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Review [Revisión]

LAMB FEEDING STRATEGIES DURING THE PRE-WEANING PERIOD IN INTENSIVE MEAT PRODUCTION SYSTEMS[1]

[ESTRATEGIAS DE ALIMENTACIÓN DE CORDEROS DURANTE LA FASE DE PRE-DESTETE EN SISTEMAS INTENSIVOS DE PRODUCCIÓN DE CARNE]

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SUMMARY

The modern consumer of sheep meat requires uninterrupted market supply with qualitatively standardized meat, without excess fat and with high tenderness, which has encouraged producers to slaughter young sheep. A lamb's diet during the pre-weaning phase was discussed in this review because it is of great importance for achieving success in a meat production system, given the high speed of lambs' growth during their first weeks of life. Supplying palatable concentrate in creep-feeders from the first days of life promotes pre-stomach development and adapts the animal to a solid diet consumption; important processes for enhancing animal performance, since nutritional requirements, especially for energy, are high during this period and can only be met by milk for a short time. An early weaning technique can be adopted from 35 days old, when adequate nutritional support is provided. Unweaned lamb slaughtering combined with creep feeding and controlled feeding have superior effects to early abrupt weaning, probably by avoiding the adverse effects generated by post-weaning stress. The use of a milk replacer is seldom reported due to the difficulty in finding specific products for sheep and its high cost. Controlled suckling does not affect the performance of lambs. Further studies investigating lamb feeding strategies need to be developed during the pre-weaning period.

Keywords: creep feeding; early weaning; rumen development; age at slaughter; controlled suckling.

RESUMEN

El consumidor moderno de cordero requiere el abastecimiento constante del mercado de la carne cualitativamente estandarizada, sin exceso de grasa y alta suavidad, esto ha motivado a los productores a sacrificar animales jóvenes. La nutrición del cordero durante el pre-destete es importante para el éxito en un sistema de producción de carne, dada la alta tasa de crecimiento de los corderos durante las primeras semanas de vida. La provisión de alimentos concentrados apetecibles en sistemas con aisladores desde los primeros días de vida promueve el desarrollo de los pre-estómagos y la adaptación al consumo de la dieta sólida, importante para un mejor desempeño, dado que los requerimientos nutricionales, especialmente de energía, son altos en este período, y pueden ser cubierto por la leche por un corto tiempo. El destete precoz puede ser adoptado a partir de los 35 días de edad cuando se proporciona apoyo nutricional. El sacrificio de corderos no destetados combinado con aisladores y alimentación controlada, tiene un efecto superior sobre un destete precoz y abrupto, probablemente porque evita efectos negativos del estrés post-destete. El uso de sustitutos de la leche rara vez se reporta debido a la dificultad de encontrar productos específicos para ovinos y su alto costo. El amamantamiento restringido no afecta al rendimiento de los corderos. Hay necesidad de desarrollar más investigaciones en las estrategias de alimentación del cordero durante la fase de pre-destete.

Palabras clave: alimentación con aisladores; destete precoz; desarrollo ruminal; edad al sacrificio; lactancia controlada.

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INTRODUCTION

Brazil is a major world producer of animal protein and the main destination of its production is its domestic market. According to the Ministry of Livestock Agriculture and Supply (MAPA, 2014), the per capita consumption of meat in Brazil is 43.9 kg/inhabitant/year for poultry, 37.4 kg for beef and 14.1 kg for pork. In the specific case of sheep meat, consumption is 0.7 kg/inhabitant/year, putting this type of food in the 5th position among traditional meats.

The increase in per capita consumption of sheep meat is something that undoubtedly depends on improving the quality of the product that is delivered to consumers. In Brazil, consumers of sheep meat suffer consequences from the lack of organization in the production chain, which is not yet able to continuously supply the market with quality carcasses. Consequently, the commercialization of carcasses that are not originated from meat production systems routinely inserts products into the market which lack a quality standard.

Projections from the "Brazilian Association of Sheep Breeders" estimated that a possible increase in sheep meat consumption to 2.5 kg/inhabitant/year would require a herd of about 50 million animals to meet domestic demand. Such information clearly shows the importance of developing animal farming strategies that enable evolving Brazilian sheep flocks in quantitative and, above all, qualitative aspects.

In this sense, sheep production in a confinement system has been widely used in Brazil - opposed to traditional pasture finishing systems - given their efficiency in reducing slaughter age, producing carcasses with satisfactory quality standards, and thus enhancing meat production (Rodrigues *et al.*, 2008). Many studies have confirmed the effectiveness of lamb production in confinement compared to other production systems (Carvalho *et al*., 2007; Poli *et al*., 2008; Ribeiro *et al*., 2009; Kowalski *et al*., 2013). It is also important to emphasize that efficiency is more significant in the Northeast, where rainfall shortages lead to nutritional challenges (Urbano *et al.*, 2013), suppressing the production potential of the species should there be no food supplementation.

A significant percentage of the experimental tests conducted with meat sheep intended for meat production addresses the problem of feeding during the slaughter phase, however, the fastest lamb growth rates occur during the first few weeks life (Owen, 1976, cited by Bernardi *et al*., 2005), leading to the conclusion that nutrition during this period is essential to obtain satisfactory production rates in a meat production system. In this context, it is essential to evaluate the feeding techniques used during this period as to the effects on the performance of lambs. Some strategies have been heavily evaluated, such as the use of creep feeding, the best age for weaning and the type of diet provided. However, the most technical systems have already been using slaughtered lambs without weaning (Ortiz *et al*., 2005; Poli *et al*., 2008).

Due to a great territorial extension and consequently the flexibility that characterizes the systematics of animal production in Brazil, it is possible to infer that it tends to become a reference for other production centers besieged in tropical and subtropical zones. Thus, defining, applying and confirming the efficacy of management practices focused on the breeding phase aimed at shortening the production cycle of sheep meat in Brazilian production systems are important, because of the possibility of enhancing sheep production in countries which have similar soil and climatic conditions to Brazil. Therefore, we consider it pertinent to address some physiological peculiarities of neonatal sheep in this review, and based on these, highlight the main feeding strategies applied between birth and weaning for intensive production of lambs specialized for meat production. Also, the main results obtained in the different situations were evaluated, aiming to highlight the most efficient way to accelerate the arrival of lambs to the finishing phase; in fact, to intensify ovine meat production in tropical conditions.

ASPECTS RELATED TO THE DIET OF LACTATING LAMBS

The consumer market for sheep meat requires qualitatively standardized meats, being soft and without excessive fat levels, yet sufficient to ensure the succulence and flavor of the meat (Osório *et al*., 2002; Zundt *et al.*, 2006). This type of product can be only obtained by the slaughtering of young animals (Bôas *et al*., 2003). To achieve this goal, sheep meat production systems require that animals go through the phases of breeding, rearing, fattening and finishing in an "accelerated" manner. Thus, it is essential that the growth capacity of a lactating lamb is enhanced, and, therefore, it is necessary that the lamb becomes capable of being fed intensively, meaning to be able to consume solid food in sufficient quantity to meet the nutritional requirements and use volatile fatty acids (VFA) as an energy source.

Forestomach development

The neonate lamb has a small and non-functional forestomach (Baldwin, 2000; Furlan *et al.*, 2006; Leek, 2006), there are no microorganisms in the rumen (Costa et al., 2003) and the ruminoreticular papillae and omasal layers are rudimentary (Church, 1993). While lambs are exclusively milk consumers, they physiologically behave as monogastric. By reflex excitation of the glossopharyngeal nerve, a tubular conduit forms the esophageal groove that conducts the esophagus milk directly to the abomasum, a compartment that is responsible for digestive activity during this period (Carvalho *et al*., 2003). At this stage, the intermediate metabolism is based on glucose, and blood glucose levels are sensitive to insulin (Leek, 2006).

At the end of the first week of life, lambs start eating small amounts of solid food, and although this minimally contributes to meeting their nutritional requirements, these foods play a significant role in the rumen colonization by micro-organisms, with the beginning of salivary secretion and ruminoreticular development (Furlan *et al*., 2006; Leek, 2006).

The development of newborns up to the functional ruminant condition involves a series of anatomical and physiological changes in the digestive tract, which particularly affect three distinct structural entities of the forestomach: its ability, mucosa and musculature (Beharka *et al*., 1998; Costa *et al*., 2003). Regarding the metabolic changes in the transitional phase, the intermediary metabolism is shifted from the use of glucose to VFA, making glucose levels less sensitive to insulin (Leek, 2006; Furlan *et al*., 2006). Thus, it is necessary that the rumen epithelium is able to absorb and metabolize fermented products, so there is no loss in the post-weaning growth rate (Bittar *et al*., 2009).

It is true that the nutritional plan has a direct influence on the development of fermentative compartments, and that the consumption of solid foods and the production of short chain fatty acids - especially butyric and propionic - are essential requirements for this process (Ortega-Reyes *et al*., 1992; Church, 1993; Baldwin *et al*., 2004; Coverdale *et al*., 2004; Furlan *et al.*, 2006; Roth *et al*., 2009). Lane and Jesse (1997) mentioned that the introduction of sponges in the rumen stimulated an increase in its capacity and musculature, without effects on papillary development. This indicates that although the presence of food "mass" is necessary for the growth and development of rumen musculature, fermentation resulting in VFA production is required to cause rumen epithelium development. In a study with sheep neonates, these authors concluded that continuous infusions of VFA physiological concentrate were effective in stimulating metabolic and morphological development of the rumen. Ortega-Reyes *et al*. (1992) added that the release of ammonia through microbial fermentation also favors papillary development.

According to Baldwin *et al*. (2004), newborn ruminants fed exclusively with milk during the first month of life showed limited development of the rumen regarding weight, capacity, papillary development and musculature when compared to grain and hay fed animals. Regarding the supply of roughage and/or concentrate, Paiva and Lucci (1972) as cited by Carvalho *et al*. (2003), reported that concentrate induces epithelial development; however, it does not have the same effect on rumen musculature and capacity. On the other hand, hay is efficient in developing musculature and the capacity of this compartment, with the advantage of increasing the pH of the rumen without promoting papillary development. Thus, we can infer that diets composed of concentrate and hay promote better results when compared to those providing hay or concentrate separately.

In small neonate ruminants, the reticulorumen occupies about 30%, while the omasum and abomasum occupy 70% of the total volume of the forestomach; the nutritional plan is largely responsible for the speed at which the inversion of measured values between the reticulorumen and abomasum stomach compartments occur (Lucci, 1989). Church (1993) highlighted the marked increase of stomach compartments in lambs that had access to a solid diet from the first day of life.

In addition to solid diet composition, other nutritional factors can influence rumen development, although the results are still inconsistent. The physical form of the diet seems to have influence on the development of fermentative compartments (Baldwin *et al*., 2004) due to the effect on ruminal environment, VFA production, and the function and structure of the papillae (Coverdale *et al*., 2004). Amaral (2002) found better morphological development of the reticulorumen of Saanen kids fed with complete pelleted feed when compared to those fed with ground feed. However, Bittar *et al*. (2009) found no effect on the physical form of the initial concentrate (coarsely ground or pelleted) on the development of the upper digestive tract of dairy calves slaughtered at 49 days. Exploring another aspect, Baldwin *et al*. (2004) claimed that the increase in metabolizable energy intake favored rumen development via cellular hyperplasia, however they noted that this relationship is still speculative due to confounding factors such as the chemical composition of the diet and the consumption of dry matter.

Inadequate development of fermentative chambers in infant lambs would invariably lead to higher weaning age (Beharka *et al*., 1998), which would result in economic loss in the production system for two main reasons; a delay in the ponderal development of the lamb and longer occupation of the ewes before they could be mated again (Bôas *et al*., 2003). Thus, the supply of solid food from the first day of life is a priority and a strategic management practice in lamb production systems (Neres *et al*., 2001).

Growth, body development and nutritional requirements

In a living being, the growth process can be defined as being general expansion and normal in size, produced by the addition of tissues of similar composition to the original organ or tissue, accompanied by one or more of the following cellular processes: hypertrophy (increase in cell size); hyperplasia (an increase in cell number); and growth (accumulation of extracellular substances). The development process, on the other hand, is related to cellular changes that allow organs and tissues to assume different roles and functions in the growth process. Therefore, despite having different definitions, growth and development do not occur in an isolated manner (Gerrard and Grant, 2006).

However, in meat producing animals, it is also necessary to emphasize the occurrence of two processes other than those mentioned above: actual growth, resulting from an increase in muscle and bone; and fattening, referring to fat accumulation (Gerrard and Grant, 2006). In infant lambs, actual growth is accelerated (Reis *et al*., 2001) and described by a sigmoid curve as for all ruminants (Prescott, 1982; Owens *et al*., 1993). However, growth curves of tissues have different patterns, so that bone tissue develops sooner than muscle tissue. The fattening process, on the other hand, is slow compared to the actual growth, and an increased fat deposition rate occurs when maturity is reached (Sainz, 1996), meaning when protein deposition ceases in the empty body.

It is known that lambs have high efficiency for weight gain in the first months of life (Reis *et al*., 2001), however, it is also true that the expression of this potential demands that nutritional requirements for maintenance and gains are met. Therefore, although breed and gender have an influence on the growth rate of these animals (Ávila, 2010), diet is unquestionably one of the greatest determining factors when it comes to this issue (Alves *et al*., 2003).

In terms of nutritional requirements of sheep, energy is the most limiting nutritional component (Susin, 1996; Mahgoub *et al*., 2000). Thus, when nutrients are insufficiently ingested by infant lambs, it constitutes the main cause of growth suppression (Waghorn *et al*., 1990; Neres *et al*., 2001). The National Research Council (1985) recommends diets containing 17% crude protein and 2.8 Mcal of metabolizable energy for lambs with moderate growth potential, weighing between 10 and 30 kg. In its latest version (NRC, 2007), the recommendations for lambs to gain 200g/day with an average weight of 20 kg are 106g/day of crude protein and 2.39 Mcal/day of metabolizable energy. In Brazil, Carvalho (1998) determined a net energy demand of 0.326 Mcal for a daily gain of 200g in whole lambs with 5kg of body weight. Santra and Karim (1999) found that in semi-arid regions, the proper content of crude protein concentrate for infant lambs is 18%, with losses occurring through feces and urine when the protein level is high.

By feeding Suffolk lambs from the first week of life with diets containing 15 or 20% of crude protein and 3.3 Mcal of metabolizable energy, Ortiz *et al*. (2005) found no significant differences for average daily gain or age at slaughter in these animals. Evaluating the supplementation of Suffolk infant lambs with isoproteic concentrate (18%) containing different energy levels (2.6, 2.8 and 3.0 Mcal ME/kg, where ME is metabolizable energy), Garcia *et al*. (2003) found that the most energetic diet promoted the greatest average daily gains.

Geraseev *et al*. (2000) cited that lambs should rely solely on breast milk until seven days of life. Generally, milk alone cannot meet the lambs' requirements after this phase, especially for scavenger breeds when births take place in a season in which there is reduced forage availability (Garcia *et al*., 2003). Thus, dietary supplementation from the second week of life is a strategy to increase growth rates of these animals during the pre-weaning period (Santra and Karim, 1999) and has heightened importance in situations where ewes' milk production is insufficient (Geraseev *et al*., 2000)

Given the current demand of modern consumers for carcasses without excess fat, it is important to point out that the supplementation of growing lambs with concentrated energy aims to enhance actual growth. Based on the sequence of tissue deposition previously discussed, it can be inferred that the energy supplied will not be primarily accumulated in the empty body as fat (Bôas *et al*., 2003). Therefore, using this feeding strategy in meat production systems does not imply a production of carcasses without a standard of quality, since the early maturity of animals means they are slaughtered at the appropriate age.

Ingredients used and types of feed

As previously mentioned, the supply of concentrates from the second week of life can complement the protein and energy supply of breast milk (Bôas *et al*., 2003), increasing the performance of lambs (Ortega-Reyes *et al*., 1992). However, animal performance is directly dependent on the intake of nutrients, which allows us to infer that the time a lamb takes to reach a certain weight is inversely related to the quantity and quality of food intake (Carneiro *et al*., 2004).

Food intake is small during the first days of supplementation, but it tends to increase (Neiva *et al*., 2004) due to adaptation to management and the increase in nutritional requirements. However, it is noteworthy that food consumption by lambs between two and six weeks of age is affected by acceptability, physical form of the feed and the conditions in which food is offered, namely accessibility (NRC, 1985).

Bispo *et al*. (2007) reported that dry matter intake is positively influenced by the palatability, which in turn depends directly on the ingredients of the diet. Neiva *et al*. (2004) point out that, in addition to being palatable, the food offered should contain true sources of protein with high digestibility, and readily digestible energy, minerals and vitamins. Ortega-Reyes *et al*. (1992) stressed that providing a reasonable amount of good quality roughage is also important because it prevents possible acidosis and decline in performance, both resulting from implementing a high-energy diet. Neres *et al*. (2001) found that feed intake by infant lambs increased in accordance with the inclusion of alfalfa hay, to 438, 475 and 529 g/day for 0, 15 and 30% levels of hay, respectively, with no effect on the average daily gain.

In addition to palatability, the choice of ingredients to be used depend, according to Neiva *et al*. (2004), on the availability, price and the inclusion of limitations in the diets of lambs during the pre-weaning period. Accordingly, corn, wheat bran, soybean meal and soybean hulls have been the most used raw materials in Brazil to feed lambs at an early stage (Silva, 2010). Eventually, powder sugar cane molasses can be used as a palatability/flavoring agent, participating in the diet composition in small percentages.

As for the physical form of the feed, the NRC (1985) cited that lambs up to four weeks prefer ground feed, after this period they accept pelleted feed better. Neres *et al*. (2001) found a higher consumption, better performance and greater weight at 56 days in lambs supplemented with pelleted feed compared to those who received ground feed. Also, in comparing ground and pelleted concentrates, Silva (2010) obtained better results in weight gain and average daily intake for infant lambs supplemented with pelleted feed.

With regard to the food supply, the available literature advocates the use of creep feeding as a more efficient way of providing solid diets, especially concentrate, to infant lambs (Geraseev *et al.*, 2000; Neres *et al*., 2001; Garcia *et al*., 2003; Bôas *et al*., 2003; Neiva *et al*., 2004; Bernardi *et al.*, 2005; Ortiz *et al*., 2005; Poli *et al*, 2008; Ribeiro *et al*., 2009). It can be said that the success of the diet in a creep feeder results from the ability of supplying a solid energetic diet during the first days of life, without needing to early wean young lambs.

Creep feeding consists of food supplementation performed in an enclosed feeder that only the young can access (Neiva *et al*., 2004). Its use is not restricted to systems in which calved ewes remain in pastures; creep feeders can be used while calved ewes remain confined within the first 15 days postpartum, preventing ewes from eating the lambs' feed. Also, systems that opt for the practice of controlled suckling can also take advantage of feeding time to supplement ewes, using creep feeders for the same aforementioned reason (Costa *et al.*, 2007).

It is important to note that the efficiency of using creep feeding is related to aspects such as location and structure. The creep feeder should be accessible to lambs and must be located close to the herd's preferential spot for resting (NRC, 1985). The structure does not need to be elaborate, but it is essential that it is functional; the creep feeder should be installed inside a cage, pen or paddock with an opening device whose size allows the young to access it. It is also important to ensure sufficient linear space of the feeder for the number of animals which are being fed (Neiva *et al*., 2004).

LAMB FEEDING STRATEGIES DURING THE PRE-WEANING PERIOD

Lamb nutrition during the pre-weaning phase is responsible for highly important aspects in a meat production system, and among which weaning weight should be highlighted, which in turn has a direct influence on the time required to slaughter a lamb and make it available to the market. Therefore, it can be inferred that the turnover of a lamb production system is partially dependent on the feed strategy used during the pre-weaning phase. Given the above, this section aims to bring together some results related to the performance of lambs fed by different strategies during the pre-weaning phase.

Early weaning

A ewe's milk production can correspond to 50% of the total lactation during the first two or three weeks after birth (Geraseev *et al*., 2000), and 75% of the total lactation will have been produced by the ewe at 56 days postpartum (Siqueira, 2000). So sheep lactation decreases while lamb development and nutritional requirements increase (Silva *et al*., 2002). In this sense, the "early weaning" technique supported by providing solid foods early has aroused the interest of sheep farmers and has been recommended by many researchers for providing an alternative for increasing weight gains and therefore the production of meat lambs (Rosa *et al*., 2007).

Weaning lambs leads to increased vocalizations and cortisol plasma concentrations, reflecting the stress of animals during this period (Maiorano *et al*., 2009; Ekiz *et al*., 2012). Therefore, the decision on the most appropriate time and conditions under which weaning should be carried out is of great importance for successfully anticipating weaning (Coimbra Filho, 1992). Different ages have been reported as "ideal" for weaning; earlier literature recommends weaning from 75 to 94 days (Oliveira *et al*., 1996), but more recent studies have suggested that weaning can be performed earlier at 34, 35, 42, 56 or 62 days (Bôas *et al*., 2003; Freitas *et al*., 2005; Müller *et al*., 2008). However, it is worth noting that the results obtained with different weaning ages depend on nutritional support provided to the animals, and it is essential to supplement infants with use of creep feeding from the second week of life (Siqueira, 2000). It can be said that the prerequisite for early weaning is that the lambs are adapted to the consumption of solid foods and exhibit minimal development, thereby ensuring continuity of its growth (Bôas *et al*., 2003).

Neres *et al*. (2001) compared the performance of ¾ crossbred Suffolk lambs weaned at 56 days of age that had or did not have access to food supplement in creep feeders. Sheep and their offspring (all from single births) were kept in stargrass (*Cynodon plectostachyus*) pickets during the trial period. The sheep were supplemented with concentrate (1% of body weight) once a day, while the group of lambs that had access to creep feeding were fed diets containing 20% crude protein and 2.96 Mcal of metabolizable energy twice a day. The animals that did not receive supplementation were weaned at 56 days weighing 18.3 kg, while the supplemented group weighed 24.5 kg at weaning.

In evaluating weaning age in Hampshire Down lambs, Bôas *et al*. (2003) kept ewes and their offspring in *coastcross* (*Cynodon dactylon*) pasture (1.1 UA/ha), where the lambs were provided with creep feeders for supplementation with a concentrate containing 17.45% crude protein and 77% TDN. Body weight stipulated for slaughter was set at 28 kg and, if necessary, the animals would be kept in confinement after weaning. The authors found that weaning at 34 days had negative consequences for the performance of lambs, showing a reduction in daily weight gain when inserted into the confinement system. The group weaned at 62 days was slaughtered at 64 days of age, without post-weaning confinement, while lambs weaned early required 49 days of confinement to achieve the stipulated weight for slaughtering.

Assuming that the amount of time it takes for lambs to reach a determined slaughter weight is partially dependent on the amount of milk consumed, Carneiro *et al*. (2004) investigated the influence of the number of lambs per litter on the performance of crossbred lambs (Texel x ½Texel: ½Ideal) weaned at 63 days of age. The animals were confined with their mothers who were fed diets containing 13.4% crude protein and 66% TDN (total digestible nutrients) (single delivery) or 13.9% crude protein and 65% TDN (twin delivery), up to 42 days, with a forage:concentrate ratio corresponding to 70:30. From 42 to 63 days, the ratio changed to 60:40, and crude protein and TDN diet levels were 16.75% and 67%, respectively. Lambs were slaughtered when they reached a body weight of 30 kg. Performance results only showed a greater weight gain for animals born in simple births in the phase between 0 and 21 days of age.

The authors highlighted that although ewes with twin delivery produce more milk than those with simple delivery, the amount (of milk) available for each twin-lamb is smaller than that available from a single delivery, which would justify the better performance of single lambs in the period of 0-21 days. This superiority was not maintained in subsequent periods, probably because the lower amount of milk produced by parous ewes instigated twin lambs to consume more solid foods. However, the best performance observed by single lambs during the first 21 days of life was reflected over the entire period, so that these animals required fewer days of confinement to reach 30 kg body weight.

Bernardi *et al*. (2005) conducted an experiment with ½ blood Texel lambs distributed into four treatments: (Min) - Sheep and lambs kept on cultivated pasture with access to mineral salt; (Prot) - similar to "Min", but with protein supplementation to sheep throughout the whole period and to lambs after 50 days of life; (Creep) - Sheep and lambs kept on cultivated pasture with creep feeder for lambs from the first day of the experiment; (Confined) - the same treatment condition as "Creep" until 60 days of age, when lambs were weaned and confined up to 105 days of age (experiment limitation time). The authors highlighted that lambs had similar performance up to 42 days, but after this period, animals from "Creep" and "Confined" treatments showed better performance, so that after 84 days they had already achieved ideal weight for slaughter. The authors have linked the decrease observed in the performance of "Confined" animals in the period of 63-84 days to the weaning stress and adaptation to the confinement system. The results of this test show the importance of providing food supplements to lambs in the first weeks of life.

On the north coast of Bahia, Santa Inês crossbred lambs were evaluated by Freitas *et al*. (2005) as to the best age for weaning: 56, 70, 84 or 98 days. Lambs were kept with the ewes in *Brachiaria humidicola* paddocks during the day and were then collected at 5 pm into barns equipped with creep feeders, where lambs had access to a corn and soybean meal concentrate (19% crude protein and 75% TDN). The animals returned to the paddocks at 7 am the next day. The authors found a quadratic effect for weaning age in relation to weight gain from birth to weaning, with maximum value at 76 days of life.

Müller *et al*. (2008) evaluated the effect of weaning ½ Ile de France:½ Texel lambs at 35 or 42 days of age on performance and carcass characteristics. Prior to weaning, lambs were confined together with their mothers, receiving a 60:40 (forage:concentrate) diet composed of sorghum silage, corn and soybean meal. The ratio was changed to 30:70 during the 21 days after weaning, and to 50:50 from the 22nd day post-weaning, until the lambs reached 28 kg. The authors found no effect of weaning age on the performance of lambs, observing an average daily gain of 0.331 kg/day and average weaning weight of 16.4 kg. Slaughter age was 105 days for animals weaned at 35 days of life, while the group weaned at 42 days was slaughtered at 97 days. No differences were observed for carcass characteristics and yield of cuts, indicating that weaning can be performed at 35 days of age in the conditions for which this trial was conducted.

Two weaning ages (45 or 60 days) were evaluated by Rosa *et al*. (2007) regarding the performance for ¾ Ile de France:¼ Bergamácia lambs. Ewes and their offspring remained confined in collective pens equipped with creep feeders during the trial period, receiving Aruana grass hay and commercial concentrate containing 17% crude protein. The lambs had different weights at weaning according to age: 23 kg (60 days) and 19 kg (45 days); however, the animals weaned at 60 days showed lower performance in the post-weaning, with daily weight gain of 150g compared to the daily 200g of the other group. Lambs weaned at 45 days were slaughtered at 107 days of age, while those weaned at 60 days had to remain confined until 111 days to reach a weight of 30 kg (recommended for slaughtering). The authors stated that weaning at 45 days of age can be applied without losses under these experimental conditions.

Poli *et al*. (2008) kept Suffolk lambs with ewes on Tifton 85 pasture until 60 days of age, when lambs were weaned and allocated into a confinement system, receiving 40% concentrate (19% CP) and 60% alfalfa hay. Lambs were slaughtered at 94 days of age, weighing 32 kg. In the same experiment, lambs that were weaned at 60 days and remained in Tifton 85 pasture without supplementation were slaughtered with similar weight at 131 days of life.

Also analyzing Suffolk lambs, Ribeiro *et al*. (2009) kept lambs and their mothers in ryegrass pasture. Lambs were weaned at 40 days, and subsequently one group was confined (corn silage + concentrate containing 20% CP) and another was kept in the same pasture. Confined lambs were slaughtered at 96 days, weighing 34.6 kg, while grazing lambs reached 33.9 kg at 159 days of age. The authors reported that the lambs kept in pasture had excellent quality forage in high supply, however, the provided nutritional support did not substitute breast milk and the stress caused by early weaning.

Table 1. Average daily gain (ADG, g) and body weight at slaughter (kg) of sheep weaned at different ages, from single or twin births.

	ADG 0-45 d	ADG 45-75 d	ADG 75-120 d	ADG 0-120 d	Slaughter weight
Group					
45 days	194.21	181.87^{b}	204.15	194.48	23.31
75 days	198.25	213.59^{a}	186.51	197.31	23.89
Type of delivery					
Single	233.45^{a}	214.78	216.98	222.28^{a}	27.05^{a}
Twin	160.43^{b}	191.55	217.19	188.97^{b}	22.46^{b}

^{a,b} in columns, within Group or Type of delivery, averages followed by different letters are statistically different (P<0.05); ADG = average daily gain.
Source: adapted from Ekiz *et al*. (2012)

In Istanbul, Ekiz *et al*. (2012) evaluated the performance of Kivircik breed lambs weaned at 45 or 75 days old. Additionally, the authors investigated whether lambs originating from single or twin births had different performances. As infants, lambs had unrestricted access to alfalfa hay (15.8% crude protein, 2.07 Mcal of ME) and concentrate (16.9% crude protein, 2.8 Mcal ME) in addition to milk. Once weaned, lambs were kept in confinement receiving the same diet until slaughter, which occurred at 120 days of age. Table 1 shows the results obtained by the team.

The authors also found lower weight gain after weaning and attributed the result to the low consumption of solid food, in addition to stress caused by weaning. The results regarding the type of delivery corroborate those obtained by Carneiro *et al*. (2004), in Brazil, being justified by a lower intake of milk by twin animals. The similarity of the results obtained by both teams highlights the growth capacity of lambs during the first weeks of life, thus emphasizing the influence of nutrition on this aspect. Still, the results allow us to infer that the consequences of a nutritional deficiency during the first days of life are not easily recovered, directly reflecting on the age and/or weight at slaughter.

Slaughtering unweaned lambs

Plasma cortisol levels in lambs before and after weaning were measured by Ekiz *et al*. (2012), with average values of 18.56 and 35.56 ng/ml being observed, respectively. These results support the claim that the weaning period is indeed stressful for the lambs, considered as a critical point for their health and performance (Maiorano *et al*., 2009). Many researchers have observed a reduction in dry matter intake and performance of lambs after weaning, even under appropriate conditions of nutritional support (Carneiro *et al*., 2004; Bernardi *et al*., 2005; Ribeiro *et al*., 2009). In this sense, some systems have been set on animals being slaughtered without weaning; some experimental trials conducted in these conditions have already presented superior results to those obtained with early weaning technique.

Garcia *et al*. (2003) kept sheep and their crossbred Suffolk offspring in stargrass (*Cynodon plectostachyus*) paddocks equipped with creep feeders. Lambs had access to supplement from their first week of life and remained in this system until they reached 31 kg weight. Concentrates consisted of 18.5% crude protein and varied in energy content (2.6, 2.8 and 3.0 Mcal/kg). Average daily gain obtained was 404.6 g, and the lambs were slaughtered at an average weight of 30.8 kg and at an average age of 63 days. Opportunely, the authors found the influence of the diet energy levels only for average daily gain. Weight and age at slaughter as well as carcass characteristics were not affected by energy level of the diet.

In seeking to reduce feeding costs, Almeida Jr. *et al*. (2004) evaluated substituting (dry) corn grains for moist corn grain silage on the performance and carcass characteristics of Suffolk lambs raised and slaughtered using creep feeding. The lambs were kept in stargrass pasture together with their ewes, which were supplemented with a diet of 16% crude protein in an amount corresponding to 0.8% of body weight. Lambs had access to food supplements (16% crude protein and 2.7 Mcal ME) from their first day of life. Dry corn grains were replaced by moist corn grain silage in concentrations of 0, 50 and 100%, constituting the three experimental treatments. There was no difference between treatments for the analyzed variables. Lambs had an average daily gain of 0.383 kg, being slaughtered at 62.5 days old with 28.4 kg of body weight. It is important to highlight the excellent values obtained for these carcass characteristics: hot carcass yield, 50.7%; cold carcass yield, 49.2%; actual yield; 54.5%.

Carneiro *et al*. (2004) compared the performance of crossbred lambs (Texel x ½Texel:½Ideal) originating from simple delivery and weaned at 63 days or unweaned. Ewe and lamb sets were supplemented from the first day postpartum with a diet containing 13.4% crude protein and 66% TDN, with a forage:concentrate ratio of 70:30. Weaned animals were fed in the post-weaning period with a diet containing 16.75% crude protein and 67% TDN in a 60:40 ratio. The animals were to be slaughtered when they reached 30 kg of body weight, which happened after 91 days of age for weaned animals and at 87 days for unweaned. It is important to note that there was no reduction in dry matter intake or performance of unweaned animals, which could not be avoided in the other group investigated.

Emphasizing the nutritional value of a good quality pasture, Tonetto *et al*. (2004) slaughtered Ile de France x Texel lambs at 62 days of age and 31 kg body weight maintained on ryegrass (checked) pasture with the ewes. Lambs kept in natural pasture receiving commercial concentrate in creep feeders reached the same weight at 75 days of life. The chemical analysis of the apparently consumed ryegrass pasture revealed the following values: 18, 35% dry matter; 9.8% of mineral matter; 19.99% crude protein; 62.81% TDN; 76.31% in vitro digestibility of dry matter (IVDMD). It is important to point out that the ryegrass pasture presented higher CP, MM and IVDMD than the commercial concentrate used.

The effect of providing diets with three different protein levels on performance and carcass characteristics of lambs created and finished in creep feeding was evaluated by Ortiz *et al*. (2005). Lambs and ewes were kept in stargrass paddocks from birth, supplemented with Tifton 85 hay (due to low forage yield) and concentrate. The diets offered to the lambs in creep feeders contained 15, 20 or 25% crude protein and 3.3 Mcal ME. The concentrate fed to sheep was in a quantity equivalent to 1% of body weight containing 16% crude protein and 77% TDN. The ideal weight of 28 kg weight was determined for slaughtering. Concentrate with higher protein yielded higher daily weight gains, and although no effect was observed on the other analyzed variables in the trial, this result was enough to encourage the authors to suggest that the concentrate must contain 25% crude protein for breeding and slaughtering lambs using creep feeding.

Poli *et al*. (2008) slaughtered unweaned Suffolk lambs kept on Tifton 85 pasture with or without creep feeder supplementation. There was no difference between either group; the animals were slaughtered at an average age of 103 days, weighing 32 kg. In a similar experiment, Ribeiro *et al*. (2009) applied the same treatments, but using ryegrass pasture. There was also no difference between treatments, and lambs were slaughtered at average weight of 34 kg and at an average age of 105 days.

Comparing the performance of unweaned Kivircik lambs with those weaned at 45 or 75 days old, Ekiz *et al*. (2012) found higher average daily gain (0.225 kg) for lambs slaughtered at 120 days without weaning. In addition to breast milk, the animals had access to alfalfa hay and concentrate (16.9% crude protein, 2.82 Mcal of ME). Body weight at slaughter (120 days) was 27.0 kg for unweaned animals and 23 kg for those who were separated from ewes at 45 or 75 days of life.

Fernandes *et al*. (2014) evaluated performance, carcass characteristics and costs of lambs slaughtered in 3 different systems: weaned at 22 kg body weight and kept on pasture with supplementation; weaned at 22 kg body weight and kept in confinement; confined and with access to controlled suckling when they reached 22 kg body weight. The authors concluded that the combination of high concentrate diet in confinement with the practice of controlled feeding until slaughter allows lambs to express their weight gain potential, reaching slaughter weight in less time and producing heavier carcasses, with optimal fat content.

The use of a milk replacer in feeding lambs

The purpose of using a milk replacer in feeding lambs is similar to its use with calves: reducing feeding costs and directing milk for commercialization (Napolitano *et al*., 2008). Therefore, sheep milk replacers are mainly used in milk production systems (Emsen *et al*., 2004), with its use in meat production systems being justified by the possible positive effect of artificial feeding on the reproductive efficiency of ewes (Napolitano *et al.*, 2008), or in the case of the mother rejecting the offspring.

The high biological value of whole milk makes its replacement by a lower-cost of similar composition product rather troublesome, representing a challenge in producing ruminants. Still, disparities in animal performance fed with a milk replacer are frequently reported (Modesto *et al*., 2002). Emsen *et al*. (2004) reported that in order to obtain good performance, it is essential that the implemented milk replacer is specifically for sheep. The composition of a good replacer for sheep is as follows: 22-24% crude protein; 25-35% ether extract; less than 1% crude fiber; 5-8% mineral matter; 22-24% lactose (Thompson *et al*., 1993; Umberger, 1997). In a search for products within the recommended standard, only two manufacturers were found; Royal Milc Inc. and Merrick's, both being North American.

McKusick *et al*. (2001) subjected two different groups of lambs to natural or artificial feeding, using a milk replacer specifically for lambs. In addition to the liquid diet provided *ad libitum*, the animals from both groups had access to a concentrate with 19% crude protein. Lambs artificially fed (on milk replacer) remained with their mothers during the first 24 hours after delivery so they could suckle colostrum, then they were separated and artificially fed until 25 days of age. The other group of lambs remained with the ewes until weaning. After weaning, both groups received a diet containing 13% crude protein. There was no difference between treatments in relation to the development of lambs up to 30 days of age, however, from 30 to 120 days the lambs that were breastfed naturally showed better performance It is worth noting that this difference in performance was sufficient to produce lambs with a weight increase of approximately 4 kg at 120 days when compared to those artificially fed.

Given the difficulty of finding the specific replacement and high costs, milk replacer intended for calves have been used for feeding lambs (Emsen *et al*., 2004), although they are not recommended because they only have a fat content of 19% and higher lactose (≈ 40%), which could cause damage to lamb performance (Berger and Schlapper, 1993; Umberger, 1997). Emsen *et al*. (2004) fed lambs with specific milk replacer for calves and reported no loss in performance of weaned animals, concluding that this type of replacer can be successfully used for artificially feeding lambs. In relation to feeding costs, the authors stated that more than 50% of costs were reduced when animals were breastfed artificially. It is noteworthy that the price of sheep's milk at the time was US$3.24/kg.

The high cost of specific replacer for sheep is a limiting factor for its use (Umberger, 1997). Knight *et al.* (1993) recommended using a system of management where lambs were kept with their mothers for a determined period to reduce costs, without the need for artificial feeding, allowing for daily milking. Using this technique, McKusick *et al*. (2001) found no difference in the performance of lambs kept with ewes 9h/day compared to those who remained with the ewes all day long.

In addition to using replacers for calves, the literature reports the use of homemade replacers in feeding lambs. Geraseev *et al*. (2006) artificially fed lambs with a compound replacer based on natural materials: 70% of cow's milk; 5% reconstituted powdered cow's milk, 5% powdered eggs; 20% water. "Homemade milk" analysis revealed that it contained 5.85% crude protein and 7.74% ether extract. Berger and Schlapper (1993) reported that cow colostrum can eventually be used as a substitute for sheep milk in feeding lambs. Other sources also claimed that goat milk can successfully replace sheep's milk in infant feeding (Thompson *et al*., 1993).

Bezerra *et al*. (2010) artificially breastfed Santa Inês lambs with cow's milk enriched and not enriched with *Spirulina platensis.* The lambs were kept with their mothers until the 16th day of life; after this period they were fed with cow's milk containing *Spirulina platensis* (0.5g, 10g) twice a day. Tifton grass hay was offered to the lambs from the 30th day of age. In the evening, the animals had access to the ewes' paddock where they stayed overnight in a creep feeding system. Lambs in the control group were weaned at 60 days weighing 22.47 kg and did not differ from those with 5 g treatment, which weighed 23.12 kg at 60 days. Animals receiving 10g of *Spirulina platensis* showed better weight gain during the experimental period, being weaned at 25.3 kg of body weight.

Suckling management

Although suckling management does not constitute a feeding strategy per se, it can be regarded as a milk supply strategy, and it should be addressed in this review for having a direct influence on the weaning process (Maiorano *et al*., 2009). There are two main forms of breast-feeding: continuous and controlled. During continuous feeding, the lamb remains with the mother full time, while in controlled feeding the offspring has access to breast milk only at certain times of the day and there are different ways of providing the encounter between mother and offspring, with variations in the frequency and duration of encounters.

Carneiro *et al*. (2004) conducted an assay with lambs weaned at 63 days of age. During the breastfeeding period, the team combined two different suckling management systems as follows: lambs remained with their mothers full-time until the 42nd day of life; from 43 to 63 days, pre-weaning was carried out to reduce the negative consequences of abrupt weaning, wherein ewes remained in separate paddocks from the offspring, who were conducted to the paddocks twice a day, remaining close to their mothers for 30 minutes. The management reached the expected goal, as no differences were observed in animal performance compared to animals that remained with the mothers fully from 43 to 63 days of life. It can be said that the pre-weaning allowed the lambs to prepare for definitive weaning.

Costa *et al*. (2007) evaluated the effect of suckling management on weight development of lambs. Santa Inês ewes and their offspring were kept together for the first 15 days after delivery, when they were divided into two experimental groups. In the continuous breastfeeding group, lambs were kept with the mothers having access to their mangers and also to creep feeding, which was stocked with concentrate containing 18% crude protein and 80% TDN. Lambs from the controlled breastfeeding group remained separate from the ewes without physical or visual contact. Mothers were conducted to the lambs twice a day to breastfeed them, with each encounter lasting 60 minutes. Lambs of this group had unrestricted access to corn silage and the concentrate described above. Lambs from both groups were definitively weaned at 60 days of age; their weight development suggests that controlled feeding is feasible regarding the performance of lambs.

Silva (2010) reported a differentiated suckling management in which the ewes were kept entirely confined with their offspring until 7 days postpartum, then the following system management was conducted: from the 8th to the 13th postpartum day the ewes were led to paddocks without their young and remained there for a period of two hours in the morning, then returning after this period to the facilities where the lambs were kept; from the 14th to the 21st day, ewes were away for four hours in the morning; from the 22nd to the 60th day, the ewes were kept in the paddock for eight hours a day, again meeting with lambs to spend the night and feed. In the 61st day postpartum, the ewes were definitively separated from lambs.

Assis *et al*. (2011) and Eloy *et al*. (2011) reported controlled suckling managements where lambs were kept with the mothers until the 15th day of life; after this period, they were breast-fed twice a day (morning and afternoon), staying with their mothers for 30 minutes at each encounter.

Santos *et al*. (2013) concluded that lambs subjected to controlled feeding management had greater weight gains and were heavier than those kept full-time with their mother (Table 2).

Table 2. Average daily gain weight (ADG) and body weight for the first, second and third month of life (1st, 2nd and 3rd month) according to suckling type.

	Continuous	Controlled
ADG (kg/day)		
1st month	0.096	0.206
2nd month	0.162	0.175
3rd month	0.123	0.148
Body weight (kg)		
1st month	7.03	10.031
2nd month	11.9	15.281
3rd month	15.6	19.741

Adapted from Santos *et al*. (2013).

FINAL CONSIDERATIONS

Consumers demand for quality sheep meat and the certainty that production will be fully absorbed by the market have motivated farmers to invest in technologies that provide the production of tender meat with sufficient fat content to ensure its taste and juiciness, instigating the slaughtering of young lambs. Thus, some more modern management practices have been applied in order to decrease age at slaughter and intensify the production of sheep meat.

Potential of lamb development in the first weeks of life is a key factor in an intensive system of meat production due to rapid actual growth that characterizes this phase. Therefore, the supply of palatable solid food in creep feeders from the lambs' first day of life seems to have fundamental importance in this regard, given its efficiency in developing the rumen and adapting the lamb to solid diet consumption. Still, literature suggests that an early supply of concentrate complements the supply of nutrients provided by breast milk, which, from the eighth day of life, no longer meets the high requirements of infant lambs.

Early weaning technique can be adopted from 35 days of age, provided adequate nutritional support is given, with a risk of affecting performance with difficult recovery if there is food restriction, invariably resulting in higher age at slaughter. However, reports of a decrease in dry matter intake and weight gain after weaning are often cited by authors. Thus, unweaned lamb slaughtering has been an efficient feeding strategy for eliminating the adverse effects caused by the post-weaning stress mentioned above. Literature suggests that the combination of supplementation in creep feeders from the first days of life with controlled feeding from the second week of life until slaughter provides superior results to those reported when an early weaning practice is adopted.

Using a milk replacer in feeding lambs seems to have no viability in meat production systems due to its high cost and the difficulty in obtaining specialized products for sheep, in addition to the possible involvement of animal performance. Artificial feeding with cow's milk or a milk replacer specific to calves is not recommended by the authors, but there are no reports of severe metabolic disorders when performed.

Controlled feeding does not compromise infant lamb performance and can be used as an efficient strategy for supplying milk to lambs. Management is also used in order to accelerate reestablishing ovarian activity in ewes, with proven reproductive performance of the flock due to the direct influence that the feeding stimulation has on the suppression of gonadotropins and energy savings that is provided to ewes.

CONCLUSION

Available literature on feeding lambs during the pre-weaning phase is scarce. Therefore, more studies to investigate the effects of different feeding strategies on the performance of lambs are needed. However, it is noteworthy that despite the lack of research in the area, the technology transfer to the field has been carried out very efficiently, and intensive sheep meat production systems that apply many of the techniques mentioned in this manuscript can already be found in Northeast Brazil, obtaining truly satisfactory results.

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