ASSESSMENT OF CARCASS TISSUE COMPOSITION IN GROWING RABBITS USING REAL TIME ULTRASONOGRAPHY †

[EVALUACIÓN DE LA COMPOSICIÓN TISULAR DE LA CANAL EN CONEJOS EN CRECIMIENTO UTILIZANDO ULTRASONOGRAFÍA EN TIEMPO REAL]

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SUMMARY

Background. Carcass yield varies depending on the relative proportions of muscle, fat and bone, therefore, the possibility of predicting its value would produce valuable information that will promote the viability and sustainability of rabbit meat production. **Methodology.** Thirty-eight male growing rabbits (New Zealand White × Californian) with body weights (BW) of 1329 ± 291 g and from 60 to 100 days of age were used. Real time ultrasonography (RTU) measurements were taken 12 h before slaughtering. For that, rabbits were shaved between the 6th and 7th lumbar vertebrae. The *longissimus thoracis et lumborum* muscle (LM) area (LDA) and also the maximum LM width (LDW) and the maximum depth LM (LDD) were measured. Data recorded at slaughtering included carcass and non-carcass components. After chilling at 4° C for 24 hours, carcasses were split longitudinally to obtain left and right halves that were later weighed. Thereafter, the right half carcass was weighed and manually deboned for recording weights of muscle (TCM), and bone (TCB). **Results.** The highest correlation ($r = 0.84$, $P < 0.001$) was observed between TCM and LDD, while the lower correlation ($r = 0.4$, $P < 0.001$) was observed between TCB and LDW. The BW were highly related to carcass characteristics ($r > 0.77 \leq 0.97$). *In vivo* RTU measurements explained a low to moderate amount of variation in TCB and TCM with an r^2 of 0.36 to 0.77 ($P < 0.001$) respectively. BW explained from 49 to 92% of variation in TCB and TCM, respectively. **Implications.** The *in vivo* ultrasound measurements it is a viable tool that allows predicting carcass value of rabbits. **Conclusion.** Our results indicated that the use of RTU measurements could accurately predict muscle from growing rabbit's carcass.
Key words: carcass; growing rabbits; body muscle; prediction.

RESUMEN

Antecedentes. El rendimiento de la canal varía en función de las proporciones relativas en términos de músculo, grasa y hueso, por lo tanto, la posibilidad de predecir su valor produciría información valiosa para garantizar la viabilidad y sostenibilidad del sistema de producción de conejos. **Objetivo.** El objetivo fue evaluar las mediciones de ultrasonografía en tiempo real (UTR) *in vivo* para evaluar la composición de la canal de conejos en crecimiento. **Metodología.** Se utilizaron 38 conejos machos en crecimiento (New Zealand White × Californian) con un peso vivo

(PV) de 1329 ± 291 g y de 60 a 100 días de edad. Las mediciones de UTR se tomaron 12 h antes del sacrificio. Para eso, los conejos se afeitaron entre la sexta y séptima vértebra lumbar. En el músculo *longissimus thoracis et lumborum* (LM) se midieron el área (ALM), amplitud máxima (ALM) y la profundidad máxima (PLD). Los datos registrados en el sacrificio incluyeron componentes en canal y no canal. Después de enfriar a 4 ° C durante 24 horas, las canales se dividieron longitudinalmente para obtener las mitades izquierda y derecha que luego se pesaron. Posteriormente, se pesó la mitad derecha de la canal y se deshuesó manualmente para registrar los pesos de músculo (MTC) y hueso (HTC). **Resultados.** La correlación más alta (r = 0.84, P <0,001) se observó entre MTC y PLM, mientras que la correlación más baja (r = 0.4, P <0.001) se observó entre HTC y ALM. El peso corporal estuvo altamente relacionado con las características de la canal (r> 0.77≤0.97). Las mediciones de RTU in vivo explicaron una cantidad de variación de baja a moderada en TCB y TCM con un r2 de 0.36 a 0.77 (P <0.001) respectivamente. BW explicó del 49 al 92% de la variación en TCB y TCM, respectivamente. **Implicaciones.** Las mediciones de ultrasonido in vivo son una herramienta viable que permite predecir el valor de la canal de los conejos. **Conclusión**. Nuestros resultados indicaron que el uso de mediciones de UTR podría usarse con precisión y exactitud para predecir el músculo en la canal de conejos en crecimiento.

Palabras clave: canal; conejos en crecimiento; músculo corporal; predicción.

INTRODUCTION

Due to the high growth rate, high prolificacy, short reproductive cycle, rabbit production systems have been increased around to the world (Blasco *et al.,* 2018). Moreover, compared to meats of other animal species, rabbit meat has lower cholesterol contents and high levels of protein with essential amino acids, especially in the *Longissimus dorsi* muscle, which also has a high digestibility value (Dalle Zotte, 2002; Dalle-Zotte and Szendrö, 2011).

The main traits of economic importance in rabbit production are feed conversion rate, litter size, and carcass yield (Montes-Vergara *et al.,* 2020). The latter, is an important trait because carcasses are generally graded and the price is established according to this value in commercial slaughter-houses (Piles *et al.,* 2004). Rabbit-meat researchers have focused their interests on how to increase live performance and carcass yield (Dalle Zotte, 2002). Carcass yield varies depending of the relative proportions of muscle, fat and bone, in the carcass, therefore, the possibility of predicting its value, would produce valuable information to guarantee the viability and sustainability of the rabbit production system (Montes-Vergara *et al.,* 2020).

It has been established that knowledge carcass composition and meat traits are important aspects of animal science to improve genetics, nutrition, physiology, and carcass value (Silva and Cadavez, 2012; Silva *et al.,* 2012). For determination of carcass composition, traditionally been used the destructive method for the determination of carcass tissue composition of farm animals. For that, in the lasts decades, the real time ultrasound techniques (RTU) have been used to predict carcass composition and *in vivo* meat traits on different animal's species (Silva and Cadavez, 2012; Silva *et al.,* 2012). In rabbits, the use of RTU for predicting carcass tissue composition is scarce (Silva *et al.,* 2009; Silva *et al.,* 2012). In other

species, especially beef cattle, ultrasound techniques for muscle measurement, back fat and marbling score are widely used both *in vivo* and *post-mortem* (Fabbri *et al.*, 2021; Fiore *et al.*, 2020). Moreover, the knowledge of the carcass tissue composition and its distribution in rabbits is valuable information because one of the main challenges in the market of meat, along with ensuring food safety, is the commercialization of a product that is both homogeneous and enjoyable. Among the most important characteristics exerting a significant influence on the aroma, tenderness, and juiciness of the meat, is the fat content in the muscle mass.

In Mexico, in the last decades because to the growth of the national market of rabbit meat, it is necessary to generate information on the carcass tissue composition to provide valuable information in order to ensure the economic viability rabbit production systems (Galan-Caballero *et al.,* 2021). As well as to optimize the decisions support system, that leads to increase the profitability of farm animal's production systems (Barba *et al.,* 2018). Because, there is no information available on the use of RTU on carcass evaluation of growing rabbits raised in tropical conditions. Therefore, the objective of the present study was to evaluate *in vivo* RTU measurements for assessing carcass composition of growing rabbits.

MATERIALS AND METHODS

Experimental site and animals

All animals were managed in compliance with the guidelines and regulations for ethical animal experimentation of the División Académica de Ciencias Agropecuarias, Universidad Juárez Autónoma de Tabasco (ID project PFI: UJAT-DACA-2015-IA-02). The climate (Am) of the region is tropical humid with rains in the summer, altitude is 9 m above sea level, average annual rainfall of 1958 mm,

a relative humidity close to 75% and an average annual temperature of 27° C.

In this study, 38 clinically healthy New Zealand White × Californian male fattening rabbits with body weights (BW) of 1329 ± 291g and from 60 to 100 days of age were used. Animals were fed a standard commercial diet (17% crude protein, 11% crude fibre, 2% fat and 11% ash) twice daily. Feed and water were provided *ad libitum*. Rabbits were housed in individual raised-slatted floor cage (45 × 30 × 40 cm), having a photoperiod and natural ventilation. Carcass management was carry out at the Meat and Meat Products Technology Laboratory from Universidad Juárez Autónoma de Tabasco.

Ultrasound measurements

Ultrasound measurements (USM) were taken 12 h before slaughter using a Mindray DP Vet-50® B-mode real-time ultrasound equipment (Mindray Ltd. and national ultrasound Inc.; China) with a 7.5-MHz linear probe. The RTU measurements were taken over the lumbar region between 6th and 7th lumbar vertebrae. For that, rabbits were previously shaved between the 6th and 7th lumbar vertebrae as described by Silva *et al.* (2009). For to obtain the RTU measurements the probe was placed perpendicular to backbone over the *Longissimus thoracis et lumborum* muscle (Silva *et al.* (2009). The *longissimus thoracis et lumborum* area (LDA), the maximum width of the *Longissimus* muscle (LDW) and the maximum depth of the Longissimus muscle (LDD) were recorded. All measurements were taken on the right flank of the animals. After capturing images, LDA, LDW and LDD were measured using digital callipers of the equipment (Figure 1).
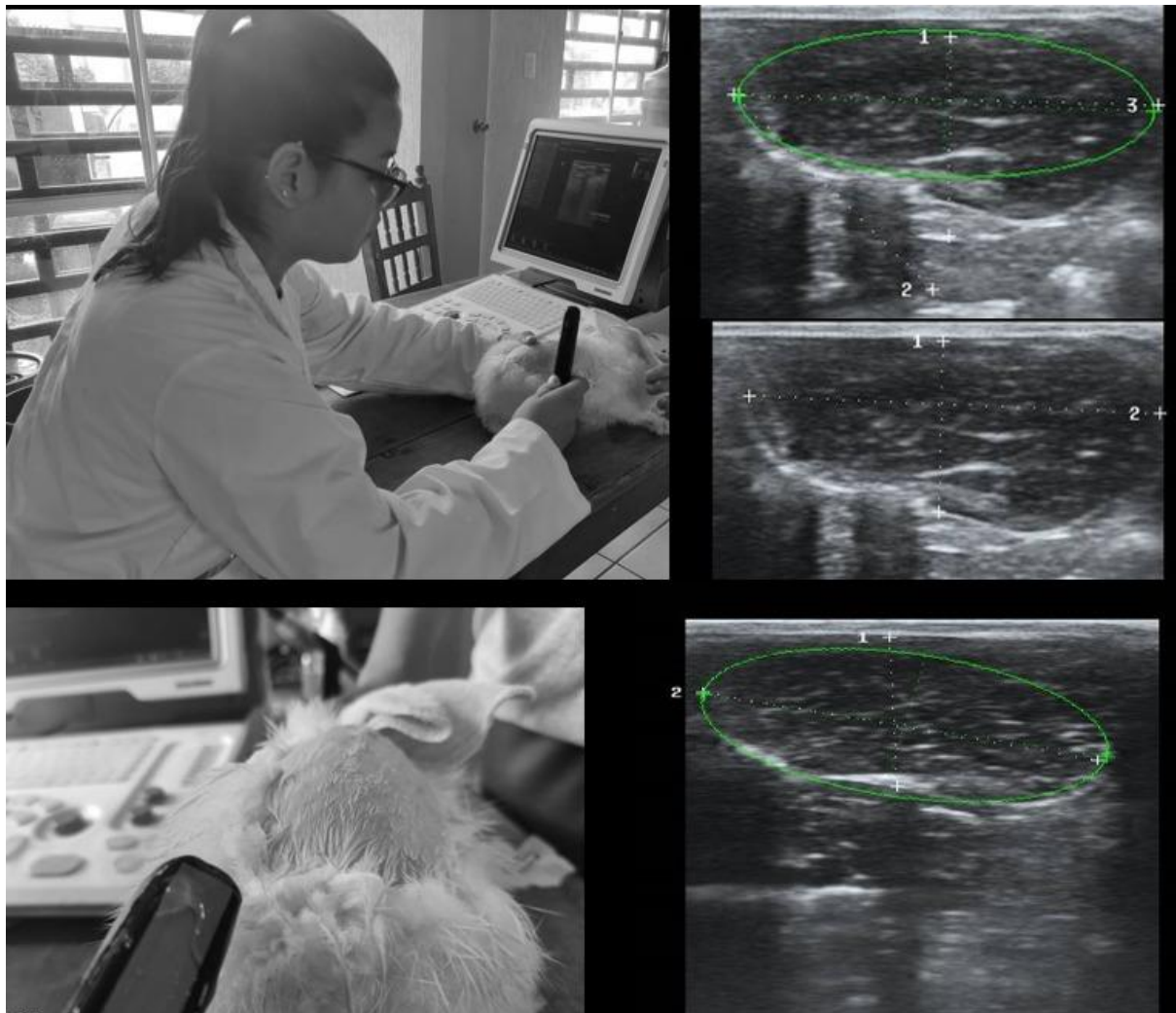

Figure 1. Real time ultrasonography (RTU) measurements and image acquisition procedure with a linear probe placed over loin region between the 6th and 7th lumbar vertebrae in male growing rabbits (New Zealand White × Californian).

Slaughter of animals and carcass dissection

Twelve hours before slaughtering, feed and water were withdrawn, and the BW was recorded. The animals were slaughtered according to the Mexican Official Standard NOM-033-SAG/ZOO-2014 for humane slaughtering of animals. Data recorded at slaughtering included carcass and non-carcass components (viscera). After storage at 4° C for 24 h, carcasses were carefully split longitudinally with a band saw to obtain left and right halves. Thereafter, the right half carcass was weighed and manually deboned to record weights of muscle (TCM), and bone (TCB). Dissected tissues of the right half carcass were adjusted as whole carcasses.

Data analyses

Data were processed and analysed using the PROC MEANS procedure from SAS (SAS Inst. Inc., Cary, NC, 2010). Pearson correlation analysis was conducted using the PROC CORR of SAS. Regressions among variables were calculated using the PROC REG of SAS. To predict the carcass tissue composition, entire carcass tissue weights as dependent variable was used. The predictors (i.e., independent variables) were the LDA, LDW and LDD. The stepwise procedure was used to select the variables for predictive equations; only variables that were significant at $P < 0.05$ were selected for the development of the predictive equations.

RESULTS

Descriptive statistics for carcass traits and RTU measurements are reported in Table 1. The BW, HCW and CCW ranged from 757 to 1906 g, 315 to 1073 g, and 312 to 1066 g, respectively. With regard to the RTU measurements, the LDD and LDW ranged from 0.93 to 1.81 cm and 2.10 to 3.56 cm, respectively, while the LDA ranged from 1.00 to 3.99 cm². The TCM and TCB ranged from 231.56 to 776.39 and 129.12 to 344.99.

Table 1. Descriptive analyses of the data measured in live animals using real time ultrasonography (RTU) (n = 38 growing rabbits).

Variable	Description	Mean ± SD	Maximum	Minimum
BW	Body weight (kg)	1329 ± 291	1906	757
HCW	Hot carcass weight (g)	696 ± 188	1073	315
CCW	Cold carcass weight (g)	690 ± 187	1065	312
LDD	Longissimus muscle depth (cm)	1.26 ± 0.22	1.81	0.93
LDW	Longissimus muscle width (cm)	2.73 ± 0.32	3.56	2.10
LDA	Longissimus muscle area (cm²)	2.43 ± 0.69	3.99	1.00
TCM	Total carcass muscle (g)	472 ± 143	776	231
TCB	Total carcass bone (g)	225 ± 52.5	344	129

SD: Standard deviation.

Table 2. Correlations coefficients between carcass traits and RTU measurements in growing rabbits.

	HCW	CCW	LDD	LDW	LDA	TCM	TCB
BW	0.97***	0.97***	0.83***	0.79***	0.77***	0.95***	0.70***
HCW		0.99***	0.86***	0.77***	0.80***	0.96***	0.76***
CCW			0.85***	0.77***	0.80***	0.96***	0.76***
LDD				0.72***	0.85***	0.84***	0.76***
LDW					0.74***	0.76***	0.44**
LDA						0.80***	0.57**
TCM							0.58***

BW: body weight (g); HCW: hot carcass weight (g); CCW: cold carcass weight (g); LDD: Longissimus muscle depth (cm); LDW: Longissimus muscle width; LDA: Longissimus muscle area (cm²); TCM: total carcass muscle (g); TCB: total carcass bone (g). [1]Correlations followed by no superscript indicate ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; ns: non-significant

Table 3. Regression equations to predict carcass traits using RTU measurements in growing rabbits [1]

No.	Equation	n	r^2	MSE	RMSE	*P-Value*
	Excluding the BW					
1	TCM (g) = - 193.56 (± 71.51**) + 526.07 (± 55.57***) × LDD	38	0.71	6045.36	77.75	< 0.0001
2	TCM (g) = - 405.77 (± 100.61***) + 378.25 (± 73.64***) × LDD + 145.79 (± 52.38***) × LDW	38	0.77	5091.54	71.35	< 0.0001
3	TCB (g) = 47.37 (± 41.53*) + 138.74 (± 31.91 ***) × LDD	38	0.36	1829.05	42.76	0.0001
	Including the BW					
4	TCM (g) = - 153.43 (± 31.34***) + 0.47 (± 0.02***) × BW	38	0.92	1673.34	40.90	< 0.0001
5	TCM (g) = - 153.78 (± 29.10***) + 0.40 (± 0.03***) × BW + 36.23 (± 13.94*) × LDA	38	0.94	1442.82	37.98	< 0.0001
6	TCB (g) = 43.55 (± 31.99 *) + 0.13 (± 0.02 ***) × BW	38	0.49	1432.27	37.84	< 0.0001

BW: body weight (g); LDD: Longissimus muscle depth (cm); LDW: Longissimus muscle width (cm); LDA: Longissimus muscle area (cm^2); TCM: total carcass muscle (g); TCB: total carcass bone (g). [1]Values within parentheses are the standard errors (SEs) of the parameter estimates. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

The correlation coefficients (r) between carcass traits and RTU measurements are presented in Table 2. All correlations between the evaluated variables were positive and significant ($P < 0.001$), of moderate to high magnitude. The highest correlation (r = 0.84) was observed between TCM and LDD, while the lower correlation (r = 0.44) was observed between TCB and LDW. Notably, the BW were highly related with carcass characteristics evaluated (r > 0.77 ≤ 0.97).

The regression equations developed to predict carcass tissue composition are shown in Table 3. For the prediction of TCM (without included BW), two equations were obtained and the best equation [Eq. 2] explained from 71 to 77% of the observed variation and considered LDD and LDW as predictors. On the other hand, for the TCB an equation [Eq. 3] was obtained with an $r^2 = 0.36$, using the LDD as a predictor variable. When BW and RTU were included simultaneously in the regression models to predict TCM [Eq. 5], an r^2 of 0.94 was observed. Finally, the BW alone explained 49% of the observed variation in the prediction equation for the TCB [Eq. 6].

DISCUSSION

In general, mean values and ranges of variation for HCW and CCW were lower than those reported by Ortiz-Hernández and Rubio-Lozano (2001) in different rabbit breeds. Such differences were due to the different mean values of rabbit's body weight used in that study (~2000 g) compared to those from the present study (1329 g). Paci *et al.* (2012) have previously reported that slaughter weight, age and genotype are important factors that affect variability on yield and composition of rabbit carcass. The observed carcass yield was consistent with that reported by Montes-Vergara *et al.* (2020) in New Zealand White (NZ) breed rabbits. However, in the present study,

animals were New Zealand White × Californian rabbits. The correlation coefficients (r^2) observed in the study suggest that RTU measurements can be used as predictors of TCM and TCB. The trend towards low correlation coefficients between assessed traits is due to the wide range of body weight of the animals and the procedures during slaughter.

The potential of real-time ultrasound (RTU) as predictor of carcass tissue composition traits was moderately good (r^2 between 36 and 77%). However, these coefficients of determination were lower compared to those reported by Silva *et al.* (2012) in crossbred rabbits (New Zealand White × Californian). These authors reported an r^2 that ranged from 41 to 81%, with the *longissimus dorsi* muscle volume being a good predictor for carcass tissues. In addition, Blasco *et al.* (1984) described that slaughtering weight and carcass weight are good predictors of total muscle of the carcass with coefficients of determination of 0.84 and 0.88, respectively. Such differences could be due to the resolving power of the equipment used in each study, since that it is an important factor of variation, particularly in small animals such as rabbits due to their small *longissimus dorsi* muscle (Silva *et al.,* 2012).

Real-time ultrasound and BW can be used as predictors for carcass quality in rabbits (Silva *et al.,* 2009; Silva *et al.,* 2012). Our results confirmed that BW combined with *in vivo* RTU measurements improved the prediction of TCM, thus agreeing with Silva *et al.* (2009). In addition, we confirmed that the use of RTU measures is a practical and easy technique for *in vivo* carcass traits prediction because it is not harmful and less stressing to the rabbit. Although studies are scarce, RTU measurements are a useful tool that has a relevant role in evaluating *in vivo* carcass characteristics in

rabbits with special focus on muscle weight (Silva *et al.,* 2009; Silva *et al.,* 2012; Silva and Stouffer, 2019).

CONCLUSION

Our results indicated that the use of ultrasound measurements could accurately; yielding equations that had r^2 that ranged from 0.71 to 0.77. The ultrasound measurements can be used as an alternative for predicting muscle from growing rabbit carcasses. In addition, more in vivo and post-mortem measurements could be evaluated to improve the predictions.

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Compliance with ethical standards and Statement of animal rights. All applicable international, national and/or institutional guidelines on the care and use of animals were followed.

Conflict of interest. The authors declare that they have no conflicts of interest.

Data availability. Data are available with the corresponding author of this publication upon reasonable request.

Author contribution statement (CRediT). All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by C. Valencia, T. Arbez, E. Vargas, and A. Chay. R. Portillo, R. Garcia, J. Herrera and F. Cigarroa. Contributed new reagents or analytical tools. C. Valencia, E. Vargas and A. Chay writing and editing the draft. The first draft of the manuscript was written by C. Valencia, E. Vargas and A. Chay and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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