Descriptive Analysis of Small Ruminant Meat Offer in Puerto Rico and Carcass Characteristics of Locally Slaughtered Animals

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ABSTRACT

This study was divided into three parts. The first part consisted of a descriptive analysis of the types of small ruminant meat (SRM) offered at retail in the 7 agricultural regions of Puerto Rico. In the second part, data were collected from 57 sheep and 28 goats from different origins, slaughtered in abattoirs in the western region of the island (Lajas, Mayagüez) to develop a data base of the carcass characteristics of small ruminant raised under traditional feeding management. The third part consisted of a feeding trial in which weaned lambs (n=6) and kids (n=6) were randomly assigned within species to one of two feeding regimes: with or without daily commercial concentrate (CC) supplementation at the rate of 0.9% of body weight (BW) on a dry basis to grazing native tropical grasses. Treatment effects on body weight gain, carcass characteristics, and meat quality were evaluated. Information gathered from the descriptive analysis showed that SRM was offered for sale in 79% or more of the supermarkets (SM) surveyed during the four-year study. In all these years, the frequency of SM offering SRM was highest in the agricultural region of San Juan (Metropolitan area municipalities). Most of the SM surveyed offered goat meat only. Respondents were not able to specify if the goat meat they sold was chevon or kid, or if the sheep meat was mutton or lamb. Most of the sellers described their level of offer as average and stated that demand was higher during certain holidays due to ethnic preferences. The data base on carcass characteristics of SR slaughtered commercially showed a highly variable dressing percentages ranging from 37 to 46%, and 32 to 38% for sheep and goat respectively, both species having similar ($p>0.05$) average values. No differences were observed in dressing percentages between sexes. Supplementation with CC increased ($p<0.05$) total and daily BW gain in lambs by 2580 and 40g respectively when compared to the non-supplemented controls. In kid-goats, BW gains with supplementation were numerically, but not significantly greater ($p>0.05$) than without supplementation. Dressing percentage, and fore and hind trunk percentages did not vary ($p>0.05$) between treatments for either species. There were no differences ($p>0.05$) in pH, moisture, crude protein, and fat percentages of *longissimus* muscle between treatments in either species. This research revealed that SRM is a well consumed

product and that its production has the potential to become an economically viable livestock enterprise. However, it is necessary to develop a local grading system to standardize the meat and improve its quality. Similarly, genetic selection of animals as well as investigation on alternative less-expensive feed resources for finishing meat-type animals are necessary to improve quantity and quality of meat from local SR.

RESUMEN

Se realizó un estudio dividido en tres partes. La primera parte consistió en un análisis descriptivo de los tipos de carne de pequeños rumiantes (CPR) ofrecidos al detal en las 7 regiones agrícolas de Puerto Rico. Para la segunda parte, se recolectaron datos de 57 ovinos y 28 caprinos, de diferentes orígenes y sacrificados en mataderos de la región oeste de la isla (Lajas, Mayagüez) para desarrollar una base de datos sobre las características de la canal de pequeños rumiantes (PR) criados bajo el manejo alimentario tradicional. La tercera parte consistió de un ensayo de alimentación en que corderos (n=6) y cabritos (n=6) asignados de forma aleatoria dentro de cada especie a uno de dos regímenes de alimentación: con o sin suplementación diaria con alimento concentrado comercial a razón de 0.9% del peso vivo (PV) en base seca para evaluar el efecto de los tratamientos sobre la ganancia de peso, características de la canal, y calidad de carne bajo pastoreo de gramíneas tropicales nativas. La información obtenida en el análisis descriptivo demostró que el 79% o más de los supermercados (SM) encuestados durante los 4 años de estudio ofrecieron en venta CPR. Para todos estos años, la frecuencia de la oferta de CPR fue mayor en la región agrícola de San Juan (Municipios del área metropolitana). La mayoría de los SM encuestados ofreció carne de cabro solamente. Los encuestados no pudieron especificar si la carne de cabro vendida era "chevon" o cabrito, o si la carne de oveja era "mutton" o cordero. La mayoría de los vendedores describieron el nivel de oferta como promedio y afirmaron que la demanda era mayor en días de festividades de índole étnica. La base de datos de las características de la canal demostró un porcentaje de rendimiento altamente variado, abarcando de 37 a 46%, y 32 a 38% para ovinos y caprinos, respectivamente, teniendo ambas especies un valor medio similar ($p>0.05$). No se observaron diferencias ($p>0.05$) en el porcentaje de rendimiento entre sexos. La suplementación con CC aumentó ($p<0.05$) por 2580g y 40g la ganancia de peso total y diaria respectivamente en corderos en comparación con los no suplementados. En los cabritos las ganancia de peso con suplementación fueron numérica pero no significativamente mayores ($p>0.05$) versus la no suplementación. El porcentaje de rendimiento y los porcentajes de cuartos delantero y trasero no variaron ($p>0.05$) entre los

tratamientos en ninguna de las especies. Tampoco hubo diferencias ($p>0.05$) en pH ni en los porcentajes de humedad, proteína bruta y grasa en el músculo *longissimus dorsi* entre tratamientos en ninguna de las especies. Esta investigación reveló que la CPR es bien consumida y su producción tiene el potencial para convertirse en una empresa pecuaria económicamente viable. Sin embargo, se precisa desarrollar un sistema de clasificación local para estandarizar la carne y mejorar su calidad. De la misma forma, es necesaria la selección genética de los animales, así como la investigación sobre fuentes alimentarias alternas menos costosas para la fase de terminación de animales tipo carne para mejorar la cantidad y calidad de la carne local de PR.

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1 INTRODUCTION

Small ruminants (i.e. sheep and goats) are among the most important domestic animals in tropical areas because of their adaptability to harsh environments. Some of the advantages of small ruminants (SR) as productive livestock include aggressive feeding behavior, small body size, and prolificacy. These characteristics allow them to be easily raised under both intensive management and extensive grazing or pastoralism, and to form part of mixed crop production systems. Additionally, sheep and goats are used for multiple purposes such as meat, milk and hides.

In Puerto Rico, sheep and goats are raised mainly for meat production under extensive conditions grazing native tropical grasses (NTG) without supplementation. During the last decade a decrease in local SR meat production has been observed; however, this decrease in production has been accompanied by an increase in the demand for sheep (lamb/mutton) and goat (kid goat/chevon) meat. This higher demand might be associated with an increase in various ethnic populations, as well as the health and gourmet food preferences of certain consumer sectors. Because of the unique taste and nutritive characteristics associated with goat and sheep meat, this increasing preference for the same in Puerto Rico is satisfied by a higher rate of importation, while local production decreases (Oficina de Estadísticas Agrícolas. Departamento de Agricultura. Compendio Estadístico 2008; Foreign Trade Statistics. U.S. Department of Commerce, 2004).

One of the problems affecting the SR enterprise in Puerto Rico is the lack of detailed information on demand, consumer preferences, niche markets, and other aspects of the meat that affect the synchrony between market preferences and product supply. This, in addition to the limited information on the nutritive value of SR meat, has caused many former producers to shift to another business during recent years.

Additionally, ruminant production in Puerto Rico is mainly supported by grazing naturalized tropical grasses (NTG) due to their low cost and availability. The poor quality of this type of forage results in low dry matter intake, animal weight loss during certain periods, increased disease susceptibility, low reproductive performance, and failure to realize animal genetic potential (Murphy et al., 1994). This explains the low rate of body weight gains, and poor carcass conformation and meat quality reported in the literature for ruminants under tropical grazing systems without supplementation (Liméa et al., 2009).

The low quality of NTG has forced progressive meat-type animal producers to implement supplementation strategies during the growing and finishing phase; commercial concentrate (CC) being the most commonly used feedstuffs for this purpose in Puerto Rico. However, local CC are compounded from imported ingredients which increases feeding costs. Different studies performed in tropical areas have yielded variable results of CC supplementation on SR performance. Some studies have shown important differences in growth rate, carcass characteristics and meat chemical composition between supplemented and non-supplemented animals (Karim et al., 2006; Liméa et al., 2009). Locally, there is little experimental evidence on the effect of CC use on performance of sheep and goats raised while grazing NTG.

Another existing problem for the SR enterprise in Puerto Rico is the lack of available information on carcass characteristics and meat quality of animals slaughtered under traditional management, and how supplementation with CC affects these variables. The lack of a grading system to compare carcasses and of the knowledge of factors affecting carcass composition and meat quality are primary obstacles to improved carcass value. Characteristics that allow comparing one animal against another include the quantity of saleable meat produced, and the quality of the meat. Factors such as hot carcass weight, dressing percentage, carcass fat percentage, and carcass to bone ratio allow determining the amount of lean meat produced by an animal. Likewise, quality characteristics are determined by factors that consumers perceive, such

as color, tenderness, and juiciness. These factors might be affected by breed, genetic potential, gender, plane of nutrition, environmental conditions, and pre-slaughter stress.

Furthermore, there has been no systematic study concerning the frequency of the offer for retail sale of SR meats on the island. Knowledge of these factors will assist in designing an adequate program of feeding, management and selection of animals to improve the quantity and quality of SR meat.

2 OBJECTIVES

1. Perform a descriptive analysis of types of small ruminant meat (SRM) offer at retail in the seven agricultural regions of Puerto Rico.

2. Develop a data base of the carcass characteristics and meat quality of small ruminants slaughtered after being raised under traditional feeding management in Puerto Rico.

3. Evaluate the effect of supplementation with a commercial concentrate on body weight gain, carcass characteristics, and meat quality of weaned lambs and kids raised by grazing native tropical grasses.

3 LITERATURE REVIEW

3.1 Small ruminants in Puerto Rico

The SR industry is organized within the Department of Agriculture of Puerto Rico under the Law 238 dated September 18, 1996. This law established the Office of Regulation and Promotion of the Small Ruminant Industry (ORPPR by its Spanish name) and the Development Fund for the Small Ruminants Industry (FFIPR by its Spanish name). The ORPPR addresses all issues related to the industry including conferring certification to small ruminant producers. The industry has two nuclei of producers (cores) certified by the Department of Agriculture; one located in the south-west and the other in the central-south area of the island.

3.2 Agricultural Regions in Puerto Rico

Puerto Rico is divided into seven agricultural regions (AR) established by the Commonwealth of Puerto Rico (Estado Libre Asociado de Puerto Rico, ELA) and used by the United Stated Department of Agriculture (USDA) for simplicity purposes. Each AR is composed of several municipalities (Figure 1).

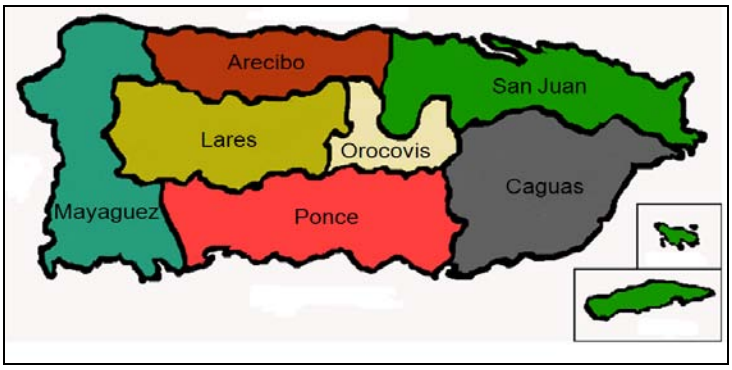

Figure 1. Agricultural regions in Puerto Rico

3.2.1 Small ruminants animals and farms

According to the most recent census from which the pertinent data are available (2007), there were 7,359 goats on 675 farms in Puerto Rico. Of the 675 farms only 32.7% (221) sold animals,

with the average number of heads sold annually being 10.9 per farm. For sheep, the inventory was 11,137 heads located on 568 farms. Only 38% (217) of these farms made sales; selling an average of 19.6 animals per farm (Agricultural Census, 2007; Cited by Fondo para el Fomento de la Industria de Pequeños Rumiantes, Plan de Trabajo 2009).

Table 1. Distribution of farms and SR animals (both sheep and goats) among agricultural regions in Puerto Rico

Agricultural Region	**Farms**		**Animals**	
	Number	Percentage	Number	Percentage
1. San Juan	171	13.8	1692	11.37
2. Arecibo	110	8.9	1099	7.39
3. Mayaguez	256	20.6	4262	28.64
4. Ponce	155	12.5	3357	22.56
5. Caguas	307	24.7	2479	16.66
6. Orocovis	126	10.2	1260	8.47
7. Lares	116	9.3	732	4.92
Total	1241	100.0	14881	100.0

Agricultural Census, 2007

According to the most recent Agricultural Census (2007), the Caguas and Mayaguez AR had the highest proportion of the farms with SR, 24.7 and 20.6%, respectively (Table 1). However, farms located in Caguas had only the third highest inventory of animals (18% of the total) after Mayaguez (26.6%) and Ponce (23.1%). These relationship indicate that the SR enterprises are seen mostly as a hobby rather than a for profit operation.

3.2.2 Market background

The local sheep and goat industry is mainly composed of small producer operations (fewer than 100 head), and marketing of the meat is performed individually. Even though SR slaughter in accordance with the law has to be done following USDA regulations, undocumented slaughter is a very common practice in Puerto Rico (Figure 2). The SR meat produced is distributed among supermarkets, public markets, restaurants, and on farm sales or used for personal consumption.

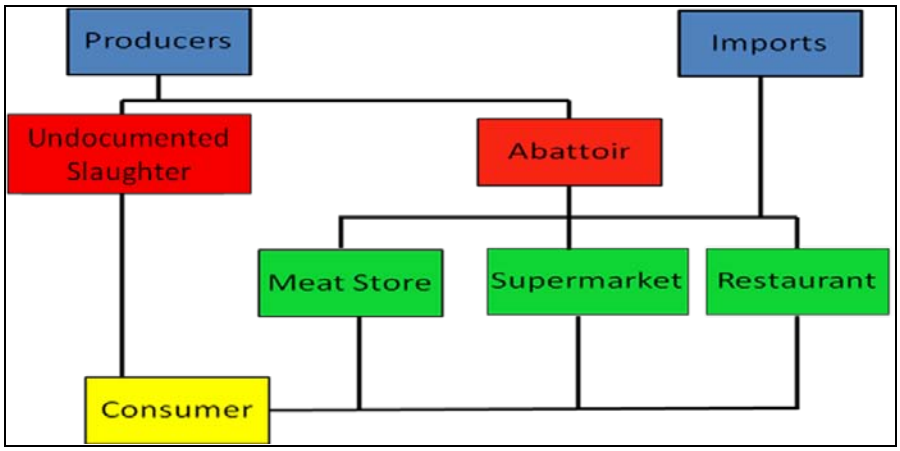

Figure 2. Flow of the distribution of small ruminant meat in Puerto Rico

The proportionate contribution of SRM to the formal gross agricultural income of Puerto Rico in 2008 was only 0.15%, reflecting very limited production. In 2008, only 147,000 pounds of small ruminant meat with a value of $429,240 ($2.92 per unit), were locally produced; representing 8.47% of the total supply (Oficina de Estadísticas Agrícolas. Departamento de Agricultura. Compendio Estadístico 2008). The registered number of sheep and goats slaughtered in abattoirs was 680 during fiscal year 2007 (Slaughter Annual Report: Accumulated July 2006 to June 2007, Department of Agriculture of Puerto Rico). However, this number does not include animals slaughtered in undocumented operations without USDA approval. This decrease in local supply was accompanied by an increase in imports of sheep and goat meat to Puerto Rico, demonstrating a growing demand for such meat.

Sheep and goat meat is classified according to the age of the animal at slaughter. Sheep can be classified as 'lamb' or 'mutton' for young and adult animals, respectively. Similarly young goats are classified as 'kid-goat', 'kid', or 'cabrito', whereas adult animals are clasified as 'chevon'. However, since there are no established standards for marketing SRM in Puerto Rico, this distinction is not always specified when selling to consumers. Other than for special markets, SRM is regularly sold as cubic pieces of the entire carcass, and is most often consumed in the form of stew.

3.3 Growth and development of meat-type animals

To evaluate live animal and carcass characteristics it is necessary to understand the changes associated with the growth and fattening processes. Because rate of growth affects efficiency of production it strongly influences profits or losses for the producer. True growth is described as an increase in the structural tissues such as bone, muscle, and connective tissues associated with muscle. Muscle growth is of prime importance because it is the component that will be consumed as meat, while bone is important in maximizing the production efficiency during growth. Meat or flesh is any edible part of the striated muscle of an animal. Development is the differential growth of the body parts that occurs from the embryonic stages through maturity. Most fattening occurs after bone development is complete and muscle is close to its maximum development. Fat content is important to ensure an acceptable juiciness of the meat and to protect the carcass during the storage and handling period (Lawrie, 1991; Boggs and Merkel, 1993).

A normal growth curve generally follows a sigmoidal shape irrespective of mature size and species (Figure 3). The increase in growth units following birth is initially very slow but is followed by a rapid increase relative to time (steep part of the curve). At this stage the animal is most efficient in weight gain because it grows rapidly in a relatively short period of time. As the animal approaches maturity the growth rate levels off (upper part of the curve) as all tissues are slowing down or ceasing their growth and development (Boggs and Merkel, 1993).

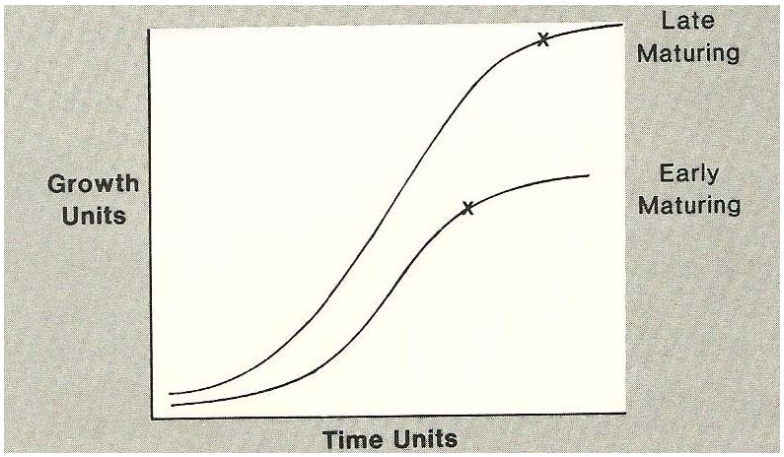

Figure 3. Growth curves of early and late maturing animals. The X at the upper inflection of the curves indicates the onset of maturity. Boggs and Merkel, 1993.

Bone is the first major tissue to mature and undergoes proportionally the least postnatal growth. Muscle tissue matures latter than bone thus its proportional growth is greater. Most of its increase in mass occurs approximately between 1/3 and 3/4 of the distance along the horizontal axis of the growth curve (time units). Fat is the last major tissue to develop. Increased fat deposition begins when muscle growth and development begins to slow down. (Lawrie, 1991)

3.3.1 Effect of nutrition on growth and development

Finishing lambs and goats are expected to consume dry matter equals to approximately 2 to 5% of body weight daily (NRC, 2007). Dietary energy and protein concentrations are the main nutritional considerations in meat animal production, but to achieve optimum growth and development all other essential nutrients must also be provided.

Energy intake is the key to efficient utilization of nutrients, and thereby the productivity and rate of gain of an animal. The energy obtained from the diet that exceeds the amount required for maintenance is then defined as energy for gain (growth) (NRC, 2007). When maintenance and gain requirements are met additional dietary energy available is deposited as fat. The major component in muscle tissue dry matter is protein, thus if the amount of protein in the diet is

limiting, the rate of muscle synthesis and growth will decrease, especially in young growing animals (Boggs and Merkel, 1993). Protein requirements increase as the leanness and growth rate increase and vary according to the kind of animal (i.e., castrate, intact male, and female). Even though ruminants benefit from substantial amounts of microbial protein synthesized in the rumen, animal utilization of amino acids from poor-quality dietary protein does not meet all the requirements for fast-growing animals. Therefore, dietary protein of sufficient quality must be supplied. Feeding energy or protein in excess of that needed for optimum performance does not improve growth rate and will result in fat carcasses. Mineral and vitamin concentrations also are an important component of a balanced diet; however these are generally met through adequate diet formulation (Schoenian, 2003).

3.3.2 Growing and finishing diets for small ruminants

Small ruminant production in the tropics is mostly based in the grazing of NTG because of its low cost. However, NTG cannot meet the nutritional requirements for rapid growth because of their low crude protein (CP) and high fiber contents. Similarly, seasonal variations in the amount of available forage result in lower intake and weight loss, increased diseases susceptibility and decreased reproductive performance (Murphy et al., 1994). Therefore, supplementation strategies are needed to satisfy the SR nutritional requirements. Commercial concentrate feed (CC) is probably the feedstuff most used in Puerto Rico during the growing and finishing phases of meat-type ruminants. However these feeds are based on imported ingredients (i.e., corn, wheat, soybean meal, grain by-products), which increases the feeding cost of the SR operation. Additionally, limited information on the effect of CC on SR performance is available.

To confront the problem of high feed costs, previous research has included a broad variety of non-traditional diets and supplements for finishing meat-type animals that seek to improve in a cost effective way the final body weight (FW), total body weight gain (TBWG), rate of gain, and dressing percentage, with minimal effects on meat quality. Some alternative less-expensive sources include legumes or other high protein forages as well as by-product feedstuffs. Several authors have reported higher FW, TBWG, and average daily gain (ADG) for grazing SR supplemented with CC than for animals under forage only management (Santra et al., 2002;

Karim et al., 2006). However, other authors have reported no differences between these two feeding regimes (Lee et al., 2008). Such discrepancies have been attributed to differences in animal type, breed, genetic potential, pasture quality, climatic conditions, and strategy and extent of supplementation.

In recent years there has been great interest in the tropics in identifying forage legume species to overcome some of the problems associated with low dietary protein intake by grazing ruminants and thus to decrease the use of CC. It has been suggested that a forage-only diet can be used for finishing meat animals (William et al., 1991). Even though weight gain is faster and less time is required to finish animals under CC supplementation compared with an all-forage diet, there can be comparable slaughter situations, such as final weight and fat thickness, under both systems (Crouse et al., 1984). In a study with bovines it was found that both the use of CC and production costs were decreased when heifers were allowed to graze *Arachis pintoi* protein banks (Argel et al., 1995). The legume's high nutritive value offset the decrease in nutrients offered in the form of CC. In another case, ADG in grazing sheep was almost doubled when supplemented with *Lablab purpeus* compared to sheep without supplementation (Umunna et al., 1995). Experiments to test mixed legumes and grasses have sometimes yielded excellent results, such as an ADG of 0.8 kg in steers grazing tropical grasses in associations with *Arachis glabrata* (Williams et al., 1991). Conversely, other authors have reported no responses to legume supplementation (Sánchez and García, 1998; Norton and Watertall, 2000). In general, animals with low production potential do not respond to supplementation. The nutritive value of the pasture grass also plays an important role in the animal's response to supplementation.

Feedstuffs based on agro-industrial by-products have become very important in recent years as the world's human population has increased, as has the production of crops and food by-products, particularly in developed countries (Grasser et al., 1995). Commonly used by-products include sugarcane molasses in combination with non-protein nitrogen (NPN), as well as residues from the citrus, poultry and distillery industries. The inclusion of NPN in growth and fattening diets has been successful in combination with soluble carbohydrates to provide the energy needed for

microbial growth (Dewhurst et al., 2000). Ingested NPN is converted to ammonia, followed by its incorporation into microbial protein, thereby supplying additional N to the host animal (Bach et al., 2005). The fermentable carbohydrates in molasses promote higher populations of rumen microbes (Pate, 1983) and the high digestibility of the soluble carbohydrates contributes to increased dry matter digestibility of the whole diet. However, as the dietary level of molasses increases, the digestibility of low-quality roughages decreases proportionally as a consequence mainly of lowered fiber digestibility (Herrera et al., 1981; Martin et al., 1981).

Poultry by-product meal (PBM) has also been used in meat ruminant diets as a N source. Lallo and García (1994) reported improvements in ADG and gain/feed ratio for lambs supplemented with PBM compared with soybean meal.

By the late 20th century, the by-products resulting from the conversion of cereal grains to fuel alcohol, dried distillers grains plus solubles (DDGS) and wet distillers grains plus solubles (WDGS), were being used extensively as feedstuffs. Because of the increased concentration of protein in the DDGS compared with corn, it was used primarily as a protein source (Klopfenstein et al., 2008). Research showed that cattle gained more rapidly when fed WDGS compared with the original corn, becoming fatter with equal days on feed. Consistent with the quadratic increase in rib fat was a quadratic increase in quality grade. No significant impact on palatability of the meat has been reported when DDGS and WDGS were fed (Roeber et al., 2005; Jenschke et al. 2007).

In Puerto Rico, the effect of supplementation on SR performance is not well documented. Most of the research conducted so far has focused on determining the effects of inclusion of legume forages or various by-products on NTG intake and digestibility.

3.4 Meat grading and evaluation

Meat grading is the procedure by which carcasses, meat or meat products are segregated on the basis of expected palatability or yield attributes, or other economically important traits. Meat

evaluation is an extension of grading that identifies carcass composition and value differences with greater precision than grades alone. The purpose of the USDA meat grading system and evaluation is to facilitate marketing and merchandising through standardization characteristics that are valuable to consumers.

There are two general types of federal grades for quantity and quality. The quantity grades or yield grades (also called cutting yield) categorize carcasses on the basis of expected yield of boneless trimmed retail cuts. The grades for quality categorize meat on the basis of its acceptability for the consumer. Factors related to palatability and acceptability of meat products are used in assigning quality grades. (USDA, 1992; Schilling, 2005).

In the United States lamb carcasses can be classified, marketed and sold according to their assigned grades by using these standards. Conversely, there are currently no published USDA grade standards for goat carcasses. Therefore, carcass measurements for goats can be taken for comparison, but not for actual marketing under USDA quality or yield grades standards (Schilling, 2005). In Puerto Rico no quality or yield grades standards exists for classification and marketing of goat meats, and those existing for sheep are not currently being implemented.

Quality and yield grades are the primary factors involved in assigning carcass value. However, other measurements could be taken to more closely define the lean muscle and proportion of weight represented by fat and muscle in carcasses such as body wall thickness, leg circumference, *longissimus* muscle area, and individual primal cut weights.

3.4.1 Quantity grades - Carcass Cutting Yield

The grades for quantity or yield categorize carcasses on the basis of expected yield of boneless, trimmed retail cuts or the amount of carcass that ends up as meat (USDA, 1992). Carcass quantity yield can be calculated by dividing the weight of the meat by the carcass weight and expressing the result as a percentage. Factors that affect the yield grade include fatness, muscling, muscle to bone ratio, and the amount of fat remaining on the meat cuts. Leaner carcasses, with

high muscularity and lean to bone ratio, will have higher yield values. Likewise, with fatter meat cuts the yield will increase (Schilling, 2005).

3.4.2 Quality grades

As with quantity grades, there are no published USDA quality standards for goat carcasses. Lamb quality grades are determined by estimating three factors: the degree of fat streaking in the flank lean, muscle conformation, and maturity of the carcass. According to these factors lamb carcasses can be assigned to one of five quality grades: Prime, Choice, Good, Utility, and Cull (USDA, 1992).

Generally the quality of the lean flesh is analyzed according to factors such as texture, firmness and marbling in a cut surface in relation to the apparent maturity of the animal carcass (USDA, 1992). However, direct observation of these characteristics is not possible in ovine carcasses. Therefore the quality of the lean is evaluated by indirect means, considering the degree of fat streakings in the flank in relation to the apparent maturity. Within each grade, the requirements for flank fat streaking increase progressively with evidences of advancing maturity. The estimation of flank fat streakings is expressed in terms of descending order of quantity: abundant (greatest), moderately abundant, slightly abundant, moderate, modest, small, slight, traces, and practically devoid (least).

Conformation is derived from visual appraisal of the muscular and skeletal system development in terms of the muscle thickness and fullness of the carcass. However, this perception is also affected by amounts of subcutaneous and intramuscular fat (USDA, 1992).

The last characteristic for estimating quality grade is maturity. The most useful indicators to estimate maturity are osification, and color and texture of lean. Cartilage is abundant in young animals at the distal end of metacarpal bones. As the animal matures, cartilage ossifies. Therefore during aging there is progression from soft cartilage, to hard cartilage, to bone (USDA, 1992; Boggs and Merkel, 1993).

3.5 Carcass characterization (Dressing)

Dressing refers to the amount of the live animal that ends up in the carcass and is calculated by dividing the carcass weight by the live weight of the animal and expressing the result as a percentage. The carcass weight or hot carcass weight (HCW) is the weight after harvest and removal of the hide, head, gastrointestinal tract, and internal organs. Carcass weight is a major factor in determining carcass value when the animal is sold on a dressed weight basis.

There are several factors such as gut fill, fatness, muscling and wool that affect the dressing percentage. The more the gut fill (contents of the digestive tract) at the time the live weight is taken the lower the dressing percentage will be. This effect can be reduced if the animal is fasted for 24 hours prior to weighing. Animals with higher fat scores generally have higher dressing percentages than leaner animals of comparable live weight. Generally, as weight increases there is an increase in fat deposition. A highly muscled animal will have a higher dressing percentage than a skinnier muscled one. Animals with long wool or hair will have a lower dressing percentage than shorn lambs (Boggs and Merkel, 1993). Additionally, dressing percentage might be influenced by animal species, type, breed, sex, and age. Dressing percentage for sheep and goats under tropical grazing conditions is variable ranging from 37 to 50% (Manso et al., 1998; Karim et al., 2006; Liméa et al., 2009). Between species, goats tend to have a lower dressing percentage and smaller carcasses with less fat cover than sheep at comparable ages of a given sex (El Khidir et al., 1998; Schilling, 2005). This makes the goat carcasses leaner with a lower proportion of subcutaneous fat compared to sheep (Tshabala et al., 2003).

3.6 Meat quality

Fresh meat refers to the product that has undergone the chemical and physical changes after slaughter but has been only minimally processed by procedures such as fabrication into retail cuts, cubing, grinding, marination, or freezing. The term ‘meat quality’ is used to describe the overall characteristics of the meat that determine or affect its level of consumer acceptability (Purchas et al., 2003). Quality characteristics are determined by factors that consumers perceive, as well as factors that affect the microbial and processing properties. The most important

perceptible characteristics include odor, color, tenderness and juiciness (Casey, 1982). Additional, quantifiable characteristics that affect the processing properties of the meat include water holding capacity (WHC), shear force, drip loss, cook loss, and pH (Purchas et al., 2003). Consumer preferences may vary among cultural backgrounds, and social and economic conditions (Casey, 2003). Meat quality attributes might be affected by breed, genetic potential, gender, plane of nutrition, environmental conditions and pre-slaughter stress (Boggs and Merkel, 1993).

3.6.1 Appearance characteristics (Color)

Meat color is one of the most important characteristics affecting consumer acceptance. Color measurements use the Commission International de I' Eclairage (CIE) color system (Figure 4). The three fundamental colors coordinates are L*, a* and b*. The L* coordinate measures the lightness and is a measure of the light reflected; a* measures red (positive) and green (negative); and b* measures yellow (positive) and blue (negative) (Commission International de I' Eclairage, 1976).

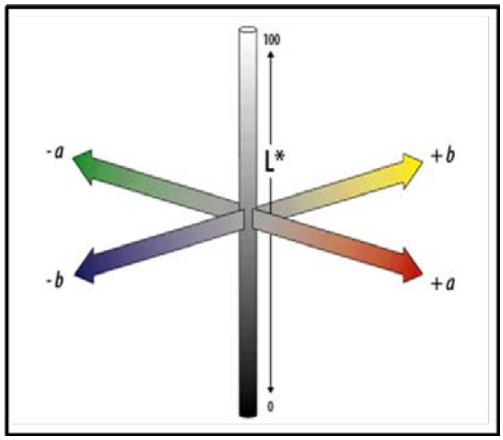

Figure 4. Representation of the CIE 1976 (L*, a*, b*) color space (CIELAB)

The color of lean meat is mainly determined by its protein content. Myoglobin is the protein responsible for the majority of the red color in meat because it is fixed in the tissue cells as a purplish color. When myoglobin is exposed to oxygen, it becomes oxymyoglobin, and produces

a bright red color which is measured by a* coordinates. The remaining color comes from the haemoglobin, which is present in a small amount in the tissues after slaughter (Priolo et al., 2001).

There is a general trend among consumers to prefer a strong bright red color, while too dark (due to a high ultimate pH) or too light (due to freezer burn) are perceived as undesirable (Purchas et al., 2003). Similarly, yellow fat color is often perceived by consumers as meat coming from an old or disease animal (Muchenje et al., 2009). Meat color may be influenced by many factors, including pre-harvest and post mortem conditions (Purchas et al., 2003). Pre-harvest conditions can include the species, breed, age and diet of the animal. Goat meat color tends to be a darker red than that of lamb or mutton (Babiker et al., 1990). However, Santos et al. (2008) found that kid meat was lighter and less yellow than lamb meat but consumers do not perceive the differences between them (Babiker et al., 1990). Variations in meat color among breed have been reported (Burke and Apple, 2007), whereas other authors have found no such effect (Kadim et al., 2003; Revilla and Vivar-Quintana, 2006). Changes in meat color can also occur with age of the animal since myoglobin content is age-dependent (Muchenje et al., 2009). The dietary history strongly influences the color of meat. Several authors reported that forage-fed animals have darker meat than those fed grain (Muir et al., 1998; Priolo et al., 2002; Lee et al., 2008). Similarly, animals fed on pasture have a yellow fat color because of the high levels of carotenoids contained in the fresh grass (Muchenje et al., 2009).

3.6.2 Palatability characteristics (Tenderness and juiciness)

Tenderness can be attributed to a person's perception of meat, such as: softness to tongue, resistance to tooth pressure and adhesion (Muchenje et al., 2009). Tenderness varies, mainly due to changes in the myofibrillar protein structure of muscle in the period between animal slaughter and meat consumption (Muir et al., 2000) and may vary according to age, sex, breed, live weight, and ante-mortem stress.

If the carcass is refrigerated immediately after slaughter, muscle fibers contract severely, which results in *cold-shortening*. This condition is accompanied by a loss of meat juiciness and tenderness (Lawrie, 1991) and might be perceived by consumers as tough meat (Muir et al., 1998). Previous research suggests that meat tenderness is influenced by the collagen content, heat stability, and the myofibrillar structure of muscle. These factors might be affected mainly by the rate of growth of the animal. Forage fed animals tends to show higher Warner-Bratzler Shear Force (WBSF) (lower tenderness) than those given concentrate based diets.

3.6.3 Processing characteristics (Water holding capacity)

Water holding capacity (WHC) is the ability of the meat to retain its water during application of external forces such as cutting, heating, grinding or pressing (Lawrie, 1991). Higher values of WHC are desired as they are related with juiciness and tenderness. WHC is affected by pH and is minimum at the isoelectric point (pI) of meat proteins (pH = 5.0-5.5). At this pint positive and negative charges on the side chains of aminoacids are equal and a net charge of zero is created, resulting in a reduction in the amount of water that can be attracted by the proteins. However, WHC can be increased by restoring the charge imbalance either by increasing or decreasing the pH away from the pI (Zhang et al., 2005). Additionally, the partial denaturation of protein at a low pH when the temperature is high accounts for a loss in WHC. When WHC is disrupted there is an excessive loss of fluid ("drip loss") from the meat. However some authors found no relationship between drip loss and WHC (Muchenje et al., 2009).

3.7 Factors affecting meat quality

3.7.1 Antemortem

3.7.1.1 Stress

When an animal is under a stressful situation blood flow to the muscles increases as a result of increased muscle contraction. The circulatory system cannot always support this increased demand which results in a temperature rise and depletion of muscle-stored oxygen. However the "stress hormones" epinephrine and norepinephrine trigger a shift in the type of metabolism to

overcome the stress situation. Epinephrine aids in the anaerobic breakdown of stored glycogen and fat as an immediate source of energy (Lawrie, 1991). Since the end product of glycogen breakdown is lactic acid, there is an accumulation of this metabolic product. However the effect of stress on the ultimate properties of meat will depend on the duration and severity of the stress, and the degree of stress susceptibly of the animal at the time of harvest.

Stress-susceptible animals generally have very high body temperatures and rapid glycolysis, which produces a rapid pH drop; and early postmortem onset of rigor mortis in the muscles. These changes occur rapidly in stress-susceptible animals and result in lactic acid accumulation. This combination of high temperature and rapid pH decline enhances protein denaturation. Meat from these animals is characterized by the Pale, Soft, Exudative (PSE) condition, which entails pale color, soft texture and poor WHC. Therefore, PSE meat has increased cooking loss and reduced juiciness. Contrarily, if the animals has met and overcome sufficient stress to deplete all its glycogen reserves, then the Dark, Firm, Dry (DFD) condition can occur. In this case the meat retains more water which results in an increased ability of the muscle surfaces to absorb light and a decreased ability to reflect light. Therefore, the dark color is observed.

3.7.1.2 Genetics

There are established heritability estimates for certain properties of meat that can be used to improve the final product through breeding. Selection can favor animals whose close relatives have muscles with the desired characteristics (Lawrie, 1991). Some of the characteristics with a moderate heritability are color, intramuscular fat, and shear force (tenderness). Some breeds are known for certain characteristics, for example tending to show lighter muscle color, with greater cooking loss and lower shear force than other breeds (Burke et al., 2007). Also, some breeds have been shown to deposit less/more external fat (Burke et al., 2007) or to have a lower/higher proportion of lean. Generally breeds that are early maturing will deposit fat at an earlier age (Cloete et al., 2000). Certain indigenous breeds are perceived to have poorer carcass characteristics, tougher meat, and greater variability in meat tenderness compared to pure-breds (Muchenje et al., 2009).

3.7.1.3 Species

Goats tend to have a lower dressing percentage and smaller carcasses with less fat cover than sheep at comparable ages of a given sex (El Khidir et al., 1998). In goats fat deposition occurs very late in terms of growth and development (Owens et al., 1983) and most of the fat is deposited in the visceral rather than subcutaneous or intramuscular sites (Dhanda et al., 1999). This makes goat carcasses lean with a lower proportion of subcutaneous fat compared to sheep (Tshabala et al., 2003). Given this fact, the criterion of subcutaneous fatness that is used as a yield predictor in lamb and mutton carcasses, is not suitable for classifying and grading goat carcasses and, if used, results in downgrading (Simela et al., 1998).

Goat carcasses are susceptible to high moisture losses during chilling because of the poor subcutaneous fat cover and these losses tend to be higher for smaller (less than 35kg) than larger carcasses (Webb et al., 2005). Therefore goat meat is considered "tough" or less tender than lamb or mutton under similar post-mortem conditions. The collagen content and solubility, as well as the muscle fiber characteristics, which can affect tenderness of the meat, differ between the two species. Goat meat has a coarser texture than sheep meat because the muscles have thicker and larger myofibril bundles.

3.7.1.4 Physiological age

The term physiological age refers to differences in growth and development achieved, fatness and proximity to maturity among animals within the same species and chronological age. It mainly describes a stage in the process of body development and thus is independent of chronological age. Physiological age is designated by stages such as puberty, attainment of maximum body weight, indicators of skeletal maturity or body composition, and varies according to animal type and sex within species.

Physiological age is used to describe breeds within species as early or late maturing because these identifiable stages occur at different chronological ages. This means that at a given

chronological age, animals from a late maturity breed would be physiologically younger than animals from an early-maturing breed (Boggs and Merkel, 1993).

3.7.1.5 Sex

The physiological age is influenced by sex. At a comparable chronological age intact males are heavier, leaner and physiologically less mature than castrate males or females. Female lambs typically show lower growth rates than males of the same breed (Falagan, 1992). In small ruminants, females reach maturity earlier (younger chronological age) and at lighter weight than males. Castrate males are intermediate between intact males and females in time to reach maturity (Boggs and Merkel, 1993).

Some studies have found greater carcass yield for females, possibly due to a lower lean to fat ratio (more fat) compared to intact males and castrated males (Falagan, 1992; Santos et al., 2008). Intact males have the highest lean to fat ratio (most lean), while castrated males are intermediate in lean to fat ratio (Boggs et al., 1993). In studies with Sereguena lambs it was found that males had a greater proportion of commercial cuts of meat in the neck and back as well as heavier skeleton. Female carcasses showed a significantly higher proportion of fat but the percentage of muscle was similar in both sexes (Peña et al., 2005). In contrast, studies with goats have shown that sex did not affect the carcass conformation measurements, but there were some differences in the regional and tissue composition of the carcasses. In females the chump and breast joints contained more fat than in males (Jimenez-Badillo et al., 2008).

3.7.2 Postmortem (Biochemical changes)

Biochemical changes that occur after harvest affect the conversion of muscle to meat and the quality of the final product. After slaughter, there is only a limited oxygen supply but this is compensated by anaerobic metabolism, which is capable of supplying energy to the muscle by consuming glycogen until it is depleted. However, anaerobic metabolism results in the production of lactic acid that cannot be removed due to the lack of a circulatory system. This lactic acid accumulation results in a decrease in muscle pH that eventually reduces the rate of

glycolysis and ATP synthesis. When the muscle pH is very low before the internal body heat (homothermic and metabolic) has been dissipated, denaturation (loss of functionality) of proteins can occur (Lawrie, 1991). Denaturation causes proteins to loss solubility, which results in decreased WHC and lower intensity of muscle color (Muchenje et al., 2009). When the muscles are subjected to a rapid or continuing pH decline the color will be pale and WHC very low because of little water attachment to muscle. Conversely, muscles that maintain a high pH will be dark and have a higher WHC (Muchenje et al., 2009). As ATP becomes limiting during the conversion of muscle to meat, *rigor mortis*, or stiffening of muscle after death begins. The stiffening observed during rigor mortis occurs as a result of the formation of actomyosin complexes, which are at maximal when the ATP supply has been exhausted and cannot be broken down because no energy is available. This results in high muscular tension. Although tension can decrease during storage, it will never reach initial levels (Lawrie, 1991). The biochemical changes involved in the conversion of muscle to meat are similar in avian and mammalian species. However, rigor mortis occurs faster in species with white fibers than in red meat species.

4 Materials and Methods

4.1 Descriptive analysis of the small ruminant meat offered at retail in the supermarkets of Puerto Rico

4.1.1 Population

The target population for years 2007, 2008, and 2009 consisted of the supermarkets (SM) located in different municipalities of Puerto Rico, but without any stratification among AR . For year 2010 the target population consisted of SM located in the seven AR. Due to the fact that locations of SM within AR are very heterogeneous with regard to area, number of municipalities, and human population, seven subpopulations (strata) were identified for each AR. This aimed to improve the representativeness of the sample by reducing sampling error and to allow comparisons of sub-populations to be performed with equal 'power'. The SM surveyed included both established chains (multiple locations around the island or in certain AR) and local (limited to only one municipality).

4.1.2 Instrument

The instrument used for collecting the information was a questionnaire type survey designed to permit a descriptive analysis (Appendix 1). The survey was conducted by means of an interview with the manager or person in charge of the meat department in each SM. The questionnaire consisted of eight questions of which four were simple choice type and four were open answer questions. Additionally, a space was left for other comments, in which respondents could offer additional remarks not included in the survey but that they might consider important. The questionnaire was submitted to a pre-test to determine its congruency with the objectives of the study.

Information was requested as to the species of SR (sheep, goat or both) that the meat offered for sale was from, whether whole carcasses or special cuts were offered and the origin of the meat

(local or imported). Additionally, respondents were asked from whom the meat was bought and the purchasing price paid to the producer/distributor, as well as the selling price to the consumer.

4.1.3 Sampling

Due to the fact that the intention of this survey was to perform a descriptive analysis of the SRM offer at retail in Puerto Rico, questionnaires were given to the students enrolled in the Small Ruminant Production course for years 2007, 2008, and 2009. Students personally performed the interviews in five SM in their hometown municipality, including chain and local SM. Students specified the name and location of the supermarket to avoid repeated data. Due to the sampling method used the first three years, the number of observations is different among years, municipalities and AR represented.

For year 2010 a sample size of 150 SM was selected to ensure that the survey included enough observations in each AR and the distribution of observations in the seven AG was proportional to the size of the population in each region (Table 2).

Table 2. Number of SM surveyed among seven AR in the years 2007, 2008, 2009, and 2010

Agricultural Region	Year			
	2007	**2008**	**2009**	**2010**
San Juan	39	10	28	63
Arecibo	0	4	12	11
Mayaguez	22	27	24	20
Ponce	19	15	5	19
Caguas	0	0	15	25
Orocovis	0	0	3	5
Lares	3	5	0	7
Total	83	61	87	150

4.1.4 Analysis

The data were analyzed to determine frequency and percentage of SRM offered for retail sale in Puerto Rico by year. Similarly information on the offer of SRM by the type of supermarket, specie of SR offered, and origin of the meat was tabulated using STATA program (STATA 9.2).

4.2 Data base of the dressing percentage of small ruminants harvested in Puerto Rico.

One of the mayor disadvantages of raising crossbred SR for meat production in tropical environments under grazing conditions is the low dressing percentage. It is well known that higher carcass yields are obtained from purebred animals raised under more intensive conditions (i.e., feedlot, supplementation programs) than from those raised under typical tropical feeding programs. The low performance of SR raised and slaughtered in Puerto Rico is common knowledge but the available data are few. To establish the carcass characteristics of SR slaughtered in the island, data were collected from eighty-five crossbred animals slaughtered at two abattoirs located in the western region of Puerto Rico (Lajas and Mayaguez), and included 57 sheep (40 females and 17 males) and 28 goats (17 females and 11 males) from different origins and raised under grazing conditions without supplementation. All animals evaluated were in the adult stage (determined by number of permanent teeth present) and had an average weight of 28kg at slaughter. Live and hot carcass weights were taken to calculate the dressing percentage.

A t-test for independent samples was performed for mean comparisons of the dressing percentage between species, sex and within the same species. The hypotheses tested were the following:

$$H_o: \mu_1 = \mu_2 , H_a: \mu_1 \neq \mu_2$$

Where:

H_o= null hypothesis

H_a = alternate hypothesis

μ_1 and μ_2= general means for sheep and goat variables evaluated for species comparison, or female and male variables evaluated for sex comparison.

The significance level used was p = 0.05. Results were compared to expected dressing percentage of SR slaughtered in temperate environments.

4.3 Effect of supplementation with a commercial concentrate feed on body weight gain, carcass characteristics, and meat quality of crossbreed weaned lambs and kid-goats.

4.3.1 Facilities, Animals and Management

The experiment was conducted in the Small Ruminant Project at the Alzamora Farm of the University of Puerto Rico, Mayagüez Campus (UPRM). Six weaned intact male crossbred kid-goats (BW=17.58 kg) and six weaned intact male crossbred lambs (BW=15.98) kg were used. These animals were obtained from commercial producers, and had been raised before weaning while grazing NTG without supplementation. Under the experimental conditions kids and lambs also grazed NTG and received grass hay. They were assigned in a completely randomized design to one of two additional feeding regimes; with (CC) or without (NCC) concentrate supplementation. Each treatment was replicated with three animals per species.

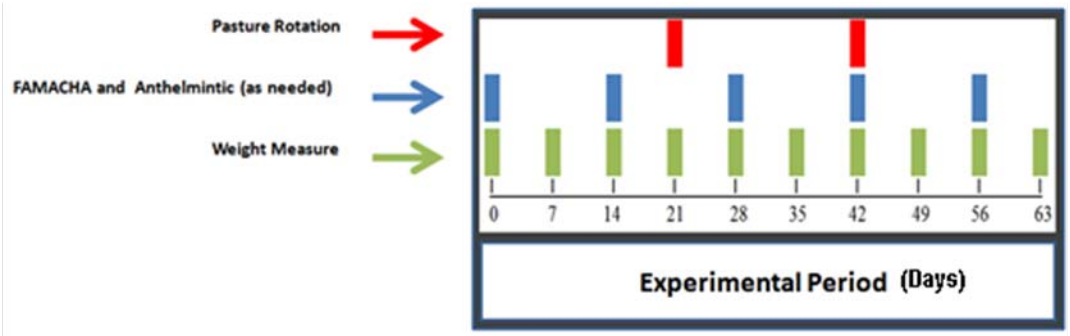

Figure 5. Management protocol during the feeding trial

The CC supplement was offered daily in the morning in individual feeders at the rate of 0.90% of animal BW on a dry matter basis (DMB) during 62 days (Figure 5). Animals had access to tropical grass pastures with swards composed mainly of guineagrass (*Panicum maximum*) for at least 6 hours of grazing during the day and were confined at night with *ad libitum* access to grass hay and water. Lambs and kid-goats were rotated among three paddocks (930, 1058, and 1333m^2) every 21 days. Prior to initiation of the feeding trial, animals were weighted, and orally dewormed with a commercial anthelminic. Body weight was taken at 0, 7, 14, 21, 28, 35, 42, 49, 56, and 62 days and weight gain was expressed on the total, weekly, and daily basis. Anemia status of the animals was evaluated every other week using the FAMACHA method to identify the need for individual anthelmintic treatment.

4.3.2 Forage and Feedstuffs Sampling

Random samples of the NTG vegetation available for grazing were taken from each paddock before grazing using a one square meter frame (1m^2). Samples for NTG hay from each new bale and concentrate feed bag were also taken for further analysis.

4.3.3 Carcass Characteristics and Meat Quality

At the end of the feeding trial the animals were harvested to evaluate carcass characteristics and meat quality. Harvesting was conducted after overnight fasting in a commercial slaughter-house located in Mayaguez, Puerto Rico. Measurements taken during the slaughter procedure included

live weight, hot carcass weight, and hind and fore trunk length. Data were used to calculate dressing and, hind and fore trunk percentages. For further meat quality characterization, the *longissimus dorsi* muscle of each carcass was dissected and individually frozen in a plastic bag.

4.3.4 Laboratory Analysis

4.3.4.1 Chemical Composition

Chemical composition analysis was performed in the Animal Nutrition Laboratory of the Department of Animal Industry. Samples of offered concentrate feed, hay, and pasture herbage were analyzed for contents of dry matter (DM), ash, crude protein (CP), neutro detergent fiber (NDF), acid detergent fiber (ADF), and lignin using standard procedures (Van Soest et al., 1991; AOAC, 2000)

Longissimus dorsi muscle samples were analyzed for moisture, fat and crude protein content. Moisture content was determined by weight loss of 15g samples oven dried for 48h at 60˚C. Fat content was determined using an ANKOM^{XT10} Extractor following the method described by the manufacturer. Crude protein content was determined by the micro-Kjeldahl method as described by AOAC (2000).

4.3.4.2 pH and color

The *longissimus dorsi* pH was measured in each muscle sample using a pH-meter equipped with a penetrating electrode and a temperature-sensitive pH adjuster. The *longisimus dorsi* muscle color was determined on the fat free surface with a Minolta colorimeter. All measurements were taken in triplicate for each muscle sample.

4.3.5 Experimental Design and Statistical Analysis

The experiment had a Completely Randomized Design with three observations per treatment within each species. Data were analyzed using the General Lineal Model of SAS (SAS Institute, 1994). The model used was as follows:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_i$$

Where:

Y_{ij} = dependent variable (growth performance, carcass characteristics, meat quality and chemical composition)

μ = estimated general mean

α_i = treatment effect

ε_i = experimental error

A t-test for mean comparisons of all the dependent variables in each treatment within each species. The hypotheses tested were the following: Ho: $\mu_1 = \mu_2$, Ha: $\mu_1 < \mu_2$. The significance level used was $p = 0.05$.

5 Results

5.1 Descriptive analysis of the small ruminant meat types offered at retail in the supermarkets of Puerto Rico

A high proportion (94%) of the surveyed SM were offering SRM in 2007, but a decrease to 79% occurred the following year (2008) (Table 3, Figure 6). Then, a pattern of slight increase to 82% and a return to 79% was observed for 2009 and 2010, respectively. A similar pattern can be observed in the amount of SRM imports reported for those years (Oficina de Estadísticas Agrícolas. Departamento de Agricultura. Compendio Estadístico 2008) (Appendix 2). The higher offer of SM in 2007 compared with the following years represented an extension of the peak in consumption reported for SRM in 2005-2006 (Oficina de Estadísticas Agrícolas. Departamento de Agricultura; Agricultural Census 2007).

Table 3. Frequency of the offer of small ruminant meat in the supermarkets during the four years 2007 through 2010

	Year			
Frequency	**2007**	**2008**	**2009**	**2010**
Not offered	5	13	16	32
Offered	78	48	71	118
Total	83	61	87	150

Figure 6. Percentage of the supermarkets surveyed offering SRM for sale for years 2007 through 2010

During all of the four years studied, the proportion of the supermarkets surveyed offering SRM was 79% or above, suggesting that there is strong consumer demand for these products in Puerto Rico (Figure 6). In 2010 the contribution of each AR to the total number of SM selling SRM was highest in the case of the San Juan region (Figure 7). Nearly one-half (47%) of the SM selling SRM were estimated to belong to the AR of San Juan. This region is composed of municipalities of the metropolitan area in which 1/3 of the population of the island lives. Furthermore, the population of this area is diverse and in general has a high purchasing capability. Also present is a highly developed gourmet sector which is scarcely found in the rest of the island.

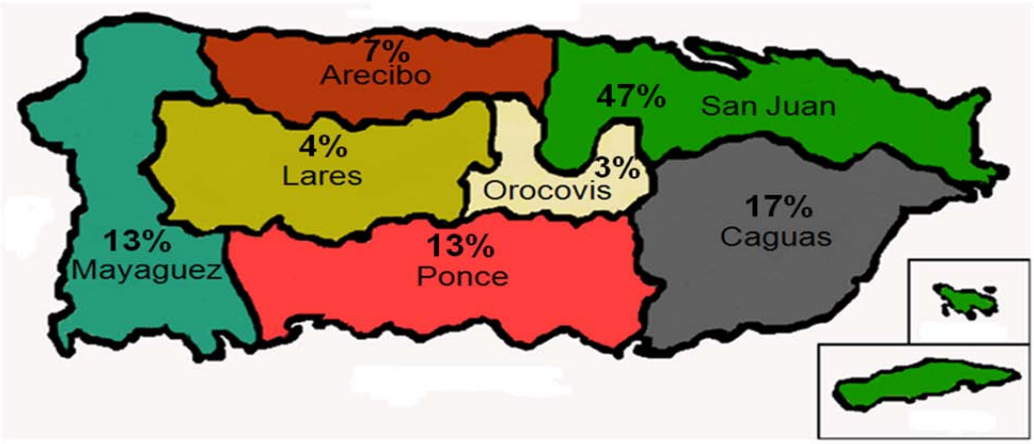

Figure 7. Estimated percentage contribution of each AR to the total number of SM in Puerto Rico that sold SRM in 2010

The proportion of total sellers of SRM in Puerto Rico represented by SM of the two types distinguished favored the chain establishments in all four years of the study, with values ranging from 54 to 66%, and showing an upward trend in time (Figure 8).

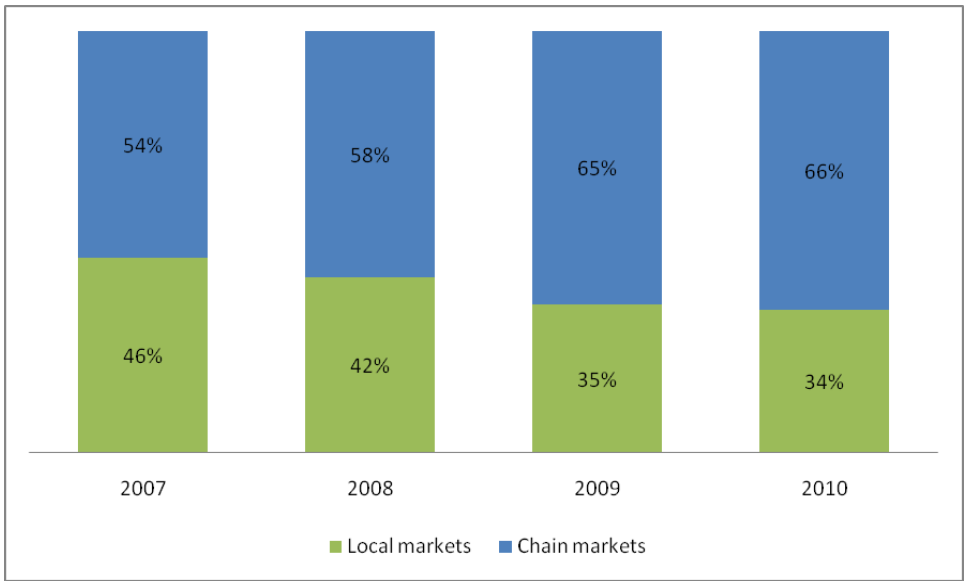

Figure 8. Proportion of total sellers of SRM represented by each type of supermarket for years 2007 through 2010

Most of the SM that sold SRM, offered only chevon meat, a smaller number offered sheep meat solely, whereas a few offered meat from both species (Figure 9). These findings are consistent with the higher imports of goat meat during recent years, mainly from Australia, which is considerably lower in price than sheep meat (Oficina de Estadisticas Agricolas. Departamento de Agricultura. Compendio Estadístico, 2008). However, most of the SM selling sheep meat mainly offered special cuts of lamb. This product is expensive and is only consumed by specific gourmet sectors. Therefore, its offer is much less frequent than that of goat meat. Additionally, a considerable part of the population of Puerto Rico perceives sheep meat as being tough, which decreases its acceptance and consumption. Most of the respondents were not able to specify if the offering of sheep meat was mutton or lamb, nor if that of goat meat was chevon or kid.

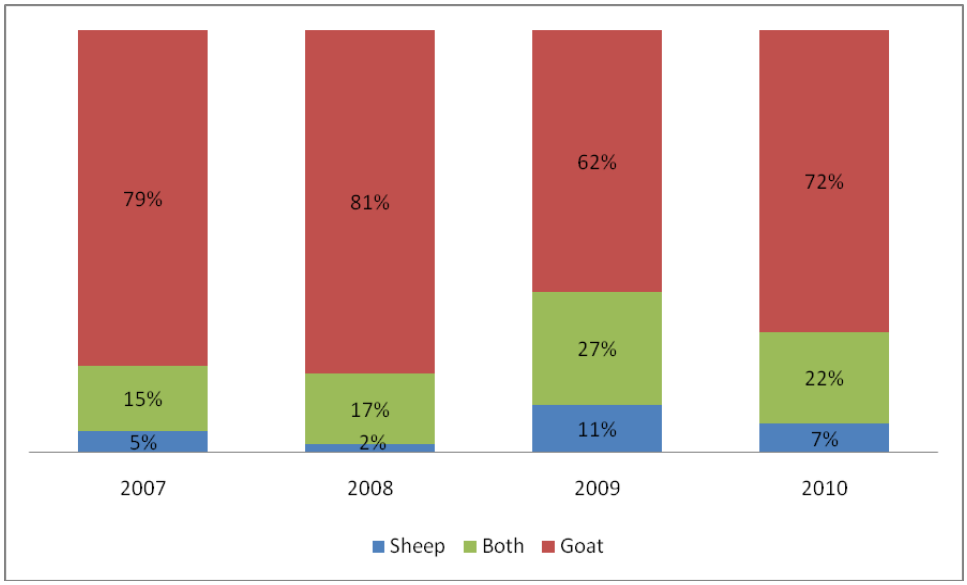

Figure 9. Proportions of total supermarket sellers of SRM that offer meat of each specie for years 2007 through 2010

Of the SM surveyed, most offered SRM of imported origin only, a smaller proportion offered local meat only and a still smaller proportion offered meat from both origins (Figure 10). This is consistent with the higher sales of SRM during recent years in contrast to declining local production shown in official statistics (Appendix 2). This trend can be attributed to the lower

prices of sheep and goat meats from the USA and Australia, which commonly cost about half the price of the locally produced SRM. The higher price of the local product is attributed in large part to the high cost of raising the animals and processing their meat as compared with other competing countries.

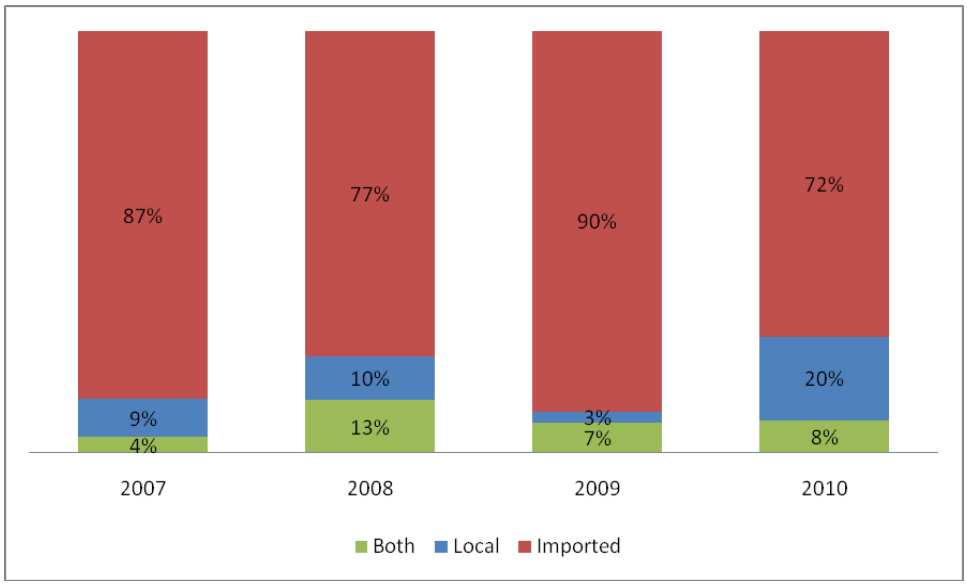

Figure 10. Proportions of total supermarket sellers of SRM that offered local or imported meat or both for years 2007 through 2010

Most of the respondents did not want to offer any information regarding the amount of meat that the SM bought annually, the prize paid or the name of the distributor/supplier. Nevertheless, respondents said that imported goat meat was mainly from Australia, while sheep and lamb meat was mainly from the USA. The prominence of imported SRM follows logically from its much lower price (Foreign Trade Statistics. U.S. Department of Commerce, 2004). The higher cost of local production of SRM puts it at a competitive disadvantage relative to meats imported from abroad. Some respondents specified that imported goat meat was supplied in boxes as quarter carcasses whereas sheep meat was mainly supplied as special cuts.

Most of the sellers described sales of the product as steady at a medium level most of the year with increases during certain holiday seasons due to ethnic preferences. Another important

observation was that often the label did not match the species that was offered for sale. Some sellers confided in the surveys that they label the packages as sheep or goat meat depending on demand even though they have meat from only one of those species to offer.

Because there are no quality or yield grades to classify the local meat, most of the product offered in the SM surveyed was cut into cubic pieces (stew or "fricase") from the entire carcass. This practice combined with the lack of distinction between sheep and goat meat results in a product of inconsistent quality in detriment to the interests of local production.

5.2 Data base of the carcass characteristics of small ruminants harvested under traditional feeding management in Puerto Rico

Results from the previous section (surveys) indicate that during recent years (2007-2010) SRM have been sold in local and chain SM around the island and that those selling local SRM only accounted for 3-20% of the total sellers for the years surveyed. In order to promote increased SRM production in Puerto Rico it is necessary to identify the type of animal presently being grown and slaughtered on the island and its carcass characteristics.

The average live weight (LW) of animals providing data for the present study was 29.63 and 28.28 kg for sheep and goats, respectively (Table 4). Dressing percentage was highly variable in both cases, ranging from 38 to 40%, and 34 to 38% for the two species in the same order. The average dressing percentage for goats observed in the present study is comparable to the value of 37% reported for intact male Sidama goats in Etiopia under *ad libitum* grass hay feeding solely (Solomon et al., 2008). However, this dressing percentage is relatively lower than those reported by several authors for indigenous and crossbred goats under similar conditions. A study in Norway a reported dressing percentage of 55% for small east African goats fed with low quality grass hay only (Safari et al., 2009). Similarly, a dressing percentage of 43% was reported for Neuquen Criollo Kids in Argentina (Zimerman et al., 2008); and 43% also in Maryland, USA

(Schoenian, 2009) for animals grazing natural grasses. In a more comparable condition, Liméa et al. (2009) reported a dressing percentage of 42% for Creole goats (indigenous Caribbean type) fed tropical forage only in Haiti. For sheep, the average dressing percentage observed in the present study is lower than those reported by Karim et al. (2006) for Kheri lambs in India and Santos et al. (2008) for sheep of a native Portuguese breed grazing natural pastures.

Table 4. Carcass yield for sheep and goats slaughtered after being raised under extensive conditions in Puerto Rico

	Specie		
Variable	**Sheep (57)**	**Goat (28)**	**SEM**[1]
Live weight (kg)	28.28	29.63	4.67
Hot carcass weight (kg)	11.50	11.01	2.35
Dressing %	40.11[a]	36.08[b]	1.27

[1]Standard Error of the Mean

Dressing percentages reported for sheep and goat carcasses under tropical conditions have been very variable and lower than those reported with meat-type animals raised under intensive conditions. One important fact in this regard is that there are different types of crossbreds, some of which, depending on the genotype, are more suitable as meat-type animals than others. The literature indicates dressing percentages as high as 49 to 55 for ideal meat- type sheep and goats (Shackelford et al., 2006; Burke et al., 2007).

The SR included in the present study did not showed suitable meat-type characteristics. They did not yield a fat carcass, which partially explains the low dressing percentage, since carcasses fatness has an important effect on dressing percentages (Boggs and Merkel, 1993). Additionally, the late stage of maturity of most of the animals in the present study could result in more compact carcasses and lower dressing percentages (Marichal et al., 2003; Zimerman et al., 2008). Other factors such as presence of wool and horns in the animals evaluated tend to negatively affect the dressing percentage. Finally, feeding of SR in tropical regions consists mainly of grazing NTG and shrubs without management of the amount of available forage to meet animal

nutritional requirements. This combination of negative factors explains a large part of the typically poor performance of SR for meat in Puerto Rico.

Table 5. Carcass yields of female and male small ruminants slaughtered after being raised under extensive conditions in Puerto Rico

Species	Variable	Female	Male	SEM[3]	*P*
Sheep[1]	Live weight (kg)	28.19	28.49	2.62	0.934
	Hot carcass weight (kg)	11.23	12.13	1.33	0.635
	Dressing %	39.62	41.24	1.91	0.484
Goat[2]	Live weight (kg)	31.15	26.76	3.80	0.258
	Hot carcass weight (kg)	11.56	9.85	1.90	0.388
	Dressing %	36.30	35.74	1.68	0.402

[1]n = 40 females, n = 17 males
[2]n = 16 females, n = 11 males
[3]Standard Error of the Mean

Comparing the two species, there were no differences in average LW and hot carcass weight (HCW) between sheep and goat. However, dressing percentage of sheep was higher ($p<0.05$) than that of goats (Table 4), which can be attributed to the smaller carcasses and poorer carcass conformation typical of goats at a comparable age (Webb et al., 2005). This is in agreement with other authors who reported differences in comparative studies of the two species (Santos et al., 2008).

In this study there were no differences in LW, HCW, and dressing percentage between sexes of either species (Table 5). These results are in agreement with the findings of Jimenez-Badillo (2008) and Santos et al. (2008) who reported that sex did not affect carcass measurements of kid-goats. This was attributed to the fact that under tropical conditions potential effects of sex on carcass characteristics at the same stage of maturity are not expressed because of the low level of management (Santos et al., 2008). In general, males show more developed carcasses than

females in both species when management levels permits (Boggs and Merkel, 1993; Peña et al., 2005).

5.3 Effect of supplementation with a commercial concentrate feed on body weight gain, carcass characteristics, and meat quality of weaned lambs and kid-goats

Chemical composition of the feedstuffs used in the present experiment is shown in Table 6. These results indicate that the NTG hay and pasture fed were not adequate to support optimum SR production, because of their low CP content. It is well documented that an equivalent of 8-12% CP is required for normal growth of ruminant animals (Van Soest, 1994). As expected, NTG (hay or fresh foliage) fed in this experiment had high cell wall and low CP contents. Similar values have been reported for forages harvested in tropical climates (Liméa et al., 2009).

Table 6. Chemical composition of the feedstuffs offered to lambs and kid-goats during the experimental period

Component (%)	Concentrate	Hay	Pasture
Dry Matter	93.5	93.1	93.1
Organic Matter[1]	95.9	93.8	93.3
Inorganic Matter[1]	4.1	6.2	6.7
Crude Protein[1]	18.2[a]	5.7[b]	5.8[b]
Neutral Detergent Fiber[1]	29.2[a]	71.2[b]	74.3[b]
Acid Detergent Fiber[1]	11.3[a]	46.9[b]	49.1[b]
Hemicellulose[1,2]	17.9[a]	24.3[b]	25.2[b]
Lignin[1]	-	6.2	6.5

Means in the same row followed by different letter differ significantly ($P < 0.05$)

[1]Dry Matter Basis, [2]Calculated by difference (NDF-ADF)

The nutritional requirements for growing lambs and kid-goats exceed the levels of nutrients supplied by the two forages even at high levels of intake. Therefore, supplementation is required to achieve desirable levels of production. In Puerto Rico, the use of CC as supplements for growing SR is a common practice among sheep and goat producers. However, there is limited information on the effects of CC supplementation on lamb and kid-goat performance.

5.3.1 Growth performance of lambs and kid-goats

Supplementation with CC increased ($p<0.05$) total and daily BW gain in lambs (Table 7) by 2580 and 40g when compared to non supplemented animals. The consistent positive weekly LW change observed in supplemented lambs indicates that the diet provided more nutrients than needed for the maintenance requirements of the lambs (Figure 11). By contrast, non-supplemented lambs showed inconsistent weekly LW gains. Even though there was an overall increase in LW, weight losses were observed during some weeks of the experimental period. Erratic LW changes in non-supplemented animals may reflect variation in quality of the pasture herbage available for grazing that together with the grass hay did not meet the minimum CP (8-12%) and energy (0.96 Mcal/kg) requirements necessary for maintenance (ENm) and LW gain. Daily LW gain for lambs was 33 and 73g for non-supplemented and supplemented animals, respectively.

Table 7. Lamb body weight responses to the two treatments

Variable	Control	Supplemented	SEM[1]	P
Initial body weight (kg)	18.18	16.97	2.31	0.63
Final body weight (kg)	20.15	21.52	2.71	0.64
Total body weight gain (g)	1966.7[a]	4546.7[b]	606.06	0.01
Average daily gain (g)	33.3[a]	73.3[b]	9.62	0.02

Means in the same row followed by different letter differ significantly ($P < 0.05$)
[1]Standard Error of the Mean

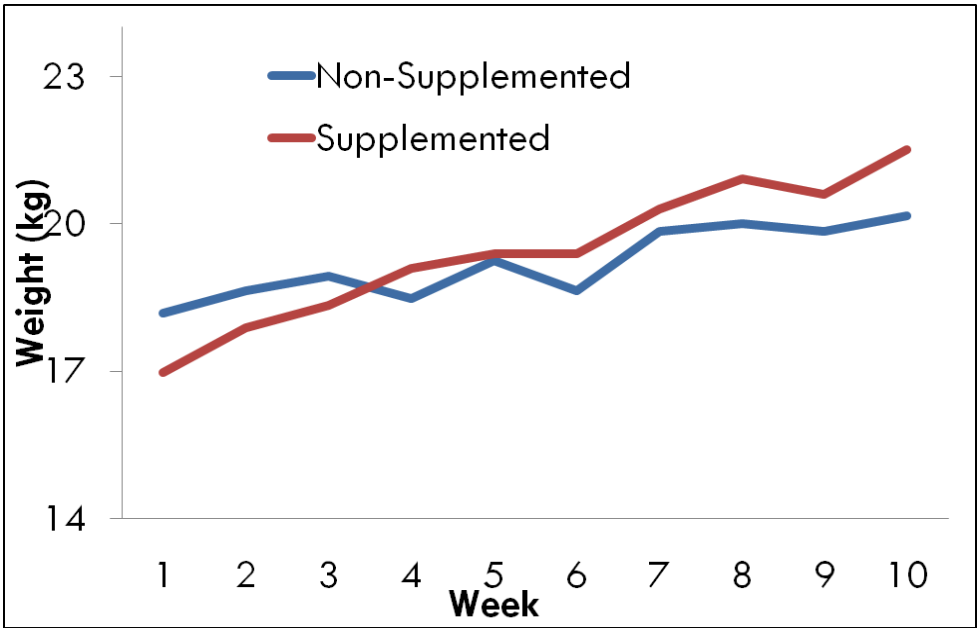

Figure 11. Weekly body weight change of lambs during the feeding trial

Average rate of daily gain obtained in this experiment with supplementation was equal to and lower than those reported by Karim et al. (2006) of 73 and 161g for lambs raised under extensive and semi-intensive management respectively. There is a marked effect of breed on ADG (Schilling, 2005). Low values (between 50-60g) during growth are common in native breeds of lambs under semi-intensive management, whereas with intensive feeding such lambs have attained 170g (Karim et al., 2006).

Total and daily BW gain in kid-goats was not different ($p>0.05$) between treatments (Table 8, Figure 12). However, supplemented kids showed numerically higher values by wide margins. Daily BW gains were 34 and 67g for non-supplemented and supplemented kid-goats, respectively. The latter finding agrees with previous work in which daily BW gain in supplemented goats did not exceed 65g (Solomon et al., 2008). Some authors attribute the low response of goats to supplementation to some inherent characteristics of the specie, which consistently lowers growth rates below those of other domestic livestock species (Schilling, 2005). Goats tend to have a high propensity to eat selectively which limits their forage intake

under grazing conditions (Rojas et al., 1984; Haenlein, 2001); and a rapid digestive rate (Haenlein, 2001) that may affect nutrient utilization. These characteristics can explain in large measure their lower performance compared to sheep under similar conditions. In addition, goats of most breeds exhibit a significantly smaller mature body size and weight than sheep, which is accompanied by slower growth. This difference could involve the increased frame size of sheep compared to goats (Mc Dowell and Woodward, 1982).

Table 8. Goat body weight responses to the two treatments

Variable	Control	Supplemented	SEM[1]	P
Initial body weight (kg)	15.76	16.21	2.25	0.85
Final body weight (kg)	17.88	20.45	2.76	0.40
Total body weight gain (g)	2123.30	4243.30	1329.50	0.19
Average daily gain (g)	33.30	66.70	21.11	0.21

[1]Standard Error of the Mean

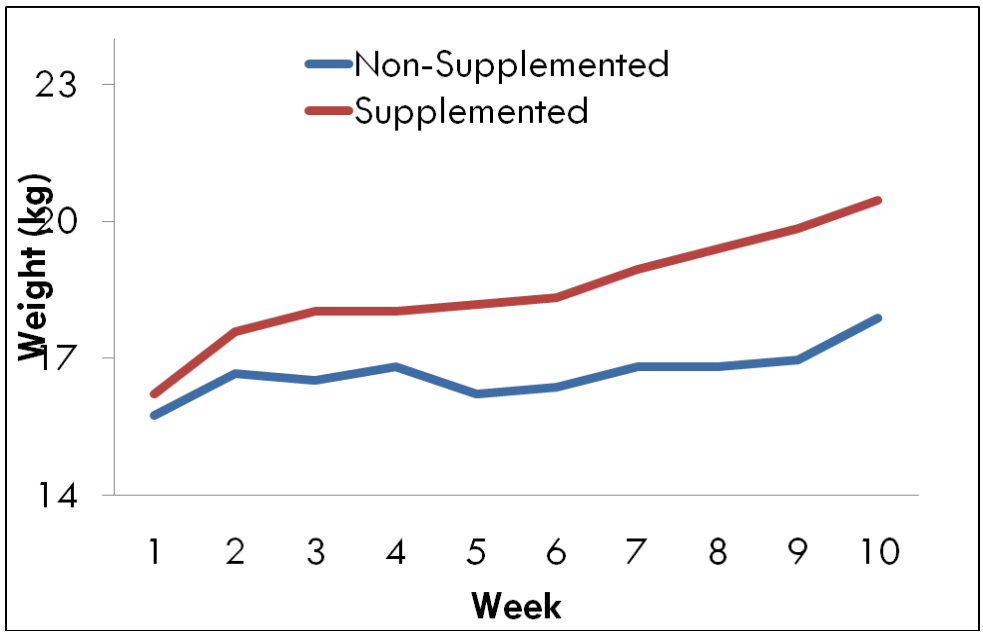

Figure 12. Weekly body weight change of kid-goats during the feeding trial

In addition to the low quality of NTG there are other factors that might have contributed to the poor performance observed in the present study, one of which could be the high mean temperature and other environmental conditions (i.e. precipitation, humidity, solar radiation) under which the study was performed that might be out of the comfort zone of the animals. This, along with the low genetic potential could lower feed intake and thus decrease performance.

5.3.2 Carcass characteristics of lambs and kid-goats

Carcass weight, dressing percentage, and fore and hind trunk percentages in lambs did not vary ($p>0.05$) with the addition of the concentrate supplement (Table 9). Dressing percentage was 30.86% and 32.37% for control and supplemented lambs, respectively. Certain other authors also reported that supplementation with concentrate feed did not significantly affect dressing percentage (Manso et al., 1998; Solomon et al., 2008). However, in some cases relatively higher dressing percentages have been reported for lamb and kid-goats that grazed native grasses with concentrate supplementation under tropical conditions. Dressing percentages of 45% were reported for Kheri lambs under extensive range management (Karim et al., 2006) and of 49% for Portuguese native breed lambs grazing natural pastures (Santos et al., 2008).

Table 9. Effects of CC supplementation on Lamb carcass characteristics

Variable	**Control**	**Supplemented**	**SEM[1]**	***P***
Hot carcass weight (kg)	6.21	6.97	0.90	0.45
Dressing %	30.86	32.36	1.11	0.25
Fore trunk %[2]	46.14	45.88	2.92	0.93
Hind trunk %[2]	53.86	54.12	2.92	0.93

[1]Standard Error of the Mean
[2]Percentage of the total length that corresponds to this trunk section

Table 10. Effects of CC supplementation on Kid-goats carcass characteristics

Variable	**Control**	**Supplemented**	**SEM[1]**	***P***
Hot carcass weight (kg)	5.00	6.89	1.04	0.14
Dressing %	28.11	33.59	2.98	0.14
Fore trunk %[2]	48.12	48.58	1.21	0.72
Hind trunk %[2]	51.88	51.42	1.21	0.72

[1]Standard Error of the Mean
[2]Percentage of the total length that corresponds to this trunk section

The supplemented animals were expected to show a higher dressing percentage due to improved nutrition. However, results have been very inconsistent regarding the effects of supplementation with concentrate feed on carcass traits. In agreement with the present study, Manso et al. (1998) reported that carcass weight or dressing percentage were not different between Merino lambs fed barley as the sole diet and those supplemented with different protein sources; and Solomon et al. (2008) reported no difference in dressing percentages with increasing daily levels (200g, 300g and 400g) of concentrate feed. This reiterates the fact that factors other than adequate nutrient supply may have a strong influence on the magnitude of response to supplementation (Chalupa, 1975). In other studies, dressing percentage increased with higher slaughter weight (Manso et al., 1998). Karim et al. (2006) reported higher dressing percentage in Kheri lambs under intensive feeding with *ad libitum* concentrate supplemented compared to those under extensive grazing.

Similarly, there were no significant differences ($p>0.05$) in carcass characteristics between supplemented and non-supplemented kid-goats (Table 10). However, dressing percentage which was 28.11 and 35.59 for control and supplemented animals respectively, did show a numerical difference of 7.48 in favor of supplementation. Other authors have reported dressing percentages in the range of 37-47 for indigenous and crossbred goats fed with low quality hay and grazing natural grasses (Santos et al., 2008; Limea et al., 2009; Schoenian, 2009).

Dressing percentage in the present study was similar ($p>0.05$) between the two species, in spite of the fact that goats tend to have lower dressing percentage than sheep of comparable age (Webb et al., 2005) as a result of poorer carcass conformation (Santos et al., 2008). However, differences between sheep and goat are minimized under semiarid conditions (Sen et al., 2004). Fore and hind trunk percentages were similar ($p>0.05$) for animals within the same species regardless of the treatment. However the proportion of hind trunk cuts in goats was lower than that in sheep of comparable carcass weight, in agreement with Santos et al. (2008).

The dressing percentages in this experiment were lower than those of the SR harvested in the western region of Puerto Rico mentioned above. Animals in the present study were in an early stage of maturity, which coincides with very poor carcass conformation, whereas those evaluated in the data base had already reached their mature carcass conformation.

5.3.3 Chemical composition of the meat and meat quality

5.3.3.1 Chemical composition

Moisture content was higher and CP and fat contents were lower, but not significantly ($p>0.05$) in *longissimus dorsi* muscle of control compared with supplemented animals regardless of species (Table 11). These results agree with other reports of minimal or no differences in carcass composition with the inclusion of supplemental dietary protein (Wilson et al., 1972; Lee et al., 2008). However, other authors have reported increases in these carcass components with increased dietary protein concentration (Kemp et al., 1976). This discrepancy in experimental results may be due to factors such as solubility of the protein, interaction of protein with other nutrients and dietary protein concentration that can negatively affect the utilization of ingested protein (Murphy et al., 1994; Bach et al., 2005). Wilson et al. (1972) noted an increase in *longissimus dorsi* protein concentration accompanying increased carcass weight. Accordingly, in the present study, the similar slaughter weight of both species resulted in similar carcass composition.

Table 11. Chemical composition of *longissimus dorsi* muscle of lambs and kid-goats from the two treatments

Specie	Variable[1] (%)	Control	Supplemented	SEM[2]
Lamb	Moisture	79.58	77.18	1.65
	Protein	16.16	19.33	1.33
	Fat	4.73	5.56	0.72
Kid-goat	Moisture	79.43	77.07	1.91
	Protein	17.75	19.28	1.65
	Fat	3.07	3.90	0.90

[1]Dry Matter Basis
[2]Standard Error of the Mean

The carcass protein contents found in the present study are similar to those previously reported for lambs and kid-goats (Manso et al., 1998; Werdi et al., 2007; Jabbar et al., 2008). The present carcass fat contents for lambs and kid-goats are also comparable to some previous findings (Murphy et al., 1994). However, other authors reported higher fat contents than those in the present study (Jabbar et al., 2008; Cameron et al., 2001) due to a higher energy density in the diet. High energy diets lead to an increase in ruminal propionate production, which after absorption stimulates fat synthesis. Therefore, reduced carcass fatness in the present study could be associated with several dietary factors including energy source and density. Likewise, the low LW at slaughter may have reduced the differences in carcass component concentrations, since lighter animals are generally leaner. Contrary to the present study, Werdi et al. (2007) reported that supplementation with concentrate feed lowered carcass fat content in grazing goats. The higher fat content obtained with supplementation in the present study may have been caused by the fact that the diet provided less available protein in relation to energy for tissue protein synthesis, resulting in more energy being deposited as fat (Manso et al., 1998). This difference could also be partially due to breed type. It has been suggested that animals with lower growth rate potential, like those used in the present study, have a higher percentage of intramuscular fat than fast-growing animals (Murphy et al., 1994).

Carcass moisture and protein contents were not different ($p>0.05$) between species; however, fat content was numerically lower for kid-goats (Table 12). This difference is due to the fact that goats tend to store a great proportion of their body fat internally, rather than subcutaneously or intramuscularly, thus producing carcasses which are leaner than those of sheep of similar ages (El Khidir et al., 1998). Likewise, fat development in goats occurs very late in maturity (Dhanda et al., 1999).

5.3.3.2 pH and color

No significant differences were found in the pH values of *longissimus dorsi* muscle between supplemented animals and those fed forage solely; however, the latter showed a numerically higher pH (Table 12). High pH values for SRM are consistent with the findings of several

authors (Werdi et al., 2007; Safari et al., 2009). The high pH found in meat from sheep and goats reflects their high susceptibility to stress (Webb et al., 2005), that results in a depletion of muscle glycogen (Dhanda et al., 2003). Similar to the present results, previous studies suggest that meat from forage-fed animals has higher pH values than that of grain-fed animals (Muchenje, et al., 2008), since the former have lower glycogen reserves due to nutritional insufficiencies (Safari et al., 2009). Therefore the high pH values in the present study could be partially attributed to a low plane of nutrition of the animals. A high muscle pH (above 5.8) occurs as a result of depleted levels of glycogen and is generally associated with darker meat color (Lawrie, 1991). When the muscle glycogen has been used up rapidly during the handling, transport, and pre-slaughter period, there is little lactic acid production after slaughter which results in Dark-Firm-Dry (DFD) meat. However, pH variations must be of a certain magnitude in order to affect the quality of the meat (Safari et al., 2009). Therefore hydrogen ion concentration in the present study was not sufficiently high to produce DFD. This conclusion was supported by the high L* value found.

The dietary treatment had a significant ($p<0.05$) influence on the *longissimus dorsi* muscle L* value of lambs, but not on the a* and b* values. The said muscle color was lighter (higher L* value) in the supplemented animals than in those fed only grass. The darker color (low L* values) in non-supplemented animals may be attributed to a decreased muscle glycogen as mentioned above. These results are in agreement with reports of other authors that forage-fed animals have darker colored meat than grain-fed ones (Priolo et al., 2002; Lee et al., 2008; Muir et al., 1998), due to the higher pH values found in meat from the former. However, other authors did not find such differences in meat pH between forage-fed and grain-fed or found lighter color for meat from concentrate-fed steers (French et al., 2000; Razminowicz et al., 2006; Lee et al., 2008). No differences in b* coordinates were found between the supplemented and non-supplemented treatments in the present study probably because marked differences due to different dietary combinations of forage-concentrate do not develop over a short period of time (French et al., 2001). Likewise, differences in meat quality caused by dietary effects are diminished when animals are harvested at light weights. Other authors reported that animals fed

on pasture solely have more yellowness (higher b* value) because of the high levels of beta-carotene contained in the grass (Muchenje et al., 2009).

When comparing meat from lambs and kids, the latter showed lower lightness and higher redness because of the lower intramuscular fat of their carcasses. However, consumers cannot readily perceive the differences in meat color between these two species (Lee et al., 2008).

Table 12. pH and color parameters of *longissimus dorsi* muscle of lamb and kid-goat carcasses from the two treatments

Specie	**variable**	**Control**	**Supplemented**	**SEM[1]**	***P***
Lamb	pH	6.02	5.66	0.35	0.367
	L*	41.70[a]	50.42[b]	1.42	0.002
	a*	11.08	10.85	0.48	0.661
	b*	10.85	9.93	0.46	0.114
Kid-goat	pH	5.94	5.59	0.25	0.233
	L*	33.95	38.18	1.00	0.013
	a*	16.18	14.66	0.66	0.083
	b*	9.66	10.31	0.40	0.182

Means in the same row followed by different letter differ significantly ($P < 0.05$).
[1]Standard Error of the Mean

6 Conclusions

Over the four years studied (2007-2010), the proportion of SM surveyed that offered SRM for sale was 79% or higher, thus the SRM enterprise has the benefit of a well established market. The frequency of offer is highest in the AR of San Juan and most SM offer goat meat only. Sellers of SRM can seldom specify if the goat meat they sell is chevon or kid, or if the sheep meat is mutton or lamb. The level of offer can be characterized as average, but demand increases during certain holiday seasons due to specific ethnic preferences.

SR slaughtered commercially in Puerto Rico were shown to have highly variable dressing percentages (observed values ranged from 37 to 46 for sheep, and 32 to 38 for goats), the mean values favoring sheep (39.6 vs. 36.3 in females and 41.2 vs. 35.7 in males). Overall sex had little effect on this variable.

Tropical grass pastures and hay used in the present feeding trial (lower than 6% in CP, higher than 70% in NDF) did not support adequate animal growth when fed as the sole diet.

Supplementation with CC increased rate of BW gain significantly ($p<0.05$) in lambs and numerically in goats above non-supplemented controls. Dressing percentage, and fore and hind trunk percentages of the carcass did not vary between treatments for either species. Lower pH and moisture content and higher CP and fat percentages of *longissimus* muscle were trends observed in supplemented animals relative to control. However, supplementation was more effective in increasing rate of gain of the animals than in improving the characteristics of the carcass or the meat composition during the relatively short duration of this study.

7 Implications and Recommendations

Small ruminant meat has a ready market in Puerto Rico and raising of SR could become an economically viable enterprise. However, the supply of local meat is poor. The lack of a grading system to standardize the meat and the lack of distinction between sheep and goat meat result in a product of inconsistent quality being offered for sale. Studies of consumer preferences, niche markets, and demand elasticity should be performed in order to improve marketing strategies. All of these efforts should be accompanied by consumer education regarding the positive nutritive attributes of locally produced SRM.

Factors such as poor pasture quality and low genetic potential of the animals might negatively affect performance under CC supplementation. Selection for improved genotypes as well as investigations on alternative, less-expensive feed sources for finishing meat-type animals, would contribute to improving quantity and quality of local SRM.

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Appendix 1

University of Puerto Rico
Mayaguez Campus
Faculty of Agricultural Sciences
Department of Animal Industry
Small Ruminant Production Course

Small Ruminant Meat Offer in Puerto Rico

Questionnaire

Date: _____

Name of supermarket: _____

Municipality: _____

Local [ ] or Chain [ ] supermarket

The supermarket sells sheep or goat meat? [ ]Yes [ ]No

If sheep is offered, what type describes the product? [ ] Lamb [ ]Mutton

If goat is offered, what type describes the product? [ ] Kid-goat [ ]Chevon

How would you describe the sales of the product [ ]Low [ ]Medium [ ]High

What amount of small ruminant meat the supermarket buys annually (lb/year)?

What cuts are bought? [ ]Carcasses [ ]Special/Mayor cuts

What is the origin of the meat sold? [ ]Local [ ]Imported

Who is the producer/distributor of the meat sold?

What is the selling price of meat of the producer/distributor?

What is the selling price of meat of the supermarket?

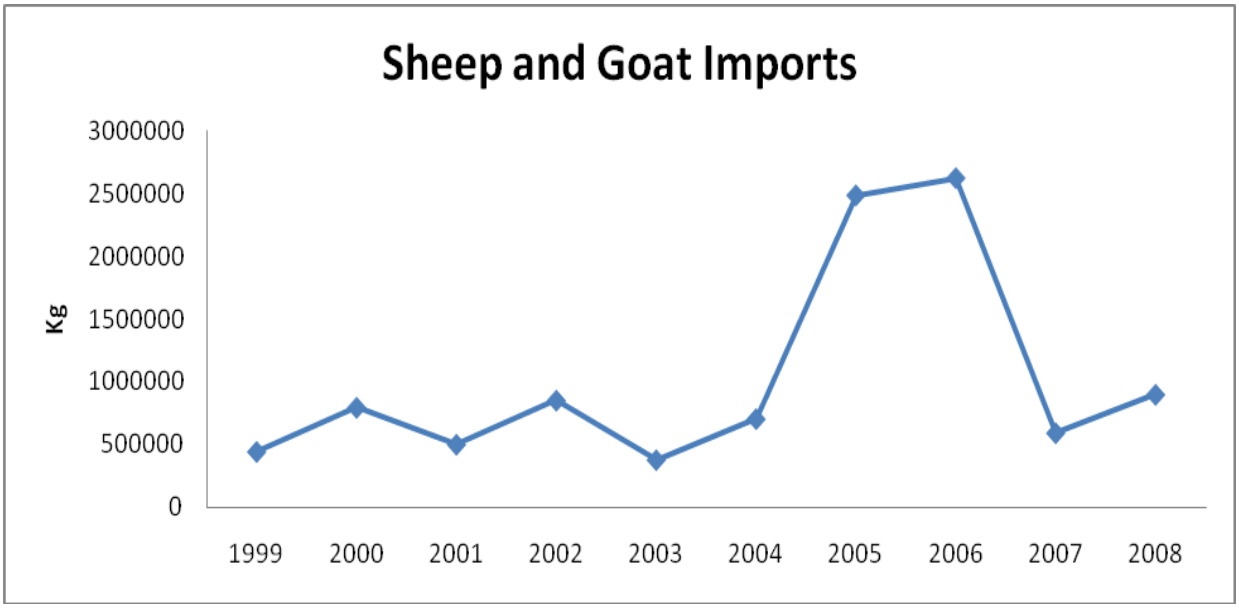
Other comments:

_____

_____

_____

Appendix 2


Sheep and Goat Imports
Kg
3000000
2500000
2000000
1500000
1000000
500000
0
1999
2000
2001
2002
2003
2004
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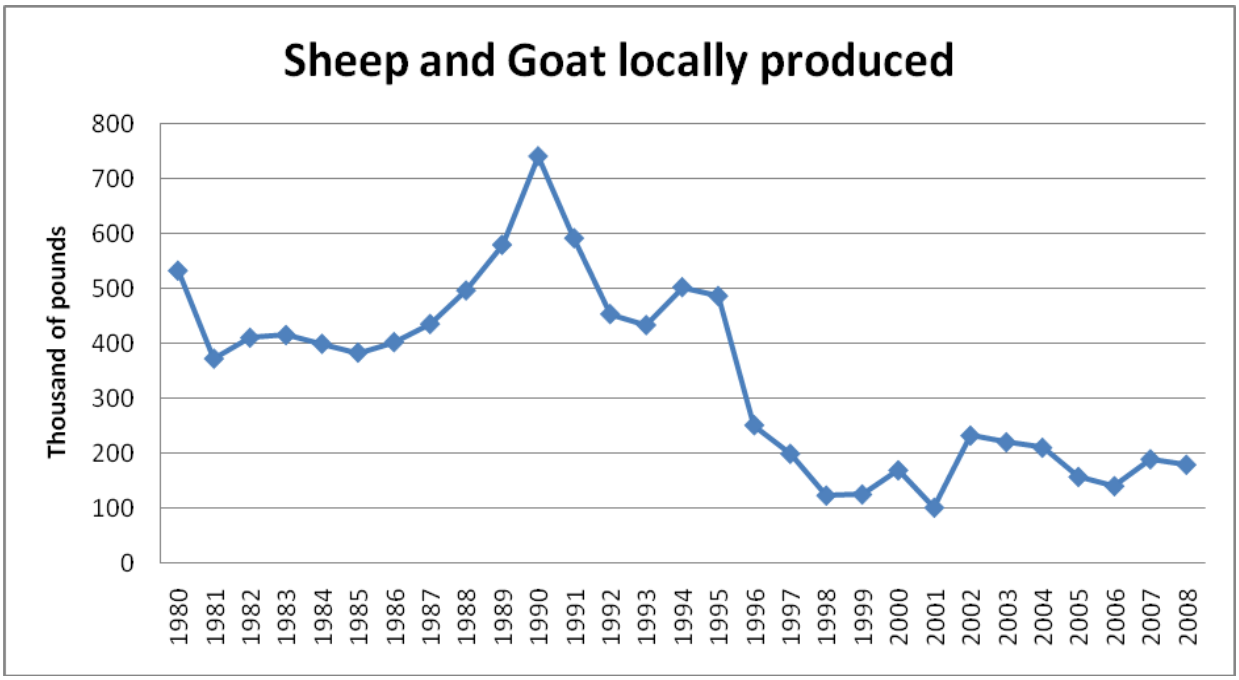
2006
2007
2008


Sheep and Goat locally produced
Thousand of pounds
800
700
600
500
400
300
200
100
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
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