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To cite this version:

Serge Landau, P. Morand-Fehr, Pierre Bas, Philippe Schmidely, Sylvie Giger-Reverdin. Nutritional efficiency for conception, pregnancy and lactation in goats with an emphasis on glucose and nitrogen metabolism. 6. International conference on goats, May 1996, Pékin, China. hal-02768038

HAL Id: hal-02768038
https://hal.inrae.fr/hal-02768038

Submitted on 4 Jun 2020

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NUTRITIONAL EFFICIENCY FOR CONCEPTION, PREGNANCY AND LACTATION IN GOATS WITH AN EMPHASIS ON GLUCOSE AND NITROGEN METABOLISM*

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SUMMARY

This presentation is an attempt to review some aspects of nutrient utilisation in goats, and to highlight some possible applications of recent findings from studies in other ruminants to the nutrition of adult goats. Overall efficiency of nutrient utilisation could be improved in goats, even submitted to extreme phases of nutrition, by better control of glucose and amino-acid metabolism. Provision of excess dietary protein during a few days prior to mating might improve fertility. Provision of energy in excess during the first stages of pregnancy could be deleterious, whereas shortage of energy, commencing after 30 days of pregnancy can be tolerated, if compensation can be supplied during late-pregnancy. In constantly-well-fed animals, some extent of maternal lipolysis at the end of pregnancy might augment litter-weight and survival. Manipulations of ruminal starch degradability can improve glucose production and utilisation, thus affecting litter weight and milk production positively, but feeding synchronous, compared with asynchronous sources of protein and energy does not improve milking performance in goats. Dietary ruminally undegradable sources of protein do not appear to modify greatly protein or casein in milk. Percentage of fat in milk increases when goats are fed ruminally inert dietary fat. The extrapolation to goats of findings from studies carried out in other species, or even from different breeds of goats, must be done carefully, owing to differences between species of ruminants and within goat genotypes, in the partition of nutrients.

Keywords: goats, nutrition, reproduction, lactation

Lactation is the outcome of a successful pregnancy that includes ovulation, embryo survival and the building-up of productive tissues in the mammary gland. Being ruminants, goats are subjected to the same limitations as sheep and cows: i) volatile fatty acids (VFA), the main end-product of ruminal fermentation are their main source of energy; ii) most glucose must be synthesised de novo in the liver, but some glucose can reach the intestine under special nutritional conditions ; iii) some sources of dietary protein are only partially degraded in the rumen, but most of them are hydrolysed, dietary amino-acids (AA) are deaminated, and microbial protein finally serves as main source of AA for the animal. These particularities lead scientists to question which mixture of VFA is optimal, if gluconeogenesis is sufficient, and whether microbial protein composition is optimal for pregnancy and lactation.

In the last 20 years, the development of total intragastric nutrition has allowed to study the efficiency of different VFA combinations for maintenance and milk production (reviewed by Orskov, 1991), the in situ "Dacron bags" technique has allowed to assess easily availability of nutrients for intestinal absorption (Tagari et al. 1995, for AA; Sauvant et al. 1994, for starch), and to formulate diets in which carbohydrate and protein ruminal degradabilities are synchronous (Bas et al. 1994a).

The classic calculations of "efficiency" are based on linear regression methods (for example, calculation of k_m, k_l, in INRA 1989). Some functions that affect goat production are non-continuous, and are probably "threshold" or "switch" functions (i.e., the occurence of estrus, shedding of ova, development of mammary tissues). Calculations of efficiency using regression is, therefore, non-valid for these functions. Nutritional requirements for these functions have not been tabulated in the most recent feeding systems for goats (e.g., Morand-Fehr and Sauvant 1989).

Goat husbandry is characterised by phases of under- and over-nutrition ("phased nutrition"). An understanding of glucose and nitrogen metabolism, and their interferences, during these phases, could help to predict utilisation of feedstuffs on goat performance.

This presentation is an attempt to review some aspects of nutrient utilisation in ruminants, mostly established on sheep and cows, and to highlight some possible applications to the nutrition of adult goats, especially when raised in "phased nutrition" systems.

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* Written cooperatively by participants of the FAO/CIHEAM subnet on small ruminant nutrition

I) NUTRITION FOR OVULATION AND PREGNANCY

A) Dietary effects on estrus and ovulation

Like sheep, and contrarily to cattle, most goats have the potential of multiple ovulations, but this ability may be impaired by inadequate nutrition. Long-term (>3 weeks) effects of over-nutrition on ovulation rate (OR) are mediated through improved body condition, whereas short-term effects are achieved through provision of nutrient that modify the hormonal environment, with no alteration of body condition. The effects of body condition and nutrient supply on OR must be separately identified in order to better translate scientific information into feeding practices.

The appearance and continuation of estrous activity of goats are less dependent on nutrition than OR. In British Saanen and Toggenburg thin goats, severe energy deprivation (25% of allowance for maintenance) during 19 days before a synchronised estrus did not affect the proportion of goats coming into estrus, but did decrease OR, and timing of ovulation was delayed (Mani et al. 1992). OR increased assymptotically in small prolific Indonesian goats, which gained body weight at 30g/d before mating (Henniawati and Fletcher 1986). Unfortunately, effects of body weight and increased supply of nutrients were confounded in this study. No negative effect of over-condition on reproduction seems to have been documented in goats, as it has been in sheep (West et al. 1991).

Surplus dietary protein affects OR positively after one week, if commenced during the late-luteal and follicular phases, whereas surplus energy must be provided for a whole sexual cycle in order to affect OR in sheep (Smith and Stewart 1990). Similar information is not available for goats.

Increased glucose availability (Teleni et al. 1989) may provide partial explanation for the effect of "medium-term flushing" (Landau et al. 1995), whereas abundant provision of branched-chain amino-acids (BCAA), particularly leucine, may be the clue for "short-term" flushing. The BCAA effect on the ovary may involve insulin (Downing et al. 1995), because: i) peripheral insulin concentration is cyclic in cows (Schrick et al. 1992) and peaks on the day of estrus; ii) leucine, the main BCAA, is the most potentful AA to elicit insulin secretion (Kuhara et al., 1991) and partly escapes first-pass removal by the liver (Lobley, 1992); iii) insulin peak amplitude is increased if BCAA-rich undegradable protein is fed (Landau et al., submitted); iiii) Both plasma insulin and IGF1 levels are related to steroidogenesis in sheep (Portsky and Kalin 1987).

An alternative to the insulin-ovary linkage would involve direct effect of nutrients on the gonadotrophic axis: i) energy restriction suppresses the increase in LH that is necessary for growth of ovarian follicles in the pre-ovulatory stage in cows and sheep (Schillo 1992; Rhind et al. 1989); ii) infusions of glucose and AA either alone or in combination maintain a high level of LH in ovariectomised lambs subjected to restricted feeding (Schillo 1992); iii) in male goats, the frequency of LH pulses is relate with dietary protein content. (Walkden-Brown 1991). The effect of nutrient supply on the gonadotropic axis may result from with high concentration of NADPH-dependent hepatic mixed function oxydases (MFO) in the liver. High MFO's result in increased steroid metabolism and in the secretion of more gonadotropins following negative feedback, which causes increased OR (Thomas et al. 1987). Diets, characterised by high-glucose-C recycling (Landau et al. 1992), generate high amounts of NADPH (Russell and Young 1990), and promote high OR in ewes (Landau et al. 1995). Ewes treated with progestagens recycle and synthesize more glucose from propionate (Wilson, 1984). This suggests that high progesterone production during the luteal phase could enhance OR by increasing glucose availability.

In intensive dairy goat production systems, the lactation period is long and goats are ordinarily mated long after parturition, when body fat stores have been repleted. The common view is that only minor dietary x reproductive interaction is anticipated in such conditions. However, contrarily to the traditional long-term flushing with energy-rich feedstuffs, short-term high-protein flushing increases fecundity in high yielding dairy ewes, even if liberally supplemented with concentrates all-year-round (Leibovitch et al. 1995).

Studies reviewed by Orskov (1991) show, on one hand, that body protein is oxidised in fasting animals to provide glucose precursors, as evidenced by urinary nitrogen excretion, but provision of VFA to supply 20-30% of energy required for maintenance reduces nitrogen excretion to basal levels, suggesting glucose shortage is unlikely in "non-productive" animals. On the other hand, glucose recycling, a glucose sparing mechanism (Russell and Young 1990), exists in goats in situations of glucose-deprivation as well as of glucose abundance (Stangassinger and Gieseke 1986). This suggests that even "non-productive" ruminants may exhibit phases of high glucose demand, possibly associated with reproductive requirements.

B) Nutrition for embryo survival and early fetal development

High levels of circulating estradiol in cows (Erb et al. 1976), and low levels of progesterone (Shelton et al. 1990), are deleterious to embryo survival. In sheep, losses have been attributed to either under- or over-nutrition and exceptionally poor or high body condition: under-fed sheep had low post-mating progesterone level, but the progesterone response to LH injection was greater in sheep fed at 0.5 maintenance level than in counterparts fed at 1.5 maintenance level (Rhind et al 1989). High post-mating nutrition resulted in reduced progesterone levels (Parr et al. 1987) and elevated embryo losses (Gunn 1983). Progesterone is produced only by the corpora lutea throughout pregnancy in goats (Tornburn and Schneider, 1972), whereas this function is fulfilled by the uterus in pregnant sheep. Therefore, the relation between nutrition, progesterone and embryo survival may be different in goats. Severe energy deprivation of goats through third month of pregnancy was associated with increased embryo loss (Mani et al. 1992). Excess rumen degradable protein impaired fertility in cows (Ferguson et al. 1986) and ova development in ewes (Madibela et al. 1995). High post-mating nutrition was beneficial to survival of triple embryos only, and was otherwise deleterious to conception rate in sheep (West et al. 1991).

High-producing dairy goats are generally milked during days 30-100 of pregnancy, and therefore, generally provided with sufficient amounts of food. The situation may be different for dairy goats milked for short periods and goats from non-dairy breeds, which may endure periods of under-nutrition during mid-pregnancy. Studies on sheep of 50 kg BW showed that 10 kg loss of maternal weight at this period did not affect litter-weight if compensation was provided in late pregnancy. However, extremely low levels of feeding may lead to fetal losses in twin-bearing ewes (Rattray 1993).

C) glucose and amino acid requirements in late pregnancy.

At the end of pregnancy, the combined effects of depressed appetite and high fetal demand for nutrients increase the risk of ketosis in prolific goats (Sauvant et al. 1991). Using intragastric nutrient supplementation of fetuses, researchers have shown that glucose, and not amino-acid, is the first limiting nutrient for growth of sheep fetuses when ewes are under-fed (Bell et al. 1988). Few differences in glucose demand and metabolism exist between empty ewes and ewes bearing one fetus (Hay et al., 1988). Adaptation to pregnancy includes changes of sensitivity to insulin, resulting in lesser glucose utilisation by maternal non-uterine tissues (Bell 1993). Insulin suppresses endogenous glucose production more in pregnant than in non-pregnant sheep (Hay et al. 1988), but this affects gluconeogenesis from lactate, and not propionate, only (Brockman and Laarveld 1986). Gluconeogenesis from propionate has been reported to be more efficient during pregnancy in sheep (Steel and Leng 1973), and its efficiency is increased throughout pregnancy (Wilson et al. 1983). Thus, given on iso-energetic basis, high dietary levels of ruminally degradable starch, yielding more propionic acid, will stimulate glucose production, and promote ovine fetal growth more than slowly degradable starches (Landau et al. 1994). Glucose synthesis and utilisation are increased, compared to non-pregnant goats, in pregnant well-fed (Chaiyabutr et al. 1982), but not in pregnant energy deficitary goats (Bas et al. 1994b). Because of the insensitivity of the uterus to insulin (Hay et al. 1988), its uptake of AA does not change during maternal starvation, establishing a short-term priority for the uterus and its contents (Brockman 1986). Provision of a diet poor in crude protein (CP, 9%) to Alpine does from week 12 of pregnancy through parturition was associated with decreased kidding rate, compared with diets containing 11% or 14.3% CP in one experiment (Sahlu et al. 1992), whereas similar treatments had no effect in another study (Sahlu et al. 1995). A practical solution to insure adequate glucose supply to fetuses and ewes through late pregnancy is feeding excess protein at the end of pregnancy because gluconeogenesis from glucogenic AA will occur in both maternal and utero-placental systems (see review by Rattray 1993).

A striking characteristics of late pregnancy is the increase in concentration of non-esterified fatty acids (NEFA) in peripheral blood, which results from reduction of lipid synthesis and increased lipolysis of maternal depots (Sauvant et al., 1991, for goats; Bassett, 1993, for sheep). Although NEFA concentrations are highest in ewes bearing multiple fetuses, they are also at higher level in single-lamb carriers than in non-pregnant sheep (Bassett, 1992). Birth-weight of single lambs are correlated with maternal NEFA, even if ewes were over-fed at 2.0 maintenance levels (Landau et al. 1994). Short-term provision of concentrates did not maximise fetal growth if prolific ewes were fed previously adequately (Kleeman et al. 1993), neither did supplementation of concentrates according to maternal levels of NEFA increase litter-weight (Stern et al. 1978), nor did concentrate allowance reduce lipid mobilisation in prolific goats (Sauvant et al. 1991). In fact, some extent of maternal lipolysis, induced by shearing, cold or physical activity seem to be essential to maximise fetal growth at the end of pregnancy (reviewed by Rattray 1993, for sheep). Such information is not available for goats, but Norwegian goats fed at 86% above maintenance gave birth to non-significantly heavier kids, as compared with counterparts fed at 21% above maintenance (prolificacy non-mentioned, Eik, 1991). Dietary energy concentration, ranging 1.8 to 2.5 Mcal ME/kg DM did not affect litter weight in goats (Sahlu et al. 1995). However, severe energy deprivation, such as an energy supply at 70% of the requirement for maintenance from day 91, increased rate of abortion between days 91 and 120 of pregnancy and reduced significantly the crop of live kids (Hussain et al. 1993). The coefficient of efficiency for transformation of ME to NE in pregnancy, k_c, is low in goats, compared with the coefficient for maintenance (0.13 and 0.72, respectively, Sauvant and Morand-Fehr 1991) and is similar to k_c in sheep (0.145). In sheep, k_c increases linearly when the dietary energy concentration increases between 8.0 and 12.4 Mcal ME/kg DM, and paradoxally, also when ewes endure energy shortage (Robinson 1983). It also decreases in the last weeks of pregnancy in goats (Sauvant and Morand-Fehr 1991). Because of this complexity, it is doubtful that one recommendation can be adequate for all prolific goats. Although requirement for energy in prolific goats is approximately twice maintenance (see calculations by Sauvant and Morand-Fehr 1991), some recommendations, formulated in countries where phases of nutrition are not extreme, are lower (for example, 27% in Morand-Fehr and Sauvant 1989) and could be inadequate for goats submitted to periods of energy deprivation in early and mid-pregnancy, or after high-yielding lactation.

In theory (Orskov 1991), some benefit could derive from including sources of ruminally undegradable proteins the diet of goats at the end of pregnancy, as applied to pregnant sheep nutrition by Robinson (1983). To our knowledge, no information exists for goats on this issue.

D) Mammary development

Too generous provision of concentrates to young Norwegian goats resulted in decreased voluntary feed intake, mammary development, and milk yield (Havrevoll et al. 1991). The number of fetuses, itself partly affected by nutrition, positively affects mammary development in goats, mediated through the activity of placental lactogen (Hayden et al. 1979). This action of placental lactogen on mammary development in goats is so effective, that it compensates fully for suppression of prolactin release (Forsyth et al. 1985). The impaired lactation of goats that give birth to twins, compared to singles (Sauvant et al 1991), results probably from ill-management of body reserves, and not from deficient mammary development.

II) EFFICIENCY OF NUTRIENT UTILISATION FOR MILK SYNTHESIS

A) glucose

Glucose is the major precursor for synthesis of lactose, which in turn dictates milk volume (Annison and Linzell 1964). Glucose availability in sheep increases if dietary starch is allowed to reach the small intestine (Janes et al. 1985). Less energy, but more glucose, is delivered to portal blood when glucose is infused to the abomasum of sheep than when propionate was infused intra-ruminally (Gross et al. 1990). If great amounts of starch escape ruminal degradation, microbial protein synthesis may decrease (see review by Sauvant et al. 1994), and splanchnic glucose utilisation, increase (Gross et al. 1990). On the other hand, arterial concentration of GH increased subsequently to intra-abomasum glucose infusion in sheep, but not to iso-energetic intra-ruminal infusions of propionate (Gross et al. 1990), and systemic concentrations of insulin increased following an intra-ruminal infusion of propionate in goats (de Jong 1982). Therefore, it is therefore, possible that post-ruminal glucose is associated with hormonal environment (GH/insulin) that is more propitious for milk production. Indeed, lactating goats fed diets containing slowly degradable starch yielded more lactose and more milk than counterparts fed diets of greater starch degradability (Giger-Reverdin et al., 1995). Glucose, as precursor of NADPH and glycerol-3-phosphate, is needed for the production of long-chain fatty acids from two-carbon units, and may be limiting not only for lactose, but also for milk fat synthesis (Orskov, 1991). Whole corn grain had a protein-sparing effect during 4 months of lactation in Saanen goats (Carasso et al. 1992). This suggests that some gluconeogenesis from AA can be spared if post-ruminal absorption of glucose increases. No difference was found in gluconeogenesis from propionate when synchronous or a-synchronous (regarding rumen degradability) sources of protein and carbohydrates were fed to goats (Bas et al. 1994a). A possible explanation is that coefficients of AA and glucose intestinal absorption are not yet well known, and synchrony of absorption of AA and glucose is not achieved.

Glucose metabolism in dairy goats is rarely in steady-state in farm situation (R.W. Russell, personal communication). Chang and Young (1992) reported that milk production is not a linear function of time, which may reflect effects of unequal glucose availability throughout the day. Also, they noted that the response of glucose concentration in the mammary vein to intra-jugular glucose infusions is different if they are given at different times of the day. Better matching between milking times and rythms of glucose metabolism could increase milk efficiency in goats.

B) Proteins

The widespread opinion that ruminants cannot store protein for long periods has been substantiated in Alpine goats, in which the labile pool represented less than 9% of body protein. Adaptation to shortage was achieved by significantly reduced output of N in urine, whereas milk and fecal outputs were modestly (Barnes and Brown 1990), or not (Schmidely et al. 1995), reduced. Goats that are adapted to desertic environments are able to overcome N-shortage by recycling more N via saliva to the rumen (Silanikove 1980). Goats that are carriers of the _-S1 casein allele excrete more protein in milk, concomitantly with reduced output of dietary N (Schmidely et al. 1995). Although lactation is associated with increased partitioning of amino-acids to the mammary gland (Baracos et al. 1991), body integrity is insured by increased ability of insulin to inhibit protein degradation (Tesseraud et al. 1993), in association with the BCAA-insulin system (Lobley 1992). This saving mechanism for body protein is set-up in periods when carbohydrate and lipid metabolism are subjected to insulin resistance.

Milk yield is generally little affected, if any, by protein ruminal degradability (Brun-Bellut et al. 1990; Hadjipanayiotou, 1992; Andrighetto and Bailoni, 1994; Sahlu et al. 1993) in goats, whether in positive (Brun-Bellut et al. 1990) or extremely negative energy balance (Hadjipanayiotou and Photiou 1995). This is not in agreement with data presented by Orskov (1991) on cows in negative energy balance, in which the lactational response to fish-meal supplementation was significant. Small improvements in milk protein and casein content (+5% and +7%, respectively) were obtained by using particular mixtures of ruminally undegradable dietary protein (Andrighetto and Bailoni, 1994). Milk from fish-meal-fed goats was richer in protein and fat, as compared with soybean-fed counterparts (Hadjipanayiotou et al. 1987). Shortage of rumen-degradable protein was associated with decreased feed intake. When rumen-undegradable protein was kept constant and rumen-degradable protein (RDP) was added to diets, milk urea levels increased when RDP exceeded 7% of DM, whereas output of N in milk was similar (Brun-Bellut et al. 1990). Milk yield is apparently less sensitive in goats, compared with cows, regarding the ratio of ruminally degradable/undegradable protein to digestible organic matter, possibly owing to more effective recycling of nitrogen (Morand-Fehr et al., unpublished). In production systems using Mediterranean rangeland or African savanna, where tree foliage is the dominant forage, much of the dietary protein is tannin-bound, and the lack of soluble protein impairs microbial activity: neutralisation of tannins with Polyethylene Glycol has the potential of increasing feed intake and digestibility in sheep (Silanikove et al 1994) and goats (Silanikove et al. 1995), and milk yield in ranging Anglo-Nubian goats increases dramatically (Gilboa et al, 1995).

In cows, the efficiency of converting supplementary essential amino acids to milk protein was found to be very low: while mammary uptake increased 34%, mammary output as milk protein increased by only 5% (Metcalf et al. 1994). Although no similar data is available for goats, this casts a doubt on the feasibility of significantly increasing the content of protein in milk by manipulating dietary protein degradability, without altering genotypes, in agreement by Morand-Fehr et al. (1991).

Including live Saccharomyces Cerevisia yeasts into the diet of dairy goats increased milk yields, especially if diets were of low nitrogen content (Giger-Reverdin et al. 1994), but mechanism is not yet elucidated.

The PDI system for protein nutrition (Morand-Fehr and Sauvant, 1989) is based on the maximisation of microbial protein supply to goats through matching organic matter digestibility and protein ruminal degradability, but does not take into account provision of individual limiting amino-acids, if any, and glucose, for high-yielders.

C) utilisation of body and dietary fat

The energetic value of lipid mobilisation from adipose tissue for milk fat production seems to be similar in dairy cows and goats, and may be higher in does from dairy, compared with "meat" breeds (Sauvant and Morand-Fehr 1991). The milk yield response of goats to daily bST injections in short-term experiments (4-6 weeks) ranged +14% (Knight 1992) to +28.6% (Disenhaus et al. 1995), similar to findings in cows (see discussion by Diesenhaus et al. 1995). Feed intake was not affected by bST, plasma NEFA increased, and milk fat content increased, which suggested that lipolysis of pre-formed depots was more active in treated animals. However the milk content of C_{18} and longer fatty acids in milk of bST-treated goats was not significantly modified, showing that the response to bST is not a mere diverting of body energy into milk (Disenhaus et al 1995).

Substitution of corn with ruminally undegradable fat (calcium salts of fatty acids) at the level of 6% in the diet of Alpine goats through 19 weeks of lactation did not result in increased milk yield in some studies (Baldi et al., 1992), whereas Morand-Fehr et al. (1991) reported on increased milk volume, fat content, and milk-fat yield. A small decrease in milk protein content was also recorded. Similar responses were recorded for cows (Ferguson et al. 1990). This decrease in goats seems to be related positively with the degree of saturation of fatty acids, and negatively with the effectiveness of ruminal protection (Morand-Fehr, unpublished).

D) Genetics and feed efficiency

The balance between the availabity of nutrients and the genetically determined demand for nutrients might affect efficiency of utilisation. Recent results from sheep and cow studies (Oldham et al. 1993) suggest that the ratio between metabolisable protein and energy affects acetate incorporation into lipid, and that acetate affects energy expenditure via the sodium pump (Na+/K+/ATPase system). The percentage of inhibition of respiration in liver snips by ouabain decreased when dietary ruminally undegradable protein was augmented: this suggests that less carbon-moieties are lost by respiration, which is consistent with the observation that more acetate is incorporated into lipid, when adequate amino acid supply is provided. An elegant application showed differences in the sodium-pump activity in the erythrocytes of high-merit vs. low-merit dairy cows: in low-merit cows, the sodium-pump activity is higher when diets contain 80% roughage, but lower when forage represents only 55% of diet, compared with high-merit counterparts. Differences in milk yield and lactation curves between breeds of goats are huge. Allowing free access to concentrates, a routine procedure for highly productive dairy goats in Israel, to local ranging Mamber goats does not maximise milk-yield: they either consume limited amounts, or get fat (David Klein, personal communication). Investigating genetic differences in the sodium-pump activity at the cellular level in goats would contribute to understand differences in the partition of nutrients and milk composition between goats that are "well adapted to their environment" and "milk-specialised" breeds.

We are indebted to Dr N. Silanikove for his comments on this manuscript.

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Table 1: Undernutrition and reproductive performance in dairy goats: goats were fed at maintenance level (1.0M) or 0.25 maintenance level (0.25M); after Mani et al. (1992)

	Estrus (%)	Ovulation rate	Conception rate (%)	Ova loss (%)	Potential kid/doe exposed
1.0M	87.5	2.00^a	92.5^a	33.3	1.46^a
0.25M	71.0	1.21^b	50.0^b	24.0	0.87^b

[a,b] Different letters above means denote statistical significance $P<0.05$.

Table 2: A brief survey of the effects of ruminally undegradable/degradable protein on the milking performance of goats.

Authors (year)	Treatments	Effects
Hadjipanayotou (1992)		NS on milk yield NS on milk solids NS on BW and feed intake
Brun-Bellut et al.(1990)	Undegradable protein constant Degradable protein varies	NS on milk yield sig. on milk urea content
Hadjipanayotou and Photiou (1995)	Soyabean meal and formaldehyde.treated soyabean meal at negative energy balance at 13, 15, 18% of CP in diet	NS on milk yield NS on milk solids NS on BW loss
Andrighetto and Bailoni (1994)	Comparison of sources of ruminally undegradable protein	NS on milk yield sig. on milk casein content

Fig.1. The body weight (BW, in lines) and ovulation rate (in bars) in goats that were fed at maintenance level (1.0M) or 1.4 maintenance level (1.4M), relative to days elapsed from initiation of dietary: after Henniawati and Fletcher (1986).

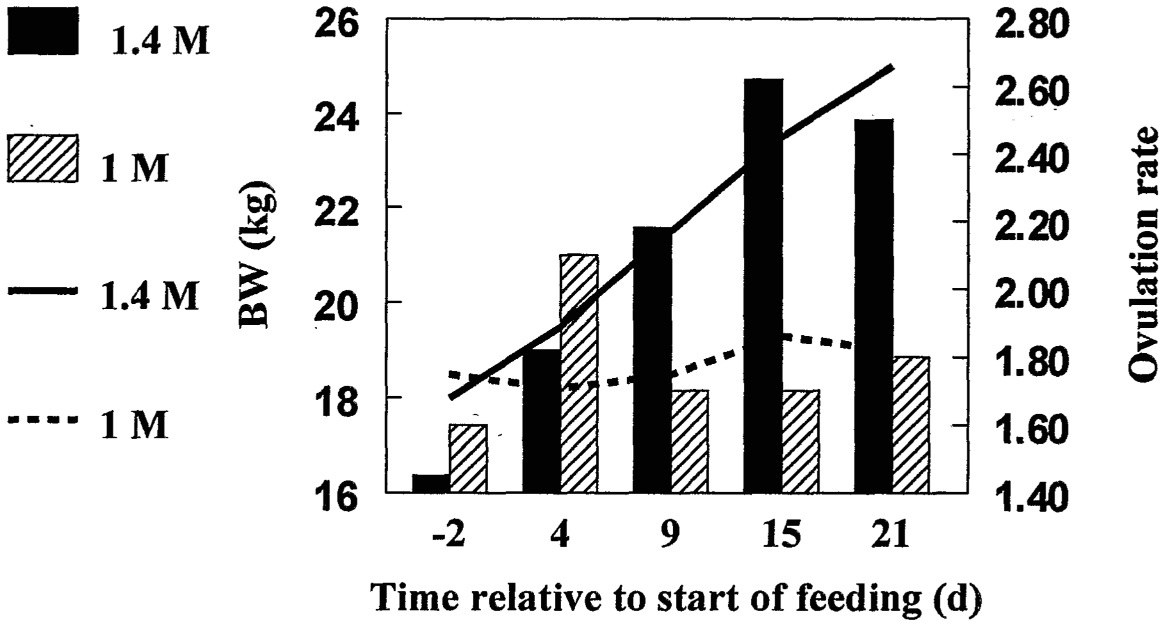

Fig. 2. Pre-prandial concentrations of urea (a), insulin (b), glucose © and the follicular dynamics before a synchronised estrus (d) in sheep fed, in addition to hay, with corn grain (--), corn gluten meal and corn grain (-.-) or soyabean-meal (- -): all diets were iso-energetic and the gluten meal and soyabean meal diets were iso-nitrogenous. Data show that insulin peaks on estrus dat and that diet affect follicular dynamics (Landau et al., in press).

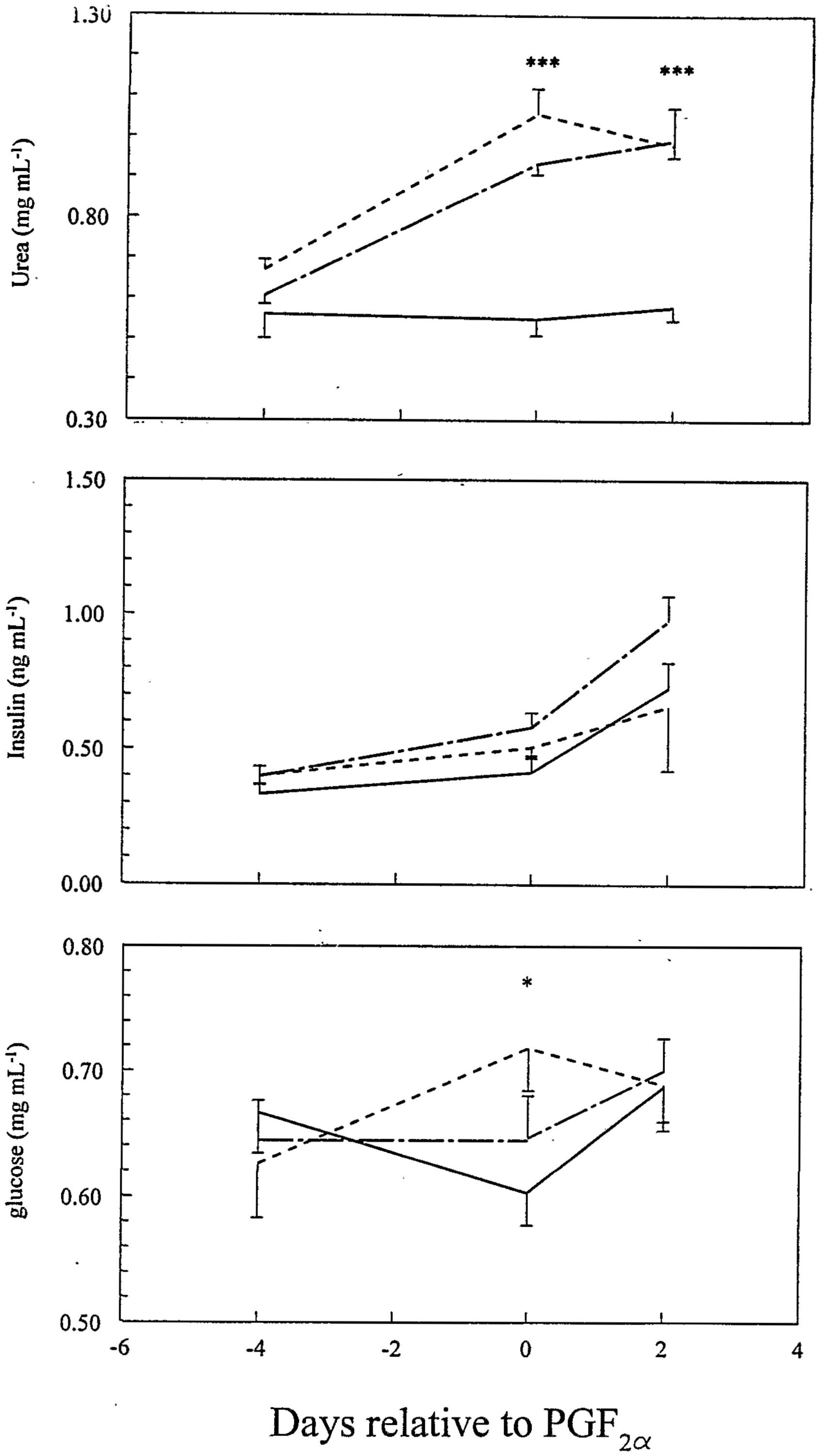

Fig. 2. (cont.) Pre-prandial concentrations of urea (a), insulin (b), glucose © and the follicular dynamics before a synchronised estrus (d) in sheep fed, in addition to hay, with corn grain (--), corn gluten meal and corn grain (-.-) or soyabean-meal (- -): all diets were iso-energetic and the gluten meal and soyabean meal diets were iso-nitrogenous. Data show that insulin peaks on estrus dat and that diet affect follicular dynamics (Landau et al., in press).