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RESEARCH OPINIONS IN ANIMAL & VETERINARY SCIENCES

Growth curves and zoometric measures from birth to slaughter bulls *Bos taurus / Bos indicus* grazing in the Mexican tropics

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Abstract

The objectives of this study were to analyze body measurements of 75 crossbred bulls Holstein/Zebu (Ho/Z), and Brown Swiss/Zebu (BS/Z) grazing tropical forage species at two Experimental Stations La Posta (LP) and Matías Romero (MR), to determine the model or function that best fit at growth in two genetic groups, evaluate the performance in their zoometric measures in two localities and determination the body conformation variables that best estimate the hot carcass weight. In order to model the growth curves Gompertz and Logistic mathematical functions were used and the changes occurred in body shape over time were recorded. The model that best fit was associated with (Gompertz) growth parameters that were similar between genetic groups Ho/Z and BS/Z. The body conformation increased over time and was homogeneous between the crosses of both localities, but higher in the BS/Z groups from MR after 24 months of age. Variables such as final weight, body length, shoulder width and height at wither, allowed significantly to estimate the hot carcass weight of crossbred bulls kept on extensive grazing in the Mexican tropic.

Keywords: Growth curve; logistic; Gompertz; crossbred bulls; zoometric measures

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Introduction

Animal growth is one of the most important aspects when evaluating productivity in units implicated in meat production and in some cases it is used as a selection judgment (Agudelo et al., 2008). This is defined as a series of complex anatomical and physiological changes which occur in the animal body (Bavera et al. 2005). These changes occur as a quantitative increase of body mass per time unit, as a result of processes that occur at a cellular level which includes an increase in the number of cells (hyperplasia) and cell size (hypertrophy). The growth of an animal has been characterized by observing the change in weight per time unit, or body weight plotted against age. The first, represented by the average daily gain, which provides values that can be used to compare the effects of treatments quickly; the second method results in the production of growth curves that are used to describe the growth patterns of animals or tissues, through the analysis of its components. Furthermore, this method allows comparison between breeds of animals, sex and even among different species (Trenkle and Marple, 1983). The best way to show size changes over time is a growth graph; that for most animals is a sigmoid shape, which is a first phase

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of slow growth rate, after it follows a rapid growth rate being almost constant and finally growth rate decreases until it is almost imperceptible (Newth, 1976). Growth graphs show the relation between the implicit impetus to grow and mature of an animal throughout its life and the environment in which these pulses are expressed either by the level of productivity of the itself, or by the quantity and quality of food consumed as well as the effort required to find, eat and digest this food (Fitzhugh, 1976). The first objective of modeling growth graph was to describe the information in the sequence of size-age and consolidate in parameters; second, the parameters of the growth graph have a predictive function to estimate growth rates, nutritional requirements or responses to selection (Fitzhugh, 1976).

In order to represent animal growth different linear and nonlinear mathematical models have been used (Agudelo et al., 2008); however, there are many factors that can affect the behavior of the growth graphs, so there is not a function that can be applied across the board to estimate parameters of a growing animal. On the other hand, it is possible to find equations to make projections of growth and serve as working tools when making decisions on farms engaged in livestock (Agudelo, 2004). For these reasons, the choice of the appropriate model is crucial. Fitzhugh (1976) mentions that the basis for comparing adjusted methods of growth curves include: a) biological interpretation of the parameters depends on the understanding of interactions between genetics and the environment, resulting in a particular pattern, b) the goodness of fit of the data minimizes the variability of the data for the points of the simulated curve.

The number of repeated measurements over time allows observing peculiarities in the growth curves; however, in the practice many measurements are not made, limiting the ability of analysis and interpretation of the factors involved in the animals weight gain. For the most accurate results on equations that fit the growth curves it is advisable to group animals with the same features (Agudelo, 2004).

Morphological descriptions of beef cattle can be made through single linear measurements or calculated indexes using different body measurements (Alderson, 1999). However, the use of simple measurements on fieldwork practices can give estimates of future body conformation. Whereas the differences in appearance, shape and conformation of dairy cattle and their crosses with beef cattle are associated with long bones, as well as the length and thickness of the muscles (McGee et al., 2007).

Zoometric studies the animal shapes by body measurements to quantify its body conformation that let us to quantify the productive capabilities of a breed or particular inclination towards animal production. Given its numerical nature, these measures allow objective comparisons between pure breeds or crosses (Parés, 2007). Height dimensions determine the height of the animal, in its various regions especially the highest. The height is the perpendicular distance from each of these regions to the horizontal ground plane, animal standing straight that is, resting on four symmetrically extremities and normal position, not shifting its center of gravity. Moreover, length measurements attempt to determine the distance between points in the body in a longitudinal direction and width measures determine the distance between points in the body that are transverse to the longitudinal axis of the body, while the perimeter measurements determining the contour of certain body regions (Torrent, 1982).

Linear measurements of height at haunch (Alderson, 1999) and thoracic perimeter (Colin et al., 2009) are used as weight estimators in cattle. They are also indicators of the type and role of livestock for the characterization of the breed (Alderson, 1999). Both the height at the withers and the haunch are of limited value as an indicator of weight and very low value as an indicator of type and function, the hip width is the preferred measure for assessing the conformation of the animal (Alderson, 1999); the hip height explains 5 to 6% of the variation in lean meat yield, however, the height at the withers helps better the prediction equations for total meat produced (Bergen et al., 2005).

Albertí et al. (2008), in a study of different breeds of bulls, reported that meat producing breeds have a high average height at the withers, unlike the dairy breeds, including higher animals such as Holstein or small as Jersey. It also mentions that this measure is more useful to classify livestock breeds than live weight or average daily gain. Body measurements are significantly higher in intensive systems than extensive systems in absolute terms, but the opposite occurs when expressed relative to body weight (McGee et al., 2007). The objectives of this study were to determine the model or function that best fit and estimate growth parameters of two genetic groups. Assessing performance in their zoometric measures in two locations and determine body conformation variables that best estimate the hot carcass weight of bulls *Bos taurus/Bos indicus* in a system of extensive grazing in the Mexican tropic.

Materials and Methods

This study was carried out at the Experimental Station (ES) of La Posta (LP) and Matías Romero (MR) which belong to the National Institute of Livestock, Agricultural and Forestry Research. The ES LP is located in Paso del Toro, Medellin, Veracruz; with a northern latitude of 19°00'49 ", west longitude

96°08'19" and a height of 10 meters above sea level (INEGI, 2009). The region has a humid sub-tropical climate type Aw_2 (Vidal, 2005), with an average annual rainfall of 1461 mm, relative humidity of 77.4% and an average temperature of 25°C. The ES MR is located in Matías Romero, Oaxaca; at northern latitude 17°12'05", west longitude 95°03'04" and a height of 50 meters above sea level (INEGI, 2009). The region has a humid tropical climate type Am, with an average annual temperature of 25.6 °C and an average annual rainfall of 2250 mm.

A total of 75 bulls Ho/Z and BS/Z, clinically healthy, produced on a dual-purpose production system at LP and MR experimental stations, between 2006 and 2007 were used. Ho/Z and BS/Z animals included remained with their mother only the first five days after breastfeeding was restricted to one of the rear quarter of the udder during milking (twice a day, 6:00 AM and 4:00 PM) and until three months of age, after they were left with their mothers after milking to take the residual milk, in addition to they were offered commercial concentrate with 18% crude protein *ad libitum*. At seven months old, they were weaned and moved to pastures for grazing. Rotational grazing paddocks were used with tropical forage species of African Star (*Cynodon plectostachyus*) and Pará (*Brachiaria mutica*), which provided sufficient forage during the rainy season, however, during the dry season, the cattle were supplemented with corn silage plus 2.0 kg/animal/day of commercial feed with 12% crude protein. Water was offered *ad libitum*. To ensure that the animals were free of internal and external parasites, a deworming program was established. To control internal parasites from weaning, every six months Ivermectin was applied and to control external parasites on the livestock Amitraz was applied using spray baths every 14 days.

To describe animal growth patterns math sigmoidal functions were used: Gompertz and Logistic (Equations 1 and 2), using the monthly weights of each animal individually, from birth to the process; using the software Scientist (MicroMath Scientific Software, Inc), in addition an analysis of nonlinear regression with age as independent variable (X) and weight as the dependent variable (Y) was developed through each mathematical function, whereby the parameters of each function were obtained.

Ecuation 1: Gompertz function

$$P = Ae^{-e[-\mu(T-B)]}$$

P = Body weight (kg)
A= Weight at maturity (kg)
µ = Growth speed (weight/time)
e = Natural logarithm base

Ecuation 2: Logistic function

$$P = \frac{A}{\left(1+Ge^{(-\mu T)}\right)}$$

B = Turning point in days
G = Integration constant
T = Time in days

The parameters obtained for each animal were grouped by genotype and function. The Sigma Plot V. 11.0 software (Systat Software, Inc. 2008) was used for simulation of the growth curves by genetic group and function. To choose the function that best estimates the growth of this type of animal goodness of fit of the models were evaluated by obtaining R^2, coefficient of determination (R), correlation (C) and finally the model selection criterion (MSC). From weaning eleven zoometric measures were taken every 30 days using: a metric stick (1.50± 0.01 m) to measure heights, a modified metric cane with a sliding caliper (0.6±0.01 m) to measure the width (Alderson, 1999), a flexible measuring tape to measure length and perimeters (10±0.001m) and a tape measure (3±0.001 m) to make head measurements. The measurement was carried out according to the technique described by Torrent (1982), the variables were determined to haunch height, height at the wither, shoulder width, hip width, thoracic perimeter, abdominal perimeter, body length, length at the wither, head length, eye to eye distance and tail perimeter. Data were analyzed using the statistical package STATISTICA V 7.0 (StatSoft, Inc., 2007) with the GLM module (General linear model), where the analysis of variance, and multiple regression was used. In reference to the parameters obtained by the growth curves were analyzed by genotype and function effect for the zoometric measures; it was analyzed by genotype and location effect with a completely random design. For multiple comparisons of means between genotypes, and ES were performed using the Tukey test. Finally, a multiple regression analysis (Backward, Stepwise) was performed to obtain prediction equations for the hot carcass weight from zoometric measures taken *in vivo* using all genotype data and ES.

Results and Discussion

The average cumulative growth of animals is shown in Figure 1 and 2. This graph is the result of mathematical Gompertz and Logistic functions which indicate that the Ho/Z animals have a greater weight at maturity than the BS/Z animal group; both functions behave similarly but when using the Logistic mathematical model there is a greater adjustment, in accordance with the results presented above, this model overestimates the initial weight age (at birth), therefore the Gompertz model was more consistent with the

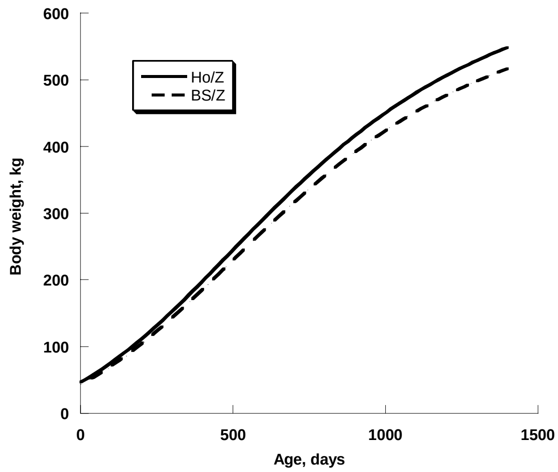


Fig. 1: Growth curve of bulls grazing, effect of genotype. Gompertz function

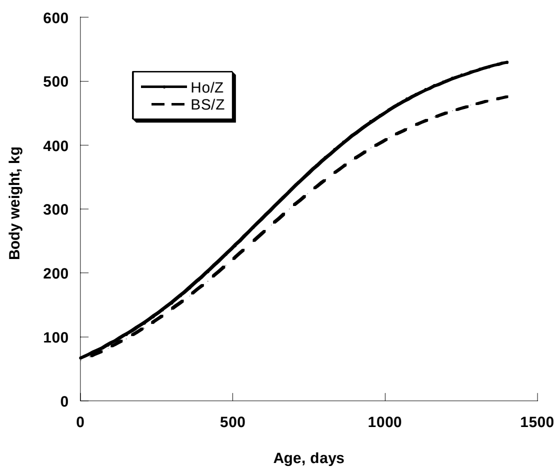


Fig. 2: Growth curve of bulls grazing, effect of genotype. Logistic function

estimated parameters. However, to evaluate the growth parameters obtained and presented in Table 1 it was found that there is no statistically significant difference between genetic groups, and the Gompertz mathematical model estimates a weight at maturity (A) statistically higher among Ho/Z animals, in contrast to BS/Z. Likewise the age at puberty (B), that is, the age at which the animals reach the highest growth rates, however, the Logistic function estimated major parameters for genotype Ho/Z, so the growth rate (μ) recorded was higher ($P<0.05$) using this model.

Zoometric measures taken repeatedly over time were adjusted at weaning and every six months for each month of age. In Figure 3, 4, 5 and 6 are represented the haunch height (HH) and height at the withers, (HW) width of shoulders (SW) and hips (HiW), thoracic (ThP), abdominal (AP) and tail perimeter (TP), body length (BL), length at the withers (WL), and head length (HL) and eye distance (DE) in genetic groups and locations over time. It is observed that these increase in relation to age; however, this increase is not performed in parallel; haunch height and height at the wither measurements and distance between eyes, head length and tail perimeter are slow growing and the rest of them have a greater increase in weight range, so they could act as predictors of hot carcass weight.

In the haunch height and wither height, no differences ($P>0.05$) between genetic group and locality were found until 18 months of age; when they were two years old, the crossbred group showed higher heights from the animals found in LP, but six months later, the group returned to be homogeneous, as animals located in MR had a rapid growth in size, which stopped after they were two years old, unlike those found in LP, which have a slow and steady growth. At no stage of growth included in this study was there found statistically significant difference ($P>0.05$) between genetic group and locality among the width of the shoulder. In particular, the BS/Z genetic group showed statistically significant differences among localities compared to the hip width, MR individuals were bigger at one year of age, where the BS/Z group stood out ($P<0.05$), which may be related to the good weaning adaptation noted before; however, this difference resulted in a decrease in the rate of increase of this measure after two years of age in contrast with the rest of the groups steadily increased; on the other hand, this same group located at LP recorded lower measures. The thoracic and abdominal perimeter was homogeneous between genetic groups, at different ages studied, except in the thoracic yearling, where Ho/Z group showed the greatest extent unlike the BS/Z from LP, such extreme match the results shown on yearling weight, due to the high correlation found between thoracic perimeter and body weight. A measurement in which genetic differences between groups were found was the body length, at 18 and 24 months there was superiority of group BS/Z from MR observed compared to the studied at LP. The advantage gained by these animals at the mentioned stages was attenuated in the subsequent stages as the rate of increase reduced per time unit. On the other side the length at the withers showed no statistical difference between groups, suggesting that the longitudinal differences between different genetic groups do not include the length at the withers, it only spans the distance from the withers to the base of the horns; although this could be influenced by the difficulty in measuring this variable.

About measurements of the bone development of the head, eye distance did not record statistical difference between genetic groups and the increase in time was constant, unlike the head length at 24 months of age, where they recorded the highest measures in the

Table 1: Growth parameters by genetic group and mathematical model

	Gompertz				Logistic			
	Ho/Z		BS/Z		Ho/Z		BS/Z	
Parameters	MEAN	SEM	MEAN	SEM	MEAN	SEM	MEAN	SEM
A, kg	643.4[a]	20.5	606.3[ab]	28.3	563.1[b]	20.5	504.0[b]	29.59
B, days	482.8[a]	25.8	484.8[ab]	35.8	588.2[b]	25.8	572.3[ab]	37.4
μ (weight/time)	0.002[a]	0.0001	0.002[a]	0.0001	0.003[b]	0.0001	0.003[b]	0.0001
Goodness of fit								
R^2	0.993[a]	0.001	0.958[b]	0.001	0.996[a]	0.001	0.993[a]	0.002
R	0.974[a]	0.004	0.947[b]	0.006	0.976[a]	0.001	0.993[ab]	0.002
C	0.987[a]	0.002	0.979[b]	0.002	0.988[a]	0.002	0.981[ab]	0.002
MSC	3.51[a]	0.099	2.95[b]	0.138	3.60[a]	0.099	3.25[ab]	0.144

Ho= Holstein, BS= Brown Swiss, Z= Zebu, SEM= Standard error of mean. A= Weight at maturity, B=Age at puberty, μ= Growth speed, R^2= R-squared, R= Coefficient of determination, C= correlation, MSC= Model selection criterion. [ab] Different letters between columns indicate statistically significant difference (P<0.05).

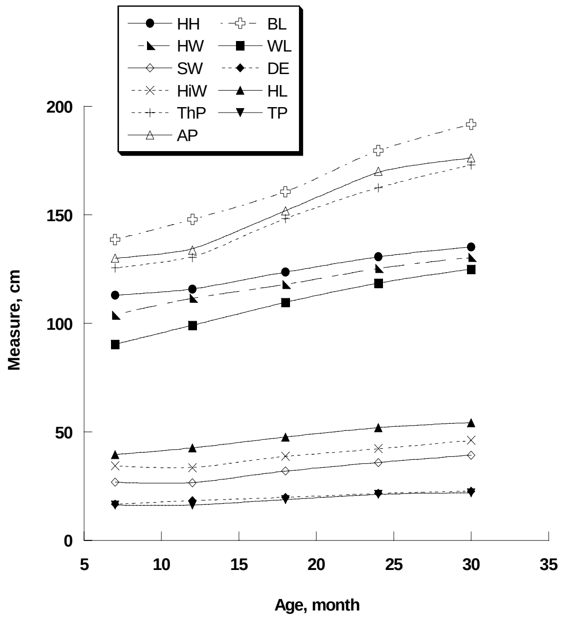
Table 2: Correlations between various measures in animals live taken and the hot carcass weight.

	FW	HH	HW	SW	HiW	ThP	AP	BL	LW	DE	HL	TP
HCW	0.97	0.66	0.67	0.80	0.60	0.88	0.86	0.87	0.73	0.68	0.73	0.18
FW		0.66	0.72	0.84	0.63	0.89	0.87	0.87	0.74	0.69	0.73	0.19
HH			0.77	0.46	0.45	0.66	0.62	0.66	0.67	0.37	0.69	0.37
HW				0.59	0.57	0.71	0.64	0.73	0.67	0.49	0.75	0.33
SW					0.64	0.78	0.75	0.83	0.59	0.72	0.68	0.04
HiW						0.62	0.73	0.54	0.43	0.44	0.56	0.19
ThP							0.91	0.76	0.64	0.65	0.72	0.16
AP								0.72	0.62	0.58	0.73	0.20
BL									0.82	0.70	0.74	0.27
LW										0.59	0.66	0.30
DE											0.60	-0.01
HL												0.12

HCW: hot carcass weight, FW= final weight, HH: haunch height, HW: height at the withers, SW: shoulder width, HiW: hip width, ThP: thoracic perimeter, AP: abdominal perimeter, BL: body length, LW: length at the withers, DE: distance between eyes, HL: head length, TP: tail perimeter

Ho/Z group in contrast to the BS/Z from LP, difference dissipated within the following ranges. Regarding perimeter tail, this remained uniform among genetic groups in different stages of growth time.

In a zoometric characterization by Ugur (2005) pure Ho and BS females at six months of age, showed that they had an average height at the haunch, chest circumference and height at the wither of 87, 112 and 87cm, respectively, lower values than the ones presented here, but it is close to those recorded by the Ho/Z genotype from MR; this situation can be explained primarily by the effect of sex, coupled with the different management; in addition, there was a month of difference between the observations compared. When relating results obtained in the present research and the one made by Gilbert et al. (1993), with Angus and Hereford weaned cattle (between six and seven months old), it was found that the males of beef breeds are smaller in size than the crossbreds evaluated, having an average height to haunch of 99.7 cm and height at the withers of 94.4 cm; however, the thickness of the hip and the thoracic measurement were similar, recording 32.1 and 129.5 cm, respectively for beef breeds, also they have a shorter head length (35.1 cm) and greater distance between eyes (18.0), so these breeds have the attribute of having compact heads. The same animals were subjected to a high post weaning energy diet, so yearling exceeded those from the present in hip width and thoracic perimeter registering 42.1 and 165.1 cm, respectively, and showed their genetic superiority with higher weight and meat quantity, characteristics related to such measures. According to morphological classification of young bulls published by Alberti et al. (2008), it was observed that the animals involved in this study showed a haunch height and hip width, at a year old, proper of dairy breeds of small size, such as Jersey, Casina or Highland, from 103-113 cm and 30 to 40 cm, respectively; however, they were in a range of 291-321 kg. Although the results obtained for the height at the wither are close to the beef breeds, the difference between the weight and thickness of the hip is important. On the other hand, high contrast with large dairy breeds in height at the withers decreased when assessing hip thickness between them. This large difference can be explained by the wide anatomic variability between breeds, in this case, between the crosses used; also the breeds studied in that investigation showed their genetic potential when receiving a diet rich in protein and energy, unlike the



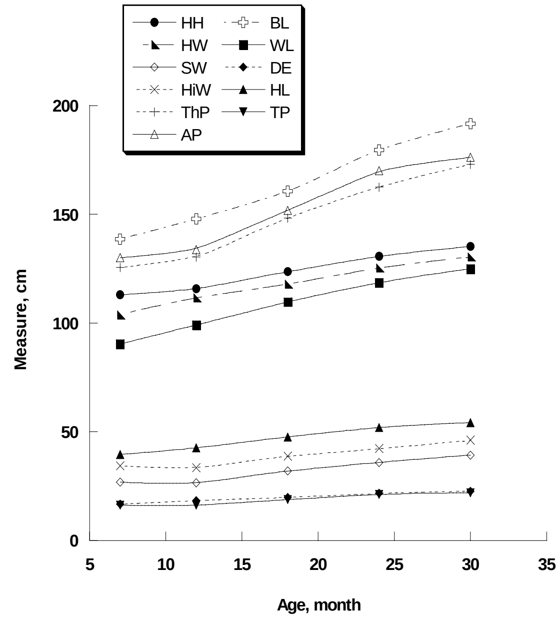
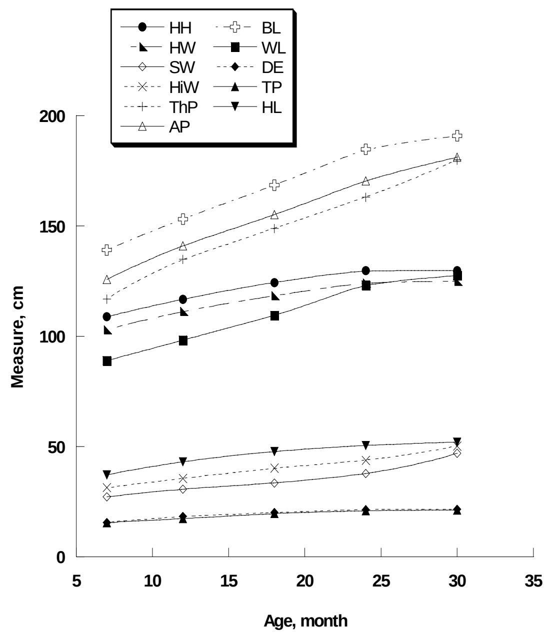


Fig. 3: Zoometric measures of male cattle Ho/Z from LP, over time

Fig. 4: Zoometric measures of male cattle BS/Z from LP, over time



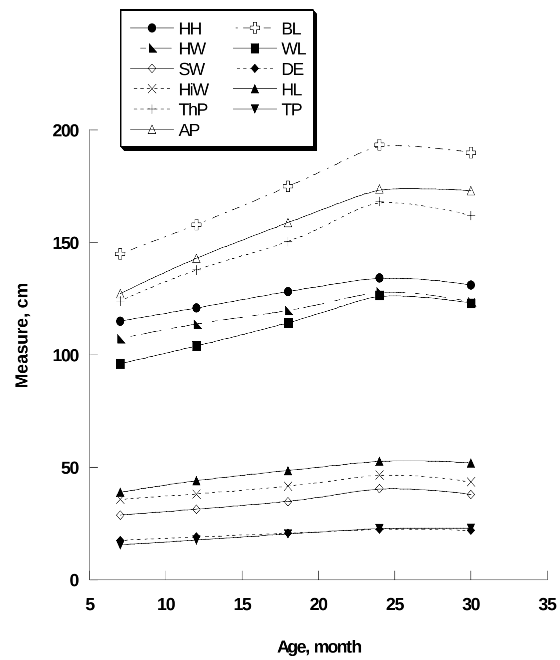


Fig. 5: Zoometric measures of male cattle Ho/Z from MR, over time

Fig. 6: Zoometric measures of male cattle BS/Z from MR, over time

HH: haunch height, HW: height at the withers, SW: shoulder width, HiW: hip width, ThP: thoracic perimeter, AP: abdominal perimeter, BL: body length, WL: withers length, DE: distance eyes, HL: head length, TP: tail perimeter

current research. Moreover, Bergen et al. (2005) also reported in animals of beef breeds with an average of 15 months of age and 645 kg body weight, height at haunch, height at the withers, width of the hip, thoracic perimeter and length of the withers: 133.5, 127.5, 57.8, 200 and 132.6 cm, respectively. Although the weight of the individuals included in this study did not exceed 500 kg, they reached a height at the haunch and at the withers similar at 24 month; chest circumference was superior to all the data presented here because of its close correlation with body weight. It is considered that the differences expressed correspond to the genetic contrasts of the individuals as well as to the continuous supply of concentrate feed for the optimum animal development; also the increase of body measurements is slow unlike meat breeds. At 30 months, individuals in this study behaved similarly to those studied by McGee et al. (2007), under an extensive grazing system, in relation to measures of the haunch height, wither height, shoulder width and withers length. This contradicts the previously discussed, as Albertí et al. (2008) consider these dairy breeds, large size; first, it is noteworthy that such a classification was made at a year old, then, the similarity was found in an extensive system and finally, the animals in this system (extensive) were castrated at the beginning of the experiment; so the relation observed can be consistent. Moreover, the results presented here differ with the system of intensive growth evaluated by McGee et al. (2007), where they found higher weights, like the above measures, which is clearly explained by the feeding system. Table 2 shows the correlation of the measures taken *in vivo* (zoometric) with the hot carcass weight, it can be observed that the measure that has a higher correlation ($P<0.05$) with this variable is the final body weight, followed by thoracic perimeter, body length, abdominal perimeter and shoulder width, in descending order, so these would be the best predictors of such a feature. The rest of the features are also correlated ($P<0.05$), although to a lesser extent, except the tail perimeter that had very low values ($P>0.05$).

Since no statistically significant differences were found between the two genetic groups evaluated against the zoometric measures and the carcass characteristics, only a prediction equation for both crosses (Ho/Z and BS/Z) and locality LP was developed.

Thus, by multiple regression analysis the following prediction equation was established:

$$HCW = -71.86+0.49\,FW+0.70\,BL-1.64\,SW-0.79\,HW$$

Where: FW= Final weight, kg; BL= Body length; SW= Shoulder width; HW= Height at the withers

This analysis selected the variables mentioned by contributing significantly ($P<0.05$) in estimating the weight of the hot carcass. Also good fitting parameters were recorded ($R = 0.98$, $R^2 = 0.96$ and adjusted $R^2 = 0.95$). Finally, a standard error of the estimate of 6.42 kg was observed.

Conclusions

The Gompertz model allowed estimating parameters of bulls crossbreed Ho/Z and BS/Z to evaluate their growth. Zoometric measures indicated that the feeding system was not affected by the locality, and then they grew uniformly and corresponded to an animal of medium size to dairy cattle. The final weight, shoulder width, body length and height at withers were able to reliably estimate the weight of the hot carcass.

References

Agudelo, G.D.A. 2004. Curvas de crecimiento de crías de vacuno levantadas en la corporación Universitaria Lasallista. *Revista Lasallista de Investigación*, 1: 42-45.

Agudelo, G.D.A., Cerón, M.M.F. y Restrepo, B.L.F. 2008. Modelación de las funciones de crecimiento aplicadas a la producción animal. *Revista Colombiana Ciencia Pecuaria*, 21: 39-58.

Albertí, P., Panea, B., Sañudo, C., Olleta, J.L., Ripoll, G., Ertbjerg, P., Christensen, M., Gigli, S., Failla, S. Concetti, S., Hocquette, J.F., Jailler, R., Rudel, S., Renand, G., Nute, G. R., Richardson, R.I. and Williams. J.L. 2008. Live weight, body size and carcass characteristics of young bulls of fifteen European breeds. *Livestock Science*, 114: 19-30.

Alderson, G.L.H. 1999. The development of a system of linear measurements to provide an assessment of type and function of beef cattle. *Animal Genetic Resources Information*, 25: 45-55.

Bavera, G., Bocco, O., Beguet, H. and Petryna, A. 2005. Crecimiento, desarrollo y precocidad. Cursos de Producción Bovina de Carne, FAV UNRC. www.produccion-animal.com.ar [En línea] [Pagina consultada el 25 de agosto del 2014]

Bergen, R., Miller, S.P., Mandell, I.B. and Robertson, W.M. 2005. Use of live ultrasound, weight and linear measurements to predict carcass composition of young beef bulls. *Canadian Journal of Animal Science*, 85: 23-35.

Colin, I.B.C., Vinay, V.J.C., Domínguez, M.B., Cervantes, A.P. and Hernández, B.J. 2009. Perímetro torácico como estimador del peso vivo en bovinos machos cruzados en el trópico mexicano. Memorias del 2do Congreso Internacional en Ciencias Veterinarias y Zootecnia. Puebla, México.

Fitzhugh, H.A. Jr. 1976. Analysis of growth curves and strategies for altering their shape. *Journal of Animal Science*, 42: 1036-1051.

Gilbert, R.P., Bailey, D.R. and Shannon, N.H. 1993. Body dimensions and carcass measurements of cattle selected for postweaning gain fed two different diets. *Journal of Animal Science*, 71: 1688-1698.

INEGI (Instituto Nacional de Estadística y Geografía). 2009. Catálogo de claves de entidades federativas, municipios y localidades. [En línea] http:// mapserver. inegi. org. mx/mgn2k/?s=geo&c=1223 [Consultada el 20 de marzo del 2014]

McGee, M., Keane M.G., Neilan, R., Moloney, A.P. and Caffrey, P.J. 2007. Body and carcass measurements, carcass conformation and tissue distribution of high dairy genetic merit Holstein, standard dairy genetic merit Friesian and Charolais × Holstein-Friesian male cattle. *Irish Journal of Agricultural and Food Research*, 46: 129-147.

Parés, P.M. 2007. Índices de interés funcional en la raza bovina "Bruna Dels Pirineus". *Revista Electrónica de Veterinaria REDVET*, 8: 1695-7504

Newth, D.R. 1976. Crecimiento y desarrollo animal. 1er edición. Publicaciones Omega. Barcelona, España. Pp: 368-420.

Torrent, M.M. 1982. Zootecnia Básica Aplicada. Editorial Aedos. Barcelona, España. pp: 498-506.

Trenkle, A. and Marple, D.N. 1983. Growth and development of meat animals. *Journal of Animal Science*, 57: 273-283.

Ugur, F. 2005. Relationships between body measurement of dairy calves at six month of ages and age at first calving and milk production. *Journal Central European of Agriculture*, 6: 191-193.

Vidal, Z. R. 2005. Región 7, Golfo de México. *En*: Las regiones climáticas de México. Instituto de Geografía UNAM, México, Pp: 121-144.