates*

The effects of the protein and fat concentrations of the milk replacers on the empty-body weights and on the contribution of DM, protein, fat and energy to these weights as well as on the protein and fat deposition rates are shown in Table 3. There were no significant interactions ( $P > 0.05$ ) in any of the analyses so only main effects are reported. Raising the protein concentration in the feed significantly increased the empty-body weights and their DM, fat and energy concentrations as well as the protein and fat deposition rates but protein concentration in empty-body weight was not affected. The concentration of fat had a significant effect only on the fat deposition rates.

### *Effects of milk replacer composition on DM and ME intakes*

The relationships between DMI ( $\text{g}/\text{kg}^{0.75}$  per d) or MEI ( $\text{kJ}/\text{kg}^{0.75}$  per d) and the composition of the diet (DP concentration ( $\text{g}/\text{kg}/\text{DM}$ ), ME concentration ( $\text{MJ}/\text{kg DM}$ ) and DP:ME ratio ( $\text{g}/\text{MJ}$ )) were established by multiple regression analysis. The linear and quadratic effects of the variables as well as their interactions were examined. When according to the corresponding confidence interval the intercept was not significantly ( $P > 0.05$ ) different from zero, the equation was re-calculated with the intercept forced through zero. The best equations (minimum residual standard deviation, RSD) with significant ( $P < 0.05$ ) terms that were obtained in this way, were:

$$\text{DMI} = 0.44 (\text{SE } 0.02) \text{ DP} - 0.00076 (\text{SE } 0.00008) \text{ DP}^2$$

**Table 2.** Protein, fat and energy digestibilities, energy metabolizability, digestible protein (DP), digestible energy (DE) and metabolizable energy (ME) concentrations and DP:ME ratio of the diets, and dry matter intake (DMI) and metabolizable energy intake (MEI) in relation to the protein and fat concentrations of milk replacers fed to pre-ruminant kid goats†

Protein concentration...	H			M			L			Level of significance		
	H	M	L	H	M	L	H	M	L	SE	Protein effect	Fat effect
<b>Digestibility</b>												
Protein	0.88	0.91	0.90	0.89	0.87	0.86	0.84	0.85	0.85	0.029	***	NS
Fat	0.87	0.91	0.89	0.84	0.82	0.75	0.77	0.78	0.55	0.055	NS	NS
Energy	0.86	0.91	0.90	0.86	0.87	0.82	0.84	0.86	0.86	0.038	***	***
Energy metabolizability	0.83	0.87	0.86	0.83	0.83	0.78	0.80	0.82	0.82	0.041	***	***
DP (g/kg DM)	249.0	248.4	236.1	212.1	202.2	192.9	162.2	163.9	159.0	7.34	***	NS
DE (MJ/kg DM)	20.8	21.1	20.0	20.2	19.5	18.5	19.1	18.6	18.3	0.85	***	***
ME (MJ/kg DM)	19.8	20.4	19.0	19.3	18.7	17.7	18.2	17.9	17.5	0.94	***	***
DP:ME (g/MJ)	12.6	12.2	12.5	10.9	10.8	10.9	9.3	9.1	9.0	0.48	***	NS
DMI (g/kg <sup>0.75</sup> per d)	45.0	49.4	48.0	43.0	46.4	44.6	44.5	43.4	42.9	5.44	**	NS
MEI (MJ/kg <sup>0.75</sup> per d)	892	1007	933	832	869	790	811	778	749	62.9	***	NS

H, high (280 g/kg DM); M, medium (240 g/kg DM); L, low (200 g/kg DM).

\*\* P < 0.01; \*\*\* P < 0.001.

† For details of milk replacers and procedures, see Table 1 and pp. 336-338.

**Table 3.** Empty-body weights (EBW), dry matter, protein (P), fat (F) and energy concentrations of EBW and protein (PR) and fat retention (FR) in relation to the protein and fat concentrations of milk replacers fed to pre-ruminant kid goats†

Protein concentration...	H			M			L			Level of significance		
	H	M	L	H	M	L	H	M	L	SE	Protein effect	Fat effect
<b>EBW (kg)</b>												
DM (g/kg EBW)	8.3	8.4	8.1	7.6	7.2	7.3	6.2	6.3	6.2	1.29	**	NS
P (g/kg EBW)	278	288	272	283	262	264	242	246	253	22.1	**	NS
F (g/kg EBW)	154	153	146	162	152	156	153	146	155	10.1	NS	NS
E (MJ/kg EBW)	95	109	97	91	82	75	76	77	69	17.6	**	NS
PR (g/kg <sup>0.75</sup> per d)	7.3	7.6	7.0	6.6	6.7	6.5	6.2	6.1	6.1	0.71	**	NS
FR (g/kg <sup>0.75</sup> per d)	4.1	3.7	3.5	4.3	3.9	2.9	3.7	3.6	3.0	0.47	***	NS
	4.3	4.4	2.6	4.2	3.1	2.3	3.4	2.1	1.9	0.68	***	*

H, high (280 g/kg DM); M, medium (240 g/kg DM); L, low (200 g/kg DM).

\* P < 0.05, \*\* P < 0.01, \*\*\* P < 0.001.

† For details of milk replacers and procedures, see Table 1 and pp. 336-338.

( $R^2$  0.985; RSD 5.57; level of significance of DP:  $P < 0.001$ ; level of significance of  $DP^2$ :  $P < 0.001$ ).

$$MEI = 6.15 (\text{SE } 0.34) DP - 0.0094 (\text{SE } 0.0016) DP^2$$

( $R^2$  0.984; RSD 108.8; level of significance of DP:  $P < 0.001$ ; level of significance of  $DP^2$ :  $P < 0.001$ ).

From these results it can be concluded that the DMI or the MEI by these animals increases with increasing DP concentration of the diets but at a reducing rate to reach a maximum at 290 g DP/kg DM for DMI and 327 g DP/kg DM for MEI.

*Effects of milk replacer compositions on empty-body-weight composition and on protein and fat deposition rates*

The relationships between the composition of the EBW of the animals: DM concentration (g/kg EBW), protein concentration (P; g/kg EBW), fat concentration (F; g/kg EBW) and energy concentration (E; MJ/kg EBW) or protein retention rate (PR; g/kg<sup>0.75</sup> per d) and fat retention rate (FR; g/kg<sup>0.75</sup> per d) and the composition of the diet (DP concentration (g/kg DM), ME concentration (MJ/kg DM) and DP:ME ratio (g/MJ) were established by multiple regression analysis. The linear and quadratic effects of the variables as well as their interaction were examined. When according to the corresponding confidence interval the intercept was not significantly different from zero, the equation was re-calculated with the intercept forced through zero. The best equations (minimum RSD) with significant terms that were obtained in this way, were:

(a) Body composition

$$DM = 2.24 (\text{SE } 0.11) DP - 0.0045 (\text{SE } 0.0005) DP^2$$

( $R^2$  0.994; RSD 20.86; level of significance of DP:  $P < 0.001$ ; level of significance of  $DP^2$ :  $P < 0.001$ ).

$$F = 0.42 (\text{SE } 0.01) DP$$

( $R^2$  0.966; RSD 16.56; level of significance of DP:  $P < 0.001$ ).

$$E = 0.052 (\text{SE } 0.004) DP - 0.00009 (\text{SE } 0.00002) DP^2$$

( $R^2$  0.990; RSD 0.70; level of significance of DP:  $P < 0.001$ ; level of significance of  $DP^2$ :  $P < 0.001$ ).

(b) Protein and fat retention

$$PR = 0.025 (\text{SE } 0.003) DP - 0.000033 (\text{SE } 0.000012) DP^2$$

( $R^2$  0.984; RSD 0.46; level of significance of DP:  $P < 0.001$ ; level of significance of  $DP^2$ :  $P < 0.001$ ).

$$FR = 0.0145 (\text{SE } 0.0006) DP$$

( $R^2$  0.947; RSD 0.71; level of significance of DP:  $P < 0.001$ ).

These results show, except in the case of the protein concentration of the empty-body weight, that the DP concentration of the feed was the dietary factor that was most closely correlated with body composition as well as with protein and fat retention.

## DISCUSSION

*Effect of treatment on component digestibilities, energy metabolizability and intakes*

The protein content of milk replacers appears to determine the digestibility both of protein and of other nutrients (Henning, 1982). From a physiological point of view, this fact may arise from the effect that the protein concentration has on the nature of the abomasal coagulum, especially when the protein is of lactic origin. This coagulum, formed from protein, fat and Ca from the feed, gradually releases these nutrients and they enter the small intestine where they are digested and absorbed. The formation of a firm and rubbery coagulum reduces the passage rate of nutrients and allows them to be more completely digested (Radostis & Bell, 1970; Roy, 1980; Thivend *et al.* 1980; Sanz Sampelayo *et al.* 1990a). It has also been suggested that the digestibility of the nutrients contained in milk replacers depends on their level of intake, because the amount of pancreatic juice secreted and its enzyme content increase with the amounts of protein and fat which remain undigested on arrival at the duodenum (Ternouth *et al.* 1974, 1975). The results obtained in the present study are in keeping with the previously-mentioned observations. Thus it is suggested that the improved digestibilities obtained when diets with a high protein concentration were used result from the nature of the abomasal coagulum formed and the greater amounts ingested. In addition, our results indicate that the DE and ME concentrations of the milk replacers increase as their fat concentration increases due to the increasing gross energy concentration of the corresponding diets, even though a high fat concentration in the milk replacers appears to decrease the values for energy digestibility and metabolizability. The effect of protein and fat concentrations of the milk replacers on the energy metabolizability and ME concentration of the diets undoubtedly reflects the effect that these dietary components have on the energy digestibility and DE concentration of the diets. For all diets, 95–96% of the DE was metabolizable.

The DM or ME intake increased as the protein concentration of the milk replacers increased. This can be explained, in the first instance, by the significant effect that the protein concentration has on the digestibility. It is well recognized that the more digestible the diet, the greater its intake. However, as has been mentioned previously, the amounts of milk replacers consumed can influence their digestibility. In other words, it is suggested that the replacers with the highest protein concentration have a higher digestibility as a result of the nature of the abomasal coagulum formed and that this in turn leads to a higher intake, which leads to greater secretion of pancreatic juice rich in enzymes enhancing the digestibility and, thus, once again stimulating the consumption of more feed. Other mechanisms whereby protein concentration may influence feed intake are considered in the next section.

*DM and ME intake as affected by feed composition*

Information is scarce on the dietary factors affecting the voluntary feed intake of pre-ruminant animals, although the few studies available seem to indicate that, while during the first 2 weeks of life the size of the abomasum may be the primary regulatory factor of feed intake, between the second and third weeks of life the amount of feed consumed is a function of the amount of energy ingested (Ternouth *et al.* 1985; Lara, 1991), there being glucostatic and lipostatic controls which function so as to maintain an adequate energy balance (Boda *et al.* 1984). With respect to what generally appears to occur in the growing animal, Webster (1986) has demonstrated that by varying the diet composition it is possible to vary the body composition, indicating that the animal has certain goals with respect to body composition and varies its intake of certain diets in order to get as close to these goals as possible. In this regard, Radcliffe & Webster (1978, 1979) feeding lean and obese rats

with diets differing in their protein concentrations found that the intake of the low-protein diet was lower than that of higher-protein diets. This finding they interpreted as indicating that in both lean and obese rats during growth, feed intake is efficiently regulated with the aim of achieving the best rates of protein retention possible.

When diets whose protein concentrations do not allow this are offered, the control of feed intake does not operate by increasing consumption of the diet so as to obtain greater protein intake and better growth, but rather induces consumption of only a sufficient amount to obtain enough ME for the limited growth rate permitted by the protein concentration of the diet. Furthermore, and as Forbes (1986) has indicated, there is never one single factor controlling feed intake. The administration of diets with increasing protein concentrations could lead to progressively higher energy intakes, the amount necessary to achieve the maximum possible protein retention being exceeded each time. The excess energy will be deposited as fat and, therefore, not only will an increasing protein concentration in the diet lead to higher growth, but it will also lead to a different body composition. In addition, Harris *et al.* (1988), using the same type of animals as Radcliffe & Webster (1978, 1979), and employing diets with different DP and DE concentrations, obtained results that led them to conclude that it is the amount of energy ingested that determines the maximum feed intake of the animals, while the protein concentration of the diets has no effect. However, despite this conclusion, it should be pointed out that in one of the trials conducted by Harris *et al.* (1988), in which lead animals were used, while the amount of energy ingested did not change in any statistically significant way with the concentration of protein in the diet, it did show an increase up to a certain protein level, after which it fell.

A possible cause of the discrepancy between the results of Harris *et al.* (1988) and Radcliffe & Webster (1978, 1979) may be the difference in the age of the animals used by each group. In both trials the feed intake was expressed as amount per animal and the size of the animals in question was not taken into account. The results obtained in the present report seem to confirm the findings of Radcliffe & Webster (1978, 1979) and Webster (1986) that the amount of ME consumed by the kid goat depends on the DP concentration of the diets, increasing up to a maximum value as the DP concentration of the diet increases. As Parks (1982) reported, different animal life processes show this same geometrical feature of increasing with diminishing slope and becoming asymptotic to a maximum value of the independent variable.

Together with this, and according to the established relationships between DM or ME intake and DP concentration of the diet, it is assumed that at zero DP concentration, DM or ME intake will also be zero. From a nutritional point of view it is not difficult to suppose that the level of intake of a diet without protein will be, on principle, very low in any animal for its first period of life and it will soon be rejected. Forbes (1986), analysing the principal dietary factors affecting voluntary feed intake, reported that this is depressed by diets of low protein concentration which lead eventually to death.

From the relationship established between the DM or ME intakes and the DP concentration of the diet, we can estimate the DP concentration at which ME intake would be greatest. This can be obtained from the corresponding first derivative equation once this has been made equal to zero and the DP value that satisfies it has been calculated. As the ME concentration of the DM for each milk replacer was different because of the effect of both protein and fat concentrations of the milk replacers on their ME concentration, it was considered more correct to estimate the DP concentration at which feed intake would be greatest, from the relationship established between ME intake and DP concentration of the diet. The resulting value is 327 g/kg DM. Once this value has been calculated, and having deduced from this study that the DP concentration is determined by the corresponding

concentration of crude protein, the general relationship existing between the crude protein concentration and the DP concentration will enable us to estimate the amount of crude protein at which ME intake would be greatest. The relationship between the DP (g/kg DM) concentration and the crude protein (CP; g/kg DM) concentration is given by the equation:

$$DP = 0.734 (\text{SE } 0.029) CP + 0.0006 (\text{SE } 0.0001) CP^2$$

( $R^2$  0.998; RSD 9.09).

For a DP content of 327 g/kg DM, the crude protein concentration is 347 g/kg DM. These values exceed the maximum concentrations studied in the present experiment and therefore require further verification.

*Empty-body weights, their composition, and protein and fat deposition rates*

For any species and for its first period of growth, the dietary factor that most clearly determines growth rate is the protein concentration of the feed, due to its stimulating effect on protein retention; this increase in live weight results in part from the water which is deposited with the protein. In pre-ruminant animals during growth there is little change in the protein concentration of the weight gains, although the fat deposits increase and the amount of water diminishes (Vermorel, 1975; Jagusch *et al.* 1983; Bas & Morand-Fehr, 1987; Sanz Sampelayo *et al.* 1990b). Furthermore, Vermorel *et al.* (1979) reported that in calves a higher ME intake results in higher protein retention and fat deposition. Blaxter (1964) studied the quantities of protein and fat retained with different milk intakes in similar animals and obtained an asymptotic response for protein retention and an exponential one for fat deposition.

The low voluntary feed intake of the pre-ruminant kid goat means that during the first 30 d of its life its body composition is only related to its live weight, independently of intake level and dietary regimen (Sanz Sampelayo *et al.* 1990b). For older or heavier animals, in order to obtain more fatty carcasses, different breeds of goat, or milk replacers with increasing fat concentrations have been used. This has given rise to changes in body composition, but these changes have always been less than expected (Bas & Morand-Fehr, 1987; Bas *et al.* 1987, 1992; Lara, 1991). Lara (1991) attributed this low response primarily to the low voluntary feed intake of the animals used, pointing out the necessity to investigate in these animals the dietary factors affecting their voluntary feed intake. The results obtained in the present study would seem to support these findings and opinions. First, the protein concentration of milk replacers affected the empty-body weight reached. At the same time, ME intake, which was itself affected by the protein concentration of the milk replacers, also influenced the empty-body composition (amount of DM, fat and energy concentrations expressed on the basis of empty-body weight) and protein and fat deposition rates. Similarly it can be concluded that DP concentration of the diet influenced empty-body composition and protein and fat deposition directly. In addition it had indirect effects by its influence on ME intake which was related to the empty-body composition and protein and fat deposition. It appears that empty-body DM and energy concentrations as well as protein deposition rate increase with increasing DP concentration of the diet up to a maximum concentration. In contrast, linear relations were established between empty-body fat concentration or fat deposition rate and the DP concentration of the diet. These results are in general agreement with those obtained by Blaxter (1964) for calves fed on different milk intakes.

In summary, and in agreement with the observations of Radcliffe & Webster (1978, 1979) and Webster (1986), during growth the kid goat appears to regulate its feed intake in order to satisfy its ME requirements, these depending on the DP concentration of the diet. As the

concentration of DP increases, the ingestion of ME also increases so that together with an increased growth rate there is also an increased deposition of fat. This process ends when the protein retention capacity of the animal is reached. For the kid goat, a lean animal, it is calculated that this point is reached at a relatively high concentration of DP or crude protein in the diet, 327 g/kg DM or 347 g/kg DM respectively.

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