HAND-REARING AND GROWTH OF TWO IBEX (*CAPRA IBEX NUBIANA*) KIDS FROM 24 HOURS TO WEANING AT 105 DAYS OF AGE

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ABSTRACT

Two male ibex kids were hand-reared from approximately 24 h after birth. Goat production and exotic captive small ruminant management systems were researched and compared to National Research Council (NRC) energy requirements in order to design a strategy for optimal feeding and growth. Weights were collected on each ibex daily or every other day throughout rearing to evaluate gain and determine feed amounts as a % of body weight. Average daily gains (ADG) matched NRC calculations for energy from formula until solids presumably became a significant contributor to the diet. Gains averaged 107 g/d, approximately 30% higher than gains previously reported for hand-reared and maternal-reared ibex kids, but closer to ADG reported for managed indigenous goat populations. The hand-rearing methodology is presented here as an example for future hand-rearing attempts.

HISTORY

Two male ibex kids were born to different dams on 4/21/2011. Within 24 hours both kids were pulled from their dams due to rejection and in order to minimize possible exposure to malignant catarrhal fever virus and brought to the Fort Worth Zoo (FWZ). It was unknown whether either kid received colostrum from their dam.

IBEX AND GOAT MILK

Information on ibex milk is available from one group of studies which are summarized by Oftedal (Maltz, 1979; Maltz and Shkolnik, 1984; Oftedal, 1984). The values reported are for peak lactation (30-60 d) and, compared to goat's milk, are significantly higher in dry matter and provide more energy in the form of fat instead of carbohydrate (Table 1). Ibex milk is therefore significantly more energy dense than goat's milk (1.62 kcal/g versus 0.69 kcal/g). However, total milk output in ibex was only 639 g per day, dramatically less than 1510 g produced by smaller native dwarf goats at the same stage of lactation. Overall, the milk energy output was ~10% lower in the ibex, but comparable to that of native goats in terms of energy output per offspring mass. These findings suggest that the differences between ibex and goat milk represent adaptations to conserve water and carbohydrate in their arid native environment, rather than significantly different nutritional needs for ibex kids as compared to goat kids. On the other hand, it may suggest that ibex kids would be tolerant of more concentrated milk formulas.

Goat's milk changes slightly in composition seasonally and over the course of lactation, generally with decreases in fat and protein (and total solids) during peak yield (Park and Haenlein, 2006). No longitudinal information on ibex milk is available and, as in the goat, such

changes are likely to be modified by environmental factors such as nutrient and water availability. Such changes more likely represent maternal limitations, rather than significant changes in offspring nutrient requirements.

MILK REPLACER FORMULAS

Numerous commercial milk replacer formulas and hand-rearing recommendations exist for domestic goats (*Capra a. hirus*) (Table 1). Goats are raised successfully on quality milk replacers, goat's milk and cow's milk. Two ibex kids were hand-reared using evaporated goat's milk at the Metro Toronto Zoo (MTZ-HR) in 1979, and demonstrated similar growth over 173 d to 2 maternal-reared (MTZ-MR) *Capra ibex nubiana* (Oyarzun et al., 1984).

Based on similarities to goat's milk and product availability (Table 1), a cow's milk formula was selected. After transitioning from colostrum over the first week, the FWZ-13 formula (1:1 evaporated cow's milk: water) was provided (Table 2). As the number of daily meals decreased, the formula was switched to a more energy/solids dense formula with added Esbilac (FWZ-17). All formula changes occurred over a transition period (Table 2).

FEEDING FOR ENERGY REQUIREMENTS

In order to determine the appropriate amount to feed, common practices for domestic goats, growth rates for various goat breeds and management systems, reported hand-rearing of the MTZ ibex (Oyarzun et al., 1984), and NRC recommendations for goats (National Research Council (NRC), 2007) were evaluated.

Most hand-reared production goats are raised with adlib access to milk or in large groups where individual consumption is impossible to determine. This practice is highly successful from a production stand-point, but may increase the risk that individual kids over- or under- feed. General and manufacturer recommendations for feeding individual goats are 15 to 30% of bodyweight per day in formula with younger (smaller) animals offered the higher amount (Sav-a-Kid, Advance, Land-o-Lakes, Purina, NuZu, (Smith and Sherman, 2007)). The MTZ offered between 8 and 16% BW per day (Oyarzun et al., 1984). General recommendations for handrearing exotic small ruminants, including goats, suggest 10 to 15% of body weight fed daily (Gage, 2008; Reiter et al., 1994). When considering the amount of formula to feed, the concentration/energy density of the formula must also be considered.

According to the NRC for small ruminants, suckling goats have a maintenance energy requirement of 116 kcal ME per kg $BW^{0.75}$ (Luo et al., 2004; National Research Council (NRC), 2007). For each g of ADG they require an additional 3.2 kcal consumed. The energy requirements for maintenance and growth of indigenous goat breeds do not differ substantially from that of meat production breeds (Luo et al., 2004; National Research Council (NRC), 2007).

Based on NRC energy requirements and 0.69 kcal/g goat's milk, 15% bodyweight of milk would be required initially to meet maintenance requirements, decreasing to 10% BW by approximately day 60. This does not account for any growth, which would require an additional 4.6 g formula for each g ADG. Thus if an ADG of 50 g were desired, the initial consumption would have to be

30% BW and would not decrease to 15% BW until day 85. According to these calculations, a feeding rate of 10 to 15% BW per day of goat's or cow's milk (13% total solids) would not be adequate for a growing goat.

GROWTH

Growth rates for domestic goats are reported as 30-200 g per day, depending on breed, nutrition, and mature weight (Gaddour et al., 2007; Gaddour et al., 2008; Islam et al., 2009; Khazaal, 2009; Mabrouk et al., 2007), (Table 3), with lower values representing pygmy breeds or herds with minimal nutritional management (Ahuya *et al.*). The MTZ presented an ADG of approximately 85 g for hand-reared and parent reared ibex (Oyarzun et al., 1984). Although higher than the growth rate of some indigenous goat populations reported by the authors, 85 g ADG is on the low end of most recently reported goat growth rates even for indigenous populations (see above). This discrepancy is possibly due to better nutritional management or introduced production strains.

A general equation for growth of Artiodactyls calculates an ADG of 160 g/d for an animal of mature bodyweight similar to the male ibex (~50 kg) (Robbins, 1993). This value matches the growth rate in domestic production goats but is double that observed in the MTZ ibex.

Most references assume liner growth rates in goats throughout the pre-weaning period. Although this assumption may be empirically adequate, its likely caprine growth follows a sigmoidal pattern, with slower initial gains restricted by body size, followed by more rapid gains as consumption capacity increases and the relative energy cost of growth decreases, then concluded by the slow taper towards the mature asymptote (Kume and Hajno, 2010; Tatar et al., 2009). For hand-rearing animals, such curves may be particularly useful during the earliest period, when establishing appropriate daily gains and feed amounts is most critical. As the MTZ ibex were pulled at 8 days of age, the current paper may be the first published report of perinatal weight gain in two ibex kids.

Based on the published values for caprine growth, 100 g ADG was set as the target growth rate, limited by a maximum of 24% BW formula offered per day and meals not to exceed 4% BW which is the expected stomach capacity (Table 4). Based on these restrictions and using a non-concentrated formula (13% total solids), we would not expect to reach the target ADG until 30 days of age. At 8 days of age the kids were consuming 100% of the offering with no loose stool and were behaving as if they were hungry so an additional feed was added, raising the daily offering to 28% BW per day.

FEEDING SCHEDULE

Ungulate hand-rearing protocols generally recommend beginning with diluted formula in order to transition to new ingredients and reduce the risk of diarrhea. The FWZ ibex received a slightly diluted colostrum on the first day, however caloric deficit in a perinatal animal resulting from a diluted formula was deemed undesirable. Rather than continuing to provide a diluted formula, smaller, more frequent meals of regular strength formula were offered and tolerated well.

Although many commercial products and hand-rearing protocols consider only a few daily feedings acceptable, the FWZ ibex kids were fed around the clock with 6-7 feeds per 24 h period for the first 27 d. This intense feeding schedule was intended to mimic ad libitum nursing and allow for smaller meals sizes but enough meals to meet energy and growth requirements. Reduction of inter-meal fasting times was also expected to reduce digestive or metabolic fluctuations which could contribute to health problems. At 20 d, the overnight fasting period was increased to 7 h, then to 9 h at 49 days and 14 h at 64 days, although at all times pellets and alfalfa hay were available. Details of the feeding schedule are presented in Table 4.

Formula was prepared 24 hours in advance and then refrigerated to allow the lacteeze to hydrolyze the lactose. On the day of feeding, meal portions were calculated based on the most recent weight for each kid, then weighed into individual bottles which were refrigerated until use. Goat kid/lamb nipples were used with no adaptations necessary. Less than 100% consumption was rare, and leftovers were weighed and discarded. Keepers maintained a detailed hand-rearing log reporting offering, consumption, weights and stool quality. Weights were collected on a daily basis until day 40 and then collected every other day.

At 14 days of age, solid food in the form of a fortified pelleted feed (20% CP, 5% Crude Fat, 32% NDF, 17% ADF; primary ingredients: wheat middlings, alfalfa meal, soybean meal) and alfalfa hay were made available. Consumption of these items was not observed until past day 60, much later than was observed at the MTZ, possibly due to greater amounts of formula available to meet needs. By weaning, kids were consuming as a pair 150 g/d of pellets (~30% of their maintenance energy requirement) and adlib alfalfa. Coastal hay was available at all times as bedding but significant consumption was not observed. Hydralyte powder (Lloyd, Inc., Shenandoah, Iowa) was added to the formula (replacing 4% of the water by weight) on day 25 to help relieve a bout of loose stool possibly caused by rancid formula. The hydralyte remained in all formulas afterwards.

RESULTS

Throughout growth, both ibex maintained a moderate body condition (as determined by observation and palpation) and high activity level. They had access to an outdoor exhibit and were observed to nibble or consume soil, wood, dead leaves, and a small amount of accessible browse (primarily mulberry). Stool quality was normal except for a period of approximately 10 d starting around d 25, which was possibly attributable to the accidental addition of expired esbilac to the formula for 2 days. From day 71-84 stool was also reported as clumpy rather than individual pellets but resolved.

As anticipated from NRC calculations, ADG did not reach the target of 100 g until approximately 30 d of age. After 30 d of age, ADG remained around 100 g for both ibex until decreasing between d 80 to 100, likely due to weaning (Figure 1).

Average daily gain was highly variable and remained close to and slightly above expected growth throughout handrearing (Figure 2). Around 60 days of age growth failed to slow as formula was reduced, presumably attributable to consumption of solids replacing energy from formula.

CONCLUSIONS

NRC estimations of energy requirements for pre-weaning goats were applicable to hand-reared ibex and provided valuable predictions for determining formula amounts and changes to reach target ADG. The following NRC equation for energy can therefore be used to estimate the energy requirement of preweaning ibex (Luo et al., 2004; National Research Council (NRC), 2007).:

$$\text{kcal ME/d} = 116 \cdot (\text{BW})^{0.75} + 3.2 \cdot \text{ADG} \quad (1)$$

where BW = bodyweight in kg and ADG = average daily gain in g.

Recommendations for feeding 10 to 15% BW in caprine kids may not supply adequate calories when formula is unconcentrated (<13% total solids) formulas. Feeding 15 to 25% BW per day allows for higher ADG. Frequent weighing of hand-reared animals and adjusting feed amounts to recent weights is invaluable in providing optimal nutrition and better understanding the relationship between nutrition and growth in captive animals.

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Table 1. Milk composition of ibex (*Capra ibex nubiana*) and goats (*Capra a. hirus*) compared to caprine milk replacer formulas. Protein, fat and sugar are on a dry matter basis.

	%Protein	%Fat	%Sugar	%Total solids	kcal/g as fed
Ibex milk (30-60 d) [1]	24	53	19	23.3	1.62[5]
Goat's milk[2]	23-29	30-33	33-38	12-13	0.69
Zoologic Ibex Formulas	26-27	42-45	14-17	23.3	1.44[5]
MTZ (evaporated goat's milk)[3]	25	25	NA	12/16	0.69/0.92
Commercial milk replacer for goats (n=6)	23-26	20-30	35	12-16	~0.69-0.9
FWZ-17[4]	29	33	31	17	0.88
FWZ-13[4]	26	29	38	13	0.67

[1](Oftedal, 1984)
[2]Multiple references (Bergman and Turner, 1936; Bosworth and van Slyke, 1916; Jenness and Sloan, 1970; Mohammed et al., 2007; Oftedal, 1984; Tufarelli et al., 2009)
[3](Oyarzun et al., 1984) Formula concentrated at day 46.
[4] Primarily evaporated cow's milk, see Table 2.
[5]High energy density is due to the lack of water in the milk. Energy calculated as described by Oftedal (Oftedal, 1984).

Table 2. Formula recipes used to hand-rear two male ibex kids at the Fort Worth Zoo.

Day of Age	2	3 to 5	6 to 8	9 to 35	36 to 44	45+
Ingredient (%)	Colostrum	Trans 1	Trans 2	FWZ-13	Trans 3	FWZ-17
Esbilac[1]	0.0	0.0	0.0	0.0	2.7	5.4
Colostrum[2]	15.0	7.5	5.0	0.0	0.0	0.0
Boiled Water	85.0	62.5	55.0	50.0	49.7	49.7
Evap. Milk[3]	0.0	30.0	40.0	50.0	47.3	44.9
Multivitamin, g[4]	0.08	0.08	0.08	0.08	0.08	0.08
Lacteeze[5]						
kcal/g	0.56	0.68	0.72	0.67	0.78	0.89

1Esbilac powder. PetAg, Inc., Hampshire, IL
[2]Bovine colostrum powder, Sav-A-Calf Products, Chilton, WI. Full strength formula is 20% powder.
[3]Evaporated cow's milk with vitamin D added
[4]Poly-Vitamin Drops (with iron), Hi-Tech Pharmacal Co, Inc. Amityville, NY
[5]Lacteeze, Lactase enzyme, Gelda Scientific, Mississauga, ON Canada. For all formulas: 0.018 g lacteeze per g lactose

Table 3. Mass, growth and formula feeding amounts reported for ibex (*Capra ibex nubiana*) and goat (*Capra a. hirus*) kids.

Species	*Capra ibex nubiana*			*Capra a. hirus*[1]		
	FWZ HR	MTZ HR	MTZ MR	Indigenous Goat	Indigenous Managed	Production Goat
Mature BW, kg	52			45-70[3]		
Birthweight, kg	1.5	1.7	1.5	2	2	3
%Bodyweight Fed	12-28%	8-16%	NA	NA	NA	15-23%
ADG, g[5]	107	79	84	30-90[4]	82-125	120-200

[1](Ahuya et al.; Gaddour et al., 2007; Gaddour et al., 2008; Islam et al., 2009; Khazaal, 2009; Mabrouk et al., 2007)
[2](Oyarzun et al., 1984)
[3]Some breeds up to 130 kg; pygmy breeds < 36 kg
[4]Low ADG are associated with high mortality, suboptimal conditions, or very small breeds.
[5]Values represent averages over pre-weaning period (approximately 0 to 100 days of age).

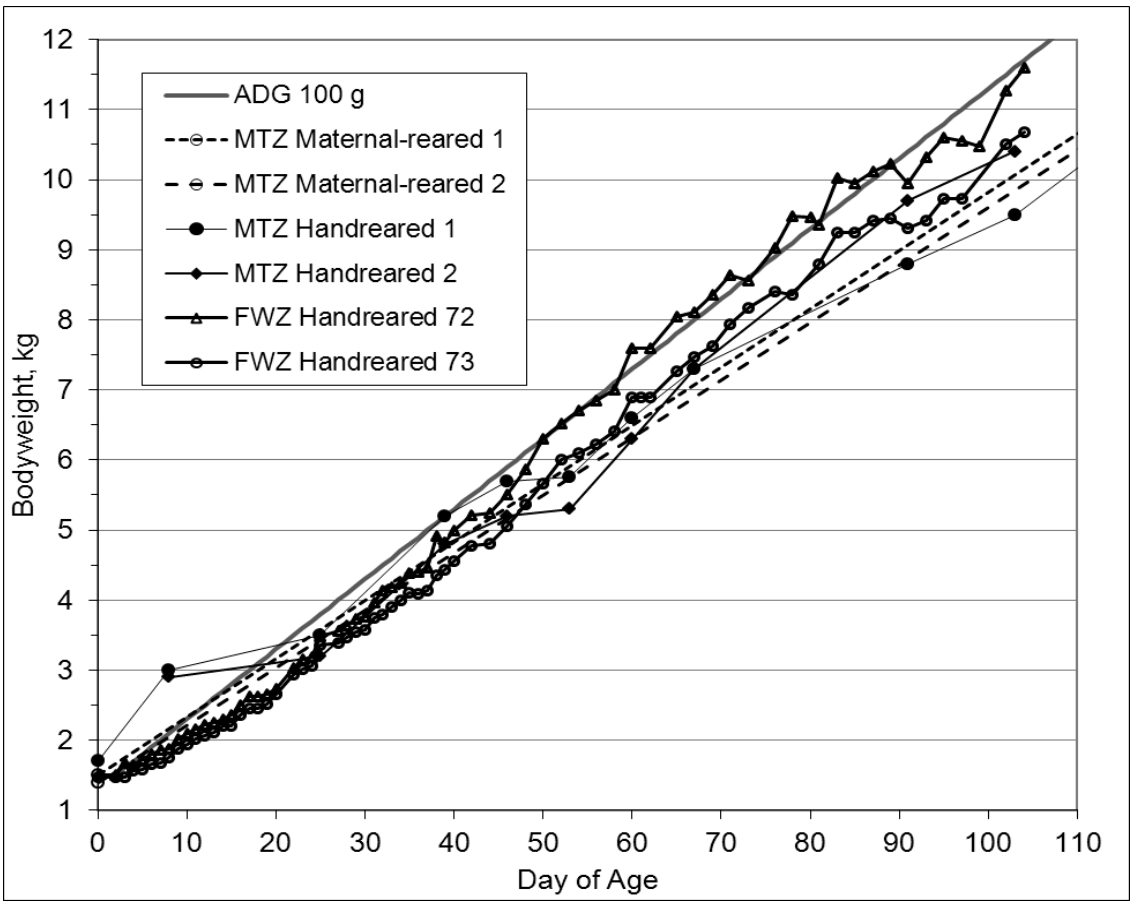

Figure 1. Growth curves for two male ibex hand-reared at the FWZ compared to ibex raised at MTZ and target average daily gain (ADG) of 100 g/d.

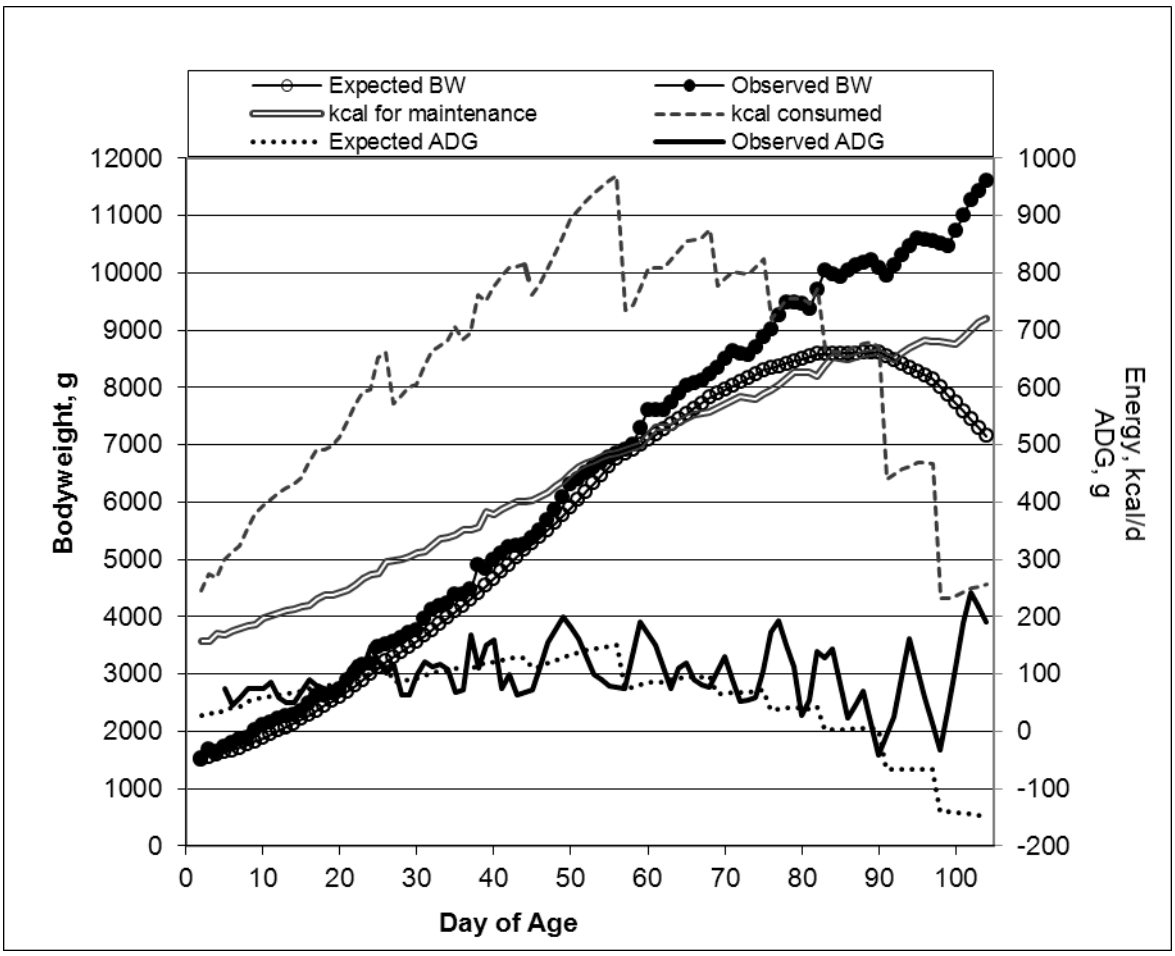

Figure 2. Energy requirements, formula consumption and growth of two hand-reared ibex. Closed circles represent BW which increased through the preweaning period. The solid double-line represents the maintenance daily energy requirement which increased with BW. Dashed line represents kcals provided by formula which increased as BW increased and decreased when number of feeds or %BW per feed decreased. The difference between the maintenance kcal (double-line) and kcal consumed (dashed line) represents the energy available for growth. Expected ADG (dotted line) represents this difference (e.g. when kcal consumed decreased to meet the kcal for maintenance, expected ADG became 0 g/d). Open circles show the expected growth curve based on energy consumed and NRC enery requirements for goat kids. This curve has an inflection point when expected ADG becomes 0. The difference between the observed growth curve (closed circles) and expected growth curve (open circles) is a reflection of the difference between observed ADG (solid line) and expected ADG (dotted line) and is mostly attributed to the consumption of solids. Observed ADG is depicted by a 4 per moving average and follows the expected ADG until 70-80 days of age when additional energy presumably became available from solids consumed.

Table 4. Formula feeding schedule for two hand-reared ibex kids at the FWZ compared to amounts offered to MTZ ibex kids. Animals were weighed daily or every other day to provide bodyweight (BW). Amounts fed per day (g/d and kcal/d) and average daily gain (ADG) are an average across the days represented unless there was a large range of values. Expected ADG was calculated from NRC energy requirements for growing goats.

BW, g	Age, d	FWZ Formula	# feeds	%BW per feed	%BW per day	MTZ HR[1], g/d	FWZ HR, g/d	FWZ HR, kcal/d	FWZ Expected ADG	FWZ Observed ADG
1500	1	Colostrum	8	3	24					
1500	2 to 4	Trans 1	6	4	24		385	262	31	73
1720	5 to 7	Trans 2	6	4	24		430	310	41	53
1880	8 to 26	FWZ-13	7	4	28	250-600	526-986	352-661	52-113	88
3560	27 to 35	FWZ-13	6	4	24	693	949	636	97	93
4400	36 to 45	Trans 3	5	4	20	747	987	770	120	108
5375	45 to 56	FWZ-17	4	4	16	840[2]	996	876	133	129
6920	57 to 68	FWZ-17	3	4	12	840	921	810	88	119
8350	69 to 75	FWZ-17	3	3.5	10.5	840	903	795	68	96
9020	76 to 82	FWZ-17	3	3	9	840	845	744	40	144
10030	83 to 90	FWZ-17	3	2.5	7.5	825	755	664	4	7
10085	91 to 98	FWZ-17	2	2.5	5	720-400	519	457	-66	81
10515	99 to 104[3]	FWZ-17	1	2.5	2.5	400-100	275	424	-143	178

[1](Oyarzun et al., 1984)

[2]At 46 d of age, MTZ formula was concentrated to approximately 0.92 kcal/g (similar to switching from FWZ-13 to FWZ-17).

[3]Ibex were weaned at 105 d of age