Journal of Animal and Veterinary Advances 8 (12): 2655-2661, 2009
ISSN: 1680-5593

Energy Retention of F1 Pelibuey Lambs Crossed with Breeds for Meat Production

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Abstract: Energy retention was estimated in F1 crossbred male lambs from different genotypes: Pelibuey x Pelibuey (PbPb), Black Head Dorper x Pb (BHDPb), White Dorper x Pb (WDPb) and Katahdin x Pb (KdPb). The energy retention was estimated by the amount energy stored in the carcass. Forty eight lambs were used with an average Live Weight (LW)±SD of 19.6±3 kg, which were given a basal diet for 21 days. At the end of this stage, three lambs of each genotype were measured the thickness of subcutaneous fat between 12th and 13th Dorsal Vertebra (DVF) with ultrasound and were weighed and slaughtered to determine the initial energy in the carcass. The rest of the animals (36), were distributed in a complete randomized design with a 4 ×3 factorial arrangement: 4 genotypes and 3 dietary Metabolizable Energy (ME) concentrations (2.2, 2.5 and 2.8 Mcal kg^{-1} DM). At the end of the experiment, all animals were measured the DVF with ultrasound and were weighed and slaughtered to determine the Final Energy in the Carcass (FEC). The KdPb had a higher Weight of Internal Fat (WIF), Energy Retained in Internal Fat (ERIF) and Total Energy Retained (TER) ($p<0.01$-0.05). The animals fed diet with 2.8 Mcal ME kg^{-1} DM, had a higher LW, carcass weight, WIF, FEC, Energy Retained in the Carcass (ERC), ERIF and TER ($p<0.05$). A higher relation was observed between the average daily gain, ME intake and TER ($p<0.001$). We conclude that higher energy retention of KdPb, is the result of highest accumulation of internal fat that they have.

Key words: Lambs, genotypes, energy levels and energy retention, DVF, slaughtered, Mexico

INTRODUCTION

Sheep production in Mexico is considered within the livestock sector as the activity that has had the greatest development in recent years, so it has grown by 40% compared with other livestock activities.

The implementation of intensive feeding systems has demostrated to be practical and has good economic returns for farmers.

However, the response of animals in these systems is a function of differences in the quality of the diet and the partition of the energy consumed for the maintenance and growth or production. Therefore, poor performance and efficiency of the energy used for such a purpose results in high costs of food. As a result, it is essential to identify those stages of the animal growth and development, which can reduce energy loss and increase its efficiency, in order to obtain greater benefits and allow a profitable production.

Efficiency is commonly expressed in terms of units of production/unit of food required (weight gain, milk or eggs in kg/kg of food consumed) and this is mainly affected by the genetic condition and by the level of food consumption of the animal.

It is essential to mention that a considerable genetic and phenotypic variation exists in the determinations of the food efficiency in cattle, due to the quality and digestibility of diet, the voluntary consumption and the food conversion (Nkrumah *et al*., 2006). This variation is mainly related to differences in the energy loss of the diet (fecal, urine and methane), metabolism (maintenance and production), activity, thermoregulation and energy retention in the animal (Oddy and Herd, 2001; Basarab *et al*., 2003).

On the other hand, new genotypes as Katahdin and Dorper breeds which have high growth rates (Milne, 2000) and desirable carcass traits (Snowder and Duckett, 2003), are being introduced to Mexico to be used in breeding schemes crossed with Pelibuey and Blackbelly breeds.

However, there is no information related to their efficiency, especially when evaluated under different conditions allowing to select crosses with a better utilization of nutrients and food.

The purpose of this study was to estimate the energy retention of F1 male lambs, from Pelibuey (Pb) dams crossed with Black Head Dorper (BHD), White Dorper (WD) and Katahdin (Kd) sires and fed different energy levels (2.2, 2.5 and 2.8 Mcal ME/kg/DM).

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MATERIALS AND METHODS

The research was carried out at the facilities of the Faculty of Veterinary Medicine of the Autonomous University of Yucatan, located at 8 height meters above sea level. The climate prevailing in the area is hot and humid type AWO, according to the Koopen classification, as amended by Garcia (1973). Average annual temperature is 24°C, with a rainfall of 750-1000 mm year^{-1} (Duch, 2002), mainly during the spring and winter.

Forty eight weaned male lambs were used, with an age and an average Live Weight (LW)±standard deviation of 98±4 day and 19.65±3 kg, respectively, from 4 different genotypes: PbPb, BHDPb, WDPb and KdPb. Before starting the experiment, animals were dewormed and were vaccinated against pneumonic pasteurellosis. Likewise, they were given a basal diet (Table 1) for 21 days to adapt to the food and pens.

The retention of energy was determined by estimating the amount of the initial and final energy in the carcass, through its content of protein and fat.

The composition of protein and fat was determined using the following predictive equations proposed by Ramsey *et al.* (1991) in sheep crossed males from New Zealand.

- Percentage of fat in the carcass:
  Y = 11.51 + 0.93 (thickness of subcutaneous fat between 12th and 13th dorsal vertebra + 0.11 (live weight)
  R^2= 0.66

- Percentage of protein in the carcass:
  Y = 21.04-0.24 (thickness of subcutaneous fat between 12th and 13th dorsal vertebra -0.04 (live weight)
  R^2= 0.51

The thickness of subcutaneous fat was measured using ultrasound equipment CHISSON VET 600 with a linear probe of 7.5 MHz frequency. The probe was placed perpendicular to the spinal cord, between the 12th and 13th dorsal vertebra, using a gel to facilitate the coupling of the probe with the skin. At the end of the adaptation stage, measurements were made with ultrasound equipment in three lambs from each genotype. Subsequently, lambs were weighed and harvested after fasting for 16 h, according to the Mexican standards (NOM-08-ZOO, NOM-09-Z00 and NOM-033-ZOO) specified for the slaughter and dressing of animals.

Table 1: Composition of the adaptation diet (DM%)

Variables	Values
Star Grass chopped hay	19.800
Sorghum ground	53.100
Soybean meal	21.000
Sugarcane Molasses	2.600
Salt	1.000
Urea	0.500
Sodium bicarbonate ($NaHCO_3$)	1.000
Phosphoric acid (H_3PO_4)	0.800
Calcium Carbonate ($CaCO_3$)	0.200
Chemical composition	
Dry matter (%)	89.810
ME (Mcal kg^{-1} DM)^a	2.700
Crude protein (%)	18.550
Calcium (%)^a	0.800
Phosphorus (%)^a	0.400

Estimation based on NRC (1985)

Carcass weight and internal fat, which included pericardial, perirenal and gastrointestinal fat was registered. The amount of initial energy in the carcass was determined, through the content of protein and fat, according to the methodology described above. The energy content of carcass and internal fat was calculated assuming that the caloric value of fat is 9.334 Kcal g^{-1} and the protein is 5.55 Kcal g^{-1} (McDonald *et al*., 2002).

The 36 remaining lambs were distributed in a complete randomized design with a 4×3 factorial arrangement (Montgomery, 2004), 4 genotypes and 3 dietary Metabolizable Energy (ME) concentrations (2.2, 2.5 and 2.8 Mcal kg^{-1} DM).

Each treatment had three replicates and each of these consisted of an animal installed in an individual pen of cement floor with roof, drinker and feeder.

Animals received diets containing two levels of Crude Protein (CP) according to their stage of growth; 19% for the initiation stage, which lasted 33 days and 14.8%, for the final stage with a average duration of 42 days (Table 2 and 3). The change in diet was made, when animals in the initial phase achieved a similar or greater live weight of 25.0 kg, approximately. Animals were fasted 16 h before they were weighed at the beginning and then every 14 days until the end of the experiment, which had a total duration of 75 days. Feed intake was recorded, daily weighing the amount offered and rejected.

At the end of the experiment, all animals (nine by genotype and twelve for each level of ME in the diet) were measured the thickness of subcutaneous fat between the 12th and 13th dorsal vertebra, with the ultrasound equipment and were weighed and harvested, according to the methodology described above, to determine the final energy in the carcass and internal fat. The total energy retained was calculated using the formula:

Table 2: Experimental diets used in the initial stage of growth (DM%)

	ME (Mcal kg^{-1} DM)		
Ingredients	2.2	2.5	2.8
Star Grass chopped hay	54.100	45.300	21.600
Sorghum ground	20.400	22.400	46.300
Soybean meal	16.800	18.000	17.600
Sugarcane Molasses	5.300	5.300	5.300
Vegetable oil	-	5.500	5.500
Salt	1.000	1.000	1.000
Urea	1.000	1.000	1.000
Sodium bicarbonate ($NaHCO_3$)	0.670	0.670	0.670
Phosphoric acid (H_3PO_4)	0.430	0.430	0.350
Calcium Carbonate ($CaCO_3$)	0.100	0.250	0.690
Minerals and vitamins	0.100	0.100	0.100
Chemical composition			
Dry matter (%)	85.410	84.320	84.970
ME (Mcal kg^{-1} DM)[a]	2.200	2.500	2.800
Crude protein (%)	19.540	18.000	19.530
NDF (%)	62.830	57.610	48.360
ADF (%)	29.410	23.050	10.140
Calcium (%)[a]	0.800	0.800	0.800
Phosphorus (%)[a]	0.400	0.400	0.400

Estimation based on NRC (1985)

Table 3: Experimental diets used in the final stage of growth (DM%)

	ME (Mcal Kg^{-1} DM)		
Ingredients	2.2	2.5	2.8
Star Grass chopped hay	54.000	45.200	21.400
Sorghum ground	27.600	29.600	53.400
Soybean meal	10.000	11.000	10.700
Sugarcane molasses	5.300	5.300	5.300
Vegetable oil	-	5.500	5.500
Salt	1.000	1.000	1.000
Urea	0.560	0.560	0.560
Sodium bicarbonate ($NaHCO_3$)	0.670	0.670	0.670
Phosphoric acid (H_3PO_4)	0.570	0.560	0.480
Calcium Carbonate ($CaCO_3$)	0.220	0.360	0.800
Minerals and vitamins	0.100	0.100	0.100
Chemical composition			
Dry matter (%)	86.250	87.740	87.090
ME (Mcal kg^{-1} DM)[a]	2.200	2.500	2.800
Crude protein (%)	14.960	14.460	14.500
NDF (%)	62.140	63.230	54.930
ADF (%)	28.820	25.830	14.920
Calcium (%)[a]	0.800	0.800	0.800
Phosphorus (%)[a]	0.400	0.400	0.400

[a] Estimation based on NRC (1985)

$$\text{Total energy retained (Kcal)} = (FEC+FEIF)-(IEC+IEIF)$$

Where:

FEC = Final Energy in the carcass (Kcal)
FEIF = Final energy in the internal fat (Kcal)
IEC = Initial energy in the carcass (Kcal)
IEIF = Initial energy in the internal fat (Kcal)

Measured variables were Metabolizable Energy Intake (MEI), Live Weight at slaughter (LW), Average Daily Gain (ADG), Carcass Weight (CW), Fat thickness at 12 and 13th Dorsal Vertebra (FDV), Internal Fat Weight (IFW), percentage of Crude Protein (PC%) and Fat (FC%) in the carcass, Initial (IEC) and Final (FEC) energy in the carcass, Energy Retained in the Carcass (ERC), which was the difference between the EFC and EIC, Energy Retained in Internal Fat (ERIF), calculated by the difference in the final and initial energy of the IFW, Total Energy Retained (TER).

The ADG was analyzed using a repeated measures model (Maxwell and Delaney, 2004), whereas the other variables were analyzed using a linear model (GLM) for fixed effects, that considered the effects of genotype and the level of energy in the diet.

The comparison between averages was made through the Minimum Significant Difference Procedure (MSD). Regression analyses were made between the variables ADG, MEI and TER. The statistical analyses were carried out with the statistical package SAS (2003) (SAS, Institute Inc.).

RESULTS

The KdPb had a higher IFW, ERIF and TER than PbPb ($p<0.05$; $p<0.01$), however, no differences were found between KdPp, DpnPb and DpbPb, nor between the two latter and PbPb for IFW and TER ($p>0.05$). No effect was detected due to genotype on the other variables studied ($p>0.05$) (Table 4 and 5).

Table 6 presents, the results of the effect of ME level on carcass characteristics. Animals receiving 2.8 Mcal ME kg^{-1} DM had the greatest LW at slaughter, CW and IFW ($p<0.05$; $p<0.01$). No differences were found for the LW and CW between 2.2 and 2.5 ME levels (Mcal kg^{-1} DM) ($p>0.05$).

A significant linear effect was observed in the ADG ($p<0.001$), because when lambs increased their consumption of energy an increase in ADG was recorded. The linear regression equation that describes the evolution of the ADG according to metabolic energy intake is presented in Table 7. Up to 55.0% of the variation (R^2) was attributable to the MEI. The ADG was related to TER ($p<0.001$), where 40% of the variation was due to this variable (Table 7).

No effect was found of ME level on the FDV, PC and FC ($p<0.05$). Lambs fed diet with 2.8 Mcal ME kg^{-1} DM had a higher FEC, ERC, ERIF and TER ($p<0.01$). No differences were found between 2.8 and 2.5 levels (Mcal ME/kg DM) for the ERIF and TER ($p>0.05$) (Table 7).

The TER was related to the MEI of the lambs, because there was a significant relationship between these variables ($p<0.001$), in which the MEI explained 37% of the variation (Table 7).

The effect of genotype was independent of the level of ME for all variables evaluated ($p>0.05$).

Table 4: Effect of genotype on carcass characteristics of growing lambs (Average)

	Genotype					
Variables	PbPb	BHDPb	WDPb	KdPb	p-value	SEM
No. of animals	9	9	9	9	-	-
ME intake (kcal kg^{-1} W$^{0.75}$)	190	190	201	206	0.345	7.13
Live weight at slaughter (kg)	30.3	32.7	33.8	34.8	0.329	1.39
ADG (g day^{-1})	182	199	211	206	0.233	11.61
Carcass weight (kg)	14.0	14.6	15.1	15.2	0.706	0.72
Fat depth in 12 and 13th DV (mm)	1.81	1.93	1.99	1.97	0.487	0.085
Weight of internal fat (kg)	0.998a	1.212ab	1.153ab	1.415b	0.041	0.106
Protein in carcass (%)	19.39	19.27	19.21	19.17	0.154	0.068
Fat in carcass (%)	16.52	16.90	17.08	17.17	0.160	0.204

DV: Dorsal Vertebra

Table 5: Effect of genotype on energy retention of growing lambs (Average)

	Genotype					
Variables	PbPb	BHDPb	WDPb	KdPb	p-value	SEM
No. of animals	9	9	9	9	-	-
Initial energy in carcass (kcal)	23639	24798	22210	23033	0.923	2772
Final energy in carcass (kcal	37345	38390	40170	42236	0.446	2070
Energy retained in carcass (kcal)	13705	14093	17961	19203	0.201	2070
Energy retained in internal fat (Kcal)	5906a	9293b	9126b	10863b	0.017	992
Total energy retained (kcal)[1]	19611a	23386ab	27087ab	30066b	0.044	3250

Energy retained in carcass + energy retained in internal fat

Table 6: Effect of energy level in the diet on carcass characteristics of growing lambs (Average)

	ME (Mcal kg^{-1} DM)				
Variables	2.2	2.5	2.8	Valor P	EEM
No. of animals	12	12	12	-	-
ME intake (kcal kg^{-1} LW$^{0.75}$)	167	190	233	-	-
Live weight at slaughter (kg)	31.1a	32.6ab	35.1b	0.044	1.210
ADG (g day^{-1})	157a	190b	252c	0.0001	10.05
Carcass weight (kg)	13.2a	14.5a	16.6b	0.008	0.620
Fat depth in 12 and 13th DV (mm)	1.89	1.92	1.96	0.813	0.074
Weight of internal fat (kg)	0.826a	1.320b	1.439b	0.0003	0.072
Protein in carcass (%)	19.34	19.28	19.17	0.140	0.059
Fat in carcass (%)	16.69	16.88	17.20	0.165	0.187

DV: Dorsal Vertebra

Table 7: Regression equations to describe the relationship between Average Daily Gain (ADG), Metabolizable Energy Intake (MEI) and Total Energy Retained (TER)

Equation	n	R^2	RSD	Significance level
ADG = - 46.77 + 1.16 *MEI	36	0.55	35.59	<0.001
ADG = 111.24 + 0.003 *TER	36	0.40	41.33	<0.001
TER = - 17241 + 218.37 *MEI	36	0.37	9794.00	<0.001

n = No. Animals; R^2 = Regression coefficient; RSD = Residual Standard Deviation. ADG (g/animal/day); MEI (Kcal/ kg LW$^{0.75}$) y TER (kcal)

Table 8: Effect of energy level on energy retention of growing lambs (Average)

	ME (Mcal kg^{-1} DM)				
Variables	2.2	2.5	2.8	Valor P	EEM
No. of animals	12	12	12		
Final energy in carcass (kcal	36199a	38340a	44442b	0.011	1793
Energy retained in carcass (kcal)	12779a	14920a	21022b	0.011	1790
Energy retained in internal fat (Kcal)	5132a	10162b	11098b	0.0002	860
Total energy retained (kcal)[1]	17911a	25082b	32120b	0.007	2814

Energy retained in carcass + energy retained in internal fat

DISCUSSION

The greater internal fat deposited by KdPb lambs (42%) as compared to PbPb can be attributed to the effect of breed and diet quality. It is important to mention that KdPb tended to show a greater weight, which probably was due to the amount of fat deposited by these animals. It is feasible that this accumulation of fat occurs after the lambs reach 30.0 kg of live weight.

It is expected a greater amount of fat in KdPb lambs, because breeds for meat production have 20-40% more body fat (Bores *et al*., 2002; Wishmeyer *et al*., 1996; Peraza *et al*., 2006). This effect has also been confirmed by Burkle and Apple (2007) who found 40% more renal fat in

Katahdin sheep compared to Dorper and Suffolk breeds. The similar percentages of protein and fat found in the carcass was probably because lambs had a similar age and weight at harvest. It is known that these components have a direct influence on the composition of the carcass (Wishmeyer *et al*., 1996; Peraza *et al*., 2006). Lopez *et al*. (2000) also reported little variation in the percentages of protein in the carcass of Pelibuey lambs and their crosses with Rambouillet and Suffolk (20.81, 21.06 and 20.72% for the three genotypes, respectively), however, Pelibuey had a higher content of fat (4.46a %) compared to Rambouillet (4.02b%) and Suffolk (4.03b%). Animals used by the latter authors had an average age and weight of 275±37 day and 35.0±1.5 kg, respectively.

The KdPb lambs retained a 53% more energy compared to Pelibuey, which was due to the greater amount of internal fat that they deposited. It is important to mention that no significant differences were found in the energy retained in the carcass. It should be noted that the energy retained in the carcass reflects its caloric value as such, while the total energy retained, represents the value of the energy deposited in the body of the animal.

We may assume that KdPb should be more efficient for using ME, because in the synthesis and accumulation of fat, the animal uses less energy compared with the protein, which is in continuous process of partitioning and synthesis in the tissue, generating greater energy expenditure. Blaxter (1989) reported in growing ruminants an energy expenditure of 16.2 and 11.4 Kcal g^{-1}, for the synthesis of protein and fat respectively.

Richardson *et al*. (2003) found an energy retention of 372-458 Kcal of gross energy in the body of Suffolk cross lambs. Similarly, Von Keyserlingk and Mathison (1993) reported energy retention of 26 Kcal kg^{-1} $LW^{0.75}$ in Dorset cross lambs, which was lower that the values found in this research.

Moreover, it has been reported that the efficiency of the animal is influenced by the voluntary intake and digestibility of the diet (Nkrumah *et al*., 2006). This explains the significant correlations found between consumption of ME with GDP and energy retained as well as between ADG and energy retained, despite the fact that they had reasonable values of R^2.

With regards to energy level, results in this study confirm the effect that it has on carcass traits, because a high concentration of energy in the diet resulted in a greater weight of the carcass and accumulation of internal fat in the animals.

About the minor variations found in the percentage of protein and fat in the carcass of animals, we must emphasize that the main effect found in ruminants related to energy consumption, is on the amount of internal fat deposited, as it was demonstrated in this experiment.

The greater energy retention (79%) obtained in lambs fed with 2.8 (Mcal EM kg^{-1} MS) compared to the 2.2 Mcal EM kg^{-1} MS, corresponded mainly to the highest growth rate and internal fat deposited by these animals, which allowed them to have more stored energy per unit of body mass at the end of the experiment. It has been suggested (Johnson *et al*., 2003) that lambs of fast growth rate retain more energy by unit of gain compared to slow growth rate lambs. Moreover, the energy expenditure attributable to fat synthesis is lower than that for protein synthesis, resulting in a greater efficiency of energy utilization by the animal (Blaxter, 1989; Black *et al*., 1987). It is important to note that animals fed with the 2.8 Mcal EM kg^{-1} DM had a higher average daily gain and better feed conversion (Canton *et al*., 2009), which confirms that was found in this research.

It is important to mention that the diet with 2.2 Mcal EM kg^{-1} DM had the lowest quality, because it had the highest proportion of chopped hay (54%), this resulted in a lower growth and energy retention of animals. It is known that energy efficiency in ruminants is lower when diets with forage are used as compared with those with including only concentrate (Black *et al*., 1987; Partida and Martinez, 1992).

CONCLUSION

The genotype Katahdin x Pelibuey present a greater retention of energy, due to the greater accumulation of internal fat that they have. The highest values for weight gain, carcass weight and energy retention were obtained using a level of 2.8 Mcal ME kg^{-1} DM.

ACKNOWLEDGEMENTS

The reearchers wish to express their gratitude to the SAGARPA-CONACYT Funds, for the financial support received for carrying out this research, through the project: Caracterización de genotipos de ovinos en sistemas de producción intensiva de carne, con base a las demandas de mercado (Clave: 2004-C01-150) and the Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (INIFAP) and the Universidad Autónoma de Yucatán (UADY), for the facilities provided for the study.

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