



REVIEW [REVISIÓN]

**UNDERNUTRITION DURING PREGNANCY IN GOATS AND SHEEP,
THEIR REPERCUSSION ON MOTHER-YOUNG RELATIONSHIP AND
BEHAVIOURAL DEVELOPMENT OF THE YOUNG**

**[LA MALNUTRICIÓN DURANTE LA GESTACIÓN EN CABRAS Y OVEJAS
Y SU REPERCUSIÓN SOBRE LAS RELACIONES MADRE-CRÍA Y EL
DESARROLLO CONDUCTUAL DEL CABRITO]**

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SUMMARY

Undernutrition during pregnancy dramatically affects physiology and behaviour of mother and offspring. In the mother, undernutrition causes low body condition, which deteriorates good milk production. Likewise, it affects metabolism endocrinology and learning processes controls on offspring. Effects on females can be observed if the animal is exposed to nutrient restriction, as well as by limiting consumption, which may induce to a state of frustration due to need for food. Once given birth, consequences in the mother are mainly reflected by a poor maternal performance, low milk production, loss of body condition and limited bonding with the neonate. In the offspring case, the effects of undernutrition in prenatal life are immediate and can be observed, such as low weight at birth, lack of vitality and viability, as well as cognitive processes deterioration. Therefore, this situation may have immediate and long-term repercussions, such as: postnatal death, and alterations in cognitive capacity and normal behaviour. Conversely, it has been shown in goats that supplemental nutrition at the end of pregnancy can be a strategy that can eliminate and revert the majority of physiological and behavioural abnormalities previously mentioned. The aim of the present work is to describe the findings of undernutrition effects, during pregnancy in goats and

ewes, on mother-young relationship and behavioural development of kids in the first months of life.

Key words: Undernutrition, pregnancy, endocrinology, sensitive period, maternal behaviour, social behaviour, goat, kid.

RESUMEN

La malnutrición durante la gestación afecta dramáticamente la fisiología y el comportamiento de la madre y sus crías. En la madre, la malnutrición provoca la pérdida de condición corporal y deteriora el inicio de una buena lactancia. De la misma manera, afecta la endocrinología relacionada con el metabolismo y con el control de sistemas de aprendizaje de la descendencia. Los efectos en las hembras se pueden observar tanto si el animal es expuesto a una restricción de nutrientes, como si se le limita su consumo, lo que a su vez puede inducir un estado de frustración por la necesidad de comer. Una vez al parto las consecuencias en la madre, se ven reflejadas especialmente por un pobre desempeño materno, baja producción de leche, pérdida de la condición corporal y limitada vinculación con su neonato. En el caso de las crías los efectos de una malnutrición en la vida prenatal son inmediatos y observables, como es el bajo peso al nacimiento, la

falta de vitalidad y viabilidad, además que deterioran sus procesos cognitivos. Por tanto dicha situación, en la descendencia puede tener repercusiones inmediatas como muerte postnatal, y a largo plazo como alteraciones en las capacidades cognitivas y la expresión de un comportamiento normal. Por su parte en las cabras se ha demostrado que una complementación alimenticia al final de la gestación puede ser una estrategia que puede eliminar y revertir la mayoría de las anomalías fisiológicas y conductuales, antes mencionadas. El objetivo de la

INTRODUCTION

Mammal pregnancy is a critical period in which the female risks part of its biological efficacy to obtain new progeny that must survive, have strength to develop and in the future reproduce. Therefore, an event so delicate in the life of an animal, such as pregnancy, can be affected by direct environmental factors which interact with the animal situation. In the case of domestic animals, feeding and nutritional status depends directly on the human responsible for its care.

Worldwide, there are approximately 750 million heads of caprine cattle (FAO, 2003), of which approximately 94% is concentrated in developing countries, mainly Asia (Glimp, 1995; FAO, 2003). In the majority of cases the socioeconomic level of caprine producers is limited; therefore, herd conditions are not always adequate (McDermott *et al.*, 1999; Schlink *et al.*, 2010), hence some factors such as animal nutrition are affected. Thus nutrition is a factor that has a direct impact on ruminant reproductive processes (Robinson, 1990; Walkden-Brown *et al.*, 1994; Rae *et al.*, 2002). A bad nutrition that can be excessive or deficient, in nutrients as well as in quantity, almost immediately affects reproductive process that may be developing in certain moment.

In the case of goats, it has been observed that a deficient nutrition during pregnancy induces offspring low weight at birth, as well as lower weight gain in females (Sahlu *et al.*, 1992; Sahlu *et al.*, 1995; Terrazas *et al.*, 2009); consequently, it causes low weight in offspring, low colostrum and milk production (Vera *et al.*, 2011 submitted).

Besides, it has also been reported that endocrinology in the female during pregnancy, is affected by nutritional restriction, especially in those hormones related with nutritional and sexual metabolism, such as: insulin, growth hormone, thyroxin (T4) and steroidal hormones (Ismail *et al.*, 2008; Dwyer *et al.*, 2008; Hefnawy *et al.*, 2010; (Ramirez-Vera *et al.*, 2001 submitted).

presente revisión es describir los hallazgos que se han encontrado sobre los efectos de la malnutrición durante la gestación en cabras y ovejas, sobre las relaciones madre cría y el desarrollo conductual del cabrito en los primeros meses de vida.

Palabras clave: Malnutrición, gestación, endocrinología, periodo sensible, conducta materna, conducta social, cabra, cabrito.

Even though undernutrition has negative effects on female reproduction and their progeny, there are few studies in goats reporting consequences of undernutrition in mother-young relationship during the first days postpartum, as well as on newborn survival.

Postnatal mortality in goats is a problem that considerably decreases productivity of this species (Mellor and Stafford, 2004). In India, for example, neonatal mortality rates that go from 15 to 51% are reported (Lall and Singh, 1949). In South Africa, 12 to 50% mortality rate (Mellor and Stafford, 2004). In Mexico, mortality rate in studies carried out in desert, temperate and tropical climates oscillate between 7 to 25% (Mellado *et al.*, 2000; Ramirez-Briebesca *et al.*, 2001). In the majority of these studies it has been reported that the period of greater mortality risk is during the first weeks of life of the kid; and the main causes of reported mortality are hypothermia, starvation, exposure to cold, maternal undernutrition, bad maternal care, infections, accidents and predation (Torres-Acosta *et al.*, 2001; Mellor and Stafford, 2004).

The objective of the present review is to show the literature information concerning to evaluate the effects of undernutrition during pregnancy in sheep and goats on some physiological factors, and on the mother – young behavior after birth. In the first part of the review is presenting the immediate and late effects of the undernutrition on corporal condition of the mother, on the some physiological process, and on the production of hormones that participates in the metabolism and those that participate in the control of reproductive process and the trigger of some behavior after partum. Basically the first part this review is concerning to the whole of pregnancy period. While the second and the third part is on the postpartum period.

The second part of this review, describes the main finding reported in sheep and goats of the effects of undernutrition during pregnancy on the mother – young behaviors, especially those occurring during the sensitive period. Finally the third part of this review describes the last studies concerning to the effect of

prenatal undernutrition on the display of some social and cognitive behavior in both sheep and goats.

PREPARTUM STAGE AND EFFECTS OF UNDERNUTRITION ON GOATS AND EWES.

Some consequences of undernutrition during breeding and pregnancy are low conception, severe embryo wastage, pregnancy toxemia and low birth weights (poor newborn survival). Nutrient requirements of dams during early pregnancy are only slightly higher than those at maintenance but increase slowly during the first 15 weeks of pregnancy as the embryo grow and exert greater demands on the maternal tissue. Requirements during the final 6 weeks of pregnancy are greatly elevated (NRC, 2007). The main negative consequences derived of undernutrition are on multiple pregnancies. For example in ewes demands of nutrient are duplicated in twin pregnancy if a low intake of nutrient is available this condition could induce pregnancy toxemia or also known as “twin lamb disease”

Often ewes that are underfed during late of pregnancy scape pregnancy toxemia but give birth to small underdeveloped lambs that may die at birth or shortly thereafter or may extraordinary care (NRC, 2007).

In other hand in goats even when many breeds had emerged to suit needs of local producers and consumers of the goat products, a substantial proportion of the world of goat population is nondescript in appearance, not belonging to any recognized breeds. These goats vary greatly in body size, color pattern, occurrence and shape of horns, size and attachment of udder, occurrence of waddles, and characteristics of fleece (NRC, 2007).

During pregnancy, goats require greater quantity of nutrients that change according to fetal development (Sahlu *et al.*, 1995; NRC, 2007). Therefore, it is important that such requirements be met to avoid immediate consequences that induce stillborns during pregnancy, or at the end of this. It is important to mention that even though caprine production has a strong impact in sustaining some economies, very few studies have considered undernutrition during pregnancy. Yet, until two decades ago nutrimental recommendations from NRC for this species production were based in only two studies (NRC, 1981). In such tables, nutritional recommendations were suggested, which not necessarily took into account the needs or characteristics of each caprine breed as size and productive function (Sahlu *et al.*, 1992; Sahlu *et al.*, 1995). Today, nutritional recommendations have been broadened and supported with more studies that have allowed considering caprine nutrition just as in other production species

(NRC, 2007). Still, there is scarce information in caprine regarding undernutrition impact on pregnancy and other productive parameters; and little has been researched on behaviour.

In the case of other production species like sheep, it has been found that changes in nutrition during pregnancy decreases weight in new born lambs, especially in twins (Louca *et al.*, 1974; Khalaf *et al.*, 1979; Rae *et al.*, 2002; Corner *et al.*, 2010; Olazabal *et al.*, submitted 2011).

It has been shown that twin-born lambs are more susceptible to be affected by maternal undernutrition and have, consequently, lower weight at birth as those single-born, even when mothers were fed with similar diets (Gunn, 1983). More recent studies, show that survival rate in triple-born lambs is lower that survival rate in single and twin-born (Scales *et al.*, 1986; Everett-Hicks and Dodds, 2007).

In the specific case of goats, when nutrition is restricted during pregnancy, adverse and immediate effects are caused on the animal. In one study where effects on cardiovascular function, including water balance and mammary circulation of a 48 hour food restriction period were evaluated, and it was found that by mid pregnancy (by day 70) the restriction period caused a decrease in volume and cardiac output. Also, peripheral resistance (which is determined by dividing mean arterial pressure by cardiac output) increased. When this nutritional restriction was done during late pregnancy (day 132), cardiac output rate, blood volume and mammary blood flow considerably decreased. Likewise, at mid pregnancy water intake decreased and the animal went through a negative fluid balance, which persisted during the two day nutritional restriction period (Chaiyabutr *et al.*, 1980).

However, when nutritional restriction is prolonged for several days, effects may be seen in the mother. Such is the case of losing body weight as well as low weight gain and body deterioration while pregnancy advances. In research studies on dairy goats, under intensive conditions, subjected to energy and protein restriction from day 70 of pregnancy to partum, it was found that approximately on day 107 of pregnancy and 40 days after the beginning of the restriction period (Figure 1), body condition and weight of females started to be lower than well fed pregnant goats (unpublished information; Terrazas *et al.*, 2009). Nutritional conditions, to which females are subjected, deteriorate significantly their body condition during pregnancy. This has been observed in Creole goats under low quality grazing conditions, as shown in studies carried out in goats kept under extensive systems and semi-arid zones (Ramírez *et al.*, 2010).

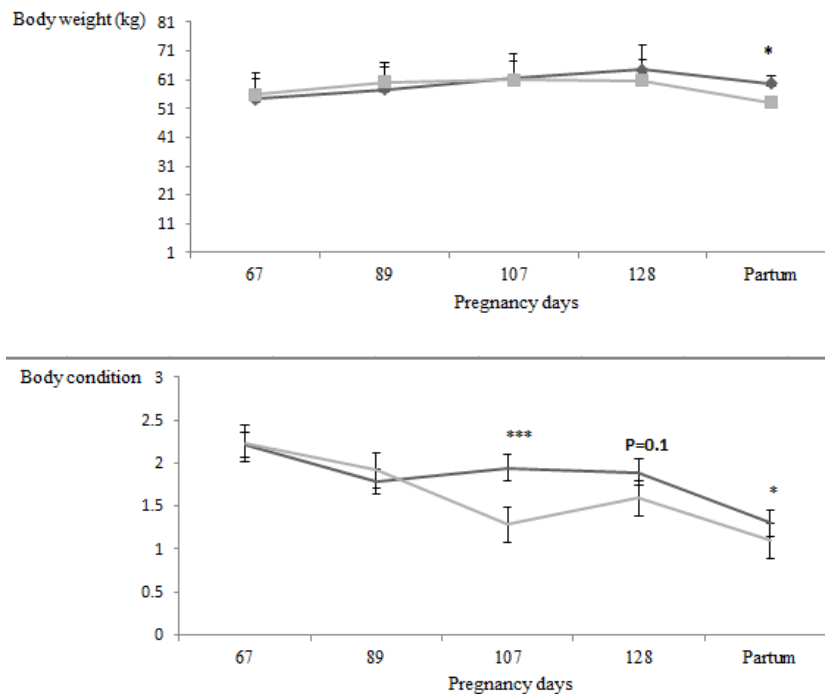


Figure 1. Mean (\pm e.e.) weight and body condition (range from 1 to 3) in goats fed with 100% of nutrimental requirements during pregnancy (n = 19, black line) and goats fed only with 70% of requirements (n = 24, gray line) on protein and energy from day 70 of pregnancy to birth. Similar process to the one described by Terrazas *et al.*, (2009). Asterisks (* $P < 0.05$ and *** $P < 0.01$) significant differences between groups.

Likewise, the condition of the pregnant female is not the only one that deteriorates as pregnancy advances; there are also endocrinological effects especially on hormones and metabolism associated with pregnancy maintenance. Several studies have shown that plasmatic concentrations of thyroidal hormones are positively correlated with energy consumption in some animal species (Davidson and Chopra, 1979; Blum *et al.*, 1980; Dauncey *et al.*, 1983). In one study carried out in goats that were restricted in their energy consumption from the last third of pregnancy and during lactation, it was found that thyroid hormone thyroxin (T4) decreased significantly as consequence or low energetic supply. In this work it was concluded that T4 is a key factor in body adaptation to consume energy in order to produce it. The decrease in T4 secretion in this adaptive process, when energetic supply is deficient, can be an essential process for survival under conditions where energy consumption in herds is limited, whether it is administered or by the animal capacity to consume it (Riis and Madsen, 1985). These hormones associated with the energetic metabolism in pregnancy are affected by a nutritional restriction in the doe. A fast drop in T4 can also be observed in nutritional problems, such as pregnancy toxemia in does that carry more than one fetal (Hefnawy *et al.*, 2010).

Conversely, glucose concentrations are also affected by the animal nutritional condition; in the case of

goats, either in those who have been exposed to nutritional restriction in intensive management (Figure 2) or when they have been kept on low quality grazing during pregnancy. In both cases, it has been shown that glucose levels significantly decrease during such undernutrition period, especially in the last third of pregnancy where energy demands increase importantly (Ramirez *et al.*, 2010). This blood glucose level drop can also be observed during the first signs of pregnancy toxemia in goats carrying more than two fetuses (Hefnawy *et al.*, 2010). Therefore, not only is glucose an indicator of an undernutrition condition in the animal, but also in a fast process of nutritional condition loss.

Other hormones like insulin, and even immune response in the case of pregnancy toxemia, can change due to undernutrition in pregnant does, especially those bearing more than one foetus (Ismail *et al.*, 2008; Hefnawy *et al.*, 2010). In a trial carried out in pregnant goats, particularly those bearing two fetuses, pregnancy toxemia was induced at the end of pregnancy and the immune and hormonal response was measured from the moment of induction to 72 hours after, and it was found that β -hydroxybutyric acid, cortisol and insulin increased; while a significant drop in glucose, thyroidal hormones and immunoglobulin (IgA, IgM and IgG) (Hefnawy *et al.*, 2010) levels were observed.

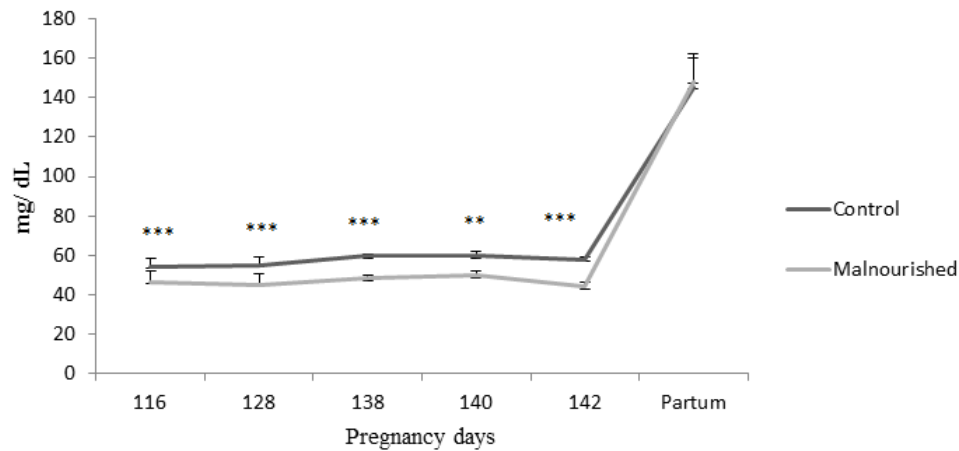


Figure 2. Mean (\pm e.e.) blood glucose concentration from day 112 of pregnancy to moment of birth, in goats fed with 100% of nutrimental requirements during pregnancy ($n=19$, black line) and goats fed only with 70% of requirements ($n = 24$ gray line) on protein and energy since day 70 until birth. Blood sample was collected in animals fast and was processed with a portable glucometer. Process similar to the one described by Terrazas *et al.*, 2009. Asterisks (** $P \leq 0.01$ and *** $P \leq 0.001$) significant differences between groups.

In goats, steroid hormones associated with pregnancy maintenance and possibly with triggering maternal behaviour, as progesterone and estradiol, during pre- and postpartum (Poindron *et al.*, 2007b; Poindron *et al.*, 2007c), can be affected due to undernourishment or low nutritional condition during pregnancy. In goats kept in a semi-extensive system, it was found that blood plasma levels of progesterone during previous days before partum were kept high and its drop delayed, in comparison to goats under the same conditions that were given an energy supplement based on corn on the last eight days previous to partum (Ramirez-Vera *et al.*, 2001 submitted). Goats that were restricted to 70% of their normal requirements of protein and energy during the second half of pregnancy and until partum, levels of progesterone, estradiol and cortisol were evaluated. In this study it was found that in days 145, 146 and 148 of pregnancy, the levels of progesterone tended to be higher in goats from the nutritionally restricted group than in control group (Figure 3). While estradiol levels did not change along the second half of pregnancy between the two groups (Figure 3). An interesting situation occurred in the case of cortisol plasma levels, since levels of this hormone were significantly greater in female control group or with complete diet than in females nutritionally restricted, this change was observed from day 109 to 140 of pregnancy; however, at the moment of partum the cortisol concentration in both groups increased considerably and there were no differences between them (Figure 3).

In the two studies previously described, in undernourished animals, plasma progesterone seems to have similar behavior at the end of pregnancy; that is,

levels superior to normal and a delay in its drop were recorded. In ruminants, a timely drop in progesterone at the end of pregnancy has two important roles, one is the start of lactogenesis to ensure good milk production (Mellor *et al.*, 1987; Hall *et al.*, 1992; O'Doherty and Crosby, 1996; Foisnet *et al.*, 2010), and the other is associated with triggering maternal behaviour along with estrogen level increase at the end of pregnancy, which has been well documented in sheep (Poindron and Le Neindre, 1980; Poindron *et al.*, 2007b). On the next chapter, the effects of undernutrition during pregnancy on maternal behaviour in goats will be described. However, with the aim to compare the effects of undernutrition during pregnancy on progesterone production at the end of pregnancy, it is important to mention that in the case of sheep it seems that there are similar results to the ones found in undernourished goats. In a study where sheep were restricted to only 65% of their daily intake, from week four of pregnancy to parturition, it was found that progesterone levels were higher from mid pregnancy forward, in contrast to the group of ewes that were not nutritionally restricted; whereas, estradiol levels were lower in the restricted than in control ones (Dwyer *et al.*, 2003). As shown by different studies carried out for researching physiological and body effects on undernourished pregnant goats, it can be observed that these may be as acute and immediate as those found in endocrinology, or chronic affecting animal welfare and therefore, productive efficiency.

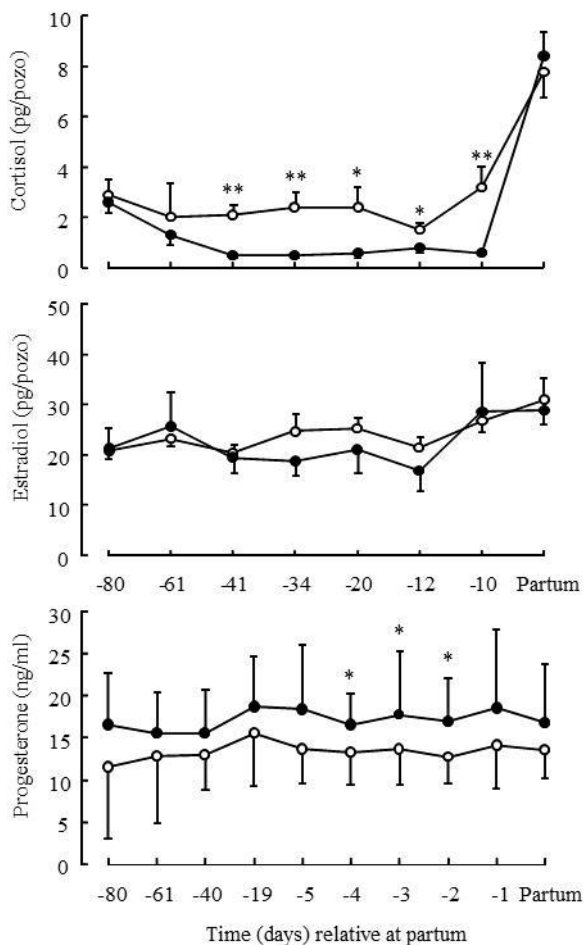


Figure 3. Mean plasma levels (\pm e.e.) of cortisol, estradiol and progesterone in goats fed with 100% of their nutrimental requirements during pregnancy (○ n=11) and goats fed only with 70% of requirements (● n= 9) on protein and energy from day 70 of pregnancy until birth. Samples were collected before morning feeding, and centrifuged at 3500 r.p.m. for 20 minutes; they were kept at -20°C . Cortisol and estradiol were analyzed by ELISA test and progesterone was analyzed by RIA. Process similar to the one described by Terrazas *et al.*, 2009. Asterisks (* $P \leq 0.05$, ** $P \leq 0.01$ and *** $P \leq 0.001$) significant differences between groups.

UNDERNUTRITION REPERCUSSION DURING PREGNANCY ON MOTHER-YOUNG RELATIONSHIP DURING THE FIRST DAYS POSTPARTUM.

As aforementioned, undernutrition during pregnancy has immediate or chronic negative effects on the mother, but also on its offspring, and it can affect other physiological systems that, in consequence, will afflict its future life and will cause an abnormal behavioural development. In the case of the mother the effects on

maternal behaviour are evident, according to several studies on sheep, and recently on goats. Studies on sheep have been broader than on goats; however, since many studies suggest that control of maternal behaviour and mother-young relationship is similar in both species (Poindron *et al.*, 2007b; Poindron *et al.*, 2007c), it is thought that undernutrition during pregnancy may have similar effects between sheep and goats. In regard to sheep, it has been reported that when a female has had inadequate food intake or restricted diet during pregnancy, negative consequences are observed, as thin and weak lambs, low milk yield and an increase in postnatal mortality (Mellor, 1983; Robinson *et al.*, 1999; Dwyer, 2008). A decrease in nutrients fed during the critical phases of pregnancy, alters prenatal growth and adequate postnatal development, not allowing manifesting the adequate cues in order to be able to reach the maximum productive potential (Robinson *et al.*, 1999). Sheep that received a restricted diet in contrast to the group fed on high nutrient level during pregnancy and postpartum, had higher incidence of dystocia and they had longer latencies for giving attention to their newborn than well fed sheep. In that group it also was observed that the offspring was weak, and when this occurred, although mothers were maternally motivated, interest decreased as the newborn got weaker. Likewise, undernourished females showed lesser or low interest and did not maintain their maternal instinct in contrast to the well fed, inclusive in the case in which the lamb was strong and active. It was also observed that in the majority of the ewes fed on low nutrient levels they did not have enough milk; and in the cases that they indeed showed maternal interest, their offspring got weak and died from starvation. Finally, in the undernourished group, lambs took longer to stand, especially in double parturition (Thomson and Thomson, 1949).

The effects of a low nutritious diet in ewes on mother-young relationship during the sensitive period (Poindron *et al.*, 2007b) have not differed in further studies. In the case of research carried out on primiparous ewes that were restricted to 65% of food intake from the second month of pregnancy until birth, it was found that these females showed greater frequency of aggressive behaviour towards their lambs, which got more complicated because it was their first parturition. It was also found that mothers spent less time licking their offspring and spent more time eating; likewise, there was greater incidence of dystocia in the undernourished group. Females from this group showed less interest towards their offspring, during three days postpartum, than those ewes well fed. Finally, it was observed that lambs born from undernourished mothers took longer to stand and nurse than lambs from the well fed group (Dwyer *et al.*, 2003).

In other study carried out in ewes under 70% energy and protein restriction, from day 70 of pregnancy until birth, it was found that the vocalizations emitted by the lambs born from these ewes were altered or different to those of the lambs born from well fed mothers during pregnancy. Likewise, in this group it was found that mother-young mutual recognition in the first day postpartum was delayed in contrast to the animals from the well fed group (Olazabal *et al.*, submitted 2011).

Previous studies have shown that when ewes are experimentally subjected to undernutrition during pregnancy, either from food intake or nutrients restriction; maternal behaviour, and vitality and behaviour of the offspring are deteriorated and affected, as well as mother-young relationship during the first day postpartum, which may determine lamb's survival and possibly cause after-effects in development. It is important to highlight that the aforementioned studies have been carried out in intensive production conditions.

In contrast, there have been similar results in studies carried out on ewes under grazing conditions. Thus when there is poor pasture quality and the lambs are already born, mothers spend less time attending them and more time eating, also when they have more than one lamb, they abandon the offspring with less vitality (Putu *et al.*, 1988; Lindsay *et al.*, 1990).

In studies on ewes where the availability of pasture has been manipulated during pregnancy, effects on behaviour, especially on lambs, have been observed. Thus a study carried out on pregnant ewes kept on grazing system, where pasture height was altered, it was found that when the pasture height was increased from 2 to 4 cm, triplet bearing ewes gave birth to a litter with 2 kg more, also weaning weight of these lambs increased 8 kg and survival rate increased 4%. The availability of pasture had greater effects on lamb behaviour, more than on mothers; and triplet lambs were the most affected in contrast to twins. The ewes offered higher pasture were more susceptible to stay with their offspring at the moment of being identified. Triplet bearing ewes offered 2 cm pasture sward heights stayed away from their offspring during 5 minutes after lamb handling, emitted high-pitched bleats and had less contact with their offspring during earring than females offered higher pasture; whereas, triplet lambs born to mothers in low availability pasture were less susceptible to stand, find udder and, consequently, follow their mother (Everett-Hincks *et al.*, 2005).

In other study, the effect of grazing ewes in two feeding levels according to pasture height, during middle and end of pregnancy, on mother-young behaviour at 12 and 24 hours postpartum was

evaluated. It was found that when pasture was offered at 2 cm high (~700 kg dry matter (DM/ha) during late pregnancy, the ewes were more reluctant to emit low-pitched bleats in contrast to the ones that were offered approximately 4 cm pasture sward heights (1300 kg DM/ha). This low-pitched bleat is associated with good maternal behaviour (Nowak, 1996), for which this author confirms that a high nutritious level during late pregnancy provides some advantages for maternal bond. In that same study it was found that 95% of lambs born to ewes offered 4 cm pasture sward heights emitted bleats in contrast to 84% of lambs born to ewes in Treatment 2 cm. Likewise, lambs born to ewes in Treatment 4-4 cm pasture sward heights, were more reluctant to move towards their mother in order to make contact, than lambs born to Treatments 2-2 or 4-2 cm pasture sward heights. This suggests that lambs born to ewes offered few pasture during late pregnancy, showed more maternal need than the ones born to well fed mothers (Corner *et al.*, 2010).

In goats, although they suffer from greater undernutrition levels that frequently affect pregnancy, there are few studies on the effects on maternal behaviour and mother-young relationship during the sensitive period. However, there are findings which report it either in intensive or grazing production conditions.

In a study where the quantity of energy and protein was restricted from the diet since day 70 of pregnancy to parturition, negative effects were observed. First of all, mothers' behaviour during the first hour postpartum was, in general, poorer than well fed females during pregnancy. Mothers' care towards their second litter was more affected, thus undernourished females spent less time licking their second newborn kid in contrast to well fed females. In the case of the kid, it was found that the latency of showing udder search behaviour and the latency to stand were shorter in kids born to well fed mothers than to undernourished. Finally, the latency to reach the udder and nurse was shorter in kids born to well fed mothers than to undernourished (Terrazas *et al.*, 2009). The proper display of mother-young behaviour implies a good bond, which will allow warranting the survival of the offspring. In this same study done by Terrazas *et al.* (2009), the capacity of the mother to discriminate its offspring from an alien one at four hours postpartum, through olfactory cues, was evaluated, and it was found that undernutrition did not alter such capacity. Conversely, in goats, as well as sheep olfactory recognition of the offspring is known as maternal selectivity (Poindron *et al.*, 2007b; Poindron *et al.*, 2007c), there are other mechanisms that the mother uses to discriminate its offspring from the alien one, and such is the case of distal recognition, where the mother uses auditory and/or visual cues coming from its offspring recognizing her (Terrazas *et al.*,

1999; Ferreira *et al.*, 2000; Poindron *et al.*, 2003; Terrazas *et al.*, 2003). In the study aforementioned on undernutrition in pregnancy, it was also observed that well fed goats showed better distal recognition capacity of its kid at 8 hours postpartum. Indeed, these goats spent more time near their offspring, looked at them for longer time and visited them more frequently than the alien ones. In contrast, undernourished goats did not show differences in time spent near or time looking at their own or alien one, although they did made more visits to their kids than to the alien ones (Terrazas *et al.*, 2009).

In the case of the kids, when they are exposed to a double choice motivation, it has been demonstrated that they are capable to discriminate their own from the alien mother, inclusive from eight hours of age (Poindron *et al.*, 2007a). When their mothers were nutritionally restricted during pregnancy, it was found that their discriminatory capacity at 12 hours of age was not altered, since kids from both groups spent more time near their mothers and visited them more frequently than the alien ones (Terrazas *et al.*, 2009).

In a further study on goats under the same nutritional restriction conditions, described by Terrazas *et al.* (2009), and in which recognition capacity of the kids at 12 hours of age was tested; also, behaviour of mothers was recorded and analyzed (own and alien mothers); these females belonged to the same group as the tested offspring. In this study, frequency of moving the head upward and downward, frequency of high and low-pitched bleats, as well as frequency of escape attempts from the pen was measured in mothers. It was found that kids' own mothers in the control group tried more escape attempts than the undernourished group (Figure 4). In both groups, kids' own mothers as well as alien ones significantly emitted more low-pitched bleats during the test (unpublished information, $P < 0.01$). Only kids' own mothers in the control group showed greater frequency of lowering their heads rather than raising it (Figure 4). Alien mothers in control group tend to rise their heads more frequently than kids' own mothers ($P = 0.08$). Whereas kids' own mothers in control group showed greater frequency of lowering their heads than alien ones (unpublished information, Pelayo *et al.*, 2010, $P = 0.05$). In summary, only kids' own mothers in control group showed a higher index of acceptance than the alien mothers (0.5 ± 0.4 vs -0.1 ± 0.3 , $P = 0.06$); likewise, kids' own mothers in control group showed more acceptance than rejection index (0.5 ± 0.4 vs -0.8 ± 0.2 , $P = 0.008$), whereas undernourished mothers did not show such differences (Figure 4). This study also allows concluding that under this undernutrition scheme during pregnancy, maternal motivation is also affected by changing the normal attraction response that the mother has towards its offspring when it is looking for her (Pelayo *et al.*, 2010).

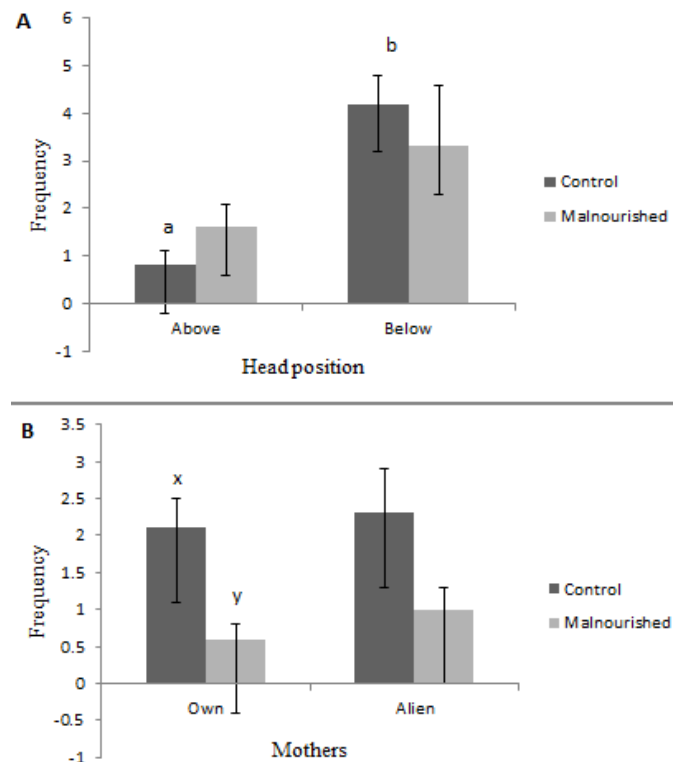


Figure 4. Mean frequency of lowering or rising head (\pm e.e.) in own mothers (A), and escape attempts (B), when used to test the ability of kids with 12 hours of age to discriminate between their own mother and an alien (test and experimental process described by Terrazas *et al.*, 2009). Kids came from does fed with 100% of their nutritional requirements during pregnancy ($n=12$), and from does fed with only 70% of their requirements ($n = 11$) on protein and energy since day 70 of pregnancy until birth. Significant a, b differences within control group between head up versus head low, and significant x, and differences between groups only from own mothers.

Other research studies on goats under extensive grazing conditions, desert climate and body condition lower than 2.5 in a scale of 1 to 4, found that mother-young behaviour during the first one and a half hour postpartum was deteriorated and there was not enough colostrum production; therefore, that may put at risk the offspring survival and its development during nursing (Ramirez, 2007; Ramirez-Vera *et al.*, subjected in 2011). During these same grazing conditions during pregnancy, it was also found that distal recognition capacity of the mothers was altered, because they were not capable to discriminate their own kid from the alien at four hours postpartum. Likewise, kids born to those mothers were also not capable to discriminate their own mother from the alien at eight hours of age (Ramirez, 2007; Santiago, 2007).

EFFECTS OF UNDERNUTRITION DURING PREGNANCY ON OFFSPRING BEHAVIOUR IN THE FIRST MONTHS OF AGE.

As it can be observed, it is evident that maternal undernutrition during pregnancy greatly affects the bond between mother and young during the first days postpartum. This may be altering the establishment of important processes that will have short or long term animal behavioural repercussions. In regard to goats and ewes, several studies have considered that the stage immediately after birth has sensitive periods (Poindron *et al.*, 2007b). This term that derived from studies on the establishment of the bond during embryonic and early life of birds has also been observed in mammal life (Poindron *et al.*, 2007b). Sensitive period is a term that was proposed for the first time by Bateson (1979) and refers to as “the characteristics of an individual may be influenced more strongly by a determined event and during a specific stage of development of the animal, rather than in other moment of its life”.

In the case of mammals, it has been suggested that maternal-filial bond, sexual bond and socialization are established during these sensitive periods (Kendrick *et al.*, 2001; Maier, 2001). Therefore, any alteration during those periods will have repercussions in the adult life of the animal.

In the case of the establishment of sexual bond, in a study carried out with cross-fostering between goats and sheep, it was found that mainly the males had strong influences on their sexual partner selection capacity in their adult life because of the type of rearing during their postnatal life. It was observed that at the moment of choosing their partner, these preferred the females with characteristics similar to the ones of their mother. In the case of cross-fostering, those kids that were taken care of by sheep, when they grew up they preferred a ewe as sexual partner rather than a doe. Whereas the lambs reared by goats, also preferred does as partners (Kendrick *et al.*, 1998; Kendrick *et al.*, 2001). If the alteration in the type of maternal care of the offspring affects partner selection, at least in this work, it would be interesting to do a research on the effects or repercussions of a poor or deficient rearing by undernourished mothers on their progeny, and not only on partner selection, but also on the reproductive performance of such animals.

Additionally, it is evident that maternal undernutrition during pregnancy or prenatal life has medium or long-term repercussions on behaviour (Erhard *et al.*, 2004); for instance, there is clear consensus that prenatal undernutrition induces lasting changes on emotional reactivity of the individual and mainly on motivational processes in humans and rodents (Smart, 1986;

Levitsky and Strupp, 1995; Strupp and Levitsky, 1995).

It has also been suggested that prenatal undernourishment may have effects on the development of the offspring and affect its cognitive system. This has been mainly reviewed in humans. Thus it is known that hyperthyroidism and hyperphenylalaninemia during early pregnancy, due to maternal undernutrition during pregnancy, causes profound mental retardation in humans, and minor effects in animals (Strupp and Levitsky, 1990; Strupp and Levitsky, 1995).

However, in studies carried out on sheep it has been observed that undernutrition during prenatal life can cause negative effects on their cognitive capacity. Although it is suggested that discrepancy between the observed effects on humans, in relation to the ones found in animals, may be because in the majority of the studies carried out on animals, only a learning test has been used as a measure variable of mental ability, it does not rule out the possibility to evaluate with other tests the cognitive capacity of animals and therefore, the effects of prenatal undernourishment (Erhard *et al.*, 2004).

In the trial carried out on sheep, the hypothesis concerning that prenatal undernutrition increased emotional reactivity and harmed cognitive flexibility of animals was tested. Lambs born to two groups were tested, one in which the mothers were fed on a diet that fulfilled nutritional requirements during pregnancy, and another group where only half of the requirements were offered, such restriction was initiated since day 1 to 95 day of pregnancy. It was observed that the animals born to undernourished group were more active during the tests; likewise, they slowly approached to a new stimulus in contrast to the animals from control group. Also, there was differential response due to gender; for instance, males from undernourished group and females from control group showed high levels of initial locomotor activity in contrast to males from control group, but this response gradually decreased; whereas, females from undernourished group initiated their response with high locomotor activity, but they rapidly changed to a complete immobility stage. In these same animals, when a double choice or two way type Y test was applied, it was observed that prenatal undernourishment induces preference towards one side of the test. From this study it is concluded that prenatal undernourishment may cause an increase in emotional reactivity and changes in the place of preference in both genders, as well as deteriorate cognitive flexibility in males (Erhard *et al.*, 2004).

In comparison, a follow up study was done on goats, where the animals went through a process of prenatal

undernutrition since their mothers were undernourished from the second half of pregnancy to parturition, under the same scheme described by Terrazas *et al.* (2009). When the animals were six months old, their response to social separation was measured, under a similar test as the described by Poindron *et al.* (1997). In this test, the animals were tested for 5 minutes in company with their co-specific and other 5 minutes in absence with. The main effects due to undernourishment during prenatal life were observed in females. In the case of males, there were no effects on different recorded behaviours, since both groups responded significantly to social separation and in both test phases they behaved in a similar way (Fierros *et al.*, 2008).

Whereas in the case of females, when these were tested in company with their co-specific, it was observed that females from control group were more active than the undernourished group (Figure 5). When

the animals were tested in absence of their co-specific or in social separation, it was found that also the females from control group were more active than the ones from undernourished group; in fact, the latter responded less agitated to social separation than the ones from control group (Figure 5).

Finally, in contrast with these two studies on undernutrition effects during pregnancy or prenatal life on behaviour of young sheep and goats, in the other study carried out on goats, the variations found were that undernourished goats during the last third of pregnancy, their 3 and 5-week-old offspring did not show effects on behavioural response, either in a water intake test or feeding test. Likewise, there were no effects on emotional reactivity. From these studies it was concluded that maternal nourishment restriction during the last third of pregnancy did not affect kids' behaviour, although it affects body condition (Laporte-Broux *et al.*, 2011).

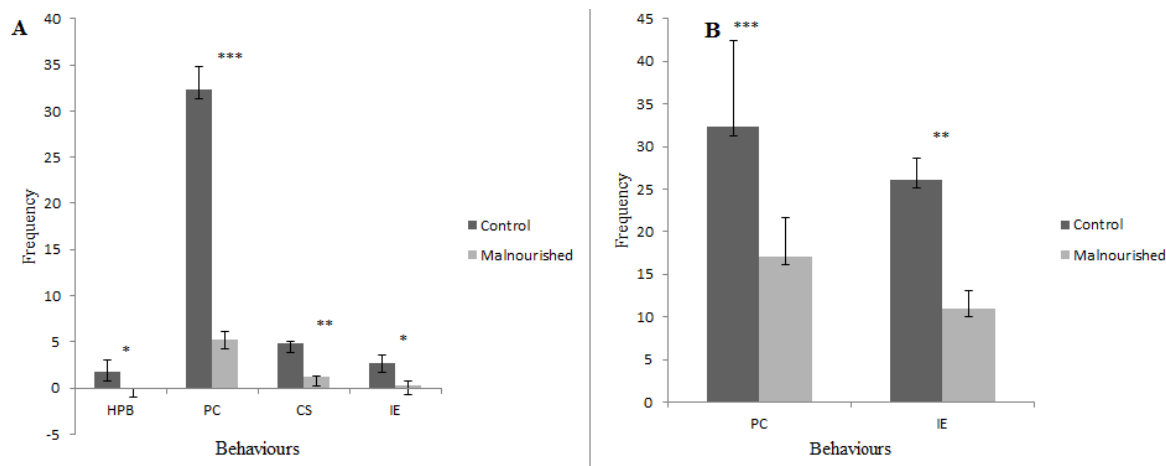


Figure 5. Mean frequency of recorded behaviours (\pm e.e.) in six-month-old doelings, during a social isolation test, in presence of their co-specifics and in absence of these. Similar test process as described by Poindron *et al.*, 1997. Doelings came from two mother groups: 1) goats fed with 100% of their nutrimental requirements through pregnancy and 2) goats only fed with 70% of their protein and energy requirements from day 70 of pregnancy to birth. Ten doelings from well nourished group and eleven from undernourished mothers during pregnancy were tested. Figure A = co-specific company test, B = social isolation test (* $P \leq 0.05$, ** $P \leq 0.01$ and *** $P \leq 0.001$) significant differences between groups. HPB: high-pitched bleats, PC: place change, CS co-specific smelling and EI: escape attempts.

CONCLUSION

Taking into account data aforementioned, it can be concluded that undernutrition during pregnancy in sheep and goats has negative effects on the animals that can lead to acute or chronic consequences. All in all may not only generate a negative situation, but also affect welfare of the animals, exposing them to stress conditions, as is the fact of hunger.

Considering that sheep and goat production systems can have nutritional limitations, especially those of developing countries, it is necessary to ensure greater attention to their herds, in such way that pregnant females can have access to an adequate diet. The repercussions of undernutrition during pregnancy generate a series of alterations that negatively affect productive performance of the animals, as well as of their progeny. Additionally, they affect behaviour or adequate expression of behavioural patterns either of

mothers or offspring. The main problem is that alterations studied until now, affect important life periods of the offspring, which may put at risk their survival. Conversely, and although more studies need to be done, there are also effects of undernutrition during prenatal life on behavioural response of the animals at long-term, which may also affect their productive and reproductive potential.

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