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Original

Prediction of carcass weight and yield in New Zealand rabbits from body measurements

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ABSTRACT

Objective. Predicting carcass weight and yield in New Zealand white rabbits from body measurements. **Materials and methods.** In 100 New Zealand (NZ) commercially reared males of 60±3 days, with a 12-hour fast, the live weight (BW) was taken, length the dorsal (LD) and ventral (LV) body length, chest circumference (CC), loin length (LL), loin width (LW), chest width (CW) head width (HW) head length (HL), thigh circumference (TC), thigh length (TL), arm circumference (AR) and arm length (AL). The rabbits were euthanized, their carcasses weighed (CAW). Descriptive statistics and carcass yield (CAY) were estimated. A regression equation of the CAW and the CAY was established with the "Stepwise Regression" procedure and the correlation coefficients between the variables were estimated from the principal component analysis. **Results.** Variables *in vivo* were homogeneous with coefficients of variation of less than 20%. The CAY was 54.7±2.4%. The regression equation that best fit the CAW was Y_i = 75.83+0.58BW-11.86HL (R^2: 0.91; $p<0.05$) and the CAY was Y_i = 49.23+0.21LD+0.25CC-0.64CW-0.57HL (R^2: 0.20; $p<0.05$). Four components were determined that explain 69% of the variation. Head, loin, and arm measurements were the most important. The highest correlation found with the CAW was the BW ($r=0.84$; $p<0.001$). **Conclusions.** The CAY is similar to other NZs of similar age. Measurements in the live animal better predict CAW than CAY. These results can be used in animal genetic improvement programs.

Keywords: Carcass quality; biometric measurements; carcass yield (*Source: CAB*).

RESUMEN

Objetivo. Predecir del peso y el rendimiento en canal en conejos Nueva Zelanda blanco a partir de medidas corporales. **Materiales y métodos.** En 100 machos Nueva Zelanda (NZ) criados de forma comercial de 60±3 días, con ayuno de 12 horas, se tomó el peso vivo (PV) el largo de cuerpo dorsal (LC) y ventral (LV), perímetro del tórax (PT), largo de lomo (LL), ancho de lomo (AL), ancho de tórax (AT) ancho de cabeza (AC) largo de cabeza (LC), perímetro de muslo (PM), largo de muslo (LM), perímetro del brazo (PB) y largo del brazo (LB). Los conejos fueron sacrificados, pesadas sus canales calientes (PC). Se realizó estadística descriptiva y se estimó el rendimiento en canal caliente

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(RC). Se estableció una ecuación de regresión del PC y del RC, con el procedimiento "*Stepwise Regression*" y se estimaron los coeficientes de correlación entre las variables a partir de un análisis de componentes principales. **Resultados.** Las variables *in vivo* fueron homogéneas con coeficientes de variación menores de 20%. El RC fue 54.7±2.4%. La ecuación de regresión que mejor se ajustó al PC fue Y_i= 75.83+0.58PV-11.86LC (R^2: 0.91; $p<0.05$) y al RC fue Y_i= 49.23+0.21LD+0.25PT-0.64AT-0.57LC (R^2: 0.20; $p<0.05$). De determinaron cuatro componentes que explican el 69% de la variación. Las mediciones de cabeza, lomo y brazo fueron las de mayor aporte. La correlación más alta que se encontró con el PC fue el PV (r= 0.84; $p<0.001$). **Conclusiones.** El RC es similar a otros NZ de edad similar. Las mediciones biométricas predicen mejor el PC que el RC. Estos resultados se pueden utilizar en programas de mejoramiento genético animal.

Palabras clave: Calidad de canal; medidas biométricas; rendimiento de la canal (*Fuente: CAB*).

INTRODUCTION

Among the main characteristics of zootechnical interest of the rabbit we have, the high growth rate, high prolificity, short reproductive cycle, white meat, with high protein and phosphorous content, as well as a low level of fat, sodium, and cholesterol, which benefits consumer health; furthermore, the initial investment cost for its production is low compared to other species (1,2). However, intensive breeding requires technical knowledge related to nutrition, reproduction, and management. In the latter, lies the success in the rabbit farm (3).

The main traits of economic importance in rabbit production are feed conversion rate, litter size, and carcass yield (4). The latter, varies directly by the weight of the carcass and, the possibility of predicting its value, would produce valuable information to guarantee the viability and sustainability of the production system (5).

The rabbit carcass in Colombia has not been characterized. However, its commercialization is carried out without skin, head, legs and thoracic viscera. Market trends are not clear, but quality in the carcass may be required in the medium term, and given this, the biometrics of specific body regions, such as the leg, arm or back, could facilitate the animal selection process. with greater genetic merit and improved meat production capacity and a better meat / bone ratio (6).

In animal genetic improvement programs, quantitative predictive tools are applied that facilitate the selection of animals based on their breeding values in order to genetically increase their productive and reproductive efficiency (6). A variety of body measurements have been used in both live and carcass animals to predict their yield, as a simple method of evaluation without harm, in pigs (7), lambs (8), birds (9), cattle (10) and guinea pigs (6). However, the reports for rabbits are not updated, the reported R^2 values vary between 34.1 and 79.7% (11, 12).

Thus, linear body measurements of various anatomical segments can be conjugated in selection indices that aim to describe the conformation of the body and, thus, predict the weight and quality of the carcass. Likewise, they can evaluate the performance of the phenotype, examine the relationships between economic characteristics, reproductive performance, and interactions between heredity and the environment (6,10).

Because of this, the objective of this research was to predict the carcass weight and carcass yield of New Zealand White rabbits from body measurements.

MATERIALS AND METHODS

Location and animals. The present investigation was carried out in the experimental farm "Los Pericos" of the University of Sucre. 100 males of the New Zealand White (NZ) breed reared in farm vivarium with commercial balanced feed (crude protein 17%, gauze 2.5%, ash 12%, humidity 13%, fiber 15% and 3200Kcal/kg of Energy were used. Metabolizable) and water at will, with an average age of 60 ± 3 days. In the procedures for sample collection, handling and conservation, the ethical, technical, scientific, and administrative standards for animal research contained in Law 84 (National Congress of Colombia, 1989) were taken into account.

Ante-mortem and sacrifice body measurements. Animals were fasted 12 hours before slaughter. After fasting, the rabbits were weighed (BW) on a precision analytical balance

(± gr) and body measurements were taken: dorsal body length (LD), taken from the tip of the nose to the last dorsal coccygeal vertebra; ventral body length (LV) measured from the tip of the nose to the last coccygeal vertebra ventrally; chest circumference (CC), taken from behind the arms at the level of the scapula; loin length (LL), from the caudal edge of the last rib to the last coccygeal vertebra; loin width (LW), at the level of the lumbosacral vertebrae, between the transverse processes; chest width (CW) from one costal plane to the other, at the height of the joint of the encounter; head width (HW) distance between zygomatic arches; head length (HL), is the distance between the tip of the nose and the atlanto-occipital joint; thigh circumference (TC), taken above the femoral-tibial-patellar joint, surrounding the entire thigh; thigh length (TL), distance between the femoral-tibial joint and the femoral-patellar joint; arm circumference (AC) above the elbow joint and arm length (AL), from the ulnar humeral-radial joint to the scapulo-humeral joint (6). Biometric measurements were performed using a millimeter Vernier Caliper ruler (± 0.02mm) and an adapted tape measure. Animals were stunned by electronarcosis and euthanized, their skin, head, legs, and viscera were removed (13). The resulting carcasses were heavy (CAW).

Analysis of data. The carcass yield (CAY) performance was estimated as CAY = (CAW / BW) * 100. Body measurements, weights, and CR were analyzed using descriptive statistics.

To establish the best prediction equation for carcass weight and carcass yield, the "Stepwise Regression" procedure of the SAS® statistical program ver 9.4 was used, implementing the method of selecting the independent variables by stages (*Forward* and *Backward*) and as a whole (*Stepwise*), based on the degree of contribution of the predictor variables, added or removed according to their level of significance (α = 0.05). For the choice of the best predictive equation, the coefficient of determination (R^2), adjusted coefficient of determination (R^2a), Cp-Mallows, mean square of the error (MSE), coefficient of variation (CV), the akaike information criterion were taken into account. (AIC) and the bayesian information criterion (BIC).

By means of an analysis of the main components, the correlation coefficients for the variables under study were obtained, validating the predictive model.

RESULTS

The descriptive statistics of the variables evaluated in white New Zealand rabbits of 60±3 days of age are presented in Table 1. The BW found was 2311.2±295.1 gr and the CAW of 1264.4±174.7 gr, with a CV of 12.8 and 13.8%. Thus, the RC obtained was 54.7±2.4%, in this variable, the CV was only 4.3%. Regarding biometric measurements, those taken on the loin were the measurements that varied the most (14.7% and 18.1% for LL and LW, respectively). On the other hand, most homogeneous measurements were LD, LV, and CC (6.3%, 7.7, and 6.7%, respectively). In the other measurements, the coefficients of variation were between 10.8% and 14.6%.

The selection procedures of the independent variables by *Forward* and *Backward* stages and, overall, *Stepwise*, showed equal values within each dependent variable (Table 2). Therefore, the values of the coefficient of determination, Cp-Mallows, mean square of the error, coefficient of variation (%), Akaike's information criterion, and the Bayesian information criterion did not vary between procedures. So then, the regression equation obtained for the CAW was:

Y_i= 75.83+0.58BW-11.86HL
(R^2: 0.91; $p<0.05$)

Where:
Y_i = is the weight (gr) of the estimated carcass
BW = is the live weight (gr) of the animal
HL = is the length of the head (cm)
On the other hand, the regression equation obtained for the CAY was:

Yi = 49.23 + 0.21LD + 0.25CC-0.64CW-0.57HL
(R^2: 0.20; $p <0.05$)

Where:
Y_i = is the estimated carcass yield (%)
LD = is the length of the dorsal body (cm)
CC = is the chest circumference (cm)
CW = is the chest width (cm)
HL = is the head length (cm)

The principal component analysis showed that the first four components explained 69% of the variation, with explained variability ratios of 29, 20, 11, and 9%, respectively. Head length (HL) and body length measured dorsally (LD) were the variables that contributed the most to the first component. In the second component, two important regions in the carcass, such as the length of the loin (LL) and the thigh (TL), were the ones with the greatest contribution. In the third component, the length of the body measured ventrally (LV) and the width of the head (HW) were the variables that contributed the most. Finally, the circumference of the arm (AC) is the variable with the highest contribution in the fourth component.

The correlation coefficients between all the variables analyzed are presented in Table 3. The highest positive correlation was found between the BW and the CAW ($p<0.001$) and the lowest between HL and TL ($p<0.001$). Regarding the variables of interest in prediction (CAW and CAY), all the variables showed a positive correlation with the CAW, but without statistical differences with LV, LW, CW, HL, TC, and AL ($p>0.05$). While, for CAY, the only CAW was positively correlated ($p<0.001$), and LD, CW, HW and HL measurements were negatively correlated ($p<0.5$). On the other hand, measurements made in related body regions showed a weak correlation between LD and LV ($r=0.23$; $p<0.03$), head measurements (CW and HW) had a positive correlation ($r=0.52$; $p<0.001$) and no correlation was found between measurements on the loin (LL and LW, $r=0.06$; $p= 0.58$), thigh (TC and TL, $r=0.01$; $p=0.94$) and on the arm (AC and AL , $r=0.1$; $p=0.38$).

Table 1. Weight and biometric measurements of white New Zealand rabbits.

Variable	Mean±SD	Maximum	Minimum	CV (%)
Live weight (gr)	2311.6±295.1	3301	1740	12.8
Carcass weight (gr)	1264.4±174.7	1852	964	13.8
Carcass yield (%)	54.7±2.4	59.3	39.0	4.3
Body length dorsal (cm)	47.1±2.9	52.5	39.0	6.3
Body length ventral (cm)	36.7±2.8	43.0	30.0	7.7
Chest circumference (cm)	27.1±1.8	31.3	23.0	6.7
Loin length (cm)	11.9±1.8	17.5	8.0	14.7
Loin width (cm)	6.5±1.2	9.0	4.3	18.1
Chest width (cm)	6.8±0.9	9.0	4.2	13.0
Head width (cm)	4.6±0.5	6.1	3.4	11.2
Head length (cm)	12.2±1.6	16.0	8.5	13.1
Thigh circumference (cm)	17.0±2.3	22.0	9.0	13.8
Thigh length (cm)	10.3±.3	13.0	7.3	12.8
Arm circumference (cm)	10.3±1.1	13.6	8.0	10.8
Arm length (cm)	7.8±1.1	11.2	5.00	14.6

SD: Standard deviation, CV: coefficient of variation

Table 2. Regression procedures, selection criteria, and prediction equations for carcass weight (CAW) and carcass yield (CAY) from biometric measurements in New Zealand white rabbits.

Variable	R^2	R^2a	Cp	Variables retained	MSE	CV	AIC	BIC
CAW	0.91	0.91	3.51	BW, HL	53.24	4.21	814.01	823.28
CAY	0.20	0.16	2.49	LD,CC, CW, HL	2.17	3.96	338.21	347.48

R^2: coefficient of determination, R^2a: adjusted coefficient of determination, Cp: Cp-Mallows, MSE: mean square of the error, CV: coefficient of variation (%), AIC: Akaike information criterion, BIC: Bayesian information criterion

Table 3. Coeficientes de correlación de Spearman entre los pesos (PV y PC), el rendimiento de la canal (RC)y las medidas biométricas de conejos Nueva Zelanda blanco.

	BW	CAW	CAY	LD	LV	CC	LL	LW	CW	HW	HL	TC	TL	AC	AL
BW	---	<0.001	0.55	<0.001	0.12	<0.001	0.12	0.01	0.02	<0.001	0.0034	0.08	0.13	0.0042	0.12
CAW	0.84	---	<0.001	<0.001	0.52	<0.001	0.07	0.1	0.14	<0.001	0.14	0.09	0.1	0.01	0.05
CAY	-0.07	0.41	---	0.22	0.16	0.41	0.09	0.03	0.02	0.09	0.01	0.8	0.06	0.56	0.06
LD	0.53	0.4	-0.14	---	0.03	0.03	0.73	<0.001	<0.001	<0.001	<0.001	0.01	0.17	0.44	0.13
LV	0.17	0.07	-0.16	0.24	---	0.59	0.67	0.67	0.63	0.02	0.66	0.12	0.37	0.36	0.17
CC	0.61	0.58	0.09	0.25	0.06	---	<0.001	0.04	0.04	<0.001	0.1	0.52	0.01	0.13	0.16
LL	0.17	0.2	0.19	0.04	0.05	0.32	---	0.49	0.6	0.51	0.01	0.52	<0.001	0.93	0<0.001
LW	0.27	0.18	-0.24	0.38	-0.05	0.23	0.08	---	0	0.01	<0.001	0.05	0.01	0.48	<0.001
CW	0.26	0.16	-0.26	0.43	0.05	0.23	-0.06	0.78	---	<0.001	<0.001	0.22	0.01	0.69	<0.001
HW	0.52	0.39	-0.19	0.41	0.26	0.38	-0.07	0.27	0.34	---	<0.001	0.07	0.09	0.09	0.07
HL	0.32	0.17	-0.28	0.59	0.05	0.18	-0.29	0.4	0.51	0.52	---	0.01	<0.001	0.96	<0.001
TC	0.2	0.19	-0.03	0.3	-0.17	0.07	0.07	0.22	0.14	0.2	0.27	---	0.74	0.96	0.06
TL	0.17	0.18	0.21	-0.15	-0.1	0.28	0.52	-0.27	-0.28	-0.19	-0.47	-0.04	---	0.05	<0.001
AC	0.31	0.28	0.06	-0.09	-0.1	0.17	-0.01	-0.08	0.04	0.19	-0.01	-0.01	0.22	---	0.36
AL	0.17	0.22	0.21	-0.17	0.15	0.16	0.44	-0.41	-0.39	-0.2	-0.44	-0.21	0.59	0.1	---

Coefficients under the diagonal. Probabilityon the diagonal. BW: live weight, CAW: carcass weight, CAY: carcass yield, LD: body length dorsal, LV: body length ventral, CC: chest circumference, LL: loin length, LW: loin width, CW: chest width, HW: head width, HL: head length, TC: thigh circumference TL: thigh length, AC: arm circumference, AL: arm length.

DISCUSSION

In the present investigation, two regression equations were obtained to predict the carcass weight and carcass yield of New Zealand White rabbits from body measurements.

The CAY found was similar to that reported in New Zealand rabbits with zero hours of fasting before slaughter, but lower than that of rabbits with a similar duration of fasting (57.6%) than that performed in this investigation (13). It has been proposed that, during fasting, the excretion of feces and urine, an index on the quality of the carcass, since the risk associated with contamination of the carcass by excretions is decreased (13). Likewise, different studies show how variations in diet during the growth phase can affect CAY. The value found here was 54.7±2.4 under an *ad libitum* feeding model and with balanced trade. On the other hand, the CAY in New Zealand rabbits fed *ad libitum* was 59.6%, with higher performance in the male (57%) than in the female (56.3%) (14). In New Zealand rabbits crossed by California fed with mini blocks of mulberry flour (*Morus alba*), the CAY was 50.03% (15). Likewise, in animals fed with *Moringa oleifera* flour, the CAY was similar to that found here (54.3%) (16). A lower CAY (52.5%) is presented in animals fed with a forage pellet (17). Other reported CAY values are 54.5% (18), 53.1% (19). While the highest CAY value found was 84.6% (20) in rabbits supplemented with keratin.

All the morphometric measurements did not show much variation, since the coefficients of variation were below 15%, except for the width of the loin (LW). In this regard, Rubio et al (6), assure that the measurements on the loin are complex and can lead to errors. The determination of the width (LW) and length (LL) of the spine, requiring precision in the identification of exact anatomical points, between the transverse process's measurement at the height of the lumbosacral vertebrae for the LW and from the caudal edge of the last rib up to the last coccygeal vertebra in the case of LL. Therefore, spine measurements are not recommended to use for a regression equation. In this investigation, the measurements on the back were not retained by the independent variable selection model.

This investigation reports that the animal's live weight (BW) and head length (HL) are the best predictors of carcass weight (R^2=0.91). According to the regression equation, the BW was directly related to the CAW, whereas, since the animal's head is not part of the carcass, this measurement was negatively related to the CAW, so much so that, for each centimeter of the head, the CAW decreases 11.86gr, although the correlation between these was positive, but not significant ($p>0.05$). The only report in this regard points to the BW as a regressive variable of the CAW, although the model adjustment was less (R^2=0.34) (11). Likewise, using the loin length (LL), the model fit increased to R^2=0.79 as (11). As already discussed, LL was not retained as a regressive variable, although it was positively correlated with CAW with p=0.07.

Biometric measurements and BW were not good predictors of carcass yield (CAY), the R^2 obtained suggests that the regression equation resulting from the analysis only explains 20% of the observed data, which is corroborated with the low value of Cp-Mallows found (Table 2).

Only the HL variable was retained in the two proposed equations with negative coefficients, this suggests that genetic selection in this character could improve the characteristics evaluated here, even more so when the correlation between HL and CAY was negative and significant (p=0.01).

Post-mortem measures from retail cuts have been used for the prediction of carcass weight in rabbits (12). The results indicated that the measures used are poor predictors of the CAW and only with the thigh perimeter (TC) was a value R^2=0.69 (12) obtained. In this investigation, the TC was not retained as a regressive variable, it did not correlate with the CAW, not with the CAY. In addition, no *post-mortem* measurements were taken, because one of the contributions of this work is to be able to predict CAW and CAY as accurately as possible from biometric measurements in live animals, in order to be used as an indicator of breeding selection in breeding programs.

Las mediciones en la región torácica del conejo, revelan que el perimetro (PT) se relaciona fuertemente con el PC y por el contrario, que el ancho (AT) se relaciona con el RC. De estas, solo el AT fue retenida como variable regresora, con coefiente negativo, al igual que con correlación negativa (p=0.02). Esto sugiere entonces, que una forma alargada o cilindrica en el conejo, podría mejorar el desempeño productivo del conejo, esta afirmación la soporta el efecto positvo de la variable largo dorsal sobre el peso y el rendimiento de la canal.

Measurements in the rabbit's thoracic region reveal that the perimeter (CC) is strongly related to the CAW and, conversely, that the width (CW) is related to the CAY. Of these, only the CW was retained as a regressive variable, with a negative coefficient, as well as a negative correlation (p=0.02). This suggests then, that an elongated or cylindrical shape in the rabbit, could improve the productive performance of the rabbit, this statement is supported by the positive effect of the dorsal long variable on the weight and performance of the carcass.

On the other hand, in pet rabbits, the length of the body and the arm have been proposed to be good predictors of the body condition and the degree of obesity of the rabbit ($p<0.001$) (21). The equations proposed here did not consider the arm length (AL) as a regressive variable, however, it presented low and positive but significant correlation values ($p<0.05$) with the two response variables studied. Likewise, the perimeter of the arm (AC) was related to the CAW ($p<0.05$) more than the CAY (p= 0.56), again highlighting the elongated shape of the body. However, it would be necessary to review the effect of this on the meat/bone ratio in the rabbit. Also, computed tomography measurements of the loin of the live rabbit have been proposed as predictors of muscle mass (22) with values of R^2=0.74. This last technique has also been used to determine meat yield and body fat accumulation in rabbits (23).

Measurements in other species of zootechnical interest indicate that live weight is strongly correlated with CAW in pigs (5) and broilers (9), which coincides with this work. However, in lambs, *post-mortem* measurements better explained the performance found (8). The greatest similarity between our results and that reported in the literature is with guinea pigs (6), wherein addition to the CAW, the head width, they integrate the equation (R^2=0.70) that best predicts the CAW.

In conclusion, the carcass yield found in this investigation is similar to other reports. Biometric measurements together with the live weight of the animal at slaughter age, better predict the carcass weight than the carcass performance.

These results can be used in animal genetic improvement programs, making selection against the long head characteristic.

Conflict of interests

The author (s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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