Comparing the economic results between feedlot noncastrated vs immunocastrated Holstein bulls

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SUMMARY

The study compared the economic results between two groups: non-castrated Holstein bulls and bulls castrated with the gonadotropin-releasing hormone vaccine Bopriva. 510 Holstein feedlot bull calves between 7 and 8 months with a 220±1.19 kg. initial live weight was included. 269 bulls were vaccinated and 241 received no treatment. The vaccinated group got four immunizations: 24 hours upon arrival and 21, 101 and 181 days after the first vaccination. Bulls in the control group received a placebo. The effects of the treatments on hot carcass weight, cold carcass weight, fat thickness, kidney, pelvic and heart fat, ribeye area, and marbling score were analyzed using the GLM procedure. The linear statistical model for this trial included the overall mean, the fixed treatment effect, the random pen within treatment effect (experimental error), and the random animal within pen component (sampling effects within experimental units). Profit was estimated by subtracting the total cost from the revenue. Hot carcass weight, fat thickness, kidney, pelvic and heart fat and ribeye area were obtained to estimate final cut yield and quality grade. The average weight of the carcasses from the treated group was higher (P<.05) and feeding costs lower, contributing to a greater profit for this group. The vaccinated group had a lower final cut yield and higher quality grade.

Resultados económicos entre novillos Holstein inmunocastrados vs no castrados, en engorda intensiva

RESUMEN

Se compararon los resultados económicos de la engorda entre animales enteros y animales inmuno-castrados con la vacuna anti GnRH, Bopriva. Se incluyeron 510 novillos Holstein entre 7 y 8 meses de edad con peso inicial de 220±1.19 kg. 269 novillos fueron vacunados y 241 no recibieron tratamiento. El grupo vacunado recibió cuatro inmunizaciones: 24 horas después del arribo a la engorda y 21, 101 y 181 días después de la primera vacunación. Los animales en el grupo control recibieron un placebo. Los efectos del tratamiento sobre peso de la canal caliente, peso de la canal fría, el espesor de la grasa dorsal, la grasa pélvica, renal y cardiaca, área del ojo de la costilla y marmoleo fueron analizados utilizando un modelo lineal que incluyó la media general, el efecto fijo de tratamiento, el efecto aleatorio de corral dentro de tratamiento (error experimental) y el componente aleatorio de animal dentro de corral (error de muestreo). La utilidad de cada grupo fue obtenida restando el costo total al ingreso total. A excepción de peso de la canal fría y marmoleo, con las variables estudiadas se estimaron rendimiento final al corte y grado de calidad. El peso promedio de las canales del grupo vacunado fue superior (P<.05) y sus costos de alimentación inferiores al compararlos con los del grupo de animales enteros, lo cual se tradujo en una mayor utilidad para el primer grupo.

INTRODUCTION

Beef production in Mexico is an important economic activity within the agricultural sector as revealed by the fact that in 2015, 1,850,133 metric tons of beef were produced. This production amounted to 9713.2 millions of dollars which was the result of an increase in production of 292,425 metric tons in the last ten years (SIAP, 2016). Northern Mexico is where beef with higher quality traits are produced, so cattle in this region is fattened in feedlots using concentrates (Delgado et al., 2005). This production system relies on technical efficiency to reduce production costs.

Theoretically, beef production may be considered as a competitive market as a consequence of the firm maximizing in the short run its profits by producing an output until marginal cost (Tucker, 1997). Because

the firm is a price taker, if the price of beef falls, the firm responds either by increasing production or by reducing costs. This may be achieved by applying new technology that results in cost reduction. Although feedlots are important users of technologies (Lawrence and Ibarburu, 2007) the adoption of new technological options by the firm comes with difficulties, so in order to promote the use of new technologies it is recommended to demonstrate its economic benefits (Schroeder and Tonsor, 2011).

Surgical castration of cattle is a common practice in feedlots because it improves carcass quality as it increases the percentage of marbling and a greater subcutaneous fat thickness, traits that are sought by the slaughter house industry, moreover the procedure reduces the frequency of undesirable sexual and aggressive behaviors (Moreira et al., 2015). This effect is important in the case of Holstein cattle which has increased rider and bull behavior when compared with beef cattle (Duff and Mac Murphy, 2007). Also, surgical castration requires additional labor, increases stress, decreases feed efficiency, and reduces the rate of weight gain (Kiyma et al., 2000), and as a result decreasing the producer´s revenue.

Surgical castration is considered a very painful experience for the calf, therefore it has been questioned from a welfare perspective, and also the acute pain of castration causes reduction of food intake and lower productive performance 1 to 3 weeks after the procedure (Martí, 2012).

The benefits of castration without its negative effect may be achieved using immunocastration as an alternative to the surgical procedure. It has been shown that inmunocastration has no effect on meat quality and improves growth performance (Amatayakul-Chantlera et al., 2013). In the male as in the female, GnRH (gonadotropin-releasing factor) plays a central role in the regulation of sexual function. Immunization against GnRH, suppresses the secretion of the gonadotropins LH and FSH (Thompson, 2000). The anti-GnRH vaccine Bopriva® (Pfizer Animal Health) is designed and marketed specifically for cattle (Janett et al., 2012).

The aim of the present study was to compare the economic results between the carcasses of entire bulls and immunocastrated bulls using the anti-GnRH vaccine Bopriva.

MATERIAL AND METHODS

The study was conducted in a commercial feedlot located in Mexicali, Mexico. It involved 510 Holstein bull calves between 7 and 8 months with a 220±1.19 initial live weight. The animals were randomly distributed into two groups: 269 immunocastrated calves and 241 non-castrated. The bulls in the treated group received four immunizations: the first one was 24 hours upon arrival, and 21, 101 and 181 days after the first vaccination. Animals in the control group received on the same days a 1 ml saline solution injection as a placebo. The animals were fed twice a day with the normal three diet program used by the feedlot, the ra-

tions ingredients were: wheat hay, sudangrass, tallow, DDG (Dried distillers grains), and a mineral premix.

After spending 239 days in the feedlot, the bulls were slaughtered in a commercial slaughterhouse. The average weight of the group was 580±4.82 Kg . The final data was obtained from 225 carcasses from the Bopriva group and 208 carcasses from the non-castrated group.

The average cold carcass weight (CCW) of both groups of carcasses was obtained. To evaluate the differences in retail cuts yield between the groups, hot carcass weight (HCW), fat thickness, kidney, pelvic and heart fat (KPH) and ribeye area were recorded; while the marbling score was used to estimate the quality differences.

The effects of the treatments (treated versus non-treated) on CCW, HCW, fat thickness, KPH, ribeye area, and marbling score were analyzed using the GLM procedure (SAS Inst. Inc., Cary, NC). The linear statistical model for this trial included the overall mean, the fixed treatment effect (Bopriva vs placebo), the random pen within treatment effect (experimental error), and the random animal within pen component (sampling effects within experimental units). When the treatments represented a significant (P≤0.05) source of variation, differences between means for treatment were compared using Tukey's procedure.

Due to the fact that a difference between the treatment effect was found, it was possible to proceed with a profit assessment for each of the groups. For this evaluation three expenditures were considered: cost of bull calves, feed and immunization with Bopriva, while as a source of revenue the payment received from the sale of the carcasses was used.

The purchase cost of the bull calves for each group was estimated by multiplying the total weight of each of the groups of bull calves times the market price paid for a kilogram of Holstein calve.

Because the feedlot uses three different rations during the production cycle and the prices of the rations are dissimilar, three partial feeding costs (PFC) were obtained.

The following procedure to estimate the cost for each feeding period was used:

PFC=TFC x P

Where:

PFC= Partial feeding costs

TFC=Total food consumption (Kg.)

P=Price of a Kilogram of feed (USD)

The three group costs were added to obtain the total feeding costs (TFC)

In the case of the immunocastrated group the cost of Bopriva was added to TFC to obtain the total cost (TC). In the non-castrated group TC was equal to TFC.

The revenue was obtained using the total cold weight of each group of carcasses and the price paid for a kilogram of meat, the formula to obtain the in-

come that resulted from the sale of the carcasses is presented next:

RG = TWG x PM

Where:

RG= Revenue per group

TWG: Total weight per group

PM = Price of one kilogram of meat (USD).

To determine the total profit (TP) obtained in each of the two groups TFC was subtracted to IG. Using the cold carcass average weight an individual profit (IP) was estimated for each group and with these values it was possible to compare the results.

HCW, ribeye area, fat thickness and KPH measurements were used to determine a difference in yield by using the USDA yield grades (Hale et al., 2013). The formula use to determine the yield grade (YG) was:

$$YG=(FT \times PYG)+(HCW \times APYG)-(KPH \times APYG)-(REA \times APYG)$$

YG= Yield grade

FT=Fat thickness (inches)

PYG=Preliminary yield grade

HCW=Hot carcass weight (Lbs)

APYG= Adjustment to PYG

KPH= Kidney, pelvic and heart fat as percentage of body weight

REA=Ribeye area (sq. in.)

Once the YG was determined the corresponding percentage of boneless, closely trimmed retail cuts (BCTRC) from beef carcasses was applied.

To obtain the quality grade of the carcasses of both groups the following marbling scores were used: 200=practically devoid, 300=Traces, 400=Slight, 500=Small, 600=Modest, 700= Moderate, 800=slightly abundant. The mean of each group was employed to assign a classification and also used in conjunction with the age of the bulls to determine the carcass quality grade.

RESULTS

After separating the bulls that were sick or had an excessive aggressive behavior, the data was obtained from 225 carcasses from the vaccinated group, and 208 from the non-vaccinated. Significant differences between the groups (P<0.05) were found in carcass weight, marbling and fat characteristics and no diffe-

Table I. Mean values ±S.E. for the carcass characteristics by group (Valores medios ± E.E. para las características de la canal por grupo).

Variable	Immunocastrated	Non-castrated	P value
CCW (kg)	357.68±3.13	347.84±2.50	0.0026
HCW (kg)	360±3.24	349±3.46	0.0006
Fat thickness (mm)	6.77±0.18	4.48±0.02	0.0001
KPH (%)	1.97±0.05	1.68±0.19	0.0001
Ribeye area (cm)	32.16±0.23	32.67±0.28	0.2021
Marbling*	433.18±4.11	367.70±3.45	0.0001

CCW: Cold carcass weight.
HCW: Hot carcass weight
KPH: Kidney, pelvic and heart fat.
*: 200=practically devoid, 300=Traces, 400=Slight, 500=Small, 600=Modest, 700= Moderate, 800=slightly abundant.

rence for rib eye area (P>.10). The average cold carcass weight (CCW) was 9.8 kg higher for the immunocastrated group. It was also found that the carcass from this group accumulated more fat **(Table I)**.

Considering that the price for one kilogram of Holstein calves at the time of purchase was 3.94 dollars, the expenditure for purchasing the calves assigned to the vaccinated group amounted to 195,030 dollars, while the amount paid for the calves in the non-vaccinated group was 180,294 dollars.

The total feeding cost for the vaccinated group was lower even though it included the cost of the vaccine **(Table II)**.

The reduction of feeding costs for the vaccinated group was evident by the second feeding period and the reduction was maintained through the third period so that the result was that the individual total cost for the vaccinated group was lower.

As a result of the lower feeding costs and the higher revenue obtained from the vaccinated group, the profit was 20.7% higher when compared with the non-vaccinated group **(Table III)**.

An interesting finding was that the individual average cost of feeding for the immunocastrated group ($555.00), it was $97.00 lower than the individual average cost of the non-vaccinated group ($652). Thus the difference in profit was not only a result of higher carcass weight for the vaccinated group but also a consequence of a lesser intake of feed.

Table II. Partial, total and unit costs per group* (Costos totales parciales y unitarios por grupo).

Group	PFC$_1$	IC$_1$	PFC$_2$	IC$_2$	PFC$_3$	IC$_3$	TFC	ITFC	Bopriva	TC	ITC
Vaccinated	8,667	38.5	88,250	392.2	24,051	106.9	120,968	537.6	4,000	124,968	551
Non vaccinated	6,378	30.6	105,405	505	23,908	114.9	135,691	652.3	-	135,691	652

PFC$_i$: Partial feeding cost for the ith period; IC$_i$: Unit cost for the ith period; TFC: Total feeding cost; ITFC: total feeding cost/unit; TC: Total cost; ITC: Total cost/unit; US dollars.

Table III. Cost, revenue and profit of vaccinated and non-vaccinated groups (Costos, ingresos y utilidad de los grupos vacunado y no vacunado).

	Vaccinated	Non-vaccinated
Bulls slaughtered	225	208
Costs		
Bull calves	195030	180294
TFC	124968	135691
Bopriva	4000	--
TC	323998	315985
Revenue		
RG	472808	425060
Profit		
RG-TC	148810	109075
IP	661	524

*US Dollars

The extra revenue obtained from the additional 9.8 kg CCW gained by the vaccinated group resulted on increased revenue of 57.8 dollars per carcass. Considering that the individual cost of vaccination was 17.8 dollars this result supports the use of the anti-GnRH vaccine by the producer.

Given that the amount of fat in the immunized carcasses was higher; this was viewed as a factor that had an effect on the greater CCW of this group. Although it leads to higher revenue for the producer, it does not necessarily mean that the amount of trimmed retail product will be larger.

The estimation of the yield grades resulted on a YG for the carcasses of the vaccinated group of 3 which indicated that the expected BCTRC for this group was between 47.7 and 50%, while the carcasses of the non-vaccinated received an average score of 2 suggesting a BCTRC of 50 to 52.3%.

On the other hand, the average beef marbling score for the vaccinated group positioned it in the slight category, while for the non-immunized group the score placed it in the traces category. Based on the marbling scores and considering that the maturity of the bulls was 15 months, the carcasses from the immunized group was classified as select while the carcasses of the non-vaccinated group were categorized as standard.

DISCUSSION

The results of this study differ with other research that found that non-castrated and immunocastrated animals yield carcasses with similar weights (Cook et al., 2000; Martí, 2012). Also other researchers report that non-castrated bulls produce heavier carcasses than immunized bulls (D'Occhio et al., 2001). A plausible explanation for the higher carcass weight found for the immunized group may be the fact that immunocastration maintains a residual level of androgen secretion that might be adequate to maintain growth and feed efficiency (Adams, 2005). Moreover, the reduced physical activity in vaccinated animals improve their bodies

condition (Janett et al., 2012). Even though it should be mentioned that due to the anabolic effect of testosterone entire bulls take more time to deposit fat (Coutinho et al., 2006), which may explain why the fat thickness of this group was lower, in accordance to what has been reported in other studies (Andreo et al., 2013).

The finding of a lower expenditure on feed in the immunocastrated group may be explained by other studies that indicate that vaccinated bulls have better feed efficiency than non-immunized bulls (Cook et al., 2000) thus improving the producer's profit.

The lower feeding cost found in this study is relevant when considering that in Mexico feedlot feeding cost is between 60 and 75% of the total production costs (Financiera Rural, 2012) and that at the final part of the feeding period the daily increase of daily costs may exceed the incremental value of gain (Streeter et al., 2012).

Because the economic value of carcasses depend mostly on its weight (Owens and Gardner, 2000), the additional weight of the carcasses obtained from the vaccinated group may be seen as the most important factor to support the use of anti-GnRH vaccine by the feedlot owner.

It is worthy to take into consideration that trimmed fat is the majority of carcass waste and that it has been reported that carcass fat thickness and KPH have an important negative relation with cutability percentage (Herring et al., 1994). This is supported by the YG result of this study which indicates that the meat packer might receive a smaller pay from the sale of beef due to the lower percentage BCTRC from vaccinated carcasses.

Considering that it has been reported that the majority of Holstein steer carcasses (59.4%) receive a yield grade of 2 (Duff and Mac Murphy, 2007), the lower yield grade obtained by the vaccinated group may be seen as an indicator that the use of Bopriva reduces the percentage of BCTRC, thus affecting the meat packer expected revenue.

The higher quality grade found in this study has also has been reported by other researchers (Amayatakul-Chantlera et al., 2012) and it is explained by the positive relation between quality grade and KPH percentage (Mckena et al., 2002). Quality grade is considered an important economic factor due to the fact that a higher quality grade is accompanied by a higher price for the beef that is sold by the packer, thus increasing his or her revenue.

The findings of this study suggests that the use of the anti-GnRH vaccine Bopriva results in an increase profit for the beef producer as a result of production rise with decreasing feeding costs, which is in agreement with what the use of pharmaceutical technologies seek (Lawrence and Irbaburu, 2007). The small cost increase that resulted from the use of the anti-GnRH vaccine and the positive effect on revenue that was found in this study suggests that feedlot owners will be willing to adopt the technology if this economic advantage is demonstrated.

In view of the fact that it has been reported that immunocastrated bulls have good production results without negative effects on carcass quality (Amatayakul-Chantlera et al., 2012), feedlots that do not physical castrate can vaccinate with Bopriva and reduce the negative effects that result from the behavior of noncastrated bulls, with the added benefit of improving handler safety (Voisinet et al., 1997).

Although this study compared results between entire and immunocastrated bulls, it is also important to consider that, based on reports that indicate that surgically castrated bulls had a lower productive performance than bulls that were immunized with the anti-GnRH vaccine Bopriva (Amatayakul-Chantlera et al., 2013; De Freitas et al., 2015). Immunocastration becomes an economical sound option to surgical castration for feedlot operations that use this procedure while also addressing concerns about animal welfare.

CONCLUSION

From an economic standpoint, the findings in this study suggest that the use of Bopriva increased the economic return to the beef producer as a result of a higher average weight of the carcasses sold. However, an important concern is that the vaccinated group accumulates more fat and that this carcass trait has an effect on the final cuts yield and quality of the beef. Notwithstanding a higher revenue may be expected from the sale of the carcass, the economic results concerning final cut yield and beef quality grading may not be as relevant. Further research on the use of Bopriva and the effect that it has on final cut yield and quality grade are required so that is possible to better understand the economic results that may be expected by the beef packer.

BIBLIOGRAPHY

Adams, TE 2005, `Using gonadotropin-releasing hormone (GnRH) and GnRH analogs to modulate testis function and enhance the productivity of domestic animals´, *Animal Reproduction Science*, vol. 88, no. 1-2, pp. 127 -139.

Amatayakul-Chantler, S, Hoe, F, Jackson, JA, Roca, RO, Stegner, JE, King, V, Howard, R, Lopez, E, & Walker, J 2013, `Effects on performance and carcass and meat quality attributes following immunocastration with the gonadotropin releasing factor vaccine Bopriva or surgical castration of Bos indicus bulls raised on pasture in Brazil´, *Meat Science*, vol. 95, no. 1, pp. 78 -84.

Amatayakul-Chantler, S, Jackson, JA, Stegner, J, King, V, Rubio, LMS, Howard, R, Lopez, E, & Walker, J 2012, `Immunocastration of Bos indicus × Brown Swiss bulls in feedlot with gonadotropin-releasing hormone vaccine Bopriva provides improved performance and meat quality´, *Journal of Animal Science*, vol. 90, no. 11, pp. 3718-3728.

Andreo, N, Bridi, AM, Tarsitano, MA, Peres, LM, da Costa Barbon, APA, de Andrade, EL, & Prohmann, PEF 2013, `Influência da imunocastração (Bopriva®) no ganho de peso, características de carcaça e qualidade da carne de bovinos Nelore´, *Semina: Ciências Agrárias*, vol. 34, no. 2, pp. 4121-4132.

Cook, RB, Popp, JD, Kastelic, JP, Robbins, S, & Harland, R 2000, `The effects of active immunization against GnRH on testicular development, feedlot performance, and carcass characteristics of beef bulls´, *Journal of Animal Science*, vol. 78, no. 11, pp. 2778 -2783.

Coutinho, JLV, Peres, RM, & Justo, CL 2006, `Produção de carne de bovinos contemporâneos, machos e fêmeas, terminados em confinamento´, *Revista Brasileira de Zootecnia*, vol. 35, no. 5, pp. 2043-2049.

Delgado, E, Rubio, MS, Iturbe FA, Méndez, RD, Cassís, L, & Rosiles, R 2005, `Composition and quality of Mexican and imported retail beef in Mexico´, *Meat Science*, vol. 69, no. 3, pp. 465 -471.

D'Occhio, MJ, Aspden, JW, & Trigg, ET 2001, `Sustained testicular atrophy in bulls actively immunized against GnRH: potential to control carcase characteristics´, *Animal Reproduction Science*, vol. 66, no. 1-2, pp. 47 -58.

Duff, GC, & McMurphy, CP 2007, `Feeding Holstein steers from start to finish´, *Veterinary Clinics of North America: Food Animal Practice*, vol. 23, no. 2, pp. 281 -297.

Financiera Rural 2012, `Monografía Bovinos de engorda´, viewed 28 July 2015, http://www.financierarural.gob.mx

Hale, DS, Goodson, K, & Savell, JW 2013, `USDA beef quality and yield grades´, viewed 9 March 2016, http://meat.tamu.edu/beefgrading

Hernández, MJ, Arieta, RR, Fernández, FJ, Alvarado, GL, Graillet, JE, Rodríguez, ON, González, AJ, & Solano, DA 2015, `Relación beneficio-costo utilizando zeranol en la empresa bovina´, viewed 9 March 2016, http://www.veterinaria.org/revistas/redvet/n040415.html

Herring, W0, Williams, SE, Bertrand, JK, Benyshek, LL, & Miller, DC 1994, `Comparison of live and carcass equations predicting percentage of cutability, retail product weight, and trimmable fat in beef cattle´, *Journal of Animal Science*, vol. 72, no. 5, pp. 1107-1118.

Janett, F, Gerig, T, Tschuor, AC, Amatayakul-Chantler, S, Walker, J, Howard, R, Bollwein, H, & Thun, R 2012, `Vaccination against gonadotropin-releasing factor (GnRH) with Bopriva® significantly decreases testicular development, serum testosterone levels and physical activity in pubertal bulls´, *Theriogenology*, vol. 78, no. 1, pp. 182-188.

Kiyma, Z, Adams, TE, Hess, BW, Riley, ML, Murdoch, WJ, & Moss, GE 2000, `Gonadal function, sexual behavior, feedlot performance, and carcass traits of ram lambs actively immunized against GnRH1´, *Journal of Animal Science*, vol. 78, no. 9, pp. 2237-2243.

Lawrence, JD, & Ibarburu, MA 2007, `Economic Analysis of Pharmaceutical Technologies in Modern Beef Production´, Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, Illini Center, Chicago, Illinois, pp. 1-18.

Mach, N, Bach, A, Realini, CE, Font Furnols, M, Velarde, A, & Devant, M 2009, `Burdizzo pre-pubertal castration effects on performance, behaviour, carcass characteristics, and meat quality of Holstein bulls fed high-concentrate diets´, *Meat Science*, vol. 81, no. 2, pp. 329 -334.

Martí Rodríguez, S 2012, `Physical castration and inmunocastration of early-naturing bulls fed high concetrate diets: Welfare, performance, and carcass and meat quality´ Doctoral Thesis, Universitat Autònoma de Barcelona.

McKenna, DR, Roeber, DL, Bates, PK, Schmidt, TB, Hale, DS, Griffin, DB, Savell, JW, Brooks, JC, Morgan, JB, Montgomery, TH, Belk, KE, & Smith, GC 2002, `National beef quality audit -2000: Survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers´, *Journal of Animal Science*, vol. 80, no. 5, pp. 1212 -1222.

Moreira De Freitas, V, Martins Leão, K, Ribeiro de Araujo Neto, F, Campos Marques T, Moraes Ferreira, R, Franco Garcia, LL, & Barbosa de Oliveira, E 2015, `Efeitos da castração cirúrgica, imunocastração e homeopatia sobre o desempenho, características de carcaça e comportamento de bovinos machos cruzados terminados em confinamento´, *Semina: Ciências Agrárias*, vol. 36, no. 3, pp. 1725-1734.

Owens, FN, & Gardner, BA 2000, `A review of the impact of feedlot management and nutrition on carcass measurements of feedlot cattle´, *Journal of Animal Science*, vol. 77, no. E-Suppl, pp. 1-18.

Rejón, M, Magaña, M, Pech, V, & Santos, J 2005, `Evaluación económica de los sistemas de producción bovina de cría y de doble propósito en Tzucacab, Yucatán, México´, Livestock Research for Rural Develop-

ment, vol. 17, no. 1, viewed 20 August 2015, http://www.lrrd.org/lrrd17/1/rejo17013.htm

Schiller, BR 1994, `The Microeconomy Today´, McGraw-Hill Press, New York, NY.

Schroeder, TC, & Tonsor, GT 2011, `Economic impacts of Zilmax® adoption in cattle feeding´, *Journal of Agriculture and Resource Economics*, vol. 36, no. 3, pp. 521-535.

SIAP, Servicio de información agroalimentaria y pesquera, Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación 2016, Resumen Estatal Pecuario, viewed 16 February 2016, www.siap.gob.mx/ganaderia-resumen-estatal-pecuario/

Streeter, MN, Hutcheson, JP, Nichols, WT, Yates, DA, Hodgen, JM, Vander Pol, KJ, & Holland, BP 2012, `Review of large pen serial slaughter trials -growth, carcass characteristics, feeding economics´, Proceedings of the Plains Nutrition Council Spring Conference, San Antonio, Texas. pp. 58-72.

Tait, RG Jr, Wilson, DE, & Rouse, GH 2005, `Prediction of retail product and trimmable fat yields from the four primal cuts in beef cattle using ultrasound or carcass data´, *Journal of Animal Science*, vol. 83, no. 6, pp. 1353-1360.

Thompson, DL 2000, `Immunization against GnRH in male species (comparative aspects)´, *Animal Reproduction Science*, vol. 60-61, pp. 459-469.

Tucker, IB 1997, `Economics for Today´, West Publishing Company. Minneapolis-Saint Paul, Minnesota.

Voisinet, BD, Grandin, T, Tatum, JD, O'Connor, SF, & Struthers, JJ 1997, `Feedlot cattle with calm temperaments have higher average daily gains than cattle with excitable temperaments´, *Journal of Animal Science*, vol. 75, no. 4, pp. 892-896.