The Belgian Blue cattle in the production of sustainable beef in Colombia

El Blanco Azul Belga en la producción sostenible de carne bovina en Colombia

O Branco Azul Belga na produção sustentável de carne bovina na Colômbia

Pascal Leroy[1], Luis-Alejandro Orrego-Coy[2], Israel Mokadi[2]

[1] *Tropical Veterinary Institute, Faculty of Veterinary Medicine, University of Liege, Belgium*
[2] *Blanc Bleu Adama S.A.S, Medellín, Colombia*

Abstract

Background: Cattle ranching is currently at the center of debates regarding its environmental impact, highlighting the need to adopt sustainable practices and intensify beef production to mitigate its negative effects. **Objective:** To implement crossbreeding between Belgian Blue (BB) and Brahman cattle in Colombia to reduce the carbon footprint by decreasing the number of animals while increasing individual productivity. **Methods:** Ten crossbred calves (five males and five females) were selected from birth to be raised in a conventional pasture-based production system, evaluating their average daily gain (ADG) until eight months of age, when they were weaned. Subsequently, one of the males was selected for finishing until slaughter weight to assess carcass value. Carcass value was estimated through the dissection of the 7th rib of the right half-carcass. **Results:** The average birth weight of the calves was 28.6 ± 3.53 kg. Pre-weaning growth showed a linear and significant weight increase with age (R^2=0.971). The regression equation derived from the data is y = 0.974x + 30.537, illustrating an estimated daily weight gain of 974 g/day. The slaughter and carcass dissection parameters of the BB × Brahman crossbred bull were obtained from an 18-month-old male with a live weight at slaughter of 403 kg and a carcass yield of 59.8%. The percentage of bone, fat, and muscle in the carcass was 15.02%, 2.41%, and 81.34%, respectively. **Conclusions:** The BB × Brahman crossbred animals demonstrated superior growth and development in terms of ADG compared to national average parameters for conventionally raised cattle, making this a viable alternative to improve productivity in Colombia's beef sector.

Keywords: *Belgian Blue; beef; carcass yield; cattle; cows; fat; muscle; sustainable; weight gain*

Resumen

Antecedentes: La ganadería bovina está actualmente en el centro de debates en relación con sus efectos sobre el medio ambiente, lo que subraya la necesidad de adoptar prácticas sostenibles e intensificar la producción de carne bovina para mitigar sus efectos negativos. **Objetivo:** Implementar el cruce en ganado bovino en Colombia del Blanco Azul Belga (BAB) con Brahman, con el fin de reducir la huella de carbono al disminuir el número de animales mientras se incrementa la productividad individual. **Métodos:** Se seleccionaron 10 teneros cruzados (5

***Corresponding author.** Carrera 104b No. 68ª-82 Medellín, Colombia. Tel: +57 323 3938154. E-mail: laorregoc@unal.edu.co

machos y 5 hembras) desde su nacimiento para ser criados en un sistema de producción convencional de pastoreo y evaluar su ganancia diaria de peso (GDP) hasta los 8 meses de edad, donde fueron destetados. Posteriormente uno de los machos fue seleccionado para ser llevado a peso de sacrificio y evaluar el valor de la canal. La estimación del valor de la canal se realizó mediante el despiece de la 7ª costilla de la canal derecha. **Resultados:** El peso promedio de los terneros al nacimiento fue de 28.6 ± 3.53 kg. En el crecimiento antes del destete se evidenció que el aumento de peso con la edad es lineal y significativo (R^2=0.971). La ecuación de la línea de regresión establecida a partir de los datos conduce a y = 0.974 x + 30.537, lo que ilustra que el aumento diario estimado por la ecuación de la línea es de 974 g/día. Los resultados de los parámetros del sacrificio y del despiece de la canal del toro cruzado BAB x Brahman, se obtuvieron de un macho de 18 meses de edad con un peso en pie al sacrificio de 403 Kg, rendimiento en canal del 59.8%. Porcentaje de hueso, grasa y músculo de la canal de 15.02, 2.41 y 81.34, respectivamente. **Conclusiones:** El cruce de animales BAB x Brahman lograron un mayor desarrollo y crecimiento desde la GDP en comparación con los parámetros promedios nacionales, considerando a ambos animales criados en sistemas convencionales, lo que resulta en una alternativa viable para mejorar los parámetros productivos del sector cárnico en Colombia.
Palabras clave: *Blanco Azul Belga; carne; ganado; ganancia de peso; grasa; músculo; rendimiento en canal; sostenible; vacas.*

Resumo

Antecedentes: A pecuária bovina está atualmente no centro dos debates sobre seu impacto ambiental, ressaltando a necessidade de adotar práticas sustentáveis e intensificar a produção de carne bovina para mitigar seus efeitos negativos. **Objetivo:** Implementar o cruzamento entre bovinos da raça Branco Azul Belga (BAB) e Brahman na Colômbia, com o objetivo de reduzir a pegada de carbono ao diminuir o número de animais, enquanto se aumenta a produtividade individual. **Métodos:** Dez bezerros cruzados (cinco machos e cinco fêmeas) foram selecionados desde o nascimento para serem criados em um sistema de produção convencional a pasto, avaliando seu ganho médio diário de peso (GMD) até os oito meses de idade, quando foram desmamados. Posteriormente, um dos machos foi selecionado para ser levado ao peso de abate e avaliar o valor da carcaça. A estimativa do valor da carcaça foi realizada por meio da dissecação da 7ª costela da meia carcaça direita. **Resultados:** O peso médio ao nascimento dos bezerros foi de 28.6 ± 3.53 kg. O crescimento antes do desmame mostrou um aumento de peso linear e significativo com a idade (R^2=0.971). A equação da linha de regressão obtida a partir dos dados é y = 0.974x + 30.537, indicando um ganho diário estimado de 974 g/dia. Os parâmetros de abate e da dissecação da carcaça do touro BAB × Brahman foram obtidos a partir de um macho de 18 meses, com peso vivo ao abate de 403 kg e rendimento de carcaça de 59.8%. Os percentuais de osso, gordura e músculo na carcaça foram de 15.02%, 2.41% e 81.34%, respectivamente. **Conclusões:** Os animais cruzados BAB × Brahman demonstraram um maior crescimento e desenvolvimento em termos de GMD, em comparação com os parâmetros médios nacionais para bovinos criados em sistemas convencionais, tornando esta uma alternativa viável para melhorar a produtividade do setor de carne bovina na Colômbia.
Palavras-chave: *Branco Azul Belga; carne bovina; gado; ganho de peso; gordura; músculo; rendimento de carcaça; sustentável; vacas.*

Introduction

According to Parodi et al. (2022) and González-Quintero (2020), Colombia is the fourth-largest country in the Americas in terms of cattle herd size, with more than 28 million head. The Colombian livestock sector is dominated by farms with fewer than 50 animals, which account for more than 80% of the national herd. Cattle are raised throughout the country, but the Andes, Caribbean, and Orinoquía regions concentrate more than 85% of the national herd, as well as the land used for livestock production. Beef production is largely extensive and is primarily based on Bos indicus and Bos taurus × Bos indicus cattle (Vergara et al., 2009).

Cattle ranching is currently at the center of debates regarding water consumption, biodiversity impacts, and greenhouse gas (GHG) emissions, highlighting the need to adopt sustainable practices and intensify beef production to mitigate its negative effects. Sustainable intensification was defined in 2009 by the Royal Society of London as a process in which yields are increased without negative environmental impacts and without cultivating additional land. According to the International Center for Tropical Agriculture (CIAT) in Cali (Rao et al., 2015), the concept of sustainable intensification should be understood as an approach that employs innovations to increase agricultural productivity while simultaneously reducing environmental footprints, promoting ecosystem services, and supporting the social development of rural communities.

Selecting for traits that enhance production system efficiency has a favorable effect on overall emissions. To simultaneously improve multiple correlated traits, selection indices and their evolution through multi-trait selection using the so-called "animal model," with or without genomic tools, constitute essential methods, according to specialists. According to Wall et al. (2010), animal selection strategies include: (1) improving animal productivity and efficiency, (2) reducing undesirable losses (involuntary culling, infertility) at the herd level, and (3) directly selecting for measurable emissions. Barwick et al. (2019) suggest that the ability to reduce greenhouse gas emissions in beef cattle depends on the cost of feed within the production system's selection objectives.

One alternative, crossbreeding for complementarity, involves combining the positive traits of different breeds to create, within the same species, individuals with enhanced desirable characteristics. In Colombia, these advancements have sparked discussions on transitioning from a

conventional cattle sector to a sustainable one, particularly focusing on an effective strategy to reduce the carbon footprint of beef production. On one hand, European breeds can only be used as purebreds in more intensive production systems without significant climatic constraints and are entirely unsuitable for harsher environments. On the other hand, Criollo and Brahman cattle are well adapted to challenging conditions due to their heat tolerance, low metabolic rate, and resistance to infectious and parasitic diseases. In this context, to reduce the carbon footprint by decreasing the number of animals while increasing individual productivity, we have proposed crossbreeding Belgian Blue cattle (BBB) with the Brahman breed in Colombia.

Material and methods

This study was approved by the Ethics Committee of the University of Liège (Reference number: 25-2786).

Several hundred inseminations of Belgian Blue-White bulls were carried out in Colombia on Brahman cows from April 2021. The inseminations resulted in the birth of numerous crossbred calves, including 10 animals (5 males and 5 females), all born between 30/12/2022 and 8/01/2023 at Hacienda Orizagua (Puerto Salgar, Cundinamarca, Colombia) after artificial insemination on April 2, 2022 of 10 Colombian-born Brahman cows by the same Belgian Blue bull Intrépide de Cras Avernas (Figure 1 & 2).

The cows inseminated were all heifers with normal reproductive systems, an average age of 45 months and an average weight of 353 kg. These animals came from the Department of Santander, municipality of Rionegro, a region situated 590 m above sea level with an average temperature of 25°C, a relative humidity of 87% and classified as tropical dry forest (Bs-T) according to the Holdridge classification.

The pasture was composed of 85% grasses and 15% weeds. Animals were kept in pastures composed of Brachipará (Brachiaria plantaginea), Guinea (Panicum maximum) and Angleton (Dichantium aristatum).

The total pasture area of 36 hectares (ha) was subdivided into 18 sub-pastures of around 2 ha each, used as a rotational grazing system with a grazing period of 2 days and 34 days rest.

Fertilization was carried out every two grazing cycles, with 200 liters of water per hectare, 10 kg of urea and 10 liters of biofertilizer composed of organic matter and micro-organisms promoting plant growth.

The slaughter of a male BBB x Brahman cross and a male Zebu Brahman took place on Thursday, July 11, 2024 at the Frigorifico Guyabito slaughterhouse, Santa

Rosa de Cabal, Risaralda, Colombia, and more specifically by its subsidiary Carne's Carnicos Espezializados SAS, which also carries out the cutting.

On the same day, the weight of the hot carcass was assessed. After 24 hours of cooling, the characteristics of the carcass were recorded.

Carcass value was also estimated by cutting the 7th rib of the right carcass. The choice of the 7th rib is linked to the separation of forequarters and hindquarters (Hanset et al. (1978) and is inspired by the work of Geay et al. (1969) on the 11th rib in France.

All animals were treated with an anthelmintic [fenbendazole at a rate of 5 ml per 100 kg body weight] at the age of 3 and 8 months (weaning).

The animals also received a daily supplement including minerals, proteins (crude protein 20%), fat (12%), fiber (crude fiber 13%) and vitamins (A, E, B12, B5, B9) at a rate of 150 g / animal / day.

Weaning took place at 8 months, was carried out using an anti-suckling device placed for 15 days.

The animals received a finishing diet in the barn, based on corn silage, hay and concentrate feed. This finishing took place over the last three months. Initially, each animal received 12 kg of silage, 4 kg of hay and 2 kg of protein-energy supplement and this diet was adjusted over time according to the animals' needs

Figure 1. Intrepide de Cras Averna , Belgian Blue bull used in Colombia

Results

Results of birth circumstances and growth until weaning at 8 months

The gestation length was on average 278.6 ± 3.78 days (278.2 ± 5.07 days for male

calves, 279 ± 2.45 days for female calves) is given in Table 1.

The weight of the cows at the time of insemination was on average 449.8 kg (452.4 kg for male calves, 420.4 kg for female calves).

The average weight of the calves at birth was 28.6 ± 3.53 kg (27.6 ± 4.28 kg for male calves, 29.6 ± 2.7 kg for female calves) (Table 2). Calving took place without difficulty and without any assistance.

Table 1. Mean and standard deviation of gestation length and weight (kg) of the Brahman mother at the time of insemination of the 10 BBB x Brahman cross calves.

Calf- ID	Sex	Gestation length (days)	Weight of the mother (kg)
029-13	Male	278	450
012-13	Male	275	465
864-122	Male	272	390
080-13	Male	285	520
057-13	Male	281	508
Mean		**278.2**	**466.70**
Standard deviation		**5.07**	**51.71**
066-13	Female	282	392
020-13	Female	277	412
046-13	Female	280	413
014-13	Female	276	455
047-13	Female	280	492
Mean		**279**	**432.90**
Standard deviation		**2.45**	**40.14**
General average		**278.60**	**449.80**
Standard deviation		**3.78**	**47.14**

Growth before weaning

Growth data from birth to 8 months (weaning) and average daily gain for the same period are given in Table 2.

The increase in weight with age is linear and significant (R^2=0.971). The equation of the regression line established from the data leads to y = 0.974 x + 30.537 illustrating

that the daily gain estimated by the equation

of the line is 974 g/day (Figure 2).

Table 2. Growth results (weight kg) from birth (BW) to 240 days (W240) and average daily gain (kg/d) at the end of the period of the 10 White Belgian Blue x Brahman cross calves.

Calf - ID	Sex	BW (kg)	W30 (kg)	W60 (kg)	W90 (kg)	W120 (kg)	W150 (kg)	W180 (kg)	W210 (kg)	W240 (kg)	ADG (kg/d)
029-13	Male	30	58	84	105	127	151	178	208	247	0.90
012-13	Male	25	58	91	121	149	176	209	243	291	1.11
864-122	Male	24	55	84	114	141	165	190	219	263	1.00
080-13	Male	25	69	107	144	171	200	232	270	304	1.16
057-13	Male	34	65	96	126	151	175	203	237	276	1.01
Mean		27.6	60.77	92.32	122	147.72	173.27	202.6	235.33	276.20	1.04
Standard deviation		4.28	5.88	9.37	14.93	16.14	17.99	20.6	23.6	22.47	0.10
066-13	Female	33	63	93	122	148	174	203	233	272	1.00
020-13	Female	30	60	89	118	142	169	198	231	279	1.04
046-13	Female	31	65	96	127	154	177	206	236	272	1.00
014-13	Female	26	61	94	128	153	180	213	248	302	1.15
047-13	Female	28	57	85	114	137	155	184	210	250	0.93
Mean		29.6	61.34	91.52	121.7	146.7	170.98	200.64	231.58	275	1.02
Standard deviation		2.7	3.15	4.37	6.06	7.12	9.74	10.96	13.73	18.63	0.08
General average		28.6	61.05	91.92	121.85	147.16	172.13	201.62	233.45	275.60	1.03
Standard deviation		3.53	4.46	6.91	10.74	11.77	13.69	15.59	18.31	19.47	0.09

BW= Birth weight; W30= Weight at 30 days of age; W60= Weight at 60 days of age; W90= Weight at 90 days of age; W120= Weight at 120 days of age; W150= Weight at 150 days of age; W180= Weight at 180 days of age; W210= Weight at 210 days of age; W240= Weight at 240 days of age; ADG= Average daily gain.

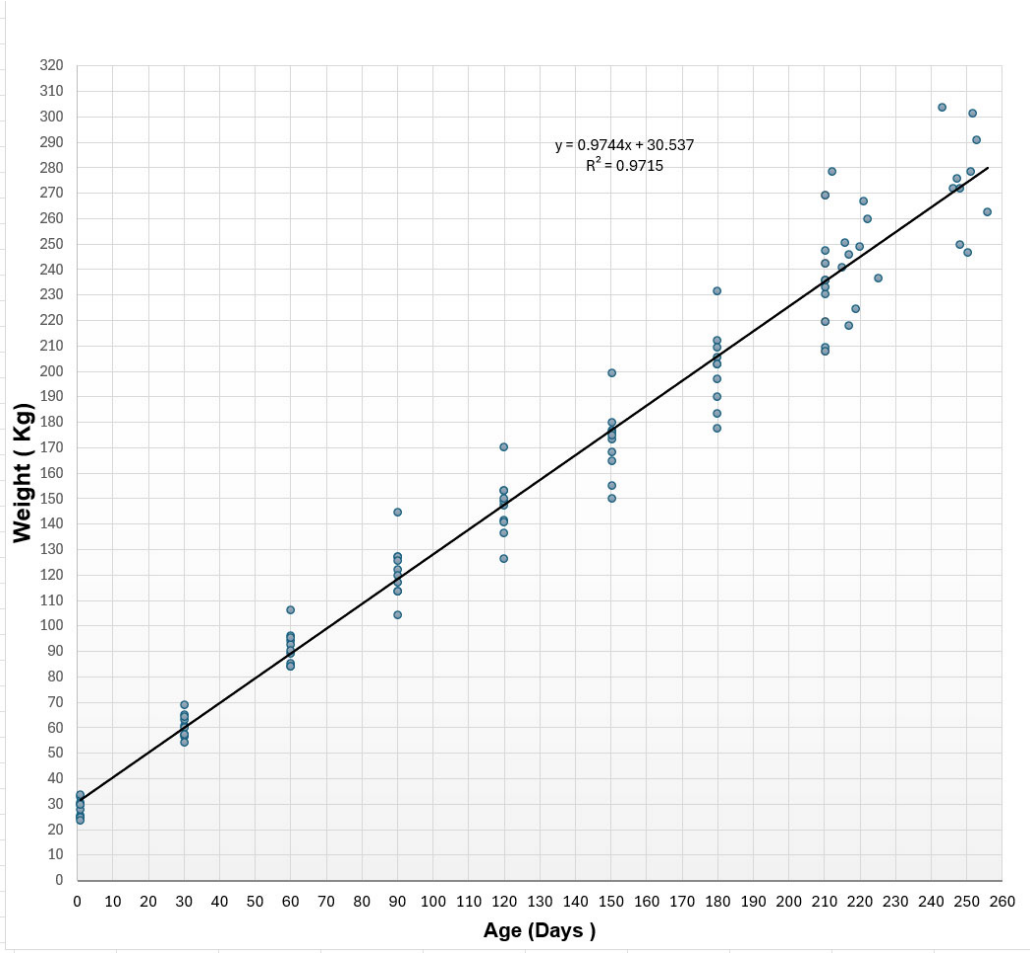

Figure 2. Evolution of weight (kg) as a function of age (days) of the 10 crossbred calves BBB x Brahman from birth to weaning.

Growth after weaning

After weaning, a significant dispersion of weight values is observed and some animals have slowed down their growth while others are still progressing to reach values of 544 kg and 557 kg respectively at the age of 565 days (18.5 months). and 555 days (18.2 months).

Figure 3. 080-13, BBB x Brahman bull born on January 12, 2023, and having reached 557 kg on 07-20-24 at 555 days or 18.2 months.

Figure 4. 012-13, BBB x Brahman bull born on January 2, 2023, and having reached 544 kg on 07-20-24at 565 days or 18.5 months.

Slaughter results

The results of the zootechnical parameters, slaughter and cutting of the carcasses of the Belgian White-Blue x Brahman cross bull, 12 months younger, and the Brahman bull are given below.

The slaughter weight value is 19 kg less for the BBB cross while the carcass weighs 9

kg more with a higher slaughter yield of 4.83% (Table 3).

The carcasses cut by the Carne's Company - Carnicos Espezializados SAS lead to more favorable results for the Belgian White-Blue x Brahman cross bull with +13.42% more muscle, -7.65% less bone and - 1.74% less fat.

Table 3. Results of the slaughter of an 18-month-old Belgian White-Blue x Brahman cross bull and a 30-month-old Brahman bull.

	BBB x Brahman Male	**Brahman Male**	**Difference**
Age (Month)	18	30	- 12
Live weight (kg)	403	422	- 19
Carcass weight (kg)	241	232	+ 9
Killing out %	59.80	54.98	+ 4.83
Bone in carcass (kg)	36.2	52.6	- 16.40
Bone carcass %	15.02	22.67	- 7.65
Fat in carcass (kg)	5.8	10.00	- 4.20
Fat carcass %	2.41	4.15	- 1.74
Muscle carcass (kg)	196.04	163.70	+ 32.34
Muscle carcass %	81.34	67.92	+ 13.42
Other losses (kg)	1.23	5.26	

Results of Carcass Cutting

By assigning a price to each piece of the cut according to the regulations in force in Colombia and summing up the monetary values for each element of the carcass cut, the following values are obtained (Table 4):

- 6,420,126.60 COP for the crossbred BBB x Brahman male
- 5,481,600.20 COP for the Brahman male

This represents a profit of 938,526.40 COP or a total gain of €205 for the Belgian White-Blue x Brahman cross.

Table 4. Results (kg) of the carcass cut of an 18-month-old crossbred Belgian Blue x Brahman bull and a 30 month-old Brahman bull.

	BBB x Brahman Male		Brahman Male		
Name of the cut of meat	**kg**	**%**	**kg**	**%**	**Difference (%)**
Bola de brazo	5.43	2.28	4.67	2.06	+ 0.22
Entrepierna	17.44	7.33	14.68	6.49	+ 0.84
Posta de res	10.99	4.61	8.14	3.60	+ 1.02
Tortuga	3.50	1.47	2.80	1.24	+ 0.23
Asado de tira	1.74	0.73	1.28	0.56	+ 0.17
Barcino	17.77	7.47	10.50	4.64	+ 2.82
Bife paletero	2.31	0.97	2.47	1.09	- 0.12
Cadera	10.18	4.28	8.86	3.91	+ 0.36
Capon	4.87	2.05	3.97	1.75	+ 0.29
Carne cogote - Crespa - Nuca	3.76	1.58		0.00	+ 1.58
Carne industrial	13.27	5.57	14.49	6.40	- 0.83
Cola	1.10	0.46	1.05	0.47	- 0.00
Costilla corriente	6.50	2.73	13.20	5.83	- 3.10
Costilla especial	13.60	5.71	1.00	0.44	+ 5.27
Decomisos res	1.20	0.50	3.62	1.60	- 1.09
Espaldilla	2.77	1.16	2.06	0.91	+ 0.25
Falda	0.55	0.23	25.00	11.05	- 10.82
Hueso blanco	23.00	9.66	8.90	3.93	+ 5.73
Hueso rojo - (hueso de carnudo)	13.20	5.55	18.70	8.26	- 2.72
Huevo de aldana	10.66	4.48	8.90	3.93	+ 0.55
Lagarto	8.94	3.76	7.89	3.48	+ 0.27
Lomo chata	7.51	3.15	5.49	2.43	+ 0.73
Lomo redondo	1.15	0.48	3.54	1.57	- 1.08
Milanesa	7.00	2.94	7.04	3.11	- 0.17
Morrillo	1.66	0.70	4.40	1.94	- 1.25
Paleterito	3.80	1.60	2.26	1.00	+ 0.60
Pecho res	11.73	4.93	9.43	4.17	+ 0.76
Punta de anca res	3.49	1.47	2.65	1.17	+ 0.29

Punta de falda	3.97	1.67	3.26	1.44	+ 0.23
Sabaleta	2.24	0.94	1.94	0.86	+ 0.08
Sebo desposte	5.80	2.44	10.00	4.42	- 1.93
sobrebarriga delgada	3.09	1.30	2.13	0.94	+ 0.35
Sobrebarriga gruesa	4.35	1.83	3.66	1.62	+ 0.21
Solomo res	4.70	1.97	3.45	1.53	+ 0.45
Tomahawk	4.78	2.01	4.88	2.16	- 0.15
Total	238.03	100.00	226.30	100.00	

Results of the Cutting of the 7th Rib of the Right Carcass

The 7th rib of the right carcass was taken on Monday, July 15, 2024, at the facilities of Carne's Carnicos Especializados SAS, and dissection was carried out on the same day at the same location, following a protocol developed at the University of Liège (Figure 5).

The dissection results of the 7th rib indicate that the crossbred BBB x Brahman bull has relatively more muscle (+0.93%), less bone (-1.28%), less fat (-1.56%), as well as a higher weight of the Longissimus dorsi muscle (+2.88%) (Table 5).

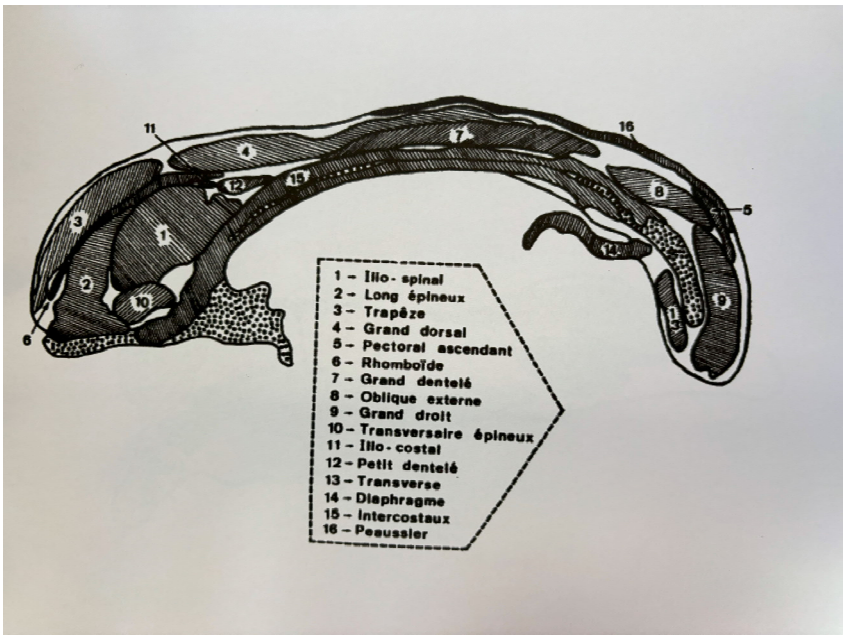

Figure 5. Protocol for cutting the 7th rib of the right carcass developed by the University of Liège

Figure 6. 7th rib of the right carcass of the crossbred BBB x Brahman male.

Table 5. Results of the dissection of the 7th rib of the right carcass of an 18-month-old crossbred Belgian Blue x Brahman bull and a 30-month-old Brahman bull.

	BBB x Brahman Male		**Brahman Male**	
7th Rib	Weight (g)	%	Weight (g)	%
Weight of the rib	1920	100.00	2540	100.00
Muscle (total dissected)	1290	67.19 **+ 0.93%**	1683	66.26
Ilio Spinal - Longissimus dorsi	180	9.38 **+ 2.88%**	165	6.50
Bone	370	19.27 **-1.28%**	522	20.55
Fat	100	5.21 **-1.56%**	172	6.77

Discussion

The average weight of calves at birth was 28.6 ± 3.53 kg (27.6 ± 4.28 kg for male calves, 29.6 ± 2.7 kg for female calves) (Table 2). Calving occurred without difficulties and required no particular assistance.

The average gestation length of local Brahman cows, 278.6 ± 3.78 days, could explain the lower average birth weight of crossbred calves as well as the ease of calving. Additionally, the average birth weight of male calves was about 2 kg lower than that of female calves. This result also

correlates with the shorter gestation period for males.

Leroy et al. (2004) analyzed data on the crossbreeding of Belgian Blue with Nelore females in Brazil. They observed gestation lengths of 278.9 ± 7.28 days for male calves and 283.7 ± 4.83 days for female calves, with birth weights slightly higher by about 4 kg.

Furthermore, the birth weights of Brahman animals born in Colombia and other regions are slightly higher than those observed in this study (Table 6).

Data presented by Burris and Blunn (1952) examined the influence of breed, dam age, calf sex, sire, year, and the interaction of sex and breed on gestation length. The average gestation lengths for the three breeds studied were: Angus, 281.7 days; Hereford, 286.1 days; and Shorthorn, 284.3 days (significant differences). In this analysis, the regression of birth weight on gestation length was significant and approximately +0.376, meaning 376 g of live weight per additional day of gestation length.

Table 6. Comparative literature analysis results on the birth weights of Brahman Zebu in Colombia, South Africa, Mexico, Brazil, Venezuela, and crossbreeds with Belgian Blue.

		Sex	**Birth weight (kg)**
Murcia Morales (2015)	Brahman Colombia	M	37.40 ± 5.25
	Brahman Colombia	F	34.78 ± 4.65
Martinez et al. (2016)	Brahman Colombia	M	33.06 ± 3.6
Bedoya Ospina et al. (2019)	Brahman Colombia	M	29.62 ± 3.13
Pico et al. (2004)	Brahman South Africa	M & F	32.3 ± 4.0
Bracamonte et al. (2007)	Brahman Mexico	M & F	32.2 ± 1.8
Estrada-León et al. (2014)	Brahman Mexico	M & F	33.10 ± 4.65
Plasse et al. (2002)	Brahman Venezuela	M & F	28.20 ± 4.30
Palacios-Espinosa et al.(2020)	Brahman Venezuela	M & F	29.50 ± 4.50
Leroy et al. (2004)	BBB x Nelore Brazil	M	33.57 ± 4.17
		F	34.84 ± 3.92

The standard deviation increases with age, which is quite typical in animal production data due to increased dispersion around the mean (Table 2 and Figure 2).

In Murcia Morales' thesis (2015), Brahman Zebu males reached weights of 344.05 ± 75.42 kg at 18 months (50 kg less than in this study), and females reached 303.28 ± 60.29 kg.

In a study on several thousand animals across three regions of Colombia—North Coast (11 farms), Andean region (14 farms), and Eastern savannas (10 farms)—Martinez et al. (2016) observed the following zootechnical parameters: Birth weight: 33.06 ± 3.6 kg, Weight at 4 months: 135.24 ± 20.53 kg, Weight at 7 months: 198.31 ± 25.99 kg, Weight at 12 months: 257.46 ± 25.47 kg, Weight at 18 months: 317.96 ± 38.6 kg . Corresponding average daily weight gains were: 0 to 4 months: 871.31 ± 272.98 g, 4 to 7 months: 794.24 ± 178.83 g, 7 to 12 months: 618.98 ± 113.46 g, 12 to 18 months: 316.49 ± 37.31 g. Bedoya Ospina et al. (2019) analyzed 1,015 data points from birth to weaning in a commercial Brahman farm. The birth weight was 29.62 ± 3.13 kg, and the weaning weight, at 270 days, was 216.71 ± 26.97 kg.

Table 7. Comparative literature analysis results on the growth of Brahman Zebu in Colombia, South Africa, Mexico, Brazil, Venezuela, and crossbreeds with Belgian Blue.

			Weight (kg)			
		Sex	**7 months**	**9 months**	**12 months**	**18 months**
Murcia Morales (2015)	Brahman Colombia	M		254.58 ± 40.81		344.05 ± 75.42
	Brahman Colombia	F		235.72 ± 36.23		303.28 ± 60.29
Martinez et al. (2016)	Brahman Colombia	M	198.31 ± 25.99		257.46 ± 25.47	317.96 ± 38.6
Bedoya Ospina et al. (2019)	Brahman Colombia	M		216.71 ± 26.97		
Pico et al. (2004)	Brahman South Africa	M & F			274.0 ± 54.0	
Bracamonte et al. (2007)	Brahman Mexico	M & F	180.70 ± 32.60		261.6 ± 57.4	352.2 ± 57.4
Estrada-León et al. (2014)	Brahman Brazil	M & F	204.05 ± 37.71			
Zuin et al. (2012)	Nelore Brazil	M & F	186.09 ± 28.04		241.40 ± 40.39	
Bertipaglia et al. (2015)	Brahman Brazil	M & F	192.26 ± 29.71		237.96 ± 40.87	317.81 ±47.08
Plasse et al. (2002)	Brahman Venezuela	M & F	163.40 ± 24.60			297.40 ± 43.20
Palacios-Espinosa et al. (2020)	Brahman Venezuela	M & F			209.90 ± 29.80	290.0 ± 34.10
Leroy et al. (2004)	BBB x Nelore Brazil	M	225.72 ± 29.08	240	280	350

		F	211.38 ± 41.77		
Silva et Leroy (2022)	BBB x Nelore Brazil	M		355.3	387.5
Leroy et al. (2024)	BBB x Brahman Colombia	M	235.33 ± 23.60	371.0 ± 12.16	395.80 ± 12.97
		F	231.58 ± 13.73	371.8 ± 12.19	389.00 ± 12.75

Crossbred BBB x Brahman cattle raised in Colombia reach an average of 400 kg at 18 months. These results are higher than those obtained by Leroy et al. (2004) and Silva and Leroy (2022) with BBB x Nelore crosses in Brazil.

The slaughter yield of 59.8% achieved in the BBB x Brahman bull weighing 403 kg at 18 months highlights the superiority of crossbred animals when raised under good conditions.

Silva and Leroy (2022) achieved BBB x Nelore males with average slaughter weights of 891.9 ± 31.17 kg at 29 months and a yield of 53.43%, while Nelore cattle averaged 535.3 ± 47.23 kg with a slaughter yield of 52.8%.

Economically, if animals consume 150 g of concentrate costing 800 pesos per day, the 10 months after weaning would cost €53.44, in addition to pasture. However, carcasses would yield an additional €205 while being produced 12 months faster.

This study shows that using reproductive biotechnologies and introducing the Belgian Blue breed in Colombia offers a viable option for producing profitable and more sustainable meat.

The Belgian Blue breed, characterized by muscular hypertrophy due to the myostatin gene (Charlier et al., 1995), influences the conformation of calves born from Colombian cows, enabling the production of more meat that is tenderer and less fatty in less time (Mokadi et al., 2023).

Brahman cows, used in the crossbreeding, contribute their high capacity to produce meat in tropical Colombian conditions, notably due to their adaptation to climatic, nutritional, and sanitary conditions.

Using terminal crossbreeding with Belgian Blue on Brahman Zebu preserves and protects Colombian bovine genetics while optimizing the rapid production of profitable and sustainable meat in a tropical environment.

Reducing the production time to reach slaughter weight, commonly practiced in

Colombia, is significant—around 12 months shorter. This reduction contributes to lower greenhouse gas emissions.

Before weaning, Colombian BBB x Brahman crossbreeds reach 250 kg (7-8 months), while in the comparative study in Table 7, Brahman cattle reach only 163 to 204 kg in several evaluated countries. Under optimal post-weaning conditions, the best crossbreeds reach 540 kg at 18 months, far exceeding pure Nelore and Brahman cattle.

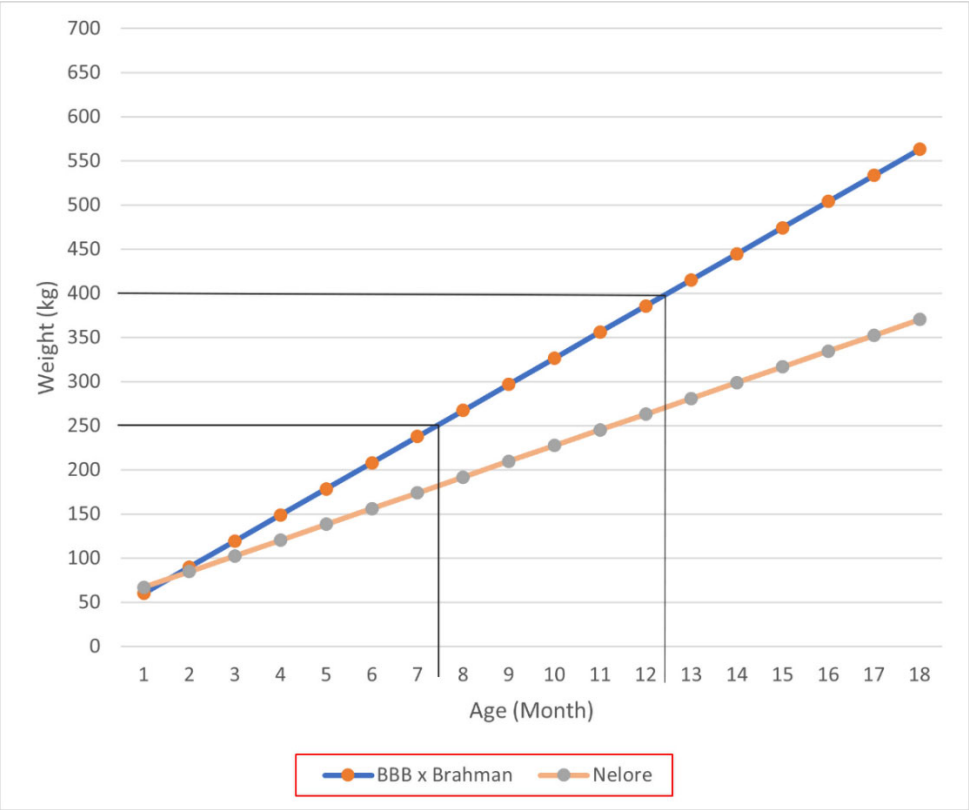

Figure 7. Evolution of weight (kg) based on age (months) for BBB x Brahman and Nelore animals.

The BBB x Brahman animal selected for the slaughter and cutting yield study weighed 403 kg at 18 months, while the pure Brahman weighed 422 kg at 30 months, representing a 12-month age difference. All these aspects related to performance, growth conditions, as well as slaughter and cutting results, have economic and environmental repercussions

Economic and environmental implications

Considering a deterministic approach where a farm has 300 Brahman animals virtually divided into five groups of 60 animals every six months, the last group would leave the farm at approximately 30 months, weighing 400 kg.

For this farm, over 30 months, 60 animals enter, and 60 animals leave.

When animals are finished at 18 months, the distribution within a 300-animal farm changes. In this case, 100 animals enter, and 100 leave after 18 months.

With crossbreeding involving the Belgian Blue, the number of fattened animals in a 300-animal farm increases by +40 animals per 300, representing a +13% increase.
The production cycle is shortened by 12 months, and the number of animals involved in different production stages increases, affecting the required pasture area. It is also possible to harvest forage planted on additional parcels.
Colombia aims to reduce greenhouse gas emissions, and crossbreeding involving the Belgian Blue while preserving local breeds addresses this goal.

References

Barwick, S.A., Henzell, A.L., Herd, R.M. 2019. Methods and consequences of including reduction in greenhouse gas emission in beef cattle multiple-trait selection. Genet Sel Evol 51, 18. https://doi.org/10.1186/s12711-019-0459-5

Bedoya Ospina, C. F., Alzate Ramirez, J. A., Ángel Cardona, J. C., Escobar R, C. S., & Calvo Cardona, S. J. (2019). Evaluación genética para características de peso en ganado Brahman comercial. *Revista MVZ Córdoba*, *24*(2), 7225-7230. https://doi.org/10.21897/rmvz.1662

Bertipaglia, T. S., Carreño, L. O. D., Aspilcueta-Borquis, R. R., Boligon, A. A., Farah, M. M., Gomes, F. J., Machado, C. H. C., Rey, F. S. B., & da Fonseca, R. (2015). Estimates of genetic parameters for growth traits in Brahman cattle using random regression and multitrait models1. *Journal of Animal Science*, *93*(8), 3814–3819. https://doi.org/10.2527/jas.2015-9164

Bracamonte G., Martinez J.., Rivas G., Garcia F., Ortega E, (2007) parámetros genéticos de variables de crecimiento de ganado brahmán de registro en Mexico. En: Revista veterinaria Mexico. Vol 38. No, 002. Pp, 217-229.

Burris M.J. et Blunn C.T. (1952). Some Factors Affecting Gestation Length and Birth Weight of Beef Cattle. Journal of Animal Science, Volume 11, Issue 1, Pages 34–41,

CEPAL, FAO, IICA (2017) Perspectivas de la agricultura y del desarrollo rural en las Américas: una mirada hacia América

Latina y el Caribe. 267p. IICA: San José, Costa Rica. https://n9.cl/pyzh

Charlier C., Coppieters W., Farnir F., Grobet L., Leroy P.L., Michaux C., Mni M., Schwers A., Vanmanshoven P., Hanset R., Georges M. (1995). The mh gene causing double--- muscling in cattle maps to bovine Chromosome 2. Mamm. Genome, 6, 788-792.

Chud, T. C. S., Caetano, S. L., Buzanskas, M. E., Grossi, D. A., Guidolin, D. G. F., Nascimento, G. B., Rosa, J. O., Lôbo, R. B., & Munari, D. P. (2014). Genetic analysis for gestation length, birth weight, weaning weight, and accumulated productivity in Nellore beef cattle. *Livestock Science*, *170*, 16–21. https://doi.org/10.1016/j.livsci.2014.09.024

De Faria Maciel, I. C., Barbosa, F. A., Tomich, T. R., Pereira Ribeiro, L. G., Alvarenga, R. C., Lopes, L. S., Rocha Malacco, V. M., Rowntree, J. E., Thompson, L. R., & Quintão Lana, Â. M. (2019). Could the breed composition improve performance and change the enteric methane emissions from beef cattle in a tropical intensive production system? *PloS One*, *14*(7), e0220247-. https://doi.org/10.1371/journal.pone.0220247

Estrada-León, R. J., Magaña-Monforte, J. G., & Segura-Correa, J. C. (2014). Estimation of genetic parameters for preweaning growth traits of Brahman cattle in Southeastern Mexico. *Tropical Animal Health and Production*, *46*(5), 771–776.

https://doi.org/10.1007/s11250-014-0563-z

Geay Y., Béranger V., Grenet N., Villeneuve G. 1969. Estimation de la composition de la carcasse de jeunes bovins a partir de la composition d'un morceau monocostal au niveau de la 11 e côte. Ann. Zootech. Volume 18, Number 1, 65-77

Gonzalez-Quintero, R., Kristensen, T., S´anchez-Pinz´on, M. S., Bolívar-Vergara, D. M., Chirinda, N., Arango, J., et al. (2020). Carbon footprint, non-renewable energy and land use of dual-purpose cattle systems in Colombia using a life cycle assessment approach. Livestock Science, 104330.

Hanset R., Bienfait JM.,Jandrain M., Nicks B., Leroy P.. (1978). L'intérêt d'un segment monocostal dans l'appréciation des carcasses de jeunes taureaux. Annales De Medecine Veterinaire, 122

Hume Da, Whitelaw CBA, Archibald Al. 2011. The future of animal production: improving productivity and

sustainability. *The Journal of Agricultural Science*. 149(S1):9-16. doi:10.1017/S0021859610001188

León-Llanos, L. M., Flórez-Díaz, H., Duque-Muñoz, L. G., Villarroel, M., & Miranda-de la Lama, G. C. (2022). Influence of temperament on performance and carcass quality of commercial Brahman steers inla a Colombian tropical grazing system. *Meat Science*, *191*, 108867–108867. https://doi.org/10.1016/j.meatsci.2022.108867

Leroy P., Leroy E., Michaux Ch., Cassart R. (2004) Comparison of Belgian Blue x Nelore cross and Braford kept on pasture conditions in Brazil 23d World Buiatrics Congress, Quebec City, Canada, July 11-16, 2004

Leroy, P., Moula, N., Huart, A., Leroy, E., Cassart, R., Ruppol, P., Levrard, O., ElFadili, M., Dang Vu Binh, Nguyen Van Thang, Do Duc, L., Nfundico, D., Nienhaus, B., Antoine-Moussiaux, N., & Farnir, F. (2012). Amélioration des performances génétiques des races tropicales par les races wallonnes.15ème Journée Outre-mer, Gembloux, Belgium, 25 aout 2012

Madalena F.E., 1986. Crossbreeding cattle in latin America in Animal genetic resources - Strategies for improved use and conservation Proceedings of the 2nd Meeting of the FAO/UNEP Expert Panel, Warsaw, Poland, June 1986 with Proceedings of the EAAP/PSAS Symposium on Small Populations of Domestic Animals

Malheiros, J. M., Enriquez-Valencia, C. E., Silva, J. A. I. de V., Curi, R. A., de Oliveira, H. N., de galerieAlbuquerque, L. G., & Chardulo, L. A. L. (2020). Carcass and meat quality of Nellore cattle (Bos taurus indicus) belonging to the breeding programs. *Livestock Science*, *242*, 104277-. https://doi.org/10.1016/j.livsci.2020.104277

McDermott, J. J., Staal, S. J., Freeman, H. A., Herrero, M., & Van de Steeg, J. A. (2010). Sustaining intensification of smallholder livestock systems in the tropics. *Livestock Science*, *130*(1), 95–109. https://doi.org/10.1016/j.livsci.2010.02.014

Martínez, R. A., Dassonneville, R., Bejarano, D., Jimenez, A., Even, G., Mészáros, G., & Sölkner, J. (2016). Direct and maternal genetic effects on growth, reproduction, and ultrasound traits in zebu Brahman cattle in Colombia. *Journal of*

Animal Science, *94*(7), 2761–2769. https://doi.org/10.2527/jas.2016-0453

Mertens A, Kokemohr L, Braun E, Legein L, Mosnier C, Pirlo G, Veysset P, Hennart S, Mathot M, Stilmant D. (2023). Exploring Rotational Grazing and Crossbreeding as Options for Beef Production to Reduce GHG Emissions and Feed-Food Competition through Farm-Level Bio-Economic Modeling. Animals. 13(6):1020. https://doi.org/10.3390/ani13061020

Mokadi I., Camargo Rodriguez O., Leroy P. (2023). Blanco-Azul Belga, historia, selección, cruce. Presentación de los primeros animales del cruce entre blanco azul belga y cebú brahman. Hacienda Orizagua, Puerto Salgar (Cundinamarca) 12pp.

Mokolobate, M. C., Theunissen, A., Scholtz, M.M.,Neser, F. (2014). Sustainable crossbreeding systems of beef cattle in the era of climate change. South African Journal of Animal Science, 44, 8-11. DOI: 10.4314/sajas.v44i5.2

Murcia Morales. 2015. Relación del peso al nacer con el peso al destete y el peso a los 18 meses en un hato de cría brahman en Tame Arauca. Univeridad de La Salle Facultad de Ciencias Agropecuarias programa de zootecnia Bogotá

Novoa, M. A., & Usaquén, W. (2010). Population genetic analysis of the Brahman cattle (Bos indicus) in Colombia with microsatellite markers. *Journal of Animal Breeding and Genetics (1986)*, *127*(2), 161–168. https://doi.org/10.1111/j.1439-0388.2009.00811.x

Palacios-Espinosa, A., Verde, O., Ávila-Serrano, N. Y., & Menéndez-Buxadera, A. (2020). Análisis genético del desarrollo en peso vivo y tasa de gestación en primer parto en bovinos Brahman de Venezuela. *Revista Mexicana de Ciencias Pecuarias*, *11*(2), 576–589. https://doi.org/10.22319/rmcp.v11i2.4813

Parodi, A., Valencia-Salazar, S., Loboguerrero, A. M., Martínez-Barón, D., Murgueitio, E., & Vázquez-Rowe, I. (2022). The sustainable transformation of the Colombian cattle sector: Assessing its circularity. *PLOS Climate*, *1*(10), e0000074-. https://doi.org/10.1371/journal.pclm.0000074

Pico, B., Neser, F., & Van Wyk, J. (2004). Genetic parameters for growth traits in South African Brahman cattle. *South African Journal of Animal Science*, *34*(6), 44–46. https://doi.org/10.4314/sajas.v34i6.3827

Plasse, D., Verde, O., Fossi, H., Romero, R., Hoogesteijn, R., Bastidas, P., & Bastardo, J. (2002). (Co)variance components, genetic parameters and annual trends for calf weights in a pedigree Brahman herd under selection for three decades. *Journal of Animal Breeding and Genetics (1986)*, *119*(3), 141–153. https://doi.org/10.1046/j.1439-0388.2002.00321.x

Pinzon E. (1984) Historia de la Ganaderıa Bovina en Colombia. Suplemento anadero (Corporacio´n de Estudios Ganaderos y Agrıcolas: Bogota) 4, 1, 208.

Rao, I., Peters, M., Castro, A., Schultze-Kraft, R., White, D., Fisher, M., Miles, J., Lascano, C., Blümmel, M., Bungenstab, D., Tapasco, J., Hyman, G., Bolliger, A., Paul, B., van der Hoek, R., Maass, B., Tiemann, T., Cuchillo, M., Douxchamps, S., Villanueva, C., Rincón, A., Ayarza, M., Rosenstock, T., Subbarao, G., Arango, J., Cardoso, J., Worthington, M., Chirinda, N., Notenbaert, A., Jenet, A., Schmidt, A., Vivas, N., Lefroy, R., Fahrney, K., Guimarães, E., Tohme, J., Cook, S., Herrero, M., Chacón, M., Searchinger, T., & Rudel, T. (2015). LivestockPlus — The sustainable intensification of forage-based agricultural systems to improve livelihoods and ecosystem services in the tropics. *Tropical Grasslands-Forrajes Tropicales*, *3*(2), 59–82. https://doi.org/10.17138/tgft(3)59-82

Sastre H. (2003) Descripcion, situacion actual y estrategias de conservacion de la raza bovina colombiana criolla Casanare, PhD Thesis. Universidad de Cordoba.

Siegel, P. B. (2014). Evolution of the Modern Broiler and Feed Efficiency. *Annual Review of Animal Biosciences*, *2*(1), 375–385. https://doi.org/10.1146/annurev-animal-022513-114132

Silva R., Leroy P. (2022) Performances des bovins F1 issus de croisements industriels Blanc-Bleu Belge x Nelore à Goiás – Brésil. Internal document.

Vergara, O. D., Elzo, M. A., & Cer´on-Mu˜noz, M. F. (2009). Genetic parameters and genetic trends for age at first calving and calving interval in an Angus-Blanco Orejinegro-zebu multibreed cattle population in Colombia. *Livestock Science, 126* (1–3), 318–322.

Wall, E., Simm, G., & Moran, D. (2010). Developing breeding schemes to assist mitigation of greenhouse gas emissions. *Animal 4*(3), 366–376.

https://doi.org/10.1017/S175173110999070X

Zuin, R. G., Buzanskas, M. E., Caetano, S. L., Venturini, G. C., Guidolin, D. G. F., Grossi, D. A., Chud, T. C. S., Paz, C. C. P., Lôbo, R. B., & Munari, D. P. (2012). Genetic analysis on growth and carcass traits in Nelore cattle. *Meat Science*, *91*(3), 352–357. https://doi.org/10.1016/j.meatsci.2012.02.018