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Effect of Different Selection Criteria on Performance, Carcass and Meat Quality of Nellore Young Bulls

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Citation: Silva, J.; Cônsolo, N.R.B.; Buarque, V.L.M.; Beline, M.; da Silva Martins, T.; Lobo, A.A.G.; Gómez, J.F.M.; Eler, J.P.; Leme, P.R.; Netto, A.S.; et al. Effect of Different Selection Criteria on Performance, Carcass and Meat Quality of Nellore Young Bulls. *Agriculture* **2021**, *11*, 294. https://doi.org/10.3390/agriculture11040294

Academic Editors: Agnieszka Ludwiczak and Vincenzo Tufarelli

Received: 9 February 2021
Accepted: 25 March 2021
Published: 29 March 2021

Abstract: This study was carried out to evaluate the effects of selection criteria for post-weaning daily gain (PWDG) and early sexual heifer precocity (PP14) on the performance, carcass traits and meat quality of Nellore bulls. In year one, 50 animals were selected according to their expected progeny differences (EPDs) for PWDG and grouped as high (HG) or low (LG) groups. In year two, 50 animals were selected according to EPD for PP14 and also grouped as high (HP) or low (LP). After slaughter, samples of the longissimus muscle area (LMA) were used to evaluate meat quality. Most of performance traits were not affected by the selection criteria. However, the HG group had higher dressing percentage ($p = 0.028$), LMA ($p = 0.02$) and fat trim in the forequarter ($p = 0.04$) compared to the LG group. The HP group tended to have greater dry matter intake ($p = 0.08$), LMA ($p = 0.05$), rump fat ($p = 0.04$), heavier striploins ($p = 0.07$), tenderloins ($p = 0.09$) and briskets ($p = 0.08$) compared with LP group. In conclusion, the selection based on divergent groups PWDG or PP14 has a small impact on performance, carcass and meat quality traits.

Keywords: *Bos indicus*; selection criteria; tenderness; weight gain; wholesale cuts

1. Introduction

Animal growth-based research over the past 50 years has had a dramatic impact in meat production, while the use of genetic selection for growth has resulted in profound increases in livestock production [1]. Growth traits, such as body weight (BW) and weight gain, have been widely used as selection criteria in beef cattle breeding programs because measurements can be easily collected on the farm and are highly heritable and relatively well correlated with carcass and several production traits [2,3].

Historically, genetic selection for growth traits has been related to increased body weight (BW), average daily gain (ADG), hot carcass weight (HCW) and the longissimus muscle area (LMA) [4]. However, selection for growth traits can also change body maturity, thus increasing maintenance requirements, which is undesirable for most production systems. Furthermore, growth changes muscle fiber characteristics [5], delays carcass fat deposition and may adversely impact eating quality, perhaps through changes in intramuscular fat content in beef cattle [6].

Precocity is a term used in beef production to describe animals that reach sexual maturity earlier, with faster growth, and depositing fat sooner than their counterparts. In commercial breeding programs, precocity has been evaluated directly by fat deposition measured by ultrasound or indirectly through scrotal circumference and early pregnancy measurements of males and females, respectively, and appears to be associated with fat deposition [7]. Brunes et al. [8] observed that subcutaneous fat thickness showed the highest discriminant power for heifer early pregnancy, probably due the effect of fatness level on reproduction.

While some studies have evaluated the effects of divergent selection for expected progeny differences (EPDs) on performance traits, no studies have attempted to use growth rate (i.e., postweaning average daily gain) or progeny EPD information to predict performance, nor have they approached the impact of using precocity EPD as a selection criterion on the performance, carcass traits and meat quality of beef cattle. Moreover, progeny EPDs have been extensively used by farmers to make breeding decisions and for keeping or culling animals from the herd, and therefore it is important to study the impact of using this information on performance and meat quality traits on the finishing phase. Therefore, this work was carried out to study the impact of divergent selection criteria for growth (post-weaning weight gain) and heifer early sexual precocity (probability of 14-month heifer pregnancy) on animal performance, carcass and meat quality traits of young Nellore bulls.

2. Materials and Methods

2.1. Postweaning Growth Evaluation and Animal Selection

Animals were sourced from University of São Paulo experimental herds located in Pirassununga/SP/Brazil. The herd was composed of purebred Nellore cattle that were part of a commercial genetic evaluation program. Animals were born from August to October 2014 and 2015 for year 1 and 2, respectively, and raised on pasture (*Brachiaria brizantha* cv. *Marandu grass*) with their mothers until weaning at 210 $\pm$ 30 days of age. After weaning, animals were pastured up to 550 $\pm$ 30 days of age and weighed for (EPDs) calculations.

All animals were allowed free access to mineral supplementation on pasture and were subjected to conventional management routine vaccination program as required by Brazilian Ministry of Agriculture, Livestock and Food Supply. After genetic evaluation, cattle remained on pasture until 600 $\pm$ 30 days of age then were transported to the feedlot facilities located approximately 5 km of distance for finishing period.

The EPDs were obtained using a multi-trait animal model (BLUP). The post-weaning average daily gain (PWDG; from 210 to 550 days) EPD was obtained using information of weaning weight (n = 494,652) and post-weaning weight gain (n = 211,005). The pedigree data included all animals (n = 583,406) with an observation plus their parents and grandparents.

The early sexual heifer precocity (PP14) for EPD was obtained using a multi-trait animal model involving information of both 14-month pregnancy (n = 32,859); stayability at 6 years of age (n = 120,941) defined as the probability a cow will remain in production at least until 6 years old; annual average cow production in kg of calves per cows per year (n = 153,085); scrotal circumference at 18 months (n = 63,000); and post-weaning weight gain (n = 202,635). The pedigree data included all animals (n = 344,023) with an observation plus their parents and grandparents.

In year one, a subset (50) contemporaneous animals (progeny from 11 sires) were selected from a group of 250 young bulls according to their EPDs value for post-weaning weight gain. All animals were then assigned to one of two treatment groups: high (HG) or low (LG) postweaning average weight gain. In year two, another subset of 50 animals (progeny from 13 sires) was selected from a group of 183 young bulls according to their

EPDs for PP14. Animals were then assigned to treatments of either high (HP) or low genetic (LP) PP14 group. Detailed information about EPDs parameters are presented in Table 1.

Table 1. Parameters of expected progenies difference (EPD), according to selection criteria (growth or precocity) and group (high or low).

Parameter	Growth [1]		Precocity [2]	
	High	**Low**	**High**	**Low**
Mean	9.7	1.5	12.1	−3.7
Standard error of mean	0.56		0.68	
Pr > F [3]	<0.0001		<0.0001	
Minimun	5.9	−9.9	9.3	−12.1
Maximun	13.8	4.7	19.0	0.9
Mean EPD percentile	4	40	8	60
Accuracy	0.24 (0.036)		0.15 (0.067)	
Heritability	0.19		0.42	

[1] Values for postweaning average weight gain (expressed kg/day). [2] Values of probability of pregnancy at 14 months of age (expressed in %). [3] Probability of F test for difference between high and low EPDs groups.

2.2. Feedlot Facilities and Diet

Animals were housed in four pens equipped with electronic feeding gates (American Calan Inc., Northwood, NH, USA) to allow for individual control of feed intake. The feedlot facility consisted of covered feed bunks, concrete floors and automatic waterers. Feed was offered ad libitum twice daily at 0800 h and 1600 h. Diets (Table 2) were formulated to meet the nutrient requirements of finishing Nellore bulls for a daily weight gain of 1.5 kg, as specified by the Cornell Net Carbohydrate and Protein System [9]. Dry matter intake (DMI) was calculated daily for each animal by subtracting refusals from feed offered. To ensure ad libitum intake, the amount of feed offered was adjusted daily to allow 3–5% refusals.

Table 2. Ingredients and composition (DM basis) of the diet.

Item	Diet (g/kg of DM)
Ingredients	
Corn silage	273
Ground sorghum	230
Ground corn	200
Ground citric pulp	200
Soybean meal	80
Urea	9
Salt	2
Mineral mixture [1]	6
Estimated nutrient content [2]	
Crude protein	138
Rumen degradable protein	92
Total digestible nutrients [3]	757
Calcium	6.4
Phosphorus	4

[1] The trace mineral mixture contained (per kilogram): zinc, 728 mg; iron, 221 mg; crude protein (minimum), 109%; fluorine (maximum), 106 mg; calcium, 116 g; selenium, 3 mg; phosphorus, 14 g; manganese, 226 mg; copper, 221 mg; cobalt, 29 mg; iodine, 21 mg; sodium, 44 g; sulphur, 43 g; potassium, 47 g; non-protein nitrogen (maximum), 109%; monensin sodium, 1.000 mg/kg. [2] Estimated using tabular values of ingredients. [3] Estimated according to Weiss [10].

2.3. Performance and Ultrasound Carcass Traits

To measure performance, animals were weighed at the beginning of the experimental period, every 28 days throughout the feeding period and the day before harvest, after 14 h fasting period with free access to water. The ADG was calculated by regression analysis using the data from all weights. Feed efficiency (G:F) was then calculated from the average daily gain (ADG) divided by the average DMI observed during the feedlot period. The DMI intake expressed as a percentage of BW was calculated using the average DMI divided by the average BW, multiplied by 100.

Ultrasound measurements were collected at days 0, 28, 56 and 90 of the experiment, using an Aloka®model SSD 500 Micrus (Aloka Co. Ltd., Zug, Switzerland) with a linear probe (3.5 mHz; 172 mm in length). Ultrasound measurements were taken between the 12th and 13th ribs to determine the longissimus muscle area (LMA) and backfat thickness (BFT), and also over the biceps femoris muscle between the ilium and ischium to determine the rump fat thickness (RFT) [11]. Images were recorded in a portable computer and then interpreted using Lince® software (M&S Consultoria Agropecuária, Pirassununga, SP, Brazil).

2.4. Carcass Data

Animals were harvested in the University of São Paulo abattoir located 500 m from the feedlot. Due to limited capacity of the slaughter facilities, animals were divided into three groups and harvested over a three-week period. Each harvest contained half of the animals from each treatment group. The average time on feed was 89 and 97 days for years 1 and 2, respectively.

Harvest procedures were performed under the Humanitarian Slaughter Guidelines, as required by Brazilian law [12]. Hot carcass weight (HCW) and kidney-pelvic fat (KPF) weight were recorded at harvest. At 24 h postmortem, muscle pH was recorded, measured, using an electrode probe attached to a portable pH meter (Hanna Instruments model HI99163, Sao Paulo, Brazil), and carcasses were fabricated into the wholesale special hindquarter, forequarter with five ribs and combined plate, flank, and short ribs. Subsequently, wholesale cuts were individually weighed and further processed into retail cuts, bones and trimmings as previously described by Brigida [13]. In addition, four steaks 2.5 cm thick each were collected from the longissimus thoracis (LT) muscle adjacent to the 12th rib, vacuum packed and aged (0–2 °C) for 0, 7 or 14 days for further analyses of color, cooking loss (CL), and Warner-Bratzler shear force (WBSF).

2.5. Color, CL and Tenderness

After each predetermined period of aging, samples were removed from the vacuum package, weighed and allowed to bloom for 30 min at 4 °C before color measurement using a Minolta CM2500d (Konica Minolta Sensing Inc., São Paulo, SP, Brazil) spectrophotometer with a D65 illuminant, a 30-mm aperture and a 10° observer angle according to the L^* (lightness), a^* (redness) and b^* (yellowness) system [14].

The WBSF and CL were determined using the methodology proposed by the American Meat Science Association [14]. Briefly, steaks were thawed for 24 h at 4 °C, weighed, and roasted in an oven equipped with a thermostat adjusted to 170 °C (Flexa de Ouro Industry, São Paulo, SP, Brazil). Internal steak temperatures were monitored using individual thermometers (Model RisePRO-Wireless Remote Digital Meat) until they reached 71 °C. After cooling to 28 °C, steaks were reweighed to calculate CL. For tenderness, steaks were cooled at 4 °C for 24 h, and six cores (diameter of 1.2 cm) were taken from each steak parallel to the orientation of the muscle fibers. Each core was sheared perpendicular to the muscle fiber orientation using a Warner-Bratzler shear blade fitted to a TMS-PRO texture analyzer (Food Technology Corporation, Sterling, VI, USA) with a 50 kg load cell and a crosshead speed of 200 mm/min $^{-1}$ according to standard procedures [14]. Shear force values of the six subsamples were averaged and converted to newtons (N).

2.6. Sarcomere Length

Measurement of the sarcomere length was performed according to Cross et al. [15] using a helium neon laser (Model # 05-LHR-021) and power supply (Model # 05-LPL-

911–065 115/230 Vac.; Melles Griot, Carlsbad, CA, USA). Samples at day 0 of aging were evaluated following instrumental analyses. Six cylinders were collected from each steak, and two fibers per cylinder were selected. Three sarcomeres were also selected for evaluation of sarcomere length.

2.7. Statistical Analysis

All statistical analyses were conducted using SAS software (SAS Institute Inc., Cary, NC). Data were analyzed as a completely randomized design using the MIXED procedure. Once the studies considering growth rate and PREC were performed in different years, they were evaluated separately considering the fixed effect of growth rate (HG or LG—year 1) or precocity (HP or LP—year 2) and the random effect of harvest group. Animal was considered the experimental unit. Live ultrasound and meat quality traits were analyzed as repeated measurements. Residual covariance structures were modeled, and the best fitted for each trait was used using the BIC criterion. The significance was declared at the $p \leq 0.05$, and tendency was considered at $0.05 < p \leq 0.10$.

3. Results

3.1. Growth Rate (Year 1)

No significant differences between HG and LG treatments were found for initial BW, despite the HG group being on average 22 kg heavier than the LG group (Table 3). Given that ADG was 1.54 and 1.55 kg/day for HG and LG, respectively, final BWs did not differ either. No differences between growth groups were observed for DMI, G:F and HCW; however, HG animals had higher ($p = 0.021$) dressing percentage compared to LG cattle. No differences between groups were observed for KPF values both expressed in kg or as a percentage of HCW.

Table 3. Performance and carcass traits of Nellore cattle according to selection criteria (growth or precocity).

Item	Growth [1]		SEM	Precocity [2]		SEM	*p*-Value	
	High	Low		High	Low		Growth	Precocity
Expect Progeny Difference	9.7	1.5	0.56	12.1	−3.7	0.68	<0.0001	<0.0001
Initial body weight (kg)	456.3	434.2	14.55	399.1	392.5	6.40	0.723	0.475
Final body weight (kg)	590.5	574.1	13.35	578.3	568.0	9.85	0.387	0.407
Average daily gain (kg)	1.54	1.55	0.08	1.89	1.77	0.10	0.630	0.261
Dry matter intake (kg/day)	11.3	11.3	0.44	11.1	10.1	0.48	0.931	0.080
Dry matter intake (% of BW)	2.2	2.3	0.09	2.3	2.1	0.08	0.449	0.050
Gain: feed (g/kg)	133.7	138.3	5.41	170.5	175.1	5.23	0.408	0.426
Hot carcass weight (kg)	348.4	338.6	19.56	343.5	338.5	5.35	0.213	0.510
Dressing percentage (%)	59.8	58.9	0.53	59.5	59.5	0.39	0.021	0.964
Kidney, pelvic and inguinal fat kg	14.7	13.5	0.59	13.5	13.7	0.55	0.132	0.814
% of hot carcass weight	4.2	4.0	0.24	3.9	4.0	0.16	0.225	0.689

[1] Values of potential for postweaning average weight gain (expressed kg). [2] Values of probability of pregnancy at 14 months of age (expressed in %).

The LMA was greater ($p = 0.028$) in the HG group, but no differences were found for BFT or RFT (Table 4). No difference between groups was observed for carcass bone and fat weights, or retail cut yield. However, fat content of the forequarter was greater ($p = 0.049$) in HG (Table 5). No effect of growth group was observed for subprimal weights from hind and forequarter (Table 6), nor for meat quality traits (Table 7).

Table 4. Carcass traits evaluated by ultrasound during the feeding period according selection criteria (growth or precocity) and time on feed.

Item	Group [3]		Days				SEM	*p*-Value		
	High	Low	0	28	56	90		Group	Days	Group × Days
Growth [1]										
Longissimus muscle area (cm^2)	64.4	61.3	54.4	61.2	65.9	69.9	2.56	0.028	<0.0001	0.925
Back fat thickness (mm)	2.6	2.3	0.5	2.3	3.1	3.9	0.33	0.199	<0.0001	0.979
Rump fat thickness (mm)	5.2	4.8	2.4	4.7	5.8	6.9	0.49	0.159	<0.0001	0.968
Precocity [2]										
Longissimus muscle area (cm^2)	68.8	66.7	58.9	65.0	70.4	76.8	1.69	0.055	<0.0001	0.963
Back fat thickness (mm)	2.3	2.0	1.0	1.5	2.9	4.3	0.27	0.171	<0.0001	0.437
Rump fat thickness (mm)	5.3	4.7	2.3	4.3	5.9	7.4	0.41	0.042	<0.0001	0.702

[1] Values of postweaning average weight gain (expressed kg/day). [2] Values of probability of pregnancy at 14 months of age (expressed in %). [3] Values represent the pooled values across all measurements along time on feed (0, 28, 56 and 90 days).

Table 5. Retail cuts, bones and trimming weights of Nellore cattle according to the selection criteria (growth or precocity).

Item (kg)	Growth [1]		SEM	Precocity [2]		SEM	*p*-Value	
	High	Low		High	Low		Growth	Precocity
Forequarter	133.8	128.6	2.63	129.0	125.4	2.91	0.168	0.403
Hindquarter	150.7	148.2	2.60	151.0	150.1	2.82	0.503	0.838
Brisket, short ribs and flank	50.9	48.6	1.26	49.1	49.5	1.27	0.202	0.805
Retail cuts								
Forequarter	83.5	80.8	2.07	78.7	74.3	1.96	0.364	0.120
Hindquarter	104.2	103.3	2.15	107.2	103.8	1.89	0.742	0.340
Total	186.0	183.6	3.75	185.1	178.1	2.65	0.502	0.185
Bones								
Forequarter	23.2	23.0	0.54	22.8	23.2	0.41	0.564	0.630
Hindquarter	27.0	26.7	0.48	27.0	27.5	0.63	0.618	0.531
Total	50.3	49.6	0.82	49.9	50.8	1.06	0.560	0.538
Fat trim								
Forequarter	15.2	13.6	0.64	14.6	14.2	0.56	0.049	0.681
Hindquarter	12.0	11.3	0.57	12.2	12.8	0.54	0.407	0.456
Total	27.3	24.9	1.00	26.9	27.0	0.94	0.111	0.890

[1] Values for postweaning average weight gain (expressed kg/day). [2] Values for probability of pregnancy at 14 months of age (expressed in %).

Table 6. Subprimal cuts weighs of Nellore cattle according to selection criteria (growth or precocity).

Item (kg)	Growth [1]		SEM	Precocity [2]		SEM	*p*-Value	
	High	Low		High	Low		Growth	Precocity
Hindquarter subprimals								
Striploin	9.2	9.4	0.22	9.4	8.9	0.19	0.605	0.070
Tenderloin	1.3	1.4	0.04	1.8	1.7	0.03	0.731	0.095
Top sirloin cap	1.3	1.4	0.09	1.6	1.5	0.11	0.898	0.354
Eye of rump tail of round	6.1	6.0	0.14	7.1	6.7	0.23	0.383	0.268
Knuckle	5.8	6.0	0.09	6.0	6.1	0.11	0.370	0.577
Eye of round	3.1	2.8	0.08	2.9	3.0	0.05	0.065	0.839
Inside round	10.8	10.7	0.22	11.1	11.0	0.19	0.857	0.873
Outside round	7.4	7.1	0.22	6.4	6.3	0.14	0.345	0.532
Forequarter subprimals								
Chuck	20.0	19.4	0.59	18.8	17.5	0.57	0.464	0.124
Shoulder	16.2	15.7	0.38	14.8	14.4	0.37	0.375	0.425
Brisket	5.4	5.2	0.27	5.6	5.1	0.19	0.506	0.081

[1] Values for postweaning average weight gain (expressed kg/day). [2] Values for probability of pregnancy at 14 months of age (expressed in %).

Table 7. Meat quality traits of Nellore cattle according to selection criteria (growth or precocity).

Item	Group		Days			SEM	*p*-Value		
	High	Low	0	7	14		Group	Days	Group × Days
Growth [1]									
Lightness (L^*)	34.7	34.5	31.6	35.0	36.8	0.39	0.663	<0.0001	0.436
Redness (a^*)	15.5	15.0	13.9	16.0	15.5	0.29	0.140	<0.0001	0.986
Yellowness (b^*)	12.8	12.9	13.2	13.4	14.1	0.38	0.659	0.005	0.999
pH 24 h	5.6	5.5	-	-	-	0.04	0.673	-	-
Sarcomere length (mm)	1.8	1.9	-	-	-	0.04	0.672	-	-
Tenderness (N)	54.2	52.4	69.0	47.8	43.2	1.83	0.216	<0.0001	0.296
Cooking loss (%)	22.3	23.1	21.8	22.8	23.6	0.62	0.320	0.165	0.373
Precocity [2]									
Lightness (L^*)	32.7	33.1	30.8	33.8	34.2	0.40	0.370	<0.0001	0.479
Redness (a^*)	16.5	15.4	16.1	16.7	15.1	0.18	0.025	0.001	0.002
Yellowness (b^*)	16.4	15.8	14.0	17.3	16.9	0.57	0.202	<0.0001	0.316
pH 24 h	5.3	5.4	-	-	-	0.03	0.385	-	-
Sarcomere length (mm)	1.7	1.7	-	-	-	0.02	0.310	-	-
Tenderness (N)	61.5	60.1	75.7	58.2	48.4	2.69	0.438	<0.0001	0.157
Cooking loss (%)	28.1	27.6	27.3	28.8	27.6	0.63	0.494	0.170	0.720

[1] Values of postweaning average weight gain (expressed kg/day). [2] Values of probability of pregnancy at 14 months of age (expressed in %).

3.2. Precocity (Year 2)

No differences between HP and LP groups were observed for initial or final BW and ADG or G:F (Table 3). However, the HP group tended to have higher DMI than LP cattle, both when expressed on a weight basis kg ($p = 0.080$) and as a percentage of BW ($p = 0.050$). No effects of the precocity were observed for HCW, dressing percentage or KPF. The HP cattle had greater RFT ($p = 0.042$) and tended to have greater LMA ($p = 0.055$) than LP cattle, but the BFT did not differ (Table 4). No effect of PP14 group was observed for retail cut yield, or bone and fat trim weights (Table 5). Most subprimal cut weights were not affected by PP14 group; however, the HP cattle tended to have heavier striploins ($p = 0.070$), tenderloins ($p = 0.095$) and briskets ($p = 0.081$).

The PP14 group did not affect most of meat quality traits (Table 7). There was a significant GP*days interaction for a^* ($p = 0.002$) between HP and LP animals. No significant effect of time was observed for CL.

All traits evaluated by ultrasound increased linearly ($p < 0.001$) with time on feed. Additionally, beef L^* values increased and WBSF decreased with aging time for both growth and precocity groups. No significant effect of time was observed for CL.

4. Discussion

A better understanding of the effects of genetic merit is important for beef producers because genetic differences mandate different feeding and management strategies if the enterprise is optimized properly [16]. Under commercial conditions, EPDs are normally used by producers to make decisions regarding retaining or culling animals from the herd and for breeding strategies. For young animals, like those used in this study, EPDs are normally based on their own performance and that from their parents (pedigree). Therefore, these predictions have lower accuracies, when compared to older animals that have been progeny tested. To that end, results reported hereinafter must be interpreted in this context, and in spite of its limited accuracy, they are still useful for the beef industry to better understand the impact of this selection practice on finishing performance and meat quality traits.

In this study, no differences were found in performance between groups with different post-weaning growth. Notwithstanding, the HG group started and finished the feeding period heavier (22 and 16 kg, respectively) than LG and had numerically heavier (16.6 kg) HCWs. The DMI and G:F also did not differ between groups, which is in line with a lack of difference in BW and ADG. On the other hand, the HG cattle group had greater dressing percentages (p = 0.012) than LG cattle, which is somewhat unexpected given that no differences were found between groups for final BW, HCW or internal fat measurements.

Carcass traits, cuts yield, and meat quality traits were mostly not different between growth groups either. However, LMA was greater and rump fat thickness was higher in the HP group, but no differences were found in backfat thickness across treatments. The LMA is an indicator trait of carcass muscularity, and it is positively correlated with the weight of retail cuts but negatively correlated with fat measurements [11]. However, in this study, differences in LMA (3 cm^2) and RFT (0.4 mm) between HG and LG cattle may not be large enough to significantly impact retail and subprimal cut weights.

Previous studies have evaluated the effects of bull EPD values for growth traits (i.e., yearling weight, carcass weight, muscularity) on performance, carcass and meat quality traits of their progeny [16–19]. In contrast to the aforementioned, animals used in this study were categorized on their own performance plus that of their ancestors. Furthermore, average daily gain (instead of BW at specific age) was used as the growth measurement in our study. However, even though all these characteristics are considered growth indicators and are correlated, they apparently are not equivalent and must reflect slightly biological outcomes.

In a similar study, Campion et al. [19] evaluated the effects of a bull's EPD for carcass weight (high or low) on performance, body scores and carcass traits using Aberdeen Angus and Belgian Blue cattle. They reported that the higher carcass weight EPD groups in Angus cattle had heavier carcass weights and had greater dressing percentages than low EPD bulls, but no differences were evident for Belgian Blue cattle across low or high EPDs. Furthermore, no EPD effect was observed for ADG, DMI, efficiency of energy use, longissimus muscle or fat depth at slaughter. The authors argued that the lack of difference of EPD for Belgian Blue cattle may be partly due to the nutrient intake, which may been insufficient to allow the high growth group to express their full genetic potential. Alternatively, it may have been because of the way EPDs are calculated and how the myostatin allele is considered in pedigree analyses.

Similarly, growth, feed intake and carcass traits of progeny from Limousin sires with low or high genetic index for growth (based on carcass weight, conformation and fat class) have also been compared [18]. These investigators failed to detect differences between groups in final BW, DMI, ADG, carcass fat and LMA due to EPDs, though greater carcass weight and dressing percentages were reported for the high growth group.

Hopkins, Hegarty and Farrell [17] also evaluated carcass and meat quality traits on the progeny of rams sires with differing genetic merit for post-weaning weight, post-weaning muscle or fat depths, or muscularity finished under high or low plane of nutrition. These researchers found that animals with high EPDs for post-weaning weight had heavier HCW and smaller fat thickness at harvest compared to controls or those with high EPDs for muscularity. No effect of post-weaning weight EPD was observed for WBSF, cooking loss, color (except for L^*), eating quality or pH.

Finally, Clarke et al. [20] evaluated the effect of bull's genetic potential for beef carcass index (composed of weaning weight, DMI, carcass weight and carcass conformation and fat scores) in cattle of different breeds across growing and finishing phase. These investigators reported no effect of genetic potential on performance, though heavier carcass weights and carcass gains (kg/day) and lower fat scores were observed in high index group. Despite the lack of broad differences, authors still observed a high profit margin for the high index group and concluded that the carcass index was still a useful tool in the selection of genetically superior sires and overall productivity.

Regardless of differences in methods, traits used to select animals, sample size and finishing system used, the overall conclusion of the aforementioned studies is that genetic differences in the specific EPD growth traits measured at early stages of animal life may not affect animal performance, carcass traits or meat quality characteristics at finishing. It is important understand, however, that all studies were performed under different environmental conditions (i.e., pasture for EPD calculations and feedlot for finishing), which can impact outcomes. Specifically, pasture-based feeding approaches are almost always considered a nutrient-limiting scenario, especially when compared to feedlot feeding. According to Raidan et al. [21], differences in response to selection of the same trait in different environments may occur, especially for traits with low heritability.

As mentioned above, the criterion used to categorize groups for early heifer sexual precocity in this study was based on the reproductive measurement of PP14 [2]. There are few studies available on the relationship between reproductive competence and finishing performance in beef cattle. Kluska et al. [3] reported a positive, albeit moderated to low, genetic correlation between probability of precocious calving with ultrasound backfat thickness (r_g = 0.35), rump fat (r_g = 0.11) and LMA (r_g = 0.11) in Nellore cattle, suggesting that selection to increase sexual precocity in females would have a favorable impact on carcass fatness in Nellore cattle. In a recent study also with Nellore cattle, [8] evaluated the association between growth, carcass and visual scores traits with occurrence of precocious calving in Nellore cattle using discriminant multivariate analysis, and the authors reported that among the carcass traits evaluated after weaning, the subcutaneous fat thickness displayed the highest discriminant power for heifer early pregnancy. This result can be explained by the influence that the body fatness level has on reproduction, through improvement of energetic status, steroidogenesis, insulin modulation and synthesis of leptin and prostaglandins [22,23].

In the study outlined herein, we observed a trend of higher DMI for the HP group, but no differences were detected in final BW, ADG or G:F, or carcass weight or dressing percentage. Similar to that observed for growth, HP animals tended to have greater LMA (2.2 cm^2) and a greater RFT (0.6 mm), but these differences did not impact retail cuts, bones and fat trim or subprimal cuts and most meat quality traits, except redness. However, it is important to note that in addition to the temporal differences in sampling, measurements (i.e., EPD and finishing performance) were taken under different environmental conditions which have a profound impact on animal performance. Even so, once these EPDs are used by commercial producers for decisions on breeding strategies, further studies should be performed to get more conclusive benefits.

5. Conclusions

The results of this study show that the selection criteria for post-weaning weight gain or early heifer sexual precocity based on progeny information has a small impact on performance, carcass, and meat quality traits of feedlot-finished animals. Although the high EPDs groups have positive effects on some meat quality traits compared to low EPDs groups, improvements in those traits will be more effective if selected directly instead of through correlated responses.

Author Contributions: J.P.E., P.R.L., A.S.N., and S.L.S. conceived and designed the research. J.S., N.R.B.C., V.L.M.B., M.B., T.d.S.M., and A.A.G.L. conducted the experiments. V.L.M.B., T.d.S.M., J.F.M.G., and N.R.B.C. contributed to the sample preparation and analysis. J.S., N.R.B.C., F.B., and S.L.S. analyzed data. J.S., N.R.B.C., J.P.E., D.E.G., and S.L.S. wrote the manuscript. All authors read and approved the manuscript.

Funding: This research was funded by São Paulo Research Foundation (FAPESP), grant number 2016/17433-5 and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brazil (CAPES)—Finance Code 001.

Institutional Review Board Statement: All procedures used in this study involving animal care were conducted in accordance with the Institutional Animal Care and Use Committee Guidelines (IACUC # 8886050916/16) and approved by the College of Animal Science and Food Engineering of University of Sao Paulo, Brazil.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Dodson, M.V.; Allen, R.E.; Du, M.; Bergen, W.G.; Velleman, S.G.; Poulos, S.P.; Fernyhough-Culver, M.; Wheeler, M.B.; Duckett, S.K.; Young, M.R.I.; et al. Invited review: Evolution of meat animal growth research during the past 50 years: Adipose and muscle stem cells. *J. Anim. Sci.* **2015**, *93*, 457–481. [CrossRef] [PubMed]
2. Eler, J.P.; Bignardi, A.B.; Ferraz, J.B.S.; Junior, M.L.S. Theriogenology Genetic relationships among traits related to reproduction and growth of Nelore females. *Theriogenology* **2014**, *82*, 708–714. [CrossRef] [PubMed]
3. Kluska, S.; Olivieri, B.F.; Bonamy, M.; Chiaia, H.L.J.; Feitosa, F.L.B.; Berton, M.P.; Peripolli, E.; Lemos, M.V.A.; Tonussi, R.L.; Lôbo, R.B.; et al. Estimates of genetic parameters for growth, reproductive, and carcass traits in Nelore cattle using the single step genomic BLUP procedure. *Livest. Sci.* **2018**, *216*, 203–209. [CrossRef]
4. Garrick, D.J.; Ruvinsky, A. *The Genetics of Cattle*; CAB International: Boston, MA, USA, 2014.
5. Greenwood, P.L.; Harden, S.; Hopkins, D.L. Myofibre characteristics of ovine *longissimus* and semitendinosus muscles are influenced by sire breed, gender, rearing type, age and carcass weight. *Aust. J. Exp. Agric.* **2007**, *47*, 1137–1146. [CrossRef]
6. Hopkins, D.L.; Stanley, D.F.; Martin, L.C.; Toohey, E.S.; Gilmour, A.R. Genotype and age effects on sheep meat production. Meat quality. *Aust. J. Exp. Agric.* **2007**, *47*, 1155–1164. [CrossRef]
7. Irano, N.; Camargo, G.M.F.; Costa, R.B.; Terakado, A.P.N.; Magalhães, A.F.B.; Silva, R.M.D.O.; Dias, M.M.; Bignardi, A.B.; Baldi, F.; Carvalheiro, R.; et al. Genome-wide association study for indicator traits of sexual precocity in Nellore cattle. *PLoS ONE* **2016**, *8*, e0159502. [CrossRef] [PubMed]
8. Brunes, L.C.; Baldi, F.; Costa, M.F.O.E.; Quintans, G.; Banchero, G.; Lobo, R.B.; Magnabosco, C.U. *Early Growth, Backfat Thickness and Body Condition Has Major Effect on Early Heifer Pregnancy in Nellore Cattle, 2020*; Anais da Academia Brasileira de Ciências: Rio de Janeiro, Brazil, 2020.
9. Fox, D.G.; Sniffen, C.J.; O'Connor, J.D.; Russell, J.B.; Van Soest, P.J. A net carbohydrate and protein system for evaluating cattle diets. III. Cattle requirements and diet adequacy. *J. Anim. Sci.* **1992**, *70*, 3578–3596. [CrossRef] [PubMed]
10. Weiss, W.P.; Conrad, H.R.; St-Pierre, N.R. A theoretically-based model for predicting total digestible values of forages and concentrates. *Anim. Feed Sci. Technol.* **1992**, *39*, 95–110. [CrossRef]
11. Silva, S.L.; Tarouco, J.U.; Ferraz, J.B.S.; Gomes, R.C.; Leme, P.R.; Navajas, E.A. Prediction of retail beef yield, trim fat and proportion of high-valued cuts in nellore cattle using ultrasound live measurements. *Rev. Bras. Zootec.* **2012**, *41*, 2025–2031. [CrossRef]
12. Brasil. *Ministério da Agricultura, Pecuária e Abastecimento Regulamento da Inspeção Industrial e Sanitária de Produtos de Origem Animal [Food Ofanimal Origin Sanitary and Industry Inspection]*; Ministério da Agricultura, Pecuária e Abastecimento: Brasília, Brazil, 1997.
13. Brigida, D.J.; Antonelo, D.S.; Mazon, M.R.; Nubiato, K.E.Z.; Gómez, J.F.M.; Netto, A.S.; Leme, P.R.; Cônsolo, N.R.B.; Silva, S.L. Effects of immunocastration and a β-adrenergic agonist on retail cuts of feedlot finished Nellore cattle. *Animal* **2018**, *12*, 1690–1695. [CrossRef] [PubMed]
14. American Meat Science Association. *Research Guidelines for Cookery, Sensory Evaluation and Tenderness Measurements of Fresh Meat*; American Meat Science Association: Chicago, IL, USA, 2012.
15. Cross, H.R.; West, R.L.; Dutson, T.R. Comparison of methods for measuring sarcomere length in beef semitendinosus muscle. *Meat Sci.* **1981**, *5*, 261–266. [CrossRef]
16. Campion, B.; Keane, M.G.; Kenny, D.A.; Berry, D.P. Evaluation of estimated genetic merit for carcass weight in beef cattle: Live weights, feed intake, body measurements, skeletal and muscular scores, and carcass characteristics. *Livest. Sci.* **2009**, *126*, 87–99. [CrossRef]
17. Hopkins, D.L.; Hegarty, R.S.; Farrell, T.C. Relationship between sire estimated breeding values and the meat and eating quality of meat from their progeny grown on two planes of nutrition. *Aust. J. Exp. Agric.* **2005**, *45*, 525–533. [CrossRef]
18. Keanes, M.G.; Diskin, M.G. Performance and carcass traits of progeny of Limousin sires differing in genetic merit. *Ir. J. Agric. Food Res.* **2007**, *46*, 63–76.
19. Campion, B.; Keane, M.G.; Kenny, D.A.; Berry, D.P. Evaluation of estimated genetic merit for carcass weight in beef cattle: Blood metabolites, carcass measurements, carcass composition and selected non-carcass components. *Livest. Sci.* **2009**, *126*, 100–111. [CrossRef]
20. Clarke, A.M.; Drennan, M.J.; McGee, M.; Kenny, D.A.; Evans, R.D.; Berry, D.P. Intake, growth and carcass traits in male progeny of sires differing in genetic merit for beef production. *Animal* **2009**, *3*, 791–801. [CrossRef] [PubMed]
21. Raidan, F.S.S.; Passafaro, T.L.; Fragomeni, B.O.; Josahkian, L.A.; Pereira, I.G.; Toral, F.L.B. Genotype × environment interaction in individual performance and progeny tests in beef cattle. *J. Anim. Sci.* **2015**, *93*, 920–933. [CrossRef] [PubMed]
22. Staples, C.R.; Burke, J.M.; Thatcher, W.W. Symposium: Optimizing energy nutrition for reproduction dairy cows. *J. Dairy Sci.* **1998**, *81*, 865–871.
23. Minick, J.A.; Wilson, D.E.; Rouse, G.H.; Hassen, A.; Pence, M.; Sealock, R.; Hopkins, S. *Relationship between Body Composition and Reproduction in Heifers*; Beef Research Report; Iowa State University: Ames, Iowa, 2001.