

TECHNOLOGIES AND STRATEGIES FOR IMPROVING HAIR LAMB FATTENING SYSTEMS IN TROPICAL REGIONS: A REVIEW

Tecnologías y estrategias para mejorar los sistemas de engorda de corderos de pelo en regiones tropicales: una revisión

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ABSTRACT. This paper addresses a literature review of lamb fattening systems in tropical regions of Mexico and other countries. In semi-intensive systems, lamb feeding is based on grasslands, and supplementation may or may not be offered; in intensive systems, lamb feeding is based on concentrated feeds. Local fodder resources could be a viable option for lamb fattening due to their low cost and the better quality and healthy meat resulting from this feeding strategy. It is suggested that further evaluations of tropical fodder resources be developed, focusing on nutritional quality, availability and possible use. Several hair sheep breeds (Pelibuey, BlackBelly, Katahdin and Dorper and their crossbreeds) have been investigated under those systems. However, there remains a lack of definition on which could be the most suitable Cross-breeding strategy in different regions of the country. The raised slatted-floor cages used in intensive lamb fattening systems were just recently introduced in Mexico, and hence, there is no scientific evidence regarding their productive and economic evaluation. Therefore, there is a need to strengthen knowledge and generate technology with precise goals and objectives. By doing so, it is possible to deliver technological options with strong scientific bases that are economically viable, socially equitably and ecologically acceptable.

Key words: Sheep, feeding resources, genetic resources, profitability, raised slatted floor cages

RESUMEN. Este artículo es una revisión sobre los sistemas de engorda de corderos en regiones del trópico Mexicano y otros países. La alimentación de los corderos en los sistemas de engorda semi-intensivos está basada en el pastoreo con o sin suplementación, mientras que, en los sistemas intensivos está basada en concentrados. Los recursos forrajeros locales podrían ser una opción viable para la engorda de corderos, por sus bajos costos y la carne sana y de mejor calidad que resulta de esta estrategia de alimentación. Se sugiere desarrollar futuras evaluaciones de recursos forrajeros tropicales, con base en su calidad nutricional, disponibilidad y posibilidad de utilización. Diferentes razas de ovinos de pelo (Pelibuey, BlackBelly, Katahdin y Dorper y sus cruza) han sido estudiadas en estos sistemas, pero falta definir la mejor estrategia de cruzamientos en las diferentes regiones del país. Los corrales elevados con piso de rejilla para los sistemas de engorda intensiva de corderos fueron introducidos recientemente en México y no existe evidencia científica sobre su evaluación productiva ni económica. Por lo tanto, es necesario fortalecer la generación de conocimiento y tecnología con metas y objetivos precisos, que proporcionen al productor soluciones tecnológicas con sólidas bases científicas y que al mismo tiempo sean económicamente viables, socialmente aceptables y ecológicamente sostenibles.

Palabras clave: Ovinos, recursos alimenticios, recursos genéticos, rentabilidad, corrales elevados

INTRODUCTION

In Mexico, the number of sheep has increased approximately 20 % during the last ten years, yielding a total population of 8 497 347 animals in the year 2013 (SIAP-SAGARPA 2013). However, this population increase has not been enough to meet the national demand for mutton. In 2008, national consumption reached 90 000 t of mutton, of which 45 % was imported from New Zealand, Australia, Canada, Chile and the United States of America (Mondragón-Alcelmo *et al.* 2012). Nonetheless, there is evidence that over the short term, the demand for mutton could not be met by these countries (Morris 2009), especially if we take into account the expected increase in national (Magaña *et al.* 2006) and international (Hartwell *et al.* 2010a) consumption of animal products. In Mexico, there is a need to search for technological alternatives that will help develop efficient sheep production systems that can contribute to more efficient agricultural production and, at the same time, create new labor opportunities.

Mexican tropical regions have great forage production potential (grass, shrubs and trees) throughout the year. For environmental and economic reasons, forages have been the main source of feed for ruminants in these regions (Hernández *et al.* 2006). The disadvantage of using these forages is that their nutritional value in growing and finishing lambs is lower than the value of grains (Góngora-Pérez *et al.* 2010). For this reason, the production of fattening lambs takes place in intensive systems based on cereal grains (Fimbres *et al.* 2002b). Additionally, the lambs used belong to genotypes resulting from the crossbreeding of early maturing breeds as a way to increase production and reduce fattening time (Partida *et al.* 2009).

In recent years, the search for technological alternatives, where feed and genetic resources have played a significant role, has been intensified to improve the productivity of fattening lambs (Fimbres *et al.* 2002a, Mata *et al.* 2006, Ruiz-Sesma *et al.* 2006, Obrador-Olán *et al.* 2007, Partida *et al.* 2009, Macías-Cruz *et al.* 2010, Vázquez *et al.* 2011, Ríos

et al. 2011, Hinojosa-Cuéllar *et al.* 2013). Fattening systems in raised slatted-floor cages (SRC) have been promoted in Mexico, and although there is a lack of knowledge about their economic and biological efficiency, they show high acceptance among producers.

In Mexico, technologies for sheep production are available; however, their application is limited. As a result of the poor performance of sheep production systems, the availability of mutton on the national market is low. A Thorough analysis of the actual situation of lamb fattening systems and the evaluation of these systems according to aspects such as productive and economic efficiency in the tropics could allow the industry to fill in the gaps in knowledge and to make proposals to solve the problems restricting the sustainability of this activity. Therefore, the aim of this study is to review the existing technologies and proposed strategies for improving lamb fattening systems in tropical regions.

SHEEP PRODUCTION SYSTEMS IN THE MEXICAN TROPICS

The systems can be classified as extensive, semi-intensive and intensive, where each farm possesses individual characteristics that make them distinctive in their classification. Sheep production systems are diverse; hence, husbandry practices (reproduction, nutrition, health) are also varied. Those systems are practiced in a range of conditions, establishments and production characteristics, (Echavarría-Chairez *et al.* 2010, Iñiguez 2011, Pérez *et al.* 2011). Broadly, they are recognized by the type of land used, labor investment, flock size and the capital held (Galaviz-Rodríguez *et al.* 2011).

Extensive System

The extensive system is characterized as having grassland or rangeland as the main source of feed, and grazing is carried out without control and independently of forage availability and stocking rate, mineral salt supplementation and limited or

null health management (Cuéllar *et al.* 2012). To find the elements necessary to meet their nutritional needs, animals walk large distances. The nutritional level of sheep based on tropical grass diets has been low, as these diets only cover the requirements for maintenance with a reduced surplus for productive functions. An additional problem in these systems is the presence of gastrointestinal parasites, such as *Haemonchus contortus*, *Trichostrongylus colubriformis*, *Cooperia curticei* and *Moniezia expansa* (López *et al.* 2013). Nuncio-Ochoa *et al.* (2001) named this type of system as traditional extensive, characterized by a diversified production, combining sheep production, crops, cattle, poultry, and backyard pig production, scant economic reinvestment, high use of local resources and low use of external resources. In these systems, an average of 53 g of live weight gains (LWG) can be achieved, and the sheep are commercialized when they reach a live weight (LW) of approximately 25 to 30 kg at the age of one year or more (Macedo and Castellanos 2004). The objective of this system is the production of animals for slaughter; hence, mutton is the main product (Pérez *et al.* 2011).

Semi-intensive System

In this production system, ewes are allowed to graze and can be supplied with a strategic feed supplementation (Galaviz-Rodríguez *et al.* 2011). Lambs are fed with maternal milk and occasionally supplied with concentrate feed by creep feeding systems. Under these conditions, LW of approximately 18 kg at weaning can be achieved at an age of 84 d with Pelibuey genotypes (Macedo and Castellanos 2004). There are farms where, after weaning, the lambs are fattened in confinement conditions or with a mixture of grazing and concentrate feed supplied after grazing in the stable (Góngora-Pérez *et al.* 2010). Unlike extensive systems, these farms are characterized by specialized sheep production, with economic reinvestment and moderate use of local and external inputs. The objective of these systems is the production of animals for slaughter or breeding (Pérez *et al.* 2011).

Intensive System

Under these systems, lamb production for slaughter or breeding is more intensive, with high use of inputs and technology (Góngora-Pérez *et al.* 2010). To increase and improve mutton production in as short a time as possible, the animals remain in confinement all the time (Partida *et al.* 2009). Therefore, the animals must be supplied with the amount and quality of feed necessary to meet their nutritional requirements (Canton *et al.* 2009a). This system, although efficient, has a high level of investment in buildings and capital (González-Garduño *et al.* 2013). One limiting factor is the lack of animals suited for the goal pursuit (Cuéllar *et al.* 2012). Although some farms have the goal to produce breeding stock, the main objective is the production of animals for slaughter (Góngora-Pérez *et al.* 2010, Pérez *et al.* 2011).

LAMB FATTENING SYSTEMS IN THE MEXICAN TROPICS

Mexican tropical areas are convenient for sheep production due to the available sources of water and land for grass and the cultivation of leguminous plants suited for feeding these animals (Hernández *et al.* 2006). Hair sheep are genotypes with potential for mutton production in these regions (Herrera *et al.* 2008) where environmental temperature and humidity are high.

Feed resources

The lambs aimed for slaughter are fattened in intensive systems, based on grain feeding, as this strategy meets the nutritional requirements to achieve both better LGW (Fimbres *et al.* 2002a) and better carcass characteristics (Fimbres *et al.* 2002b) and to reduce the fattening period (Partida *et al.* 2009). Nonetheless, the increment in cereal grain prices is a threat to the sustainability of such production systems, (Rihawi *et al.* 2010a, Hartwell *et al.* 2010a, Hartwell *et al.* 2010b). On this matter, it has been demonstrated that supplementation with concentrate or foliage of shrub species after grazing improves carcass yield and other car-

Table 1. Initial weight (IW), final weight (FW), daily weight gain (DWG), carcass weight (CW) and carcass yield (CY) of lambs under different feeding systems.

Management	IW (kg)	FW (kg)	DWG (g)	CW (kg)	CY (%)	Country/Region	Reference
Only feed concentrate of different commercial brands in intensive systems	25.2	28.8 28.1 28.4 28.0	260.0 216.0 285.0 202.0	-	-	Mexico, State of Mexico	Mendoza et al. (2007)
Concentrate (g)							
0		33.6	134.0	13.1	39.0	Guadeloupe	Archimède et al. (2008)
150	20.0	33.0	166.0	13.9	41.0		
300		34.6	188.0	14.4	42.0		
600		35.1	203.0	15.6	46.0		
Grazing	29.6	43.7	300.1			Syria	Rihawi et al. (2010)
Intensive	29.3	44.7	305.6				
Semi-intensive	29.4	45.2	321.8				
C, 0	21.4		45.5 ^c			Mexico, Yucatan	Ruiz-Sesma et al. (2006)
R. C-H, 0-40	21.5	-	96.3 ^b				
R. C-H, 40-60	22.4		124.5 ^a				
R. C-H, 20-80	23.4		106.4 ^{ab}				
Grazing			46.1 ^b			Mexico, Tabasco	Mata et al. (2006)
Grazing + concentrate			81.6 ^a				
Grazing + Gs	18.2	-	48.1 ^b	-	-		
Grazing + Morus alba			63.2 ^{ab}				
Grazing + Hr			77.1 ^a				
0% of Gd	36.1	50.8	170.0		58.3	Mexico, Sinaloa	Rios et al. (2012)
15 % of Gd	35.9	50.8	180.0		57.0		
30% of Gd	36.0	54.0	210.0	-	57.8		
45 % of Gd	36.2	53.1	200.0		57.3		
60% of Gd	35.8	51.6	190.0		58.6		

C, 0 = *Cynodon nlemfuensis*, R. C-H = Relation *Cynodon nlemfuensis-Hibiscus rosa-sinensis*, Gs = *Gliricidia sepium*, Hr = *Hibiscus rosa-sinensis*, Gd = Chick peas (discarded from human consumption) in intensive systems. ^{a,b,c}, means in the same column with different superscripts indicate significant differences.

cass characteristics. Thus, production costs are decreased. This strategy has been rarely used in Mexico; however, several authors have reported the viability of this feeding system for lamb fattening (Table 1). For instance, Archimède et al. (2008), observed an increase in feed consumption and digestibility with supplementation of concentrate feed. Rihawi et al. (2010) noted that semi-intensive systems reduce feeding costs and promote better growth of lambs compared with lambs fed with grains in an intensive system and those under grazing with supplementation.

Another feed alternative with great potential for growing lambs is foliage of various shrub species such as *Hibiscus rosa-sinensis* and *Morus alba*, which provide similar LWG to that of concentrate feeds. Mata et al. (2006) report that production performance of lambs fed with *Hibiscus rosa-sinensis* is similar to the performance of

animals fed with concentrate. The use of this shrub (as approximately 60 % of the diet) improves the digestibility of the provided diet and also the productivity of the animals (Ruiz-Sesma et al. 2006). Obrador-Olán et al. (2007) reported a better daily gain (131.6 ± 4.3 g) when animals were supplemented with concentrate in addition to grazing; however, these authors propose a harvest of *Morus alba* and *Hibiscus rosa-sinensis* leaves between 60 and 90 days to obtain daily gains of 90.5 ± 4.3 and 107.9 ± 4.4 g, respectively. Chick peas (discarded from human consumption) were also tested as an alternative feed supplement for intensive systems for finishing lambs. The results indicate an improvement between 15-30 % in production; therefore, it can be seen as a possible alternative feeding source to reduce feeding costs (Rios et al. 2012). Duarte and Pelcastre (1998) showed that cassava (*Manihot esculenta*) can replace corn as an

energy source with similar results in daily gain (276 and 283 g d⁻¹ for corn and cassava, respectively).

There are many other available feed resources in the tropics of potential use in ruminant feeding, particularly in the development of food-feed systems that are not only beneficial for human and animals but also for the environment (Wanapat 2009). The inclusion of energy sources such as molasses and citrus byproducts has been suggested to increase microbial protein synthesis and volatile fatty acid production, which results in improved animal performance (Ramírez *et al.* 2006, Salinas-Chavira *et al.* 2011). Nonetheless, feeding ruminants with large amounts of tree foliage, in addition to not being economical, could result in a substitution effect (Ramírez *et al.* 2006), which can also be observed when large amounts of grain are included in diets. This finding suggests that for the inclusion of high-quality foliage and concentrates, the feed must be supplied in suitable quantities. According to the above, the use of foliage can be a viable option for lamb fattening production (Ekiz *et al.* 2012).

Animal genetic resources

Regarding breed use, Pelibuey (Pb), Blackbelly (Bb), Dorper (D) and Katahdin (Kt) have been the most used (Martínez-Partida *et al.* 2011, Pérez *et al.* 2011, Góngora-Pérez *et al.* 2010). The Pb breed is used in several types of production systems (Herrera *et al.* 2008) and, together with the Bb breed, has shown a great rusticity and adaptation, good reproductive rate, less breeding seasonality and less fat content in the carcass (Cantón *et al.* 2009). Because of their precocity, fertility rate, and prolificacy, the Pb and Bb breeds should be advantageous for mutton production. However, their low growing and finishing rates do not permit these breeds to achieve a better productive potential, particularly when production takes place in extensive systems (Huerta 2008). Extensive systems only allow modest production, which conflicts with the current economic condition of an increasing demand for higher meat yield. The D and Kt breeds, either as pure or crossbreeds, represent a viable alternative as part of fattening programs in regions

with humid hot climates (Hinojosa-Cuéllar *et al.* 2009) and in the arid zones of Northeast Mexico (Macías-Cruz *et al.* 2010). In sub-tropical regions, the productive response of these breeds and their crosses with Pb do not appear to have important differences when compared with the pure Pb breed (Table 2). However, there is a need to move forward in the evaluation of this type of crossbreeding for an assessment of the effect of the F1 genotypes on productivity and carcass characteristics in these regions.

The differences between breeds and sex in conformation and fatness are evident in different studies (Partida *et al.* 2009, Vázquez *et al.* 2011). There are breeds with early maturity (D, Kt) and late maturity (Pb) that define the pattern of adipose tissue deposition (visceral fat, subcutaneous, intramuscular or marbling). For example, the Pb breed, due to its rusticity, tends to accumulate more visceral fat compared with the Kt breed, which accumulates more fat in the carcass (Cantón *et al.* 2009). There is disagreement regarding productive performance and carcass composition attributes of hair sheep in the sub-humid tropic, which makes it difficult to decide which breed or crossbreed is the right option for fattening systems in the region.

In other countries, the capacity of different genotypes to achieve the commercial goal in accordance with the seasons that limit or might limit growth is taken into account (Álvarez *et al.* 2013). This suggests that in an evaluation of available genetic resources it is important to determine the breed or crossbreed that can accomplish a specific production and market goal, above other subjective issues that farmers could prefer. In the sub-humid tropic, farmers are focused on terminal crossbred animals such as Pb x Bb x D and Pb x Kt x D (Góngora-Pérez *et al.* 2010). The criteria for the implementation of such crossbreeding schemes are unknown, and there is no evidence in the literature indicating the productive performance of such crossbreeds. The use of Kt x Pb genotypes could offer important productive yield (Cantón *et al.* 2009, Macías-Cruz *et al.* 2010) and economic profit in tropical regions and in other regions with simi-

Table 2. Daily weight gain (DWG), final weight (FW), carcass weight (CW) and carcass yield (CY) of Pelibuey (Pb) lambs and their crossbreeds with specialized breeds for mutton production.

Genotypes	DWG (g)	FW (g)	CW (kg)	CY (kg)	Country/Region (%)	Reference
Pb	182.0	30.3	14.0	46.2	Mexico, Yucatan	Cantón <i>et al.</i> (2009a, 2009b)
Db x Pb	199.0	32.7	14.6	44.6		
Dw x Pb	211.0	33.8	15.1	44.6		
Kt x Pb	206.0	34.8	15.2	43.6		
Pb x Bb	116.0 ^a	37.2 ^a	-	-	Mexico, Tabasco	Hinojosa-Cuéllar <i>et al.</i> (2013)
Pb x Bb x D or Kt	110.0 ^b	35.6 ^b				
Pb	-	36.6	18.6	50.3	Mexico, Jalisco	Ruiz <i>et al.</i> (2009)
D		37.3	18.7	53.3		
Pb	310.0 ^a	49.9 ^b	56.9 ^b	56.9 ^b	Mexico, Sinaloa	
Pb x Kt	260.0 ^b	49.6 ^b	58.5 ^{ab}	58.5 ^{ab}		Ríos <i>et al.</i> (2011)
Pb x D	210.0 ^c	51.9 ^a	59.0 ^a	59.0 ^a		
Pb	180.0 ^b	34.2 ^c	18.3 ^b	54.5	Mexico, Baja California	Macías-Cruz <i>et al.</i> (2010)
D x Pb	240.0 ^a	39.9 ^a	20.1 ^a	52.6		
Kt x Pb	200.0 ^b	36.6 ^b	18.9 ^{ab}	52.4		

Pb = Pelibuey, D = Dorper, Kt = Katahdin, Db = Black head Dorper, Dw = Dorper White, D = Dorper (type not specified). ^{a,b,c} means in the same column with different superscripts indicate significant differences.

lar climatic characteristics, as both breeds possess the characteristics designed for mutton production: middle size, strength and muscularity, early puberty, and long productive life. Additionally, these genotypes are prolific, with excellent maternal ability, good milk production and possible resistance to parasites (Esteban-Andrés *et al.* 2013).

A new emerging fattening system

In recent years, lamb production under intensive fattening systems in (SRC) has emerged. Some authors mention that these systems allow adequate comfort to the animals, which in turn results in better growth, body development and health (Lupton *et al.* 2007, Hernández-Cortazar *et al.* 2014). Such asseveration has caused the development of projects aimed to implement this type of infrastructure for lamb fattening. A tangible example of this model is found in the state of Tabasco, Mexico. However, there are no scientific reports on lamb productive performance and the profitability of fattening systems using SRC compared to conventional pens on the ground. It is possible that fattening systems in SRC can accomplish the features stated (Lupton *et al.* 2007) but suggesting such a type of technology without a scientific basis can be a mistake. In addition, the cost of that infrastructure plus the cost of feeding, could cause

the recurrence of farmers using intensive production systems in pens at ground level, grassing systems or even abandoning the activity.

Profitability of lamb fattening systems

Profitability can be defined as the net income on the total costs of production (fixed and variable), as the net income on the variable costs for a farm or by input unit such as one hectare or one cow (Nicholson 1998). Thus, sheep production systems and the management decisions regarding them play an important role in profitability and flock dynamics. Livestock production involves complex systems that are not always easy to understand or achieve, including production processes, financial processes or a combination of both (Turner *et al.* 2013). For example, when different resources are used (land, labor or feeds) in production, a greater productivity by resource unit (such as land or feeds) does not necessarily imply greater profitability (Nicholson 1998). Understanding how associated changes in production decisions can affect a system's profitability in the long term is not an easy task. An analysis of production systems could be an effective tool to alleviate those risks (Turner *et al.* 2013).

It has been argued that technologies and practices that provide the basis for the intensification of

production systems could be successfully transferred if they are managed with ability and with a minimum of additional investments (Nicholson 1998). In Mexico, the increase in demand for mutton has led to a change in the traditional farm structure. At present, sheep production systems that are characterized by a high level of investment in infrastructure and equipment and by the use of high amounts of grains have emerged (Góngora-Pérez *et al.* 2010, Pérez *et al.* 2011). The use of SRC and commercial concentrated feeds are two concrete examples of the adoption of technologies or practices considered to be beneficial by farmers. However, these technologies could have a negative effect on the profitability of the production system as production costs rise. Macedo and Castellanos (2004) indicated that the cost of a weaned lamb and its feeding until finished represents the highest cost of production, 50 and 43 %, respectively. Labor, health practices and financial costs represent the last 7 %. These authors calculated the total cost for production of a single lamb at \$37.45 USD and the total value of production at \$49.41 USD, resulting in 1.32 for the cost/benefit ratio. González-Garduño *et al.* (2013) also observed that the highest production cost was the feeding (89.9 %). They concluded that lamb production using high levels of concentrated feeds for intensive systems is unprofitable, and they proposed grazing plus supplementation as a strategy to increase profitability in lamb fattening systems.

Several studies around the world support the idea that the feeding cost represents the greatest cost in livestock production systems (Hartwell *et al.* 2010a, Hartwell *et al.* 2010b, Theodoridis *et al.* 2012, Turner *et al.* 2013); hence, the feeding practice that is utilized is one of the major factors affecting profitability. With regard to infrastructure, specifically SRC, there is no evidence of its profitability despite the great number of farmers that use it as a way to increase production, although its efficiency could imply the use of high quality animals.

According to Theodoridis *et al.* (2012), the technical efficiency level is used as a criterion for systems classification. Accordingly, the main produc-

tive and economic indicators of farms are analyzed to elucidate their contribution to the improvement of technical efficiency. In this sense, the intensive fattening systems in SRC can be considered technical efficiencies. For example, the population density in such cages can be raised to two animals per m² (0.5 m² animal)⁻¹, and this change could increase profitability by reducing the cost per animal reared (Toro-Mujica *et al.* 2012).

Additionally, it is unknown whether high density is in fact used with this type of system or its effect on animal productivity. Therefore, despite the belief that fattening systems in SRC can yield large production volumes, this is not a warranty of return on the investment in infrastructure for the short or middle term. The efficient use of existing farm resources is essential for an improvement in profitability and hence in competitiveness. In this context, measurement of efficiency can be a tool of practical decision-making for the adoption of strategies that might guide the producers to increase productivity. The productive and economic analysis could allow the detection of factors that can influence both the productivity and the profitability of the farms (Theodoridis *et al.* 2012). In the same way, the analysis of different technological options that could be potentially useful for farmers can be an efficient tool to mitigate the risk of production and financial perspectives (Turner *et al.* 2013).

CONCLUSION

The literature shows that there is a wide range of different fattening systems, but recently more intensive ones have gained importance. Because of the high dependence on external inputs, especially of feed sources, it is questionable if these systems are sustainable over the long term. The inclusion of good quality foliage in integral diets and supplements used with grazing, based on protein and energy requirements, for the growing and fattening of lambs could be viable options to reduce production costs. The assumption that SRC allows appropriate lamb comfort, which improves growth, remains to be tested.

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