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Carcass traits and meat quality of Nellore bulls submitted to different nutritional strategies during cow-calf and stocker phase

--Manuscript Draft--

| | |
|-------------------------------------|--|
| Manuscript Number: | ANIMAL-17-60324 |
| Full Title: | Carcass traits and meat quality of Nellore bulls submitted to different nutritional strategies during cow-calf and stocker phase |
| Short Title: | Nutritional strategies on carcass traits of bulls |
| Article Type: | Research Article |
| Section/Category: | 6. Product Quality, Human Health and Well-being |
| Keywords: | backgrounding; conformation degree; longissimus thoracis; suckling; weaning. |
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| Manuscript Region of Origin: | BRAZIL |
| Abstract: | <p>There have been few studies done that evaluate the effects of adopting different nutritional strategies in more than one phase of cattle production on carcass and meat parameters. The aim of this study was to evaluate carcass and meat variables of bulls submitted to different nutritional strategies during two phases of production. The trial was conducted at Figueira's farm during two phases of production: Phase I (Cow-calf) - 80 calves (99.58 ± 2.72 days of age and 109.73 ± 2.99 kg of body weight) with their mothers, were randomly assigned into two supplemental diets: mineral supplement (CM; n = 40) or creep-feeding (CC; ; n = 40); Phase II (Stocker) - the same 80 calves (201.20 ± 2.11 days of age and 190.20 ± 3.37 kg of body weight) were redistributed into two production systems: pasture (SP; n = 40) or feedlot (SF; n = 40). After that, all 80 animals were kept on a pasture system (Phase III) for 290 days, and then finished on a feedlot system (Phase IV) for another 135 days. Then, they were harvested at an average 764.26 ± 3.06 days of age and at 499.20 ± 3.33 kg of final body weight. After harvest, the average daily gain was calculated and the carcass and meat parameters were measured. The statistical model design used was completely randomized in a 2x2 factorial arrangement (two treatment groups on cow-calf phase and two treatment groups on stocker phase). The single effects between the groups in each phase and the interactions between both phases (cow-calf versus stocker) were analyzed. The results were compared with Fisher test, using the R statistical software. A Cow-calf by Stocker phases interaction occurred for carcass conformation and fiber diameter. For single effects, the greatest influences observed were in the stocker phase. The feedlot group was harvested 17 days earlier, with greater final body weight (+ 3.8%), hot carcass weight (+ 5.7%), average daily gain (+ 6.9%), and dressing percentage (+ 1.8%), carcass length (+ 1.8 %), carcass width (+ 1.5 %), ribeye area (+ 4.8 %) and muscle depth (+ 2.3 %) than pasture group. The SF group also had influence on fat color, showing higher L* and lower b* values. These results reveal that bulls reared in the feedlot at the stocker phase have higher muscle development and that the stocker</p> |

| | |
|-----------------------------|--|
| | phase has the greatest potential to influence carcass traits and meat quality. |
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1 **Carcass traits and meat quality of Nellore bulls submitted to different**
2 **nutritional strategies during cow-calf and stocker phase**

3

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17

18 Short title: Nutritional strategies on carcass traits of bulls

19

20 **Abstract**

21 There have been few studies done that evaluate the effects of adopting different
22 nutritional strategies in more than one phase of cattle production on carcass and
23 meat parameters. The aim of this study was to evaluate carcass and meat variables
24 of bulls submitted to different nutritional strategies during two phases of production.
25 The trial was conducted at Figueira’s farm during two phases of production: Phase I

26 (Cow-calf) – 80 calves (99.58 ± 2.72 days of age and 109.73 ± 2.99 kg of body
27 weight) with their mothers, were randomly assigned into two supplemental diets:
28 mineral supplement (CM; $n = 40$) or creep-feeding (CC; ; $n = 40$); Phase II (Stocker)
29 – the same 80 calves (201.20 ± 2.11 days of age and 190.20 ± 3.37 kg of body
30 weight) were redistributed into two production systems: pasture (SP; $n = 40$) or
31 feedlot (SF; $n = 40$). After that, all 80 animals were kept on a pasture system (Phase
32 III) for 290 days, and then finished on a feedlot system (Phase IV) for another 135
33 days. Then, they were harvested at an average 764.26 ± 3.06 days of age and at
34 499.20 ± 3.33 kg of final body weight. After harvest, the average daily gain was
35 calculated and the carcass and meat parameters were measured. The statistical
36 model design used was completely randomized in a 2x2 factorial arrangement (two
37 treatment groups on cow-calf phase and two treatment groups on stocker phase).
38 The single effects between the groups in each phase and the interactions between
39 both phases (cow-calf *versus* stocker) were analyzed. The results were compared
40 with Fisher test, using the R statistical software. A Cow-calf by Stocker phases
41 interaction occurred for carcass conformation and fiber diameter. For single effects,
42 the greatest influences observed were in the stocker phase. The feedlot group was
43 harvested 17 days earlier, with greater final body weight (+ 3.8%), hot carcass weight
44 (+ 5.7%), average daily gain (+ 6.9%), and dressing percentage (+ 1.8%), carcass
45 length (+ 1.8 %), carcass width (+ 1.5 %), ribeye area (+ 4.8 %) and muscle depth (+
46 2.3 %) than pasture group. The SF group also had influence on fat color, showing
47 higher L* and lower b* values. These results reveal that bulls reared in the feedlot at
48 the stocker phase have higher muscle development and that the stocker phase has
49 the greatest potential to influence carcass traits and meat quality.

50

51 **Keywords:** Backgrounding, Conformation degree, *Longissimus thoracis*, Suckling,
52 Weaning

53

54 **Implications**

55 Studies that assess the effects of nutritional strategies along more than one phase of
56 cattle production and their interactions and effects on carcass and meat traits are
57 limited. The current research provides new information about the integration between
58 cow-calf and stocker phases on carcass and meat traits. Our results can help the
59 livestock industry decide which nutritional strategy is best suited to its production
60 system. The adoption of the adequate nutritional strategy can improve the productive
61 indices and carcass traits, resulting in animals with increased muscular development
62 and decreased harvest age, leading to economic, environmental, and social benefits.

63

64 **Introduction**

65 Meat is one of the most important foods in the world and in some countries it is
66 considered an essential product with very high consumption rates. For many people
67 around the world meat provides valuable amounts of protein, fatty acids, vitamins,
68 minerals and other bioactive compounds. However, meat varies with respect to
69 numerous intrinsic and extrinsic factors of the animal. These include pre and post-
70 slaughter technology and factors related to consumer sciences, such as sociology,
71 acceptability, economy, and marketing. Animal diet is an extrinsic factor and it is the
72 most easily manipulated, with the most profound effects on meat composition
73 (Guerrero *et al.*, 2013a).

74 Because of the increased demand for meat, several segments of the beef
75 industry are striving to increase product quality, efficiency, and economic returns. It is

76 well known that these variables may be determined by different growth paths during
77 early and later stages in the life of the animals. Cattle nutrition and growth after birth
78 have a great influence on feed intake efficiency, carcass composition, and meat
79 quality. Furthermore, growth patterns can be affected by climate, availability and
80 quality of the pasture, and the entire offered diet (Brito *et al.*, 2014). According to
81 Dunne *et al.* (2009) beef production systems depend on climatological and
82 socioeconomic factors which frequently dictate management practices and decisions,
83 and thus are a composite of interacting factors that influence the biology of the
84 bovine.

85 The effect of the production system on meat quality has been looked at from
86 many different points of view since it may be considered the result of multi-causal
87 factors (Guerrero *et al.*, 2013a). However, scientific literature still has only a few
88 studies that have assessed the effects of different nutritional strategies along more
89 than one phase of production of cattle on carcass and meat variables. Thus, the aim
90 of the current study was to evaluate the carcass traits and meat quality of bulls
91 submitted to different nutritional strategies during cow-calf and stocker phase. We
92 hypothesized that carcass traits and meat quality of bulls may be influenced by better
93 nutritional support during both phases of production. Besides that, we also
94 hypothesized that certain phases would exert higher or lower influence on carcass
95 and meat traits.

96

97 **Material and methods**

98 The study was approved by the Ethics Committee on Animal Use of the School of
99 Veterinary Medicine and Animal Science of University of São Paulo, under protocol
100 number 2833/2012.

101

102 *Experimental place*

103 The trial was conducted in two phases of production, cow-calf and stocker phases, at
104 Figueira's Farm (experimental station Hildegard Georgina Von Pritzelwitz) located at
105 Londrina, Paraná state, Brazil with latitude of 23°34'25" S, longitude 50°58'17" W and
106 altitude of approximately 560 m. According to Koppen global climate classification,
107 the region climate is type Cfa, being humid subtropical with an annual mean
108 precipitation of 1,626 mm and annual mean temperature of 21.1 °C. Droughts may
109 occur in the winter period (Instituto Agronômico do Paraná, 2017), as occurred in this
110 experiment.

111

112 *Animals and treatment groups*

113 From a herd of 498 pregnant cows (6.89 ± 0.23 years old; mean \pm SEM), 80 Nellore
114 similar calves born between November and December (wet season) 2010 were
115 selected. The first phase (Phase I – Cow-calf) began when the calves were $99.58 \pm$
116 2.72 days old and weighed 109.73 ± 2.99 kg. The cow-calf pair was assigned
117 randomly into two treatment groups: 1) cow-calf mineral supplement (CM; $n = 40$) or
118 2) cow-calf creep-feeding (CC; $n = 40$). The calves from the CM group received
119 mineral supplement (BellMais, Bellman[®], Brazil) *ad libitum* in the same trough as the
120 cows and the CC group received supplement (BellPeso, Bellman[®], Brazil) *ad libitum*
121 in creep-feeding stations.

122 The mineral supplement (BellMais, Bellman[®], Brazil) content for each kilogram
123 was: Ca, 164 g; P, 60 g; Mg, 10 g; S, 40 g; Na, 140 g; Cu, 1,010 mg; Mn, 780 mg;
124 Zn, 3,750 mg; I, 75mg; Co, 60 mg; Se, 19 mg. The content for each kilogram of
125 supplement (BellPeso, Bellman[®], Brazil) offered in creep-feeding system was: Ca, 26

126 g; P, 6 g; Mg, 1 g; S, 3.6 g; Na, 4 g; Cu, 35 mg; Mn, 100 mg; Zn, 128 mg; I, 2.6 mg;
127 Co, 2.1 mg; Se, 0.7 mg; monensin, 48 mg; vitamin A, 10,000 UI; vitamin D3, 1,400
128 UI; vitamin E, 100 UI; dry matter total, 880 g; crude protein, 220 g; ether extract, 1 g;
129 neutral detergent fiber, 180 g; estimated total digestible nutrients, 620 g; mineral,
130 250 g.

131 For the CM group, there were two creep stations available, which were placed
132 inside the management centers, close to the troughs for mineral supplement and
133 drinkers. In each *creeper*, where only calves had free access, there were two troughs
134 of 2.63 m of length; 0.42 m of width and 0.3 m of depth. Marking, vaccination and de-
135 worming of the animals was done according to the routine of the farm and
136 recommendations of the local Agricultural Defense Agency. Until the end of Phase I
137 all animals were allocated on pasture of *Panicum maximum* cv. Tanzania with
138 estimated content: dry matter total, 23.3%; crude protein, 9.57%; ether extract, 2.6%;
139 neutral detergent fiber, 72.22%; estimated total digestible nutrients, 49.1%; mineral,
140 9.9%. A pasture rotation between both groups was done every 30 days to avoid the
141 effect of pasture variation. The calves remained at these treatments (CM and CC) for
142 101.60 ± 1.33 days, coinciding with weaning which occurred around 6.7 ± 0.07
143 months of age.

144 The second phase (Phase II - Stocker) started after weaning (beginning of
145 stocker phase) which occurred in June and July (dry season) 2011 when the calves
146 were on average 201.20 ± 2.11 days of age and 190.20 ± 3.37 kg. Twenty calves
147 from each previous group, CM and CC, were assigned randomly into another two
148 treatment groups: 1) stocker pasture (SP; $n = 40$) or 2) stocker feedlot (SF; $n = 40$).
149 Animals from the SP group were allocated on pasture receiving only mineral
150 supplement (BellMais, Bellman[®], Brazil) and the animals from the SF group were fed

151 in a feedlot system with a diet formulated for a gain of 0.7 kg per day. The pasture
152 was composed mainly of *Panicum maximum* cv. Colonião and *Brachiaria brizantha*
153 cv. Marandu. The chemical analysis of forage in the entry of Phase II was: dry matter
154 total, 27.6%; crude protein, 11.2%; ether extract, 2.9%; neutral detergent fiber,
155 52.0%; mineral, 10.4%. A pasture rotation inside the SP group was done every 30
156 days to avoid the effect of pasture variation. The feedlot ration was provided twice a
157 day (7:30 am and 4 pm) in sufficient quantity to maintain orts between 5 and 10% of
158 the offered. In the feedlot area there were drinkers and 30 cm of trough line per
159 animal. The ingredients used in the feedlot diet were (as fed basis): 63.5% of grain
160 sorghum silage; 20.3% corn meal; 15.2% of soybean meal and 1.0% mineral
161 supplement (BellMais, Bellman[®], Brazil) and the feed nutritive value was: dry matter,
162 38.5%; crude protein, 16.3%; ether extract, 3.6%; neutral detergent fiber, 57.4%;
163 estimated total digestible nutrients, 66.5%; and mineral, 1.3%. The calves remained
164 at these treatments for 136.58 ± 2.07 days, until November (wet season) 2011.

165 After that, all 80 animals were allocated to a pasture system (Phase III)
166 receiving only mineral supplement for 290 days, followed by a finishing phase in a
167 feedlot system (Phase IV) for another 135 days. The diet and the management were
168 the same for both groups on pasture phase and feedlot phase. The cattle were
169 weighted using an electronic scale (SOLO 900[®], Beckhauser, Brazil) at the beginning
170 of Phase I, Phase II, Phase III, Phase IV and also at harvest. The average daily gain
171 was calculated for Phase I and Phase II. Days of age and initial body weight of each
172 group (CM, CC, SP and SF) from Phase I until harvest are presented in Figure 1.

173

174 *Harvest and analysis*

175 The time for harvest was determined using visual estimation of the fat deposition at
176 the tail head of each animal. At the end of the finishing period, cattle were shipped to
177 a commercial abattoir at Apucarana, Paraná, Brazil, where they were harvested at
178 764.26 ± 3.06 days of age and 499.20 ± 3.33 kg of final body weight (FBW) on
179 average. The animals were stunned using a pneumatic penetration pistol and were
180 then immediately exsanguinated (Chambers and Grandin, 2001) and the carcass and
181 meat analyses proceeded. The left half of the carcass of each animal was identified
182 with a plastic label. Hot carcass weight (HCW) was taken and dressing percentage
183 was calculated by dividing the HCW by the FBW and expressed as a percentage.

184 After a 24-hour chilling period, the hydrogenionic potential (pH) was measured
185 at the *longissimus thoracis* muscle between the 12th and 13th ribs using a digital
186 potentiometer (Testo 205®). At this moment, the carcass length and carcass width
187 were also measured and carcasses were classified according to conformation degree
188 using a photographic standard, in which 1 is inferior and 5 is superior, and classified
189 according to fatness scores, in which 1 is low fat and 5 is very fat (Comunidad
190 Económica Europea, 1981). Then, the left halves of the carcasses were cut between
191 the 12th and 13th ribs to expose the *longissimus thoracis* muscle and then the ribeye
192 area, and muscle depth and backfat were measured (United States Department of
193 Agriculture, 1996).

194 The HH section (10th, 11th and 12th ribs) was removed from the left half of the
195 carcass and a physical separation of muscle (M), fat (F) and bone (B) was carried
196 out. Finally, these three portions were weighed to determine their percentages in the
197 HH section. Then, the percentages of muscle (M %), fat (F %) and bone (B %) of the
198 carcass were calculated according to Hankins and Howe (1946) adapted by Müller *et*

199 *al.* (1973) using the following formulas: $M \% = 15.56 + 0.81 * M$; $F \% = 3.60 + 0.82 * F$;
200 $B \% = 4.30 + 0.61 * B$.

201 The *longissimus thoracis* muscle of each animal was split into sub-samples
202 (obtained along the caudal-cranial axis) for meat quality evaluations. The first sub-
203 sample (2 cm width) obtained was used to evaluate marbling, water holding capacity,
204 meat color, and fiber diameter. Marbling was evaluated using a marbling
205 photographic standard, in which 1 represents no marbling and 10 represents
206 abundant marbling (USDA, 1996). In the same sub-sample, the water holding
207 capacity was determined through the water loss caused by physical pressure
208 (Hamm, 1960). Fat color was measured around the 12th rib and the meat color was
209 evaluated in the *longissimus thoracis* muscle. Both measurements were performed in
210 triplicate using a portable colorimeter (Minolta CR10) which provides the values of L*
211 (lightness), a* (redness) and b* (yellowness) by the CIELAB system (CIELAB, 1976).
212 In which: L* runs from 0 (black) to 100 (white), a* runs from negative (green) to
213 positive (red) and b* runs from negative (blue) to positive (yellow). The sub-sample
214 for fiber diameter analysis was cut in 3 sub-sub-samples (1 cm³ each), placed for 24
215 hours in Bouin solution, and washed and stored in 70% alcohol solution. The material
216 was then dehydrated, immersed in paraffin, roughly trimmed, placed on a microscope
217 slide and colored by hematoxylin and eosyn. For the determination of fiber diameter,
218 10 fields were captured for each microscope slide and the 15 lowest diameters per
219 field were measured, totaling 150 fibers per microscope slide.

220 The sub-samples for shear force and meat composition were stored at the
221 Animal Nutrition Laboratory at Universidade Estadual de Londrina after being
222 individually packed in plastic bags and immediately frozen at -18° C pending further
223 analyses. The second sub-sample (3 cm width) was used to determinate the meat

224 shear force. The sub-samples were thawed at 4°C for around 24 hours before
225 cooking. After thawing they were cooked to an internal temperature of 71°C and then
226 chilled overnight at 4°C before coring. Six round cores (1.27 cm diameter) were
227 removed parallel to the longitudinal orientation of the muscle fibers. The shearing
228 action was perpendicular to the longitudinal orientation of the muscle fibers, using a
229 Warner-Bratzler shear machine (Wheeler *et al.*, 1996; American Meat Science
230 Association, 2015). The third sub-sample (1 cm width) obtained was used to
231 determinate the percentage of dry matter, ether extract, crude protein, and mineral
232 matter of the sample (Association of Official Agricultural Chemists, 1995).

233

234 *Experimental design*

235 The statistical model design used was completely randomized in a 2x2 factorial
236 arrangement, with two treatment groups in the cow-calf phase (mineral supplement
237 and creep-feeding) and two treatment groups in the stocker phase (pasture and
238 feedlot). The single effects between the groups in each phase and the interactions
239 between both phases (cow-calf *versus* stocker) were analyzed. The experimental unit
240 was composed by each animal, totaling 20 experimental units for each treatment
241 group. All statistical procedures were performed adopting 0.05 as the critical level of
242 probability. The results were expressed as mean and were compared with Fisher
243 test. The statistical analysis was performed using the R statistical software (R
244 Development Core Team, 2015).

245

246 **Results**

247

248 *Interactions effect*

249 There were significant ($P < 0.05$) cow-calf and stocker phase interactions, but only for
250 conformation degree (Table 1) and fiber diameter (Table 2). For all other variables,
251 there were no significant interactions ($P > 0.05$) between phases. For carcass
252 conformation degree and for fiber diameter the mean of mineral supplement and
253 feedlot interaction was greater than creep-feeding and feedlot interaction (Table 3
254 and Table 4). Besides that, only for conformation degree was the mean of mineral
255 supplement and feedlot interaction greater than mineral supplement and pasture
256 interaction (Table 3).

257

258 *Performance and carcass traits*

259 Data describing the single effect of different nutritional strategies during cow-calf and
260 stocker phases on carcass traits of bulls is presented in Table 1. Cow-calf phase did
261 not influence ($P > 0.05$) any variables of carcass traits. On the other hand, stocker
262 phase influenced ($P < 0.05$) harvest age, final body weight, average daily gain, hot
263 carcass weight, dressing percentage, carcass length, carcass width, ribeye area, and
264 muscle depth (Table 1). Bulls fed on feedlot system in Phase II were harvested 17
265 days earlier, with an additional 19.0 kg (+ 3.8%) of final body weight, 15.2 kg (+
266 5.7%) of hot carcass weight, 0.04 kg (+ 6.9%) of average daily gain, and 0.98% of
267 dressing percentage than those fed on pasture. The feedlot group also had higher
268 carcass length (+ 1.8 %), carcass width (+ 1.5 %), ribeye area (+ 4.8 %), and muscle
269 depth (+ 2.3 %) when compared to the pasture group during Phase II (Table 1).

270

271 *Meat quality*

272 Data describing the single effect of different nutritional strategies during cow-calf and
273 stocker phases on meat quality of bulls is presented in Table 2. Color fat parameters

274 were influenced by cow-calf and stocker phases (Table 2). Feedlot group in relation
275 to pasture group had higher L* value (67.05 vs. 64.88) and lower b* value (16.31 vs.
276 17.70). The creep-feeding group had lower a* value compared to the mineral
277 supplement group (3.80 vs. 4.68).

278

279 **Discussion**

280

281 *Interactions effect*

282 As previously mentioned, a cow-calf by stocker phase interaction occurred for
283 carcass conformation degree and fiber diameter. The results obtained for
284 conformation degree were possibly a consequence of the result obtained for fiber
285 diameter, because muscle mass (such as carcass conformation) is largely
286 determined by the size of the muscle fibers (Picard *et al.*, 2006). At the cellular level,
287 muscle accretion can be defined as the increase in myofiber diameter (hypertrophy)
288 (Bonnet *et al.*, 2010).

289

290 *Performance and carcass traits*

291 Due to the better nutritional support received, it was expected that the creep-feeding
292 group would have better carcass traits than the mineral supplement group in the cow-
293 calf phase, however, there were no differences observed between the two groups. A
294 possible reason for do not find difference between these groups, is that maybe the
295 animals in creep-feeding had an excessive intake due to the diet composition
296 (minerals, vitamins, and concentrate), leading to more onerous gains, and as
297 consequence, a similar performance of animals that received only mineral
298 supplement. However, on stocker phase the higher final body weight reached in

299 fewer days by the feedlot group, when compared to pasture group, is explained by
300 the greater daily gain observed for the feedlot group during Phase II (Table 1). The
301 higher dressing percentage for the feedlot animals (54.88%) versus the pasture
302 animals (53.90%) was expected since dressing percentage is based on the
303 relationship between hot carcass weight and final body weight. Possibly, the higher
304 dressing percentage for the feedlot group was due to the increased weight and
305 muscle development of this group when compared to the pasture group (Table 1)
306 because dressing increases as live weight increases, and heavier muscled cattle
307 show higher dressing percentages than lighter muscled cattle (McKiernan *et al.*,
308 2007; Halfman and Schaefer, 2015).

309 Another possible reason for the lower dressing for the pasture group would be
310 the physical composition of the diet, because as reported in literature, a pasture diet
311 can result in cattle with a larger digestive tract than found in those on a feedlot diet
312 (McKiernan *et al.*, 2007; Halfman and Schaefer, 2015). However, in the current study
313 this reason is improbable since the feedlot group diet, due to a high percentage of
314 roughage in its composition, was not too much different from the diet of the pasture
315 group. Besides that, even if we had a difference in the digestive tract size because of
316 the diet adopted in Phase II (pasture or feedlot), the difference would not have
317 persisted until harvest (time when dressing percentage was measure), because the
318 harvest happened several months after Phase II.

319 Superior carcass dressing percentages for animals fed with concentrate when
320 compared to those fed on pasture is consistently reported in the literature (Duckett *et*
321 *al.*, 2013; Esterhuizen *et al.*, 2008; Neel *et al.*, 2007). As clearly seen by the results in
322 this study, different nutritional strategies during the stocker phase will have an
323 influence on animal development and as a consequence, on its carcasses.

324 It is known that cattle raised in a feedlot system will grow faster and produce a
325 larger carcass than cattle raised on conventional pastures (Esterhuizen *et al.*, 2008)
326 indicating that a pasture system does not meet the nutrient requirements for
327 maximum growth and tissue accretion (Brown *et al.*, 2006). According to Webb and
328 Erasmus (2013) grass feeding normally results in slower growth rates because feed
329 supplements are usually limited to strategic mineral, energy and protein supplements.
330 Rehfeldt *et al.* (1999) assert that malnutrition during postnatal growth reduces body
331 weight and skeletal muscle weight because adequate nutrition is essential for normal
332 skeletal muscle growth.

333 As previous supported by Webb and Erasmus (2013) in their research, in the
334 current study the pasture group also received only mineral supplement while the
335 feedlot group received better nutritional support. However, even if the same energy
336 input is provided in a feedlot in comparison with equivalent animals on pasture, one
337 should expect higher gains in the feedlot because the animals at pasture have higher
338 maintenance expenditures due to grazing activity. According to Kaufmann *et al.*
339 (2011) there is a positive correlation between energy expenditure and time eating
340 and/or walking, confirming that the higher energy expenditure of pasture cattle is
341 influenced by feeding behavior and greater physical activity required to forage.

342 Supporting these statements, Rashid *et al.* (2015) explain that a concentrate
343 diet is more digestible than forage, decreasing the animal maintenance requirement,
344 leaving more nutrients for muscle growth. In the current study both groups were
345 maintained in the stocker phase for the same number of days and during the same
346 period of the year. Thus, the lower final body weight, hot carcass weight, average
347 daily gain, and dressing percentage of the pasture group in relation to the feedlot
348 group can be attributed mainly to the lower levels of nutrition and higher energy

349 expenditure due to grazing, which may have led to an inferior condition for its full
350 development.

351 In the stocker phase, as shown by the results of carcass length, carcass width,
352 ribeye area, and muscle depth (Table 1), the feedlot group had greater lean body
353 mass than the pasture group. This may be in response to the higher body weight,
354 because researchers have shown that body protein mass closely correlates with
355 body weight increasing linearly, whereas the mass of body fat increases quadratically
356 with body weight (Owens *et al.*, 1995). Thus, a small backfat measurement at
357 slaughter for all animals is an indication that they were possibly still in a linear phase
358 of growth. Another explanation is that total protein deposition can be limited by
359 nutrient supply. It is possible that because the pasture group had a lower supply of
360 nutrients they consequently accumulated a smaller protein body mass (as mentioned
361 in the carcass data previously). According to Owens *et al.* (1995) longer grazing
362 periods, and perhaps a protein shortage during backgrounding tends to lead to a
363 slower protein growth rate during finishing. Moreover, it could be deleterious to the
364 future performance of the animal if grazing expands the internal organs, decreases
365 digestibility, or increases maintenance requirements, as it usually happens (Owens *et*
366 *al.*, 1993). In agreement with the current research, the evaluation of Koch *et al.*
367 (2016) on the effects of post-weaning feeding strategy on live performance, carcass
368 characteristics, and meat quality also found that cattle consuming concentrate had a
369 larger ribeye area than those that consume pasture. This is further confirmed by Neel
370 *et al.* (2007) who also observed an increased ribeye area in feedlot animals (79.4
371 cm²) than for pasture (66.2 cm²).

372 Even assuming that the feedlot group received a higher energy content diet due
373 to the inclusion of grains in relation to the pasture group, higher amounts of fat

374 variables (fat score, backfat and fat percentage) for the first group (Table 1) were not
375 observed ($P > 0.05$). This result can be explained probably because these nutritional
376 strategies were adopted in Phase II, before the animals had reached the higher point
377 of fat tissue deposition (the latest to occur) (Owens *et al.*, 1993) and also because
378 the feedlot diet was formulated for a low level of gain (0.7 kg/day).

379

380 *Meat quality*

381 Higher L^* value and lower b^* value for fat color in the stocker phase (Table 2)
382 indicates that fat from feedlot animals is clearer (whiter) and less yellow, possibly due
383 to the high concentrations of yellow pigments in fresh pastures which are the
384 ingested and absorbed (Guerrero *et al.*, 2013b). These pigments have been
385 identified as carotenoids, with β -carotene being the major component present in fresh
386 pastures, responsible for causing yellow color to develop in the fat of bovines when
387 such forages are eaten regularly (Commonwealth Scientific and Industrial Research
388 Organisation, 1993; Dunne *et al.*, 2009). According to CSIRO (1993) lush green
389 pasture may have as much as 500 ppm carotenoids in its dry matter, whereas most
390 grains contain only a small concentration of carotenoids (usually less than 5 ppm dry
391 matter).

392 Therefore, the results found for fat color (L^* and b^*) in the current study are in
393 accordance with Dunne *et al.* (2009) that confirm the long recognized relationship
394 that exists between carotenoid concentration in subcutaneous adipose tissue and its
395 yellow color. Many researchers have reported higher b^* value in subcutaneous fat for
396 cattle fed on pasture than for cattle fed a concentrate diet, indicating more yellowness
397 compared with fat from the concentrate treatment (Realini *et al.*, 2004; Varela *et al.*,
398 2004; Del Campo *et al.*, 2008; Guerrero *et al.*, 2013b). In addition, Guerrero *et al.*

399 (2013b) also found a higher L* value for cattle fed a concentrated diet (72.0) than for
400 cattle fed on pasture (69.7), showing similarity between both studies.

401 The higher a* value found in the fat for the mineral supplement group in the
402 cow-calf phase (Table 2) could be because they received only the mineral
403 supplement when on pasture, while the other group received a concentrate diet in the
404 creep-feeding system plus pasture. It is possible that the last group ate less pasture
405 and consequently, fewer pigments. Probably, the lack of differences for fat color (L*
406 and b* values) between groups in the cow-calf (CM vs. CF) phase (Table 2) may be
407 due to the composition of the diets offered in this phase, which were not that different
408 from the diet fed in the stocker phase, between the pasture and the feedlot groups.

409 With the data collected it was shown that the stocker phase, when compared to
410 the cow-calf phase, exerted the greatest influence on carcass traits, possibly due to a
411 higher difference in feed composition between the treatments in this phase. Bulls in
412 the feedlot during the stocker phase had greater growth and muscle development
413 compared to those on pasture, showing that keeping animals on a feedlot diet during
414 the stocker phase may be an alternative method to obtain heavier animals at harvest
415 with greater muscle development in their carcasses. However, an economic analysis
416 should be encouraged for future studies in order to find out if the expenses of a
417 feedlot diet are compensated by the improved carcass traits.

418

419 **Acknowledgment**

420 The authors acknowledge the experimental support of Escola Superior de Agricultura
421 “Luiz de Queiroz” - USP and Fazenda Figueira. The first author gratefully
422 acknowledges the International Program CAPES (Brazilian Federal Agency) for the

423 receipt of sandwich doctorate scholarship, developed at UC Davis University,
424 California, USA.

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526 **Table 1** Effect of different nutritional strategies during cow-calf (mineral supplement vs. creep-feeding groups) and stocker (pasture vs. feedlot
527 groups) phases on performance and carcass traits of Nellore bulls

| Variables | n | Phases ¹ | | | | SEM ² | p-value ³ | | |
|----------------------------------|----|---------------------|--------|---------------------|---------------------|------------------|----------------------------|--------------------------|-------|
| | | Cow-calf (C) | | Stocker (S) | | | Single effect ⁴ | Interaction ⁵ | |
| | | CM | CC | SP | SF | | | | C |
| Harvest age (days) | 80 | 768.00 | 760.00 | 773.00 ^b | 756.00 ^a | 3.050 | 0.206 | 0.005 | 0.280 |
| Final body weight (kg) | 80 | 503.25 | 495.12 | 489.67 ^b | 508.70 ^a | 3.332 | 0.203 | 0.003 | 0.356 |
| Average daily gain (kg) | 80 | 0.60 | 0.60 | 0.58 ^b | 0.62 ^a | 0.006 | 0.935 | < .001 | 0.185 |
| Hot carcass weight (kg) | 80 | 274.62 | 268.68 | 264.07 ^b | 279.24 ^a | 2.265 | 0.163 | 0.001 | 0.815 |
| Dressing (%) | 80 | 54.53 | 54.25 | 53.90 ^b | 54.88 ^a | 0.197 | 0.465 | 0.012 | 0.201 |
| pH | 80 | 5.61 | 5.57 | 5.57 | 5.61 | 0.014 | 0.131 | 0.081 | 0.992 |
| Carcass length (cm) | 80 | 125.32 | 125.17 | 124.10 ^b | 126.40 ^a | 0.357 | 0.824 | 0.001 | 0.418 |
| Carcass width (cm) | 80 | 44.68 | 45.14 | 44.60 ^b | 45.23 ^a | 1.240 | 0.082 | 0.019 | 0.686 |
| Conformation degree ⁶ | 80 | 3.11 | 3.05 | 2.90 ^b | 3.26 ^a | 0.069 | 0.634 | 0.007 | 0.019 |
| Fatness score ⁷ | 80 | 3.25 | 3.21 | 3.14 | 3.32 | 0.064 | 0.788 | 0.158 | 0.645 |
| Ribeye area (cm ²) | 78 | 79.85 | 79.11 | 77.62 ^b | 81.34 ^a | 0.833 | 0.652 | 0.025 | 0.799 |
| Muscle depth (mm) | 78 | 136.72 | 136.81 | 135.24 ^b | 138.37 ^a | 0.768 | 0.939 | 0.045 | 0.220 |
| Backfat (mm) | 80 | 2.76 | 2.85 | 2.69 | 2.92 | 0.124 | 0.711 | 0.356 | 0.169 |
| Muscle (%) | 80 | 64.47 | 64.49 | 64.16 | 64.79 | 0.352 | 0.973 | 0.379 | 0.885 |
| Fat (%) | 80 | 19.53 | 19.53 | 20.01 | 19.05 | 0.350 | 0.997 | 0.180 | 0.644 |
| Bone (%) | 80 | 16.62 | 16.60 | 16.49 | 16.72 | 0.131 | 0.951 | 0.382 | 0.536 |
| Marbling degree ⁸ | 80 | 1.26 | 1.20 | 1.22 | 1.24 | 0.035 | 0.387 | 0.862 | 0.603 |
| Water loss (%) | 80 | 27.58 | 27.37 | 27.55 | 27.39 | 0.395 | 0.792 | 0.847 | 0.950 |

528 ¹ CM = cow-calf mineral supplement; CC = cow-calf creep-feeding; SP = stocker pasture; SF = Stocker feedlot; ² Standard error of the mean; ³ Significant differences at 5%
529 probability (P ≤ 0.05); ⁴ C = main effect during cow-calf phase; S = main effect during stocker phase; ⁵ CxS= cow-calf x stocker phases group interaction; ⁶ Conformation degree =
530 (1) inferior and (5) superior; ⁷ Fatness score = (1) low and (5) very fat; ⁸ Marbling degree = (1) no marbling and (10) abundant marbling.

531 **Table 2** Effect of different nutritional strategies during cow-calf (mineral supplement vs. creep-feeding groups) and stocker (pasture vs. feedlot
 532 groups) phases on meat quality parameters of Nellore bulls

| Variables | n | Phases ¹ | | | | SEM ² | p-value ³ | | |
|---------------------|----|---------------------|-------------------|--------------------|--------------------|------------------|----------------------------|-------|--------------------------|
| | | Cow-calf (C) | | Stocker (S) | | | Single effect ⁴ | | Interaction ⁵ |
| | | CM | CC | SP | SF | | C | S | CxS |
| Fat Color | | | | | | | | | |
| L* ⁶ | 80 | 65.94 | 65.98 | 64.88 ^b | 67.05 ^a | 0.450 | 0.965 | 0.015 | 0.641 |
| a* ⁷ | 80 | 4.68 ^a | 3.80 ^b | 4.32 | 4.16 | 0.181 | 0.015 | 0.640 | 0.698 |
| b* ⁸ | 80 | 17.06 | 16.93 | 17.70 ^b | 16.31 ^a | 0.324 | 0.846 | 0.031 | 0.678 |
| Meat color | | | | | | | | | |
| L* ⁶ | 80 | 37.76 | 37.52 | 38.03 | 37.25 | 0.232 | 0.616 | 0.091 | 0.338 |
| a* ⁷ | 80 | 16.89 | 16.86 | 16.97 | 16.78 | 0.167 | 0.918 | 0.574 | 0.564 |
| b* ⁸ | 80 | 9.80 | 9.54 | 9.66 | 9.68 | 0.105 | 0.238 | 0.931 | 0.588 |
| Fiber diameter (µm) | 48 | 43.99 | 41.28 | 42.72 | 42.50 | 0.884 | 0.115 | 0.873 | 0.021 |
| Shear force (Kgf) | 78 | 6.60 | 7.31 | 6.93 | 6.98 | 0.259 | 0.150 | 0.835 | 0.722 |
| Dry Matter (%) | 80 | 25.03 | 25.23 | 25.07 | 25.19 | 0.114 | 0.377 | 0.593 | 0.407 |
| Ether extract (%) | 78 | 0.96 | 0.97 | 0.97 | 0.97 | 0.011 | 0.915 | 0.974 | 0.894 |
| Crude protein (%) | 78 | 21.26 | 21.52 | 21.25 | 21.54 | 0.106 | 0.213 | 0.174 | 0.129 |
| Mineral matter (%) | 78 | 1.04 | 1.05 | 1.05 | 1.05 | 0.011 | 0.550 | 1.000 | 0.647 |

533 ¹ CM = cow-calf mineral supplement; CC = cow-calf creep-feeding; SP = stocker pasture; SF = Stocker feedlot; ² Standard error of the mean; ³ Significant differences at 5%
 534 probability (P ≤ 0.05); ⁴ C = main effect during cow-calf phase; S = main effect during stocker phase; ⁵ CxS= cow-calf x stocker phases group interaction; ⁶ L* = zero (black) and
 535 100 (white); ⁷ a* = negative (green) and positive (red); ⁸ b* = negative (blue) and positive (yellow).

536
 537
 538

Table 3 Interaction effect with cow-calf (mineral supplement vs. creep-feeding groups) by stocker (pasture vs. feedlot groups) phases groups for conformation degree

| Conformation degree | | |
|---------------------|---------------------|----------------------|
| Stocker phase | Cow-calf phase | |
| | Mineral supplement | <i>Creep-feeding</i> |
| Pasture | 2.77 ^{a,A} | 3.02 ^{a,A} |
| Feedlot | 3.45 ^{b,B} | 3.07 ^{a,A} |

^{a,b} Within a row, means without a common superscript letter differ at $P < 0.05$;

^{A,B} Within a column, means without a common superscript letter differ at $P < 0.05$.

Table 4 Interaction effect with cow-calf (mineral supplement vs. creep-feeding groups) by stocker (pasture vs. feedlot groups) phases groups for fiber diameter

| Fiber diameter | | |
|----------------|----------------------|----------------------|
| Cow-calf phase | | |
| | Mineral supplement | Creep-feeding |
| Pasture | 41.89 ^{a,A} | 43.11 ^{a,A} |
| Feedlot | 46.29 ^{b,A} | 39.44 ^{a,A} |

^{a,b} Within a row, means without a common superscript letter differ at $P < 0.05$;

^{A,B} Within a column, means without a common superscript letter differ at $P < 0.05$.

Figure caption

Figure 1 Days of age and body weight of each bovine group (CM, CC, SP and SF) in the beginning of phase I (cow-calf), phase II (stocker), phase III (pasture system), phase IV (feedlot system) and at harvest.

a) Days of age of cow-calf groups; solid line = mineral supplement group; dotted line = *creep-feeding* group; **b)** Days of age of stocker groups; solid line = pasture group; dotted line = feedlot group; **c)** Initial body weight of cow-calf groups; solid line = mineral supplement group; dotted line = *creep-feeding* group; **d)** Initial body weight of stocker groups; solid line = pasture group; dotted line = feedlot group.

