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Performance Efficiency of Pasture-raised Primiparous Beef Cows of Three Different Biotypes and Two Milk Production Levels

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ABSTRACT

***Background*:** Productivity and efficiency of beef production systems should be estimated based on cow size, calf growth rate and cow reproduction rate, which are critical factors for the evaluation of production characteristics of beef cattle of different biological types. One of the ways to measure beef cow productivity is based on the ratio of calf weaning weight to cow weight. The purpose of this study was to evaluate the performance and reproductive efficiency of primiparous beef cows of three different biotypes and two milk production levels, from calving to weaning, in pasture-raised beef systems.

***Materials, Methods & Results*:** Forty-two primiparous Angus cows were classified according to body weight at calving, as follows: Heavy (431 kg); Medium (388 kg); and Light (348 kg). Cow efficiency as a function of biotype was evaluated at two different moments: calving and weaning, based on the ratio of calf weight to cow weight*100 (in kilograms). Calf production efficiency was determined based on the ratio of calf weaning weight (CWW) to cow pregnancy rate (PR), resulting in the calf production index = kg of weaning calves per cow (CWW*PR/100). The experimental design was a completely randomized factorial 3 x 2 x 2 design (three biotypes x two calf sexes x two milk production levels). The results were subjected to ANOVA and F-test. The Light and Medium cow groups produced more ($P < 0.05$) kilograms of calf per kilogram of cow (16.0 and 15.1 kg, respectively) than the Heavy group (14.0 kg). Light cows showed lower ($P < 0.05$) milk production and, as a result, lighter ($P < 0.05$) calves at weaning (151.9 ± 4.3 kg) than Medium and Heavy groups, 166.0 ± 3.7; 166.5 ± 4.0 kg, respectively. At beginning of the breeding season, cows of the Lower milk production group were on average 27.49 kg heavier than cows in the Higher milk production group. There was an interaction ($P < 0.05$) between total milk production and calf sex on characteristics of performance in calves and performance efficiencies of the system. Light and Medium cows showed 51 and 25 kg total weight gain from calving to weaning, corresponding to 14.7 and 6.4% of body weight, respectively. The Heavy group, however, showed a 3 kg loss (0.5% of body weight) during the same period.

***Discussion*:** A higher growth rate was observed in the pre-weaning period of the calves of heavy cows; as a result, these calves were heavier at weaning. To achieve this result, heavier cows may compensate this higher nutritional requirement using body reserves. This biological adjustment may not be economically efficient, since the subsequent reproduction of these cows could be impaired by increases in milk production. Therefore, the target cow in a pasture-raised beef system is one whose low nutritional requirements enable her to produce milk, resulting in heavier calves, and whose physiological conditions enable her to conceive again during the breed season. Light cows can be considered an efficient group, since their pregnancy rate enabled them to create a positive difference for the group, notwithstanding their lower milk production and lighter calves ($P < 0.05$) at weaning. This tendency is expected, since increased growth rates are associated with a decrease in puberty and early finishing age. It is essential to select animals according to their efficiency in order to reduce the cow's requirements, since this favors the increased productivity of cows of lower maintenance cost in relation to their body weight, leading to higher biological and economic efficiency in the beef production system. In conclusion, because of their lower nutritional requirements, cows of small and moderate biotypes and lower total milk production are more efficient than cows of larger biotypes and higher milk production in pasture-raised beef systems.

Keywords: calving season, reproduction, beef cattle.

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INTRODUCTION

The beef cattle enterprise in Brazil is essentially based on native ranges. Therefore, due to environmental and climate conditions [23], differences in grass species [7] and management [21] determine differences in production and quality during different productive periods [26]. In such production system the goal is to meet forage availability with beef cow requirements throughout year, minimizing variations and, as a result, improving productive responses. Nevertheless, when this aims cannot be reached, there is a reduction in beef cow production, and a direct impairment on reproductive rates [13].

It is expected that each cow in herd wean approximately 50 to 60% of their weight, which would represent one calf/cow/year to be considered efficient. This production level is difficult to reach in range systems once the nutritional plan can be limited by climate influences and the low forage production, which are reflected by high stocking rates used by producers [9]. Therefore, it is important to understand how different beef cows respond to the pre and postpartum management process, their requirements as well as, their adaptation to range systems, which will eventually contribute to increase in conception rates during the following breeding season. During the lactation period nutritional requirements increase by 57% [31] which may be an obstacle to the reproductive resumption in beef cows [32,37]. The interaction between nutritional stress and milk production (suckling stimulus) is primary factors in determining the extremely long anestrous period in range beef cows [15].

Although the conception rates in beef cows during the postpartum period is low in range systems, there are well adapted animals that may have genetics adaptations which allow them to produce under such conditions [33]. Thus, one of the alternatives to improve beef production in range systems is identify and select adapted animals to such restrictive nutritional environments [19]. Therefore, the aim of this study was to evaluate the performance and reproductive efficiency from calving to weaning in primiparous beef cows in three different biotypes and two milk production levels in a free-range beef production system.

MATERIALS AND METHODS

Animals

This study was performed in a commercial beef farm in Southern Brazil (30º 30’and 31º 56´S and 55º 30’and 54º 30´W). Forty-two primiparous Angus cows (three years of age) in body condition score (BCS) 3, based on a five-class scale (1 = extremely thin to 5 = extremely fat) [25], were selected homogenously from a 145 cows herd and classified into three biotypes according to body weight at calving: Heavy (431 kg on average, ranging from 405 to 485 kg); Medium (388 kg on average, ranging from 373 to 403 kg); and Light (348 kg on average, ranging from 293 to 369 kg).

Experimental conditions

Cows were kept under the same grazing system at a stocking rate of 315 kg body weight per hectare. Adjustments were made throughout the experiment considering the grass production and cows weight variation. Native pastures included a mixture of bahiagrass (*Paspalum notatum*), louisiana grass (*Axonopus affinis*), rye grass (*Lolium multiflorum* spp.) and clover species (*Tripholium* spp.). Cow body weight was measured at calving and then every 21 days until weaning. An electronic scale (Tru-test®)[1], total capacity of 1,500 kg and accuracy of 0.100 kg, was used.

Methodology

Cows were subjected to an estrus synchronization protocol [8] 60 ± 15 days after calving. On day 0 cows received an intravaginal device impregnated with 250 mg of medroxi-progesterone acetate (MAP)[2] and were given a estradiol benzoate injection (EB) (5 mg, Gonadiol®, im)[3]. On day 7 the device was removed and another of EB (0.5 mg, Gonadiol®, im)[3] shot was given. After this procedure, calves were separate from their dams for 4 days, when cows were observed for estrus signs and then artificially inseminated (AI) 12 h after. Fifteen days after AI, cows were sired by natural service bulls (Hereford) for a 50-day period. Pregnancy diagnosis was performed 60 days after breeding season by rectal palpation.

Milk production was estimated by the weigh--suckle-weigh procedure as described by Beal [4] and adapted to the experimental conditions by Pimentel *et al.* [29], every 21 days from calving to weaning (189 d total). Cow-calf pairs were gathered from native pastures to a central handling facility in the morning prior to data collection. Calves were separated from their dams between 8:00 a.m. and 6:00 p.m., then reunited with their dams and allowed to nurse. This preliminary separation period and subsequent nursing was designed to leave only residual milk in the mammary gland at the beginning of the measurement period. After nursing, the calves were again separated from their dams and remained apart until 6:00 a.m. the next morning, when they were weighed, allowed to nurse until either satiated or milk was exhausted, and quickly reweighed. The difference between weights was assumed to reflect the milk consumed by the calf and to measure milk produced by the cow in the preceding 12 h. The 12 h milk production data were doubled to estimate 24 h milk production. Cows were divided into two groups according to total milk production: Higher (average 1218.33 kg) and Lower than 1,000 kg (average 796.81 kg).

Data description

Cow efficiency according to biotypes was performed at two different moments, at calving and weaning by following the adjustment: kilograms of calf weight/kilograms of cow weight*100 [14]. To investigate the performance and efficiency among the different biotypes, the total weight gain (kg) of cows and calves from calving to weaning was considered. Calf production efficiency was determined by the adjustment of calf weaning weight (CWW) and pregnancy rate (PR) of cows, resulting in calf production index = kg of weaning calves per cow (CWW*PR/100), in accordance with the procedure described by Vaz *et al.* [34].

Statistical analysis

The experimental design was a completely randomized factorial 3 x 2 x 2 (three biotypes x two calves gender x two milk production levels). The results were subjected to ANOVA and F test. The following model was used:

$Y_{ijk} = \mu + B_i + S_j + (B*S)_{ij} + MPL_k + (B*MPL)_{ik} + (S*MPL)_{jk} + (B*S*MPL)_{ijk} + IN_l \Sigma_{ijkl,}$ where: Y_{ijkl}= the dependent variables value; μ - the mean; B_i = the effect of Biotype (i=1 (heavy); 2 (median) and 3 (lightweight); S_j = the effect of calf gender (j= male or female); $T*S_{ij}$ = the effect of interaction B*S; MPL_k = the effect of milk production level (k=1 (higher); 2= (lower); $B*MPL_{ik}$ = the effect of interaction biotype and milk production level ; $S*MPL_{ik}$ = the effect of interaction calf gender x milk production level; $B*S*MPL_{ijk}$= the effect of interaction biotype x calf gender x milk production level; IN_l the effect of calves age as a covariate; Σ_{ijkl}= Residual Errors.

Once the interactions $(B*S)_{ij;}$ $(B*MPL)_{ik\,;}$ $(B*S*MPL)_{ijk}$ were not significant ($P > 0.05$), these were removed from the final statical model. Data were analyzed using GLM procedures at SAS software, and the means were compared using the '*t*' test. Pregnancy data were analyzed using the categorical modeling procedure (PROC CATMOD).

RESULTS

The results are presented and discussed separately according to the biotypes effects once these did not interacted ($P > 0.05$) with milk production level and calf gender. However, these two last items showed interaction ($P < 0.05$). The groups classification according to cow development presented weight differences ($P < 0.05$) at calving and throughout the breeding season until the end of lactation, demonstrating variation between groups (Table 1).

As expected, calves from Heavy and Medium groups were heavier ($P < 0.05$) as compared to Light cow calves being the later 9.5% lighter than the former groups. This result was directly affected by milk production (Table 1) which demonstrated the same trend. When performance efficiency results are considered at weaning and calf production index (Table 1) a similarity between the three biotype groups is found.

There were cows performance differences ($P < 0.05$) during the breeding season (Table 2) according to milk production levels (higher or lower than 1,000 kg). At beginning of the breeding season cows from the Lower milk production group were on average 27.49 kg heavier than those cows in the Higher milk production group. This trend persisted until the weaning.

There was an interaction ($P < 0.05$) between total milk production and calf sex on characteristics of performance in calves and performance efficiencies of the system (Table 3).

Light and Medium cows had 51 and 25 kg total weight gain from calving to weaning, corresponding to 14.7 and 6.4% body weight, respectively. The Heavy group, however, had a 3 kg loss (0.5% body weight) during the same period.

Table 1. Means and standard errors for cows and calves performance, reproductive performance and efficiency in beef cows in three different biotypes.

Parameter	Biotypes		
	Light	Medium	Heavy
Cows, n	12	16	14
Pregnancy, %	41.7	37.5	35.7
Cows weight, kg			
At calving	348 ± 5.4^{c}	388 ± 4.6^{b}	431 ± 5.0^{a}
Begning breed season	397 ± 8.8^{b}	414 ± 7.6^{ab}	430 ± 8.2^{a}
Final breed season	400 ± 7.6^{b}	412 ± 6.6^{b}	435 ± 7.1^{a}
Weaning	399 ± 7.5^{b}	413 ± 6.4^{ab}	428 ± 7.0^{a}
Calves weight, kg			
At birth	36.57 ± 1.31	35.99 ± 1.13	36.55 ± 1.22
Weaning	151.9 ± 4.3^{b}	166.0 ± 3.7^{a}	166.5 ± 4.0^{a}
Daily gain, kg			
Calves from birth to weaning	0.676 ± 0.02^{b}	0.782 ± 0.02^{a}	0.809 ± 0.02^{a}
Cows from calving to weaning	0.281 ± 0.05^{a}	0.140 ± 0.04^{b}	-0.020 ± 0.05^{c}
Cow sat breeding season	0.047 ± 0.08	-0.020 ± 0.07	0.068 ± 0.07
Efficiency			
Weaning efficiency, kg[1]	38.2 ± 1.1	40.3 ± 1.0	39.1 ± 1.0
Calf production efficiency[2], kg	16.0 ± 0.4^{a}	15.1 ± 0.4^{a}	14.0 ± 0.4^{b}
Calf production index[3], %	63.4 ± 1.6	62.2 ± 1.4	59.6 ± 1.5
Milk production conversion[4], %	13.0 ± 0.73	13.2 ± 0.63	13.0 ± 0.68
Milk production efficiency, kg of milk/kg of calf[5]	8.0 ± 0.48	8.2 ± 0.42	8.2 ± 0.45
Total milk production, kg	914 ± 45^{b}	1065 ± 39^{a}	1044 ± 42^{a}

^{a,b,c}Within a row, means with different superscripts differ ($P < 0.05$). [1]Weaning calf weight/weaning cow weight*100. [2]Weaning calf weight x pregnancy rate/ weaning cow weight. [3]Weaning calf weight calf * pregnancy rate/100. [4]Milk production conversion, (Calf weight gain/milk production)*100. [5]Milk production/ Calf weight gain.

Table 2. Means and standard errors for characteristics of performance and reproduction in beef cows with different milk production levels (higher or lower than 1,000 kg).

Parameter	Lower (796.81 kg)	Higher (1218.33 kg)
Cows, n	20	22
Cows weight, kg		
At calving	387.85 ± 4.2	390.14 ± 3.9
Begning breed season	428.26 ± 6.9^{a}	400.77 ± 6.6^{b}
Final breed season	428.55 ± 6.4^{a}	403.91 ± 6.1^{b}
Weaning	421.97 ± 5.9^{a}	404.75 ± 5.5^{b}
Weight daily gain, kg		
From calgin to weaning	0.188 ± 0.04^{a}	0.079 ± 0.04^{b}
Breeding season	0.011 ± 0.63^{a}	0.053 ± 0.60^{a}
Pregnancy rate, %	50.0	27.27

^{a,b}Within a row, means with different superscripts differ ($P < 0.05$).

Table 3. Means and standard errors for calves performance and productive efficiency of cows according milk production level, Higher (average 1,218.33 kg) and Lower (average 796.81 kg) than 1,000 kg.

Gender	MPL	Birth weight, kg	ADG, kg	Weaning weight, kg	Weaning efficiency^{1}, %	Calf production efficiency^{2}, %	Calf production index^{3}, %	Milk production conversion^{4}	Milk production efficiency^{5}
Male	Lower	35.95 ± 1.58	0.826 ± 0.02^{a}	163.90 ± 5.16^{a}	38.64 ± 1.33^{a}	14.78 ± 0.50^{a}	82.05 ± 2.19^{a}	16.8 ± 0.88^{a}	6.14 ± 0.58^{c}
Female		36.80 ± 1.30	0.733 ± 0.02^{b}	146.0 ± 4.25^{b}	34.78 ± 1.09^{b}	13.35 ± 0.42^{b}	73.27 ± 1.80^{b}	13.3 ± 0.72^{b}	7.72 ± 0.48^{b}
Average		36.37 ± 1.03	0.779 ± 0.02^{A}	154.95 ± 3.4^{B}	36.71 ± 0.87^{B}	14.07 ± 0.3	77.66 ± 1.43^{A}	15.1 ± 0.58^{A}	6.93 ± 0.38^{A}
Male	Higher	38.29 ± 1.28	0.754 ± 0.02^{b}	165.14 ± 4.19^{a}	41.33 ± 1.08^{a}	15.87 ± 0.41^{a}	44.92 ± 1.78^{c}	10.6 ± 0.71^{c}	9.76 ± 0.47^{a}
Female		34.43 ± 1.45	0.710 ± 0.02^{b}	170.94 ± 4.72^{a}	42.01 ± 1.21^{a}	16.06 ± 0.46^{a}	46.96 ± 2.0^{c}	11.3 ± 0.81^{bc}	8.96 ± 0.53^{ab}
Average		36.36 ± 0.96	0.732 ± 0.02^{B}	168.04 ± 3.14^{A}	41.67 ± 0.81^{A}	15.96 ± 0.3	45.94 ± 1.33^{B}	11.0 ± 0.54^{B}	9.36 ± 0.36^{B}

^{a,b,c}Within a column means with different superscripts differ ($P < 0.05$). ^{A,B}Within the column differ in mean levels of milk production ($P < 0.05$). ^{1}Weaning calf weight/weaning cow weight*100. ^{2}Weaning calf weight x pregnancy rate/ weaning cow weight. ^{3}Weaning calf weight calf* pregnancy rate/100. ^{4}Milk production conversion. (Calf weight gain/milk production)*100. ^{5}Milk production efficiency. Milk production/ Calf weight gain.

DISCUSSION

Cows showing low body condition score or weight loss usually have a negative impact on reproductive performance. This is dueto a nutrient portioning priority [20,32]. The beginning of lactation is the most deleterious physiological period for cows when energetic demands are high, and this coincides with breeding season. Such biological functions compete with each other and lactation has priority over reproduction, resulting in nutrient deviation to milk yield [32]. Therefore, it supports that cows considered in the Heavy group are not well adapted in such environmental conditions, demanding more nutritional inputs during the postpartum period.

A higher growth rate was observed at pre weaning period in heavy cow calves, as a result, these calves were heavier at weaning. To reach this result, heavier cows may compensate this higher nutritional requirement using body reserves [22]. This biological adjustment may not be economically efficient once these cows could have their subsequent reproduction impaired by the increases in milk production [17,29].

Therefore, it is possible to suggest that the kilograms of calf weaned per kilograms of cow at weaning and the likely kilograms of calves produced per cow maintained in the herd in the following year may not have been affected by the biotypes of cows studied, although the nutritional condition did not necessary determine a lower number of calves produced.

Thus, the target cow in a range system is that demanding low nutritional requirements that allow the female to produce milk and as a consequence heavier calves and exhibits physiologic conditions to conceive again during the breed season. Light cows would be considered an efficient group once they had a pregnancy rate able to create a positive difference for the group, although they showed lower milk production and lighter calves ($P < 0.05$) at weaning. This is an expected trend, once the increase in growth rate is associated with a decrease in puberty and early finishing age [10]. Nutritional restrictions caused by differences between requirements due to greater extension of lactation period in Braford cows found productions of 73.9% more kilograms of calves in the following calving season for early weaned cows and, as a result, lower energy costs [34]. However, not always the higher calving rates have the same meaning of higher kilograms of calves production per hectare. In two different calving rates (82.5 and 92.5%), found 83.9 and 77.9 kg/ha of calves production, respectively [5].

Although total milk production was different between groups, which was expected because of the different biotypes, both milk production conversion and efficiency were similar among groups. Therefore, it can be postulated that the difference in the weaning weight between groups was product of calf development acceleration and other diet components than milk, basically native grass. Since the fifth month of age net energy for gain (NEg) available in milk does not meet the calves requirements anymore and this relation begin to decline from this point until the weaning [29].

Cows gaining more weight from calving to the beginning of the breeding season showed higher milk production and postpartum ovulation rate [28]. Therefore, in the present study it is possible to assume that cows producing more kilograms of milk have additional nutritional requirements, resulting of weight loss [31]. This tendency is particularly evident in range systems based on native grasses, in which in most conditions have nutritional restrictions. Consequently, a reproductive impairment is expected in those cows with higher nutritional demands. In agreement of it, higher milk production cows had a 22.23% lower pregnancy rate than the other group. Although this difference was not significant ($P < 0.05$), it something that should be consider in the whole system. This result is in accordance with several studies which suggested a lower reproductive efficiency in cows that produce more milk [2,9,18]. According to NRC [27], the energy requirement for maintenance of higher milk production cows is greater than that of lower milk production. Raising higher demanding cows in nutritionally limiting environments, such as range systems based on natural pastures, impacts production efficiency negatively, because of its restrictive effect on reproduction.

Studies evaluating calf performance during the pre-weaning period found phenotypic correlations between milk production and weaning weight which range from 0.47 to 0.93 [1,3,24]. In an experiment that quantifying the relation between milk consumption and weaning weight of Hereford calves [6], the results indicated that was an increase of 7.20 kg in weight at 205 days of age for each kilogram of milk consumed per calf per day. Male calves of cows in lower MPL, were more efficient in conversion of milk ingested to body live weight, once they showed higher ADG and weaning efficiency then female calves. However, this trend appears to be more related to the fast male development, once milk production efficiency of their dams were lower than the other groups.

As to system efficiency, both cows that had produced 1,000 kg and those which had a lower MPL, which calved males, were more efficient at weaning, since they produced more kilograms of calf per 100 kg of cow. However, upon evaluating herd efficiency, reproductive rates must be taken into account [12,33]. Therefore, higher milk production cows tend to wean heavier calves [30] and even they were more efficient at weaning. Nevertheless, the higher level of milk production can negatively affect the cow body condition score and, consequently, the reproductive efficiency in a beef cattle range system [2,18,35,36]. This trend was observed when calf production index was assessed, in which cows with lower MPL were more efficient (31.72%) and showed higher pregnancy rates, tough not significant. These results indicate that beef cows which produce more milk wean heavier calves under extensive condition, being more efficient, however, they have impairment in their reproductive performance, once higher milk production cows require a higher nutritional plane to conceive and maintain in the same production levels in the next season.

Cow milk production is essential for the proper development of calves, and a main factor contributing to the increase of higher weight at weaning, where the increased in milk production is positively correlated with the kilograms of weaned calves [30]. However, higher milk yields are associated with higher depletion of body reserves [16]. Positive correlations between milk consumption per calf and their body weight gain [11], as well as negative correlations between milk production and cows reproductive performance of cows [34] suggest the selection of animals should be carefully performed aiming not only to increase the animal size but also several factors that evolving reproduction associated with weight gain and milk production.

CONCLUSION

When combining body development and reproductive performance, cows in light and medium biotypes and lower total milk production are more efficient as compared to larger biotypes and higher milk production in extensive production systems, as a result of their lower nutritional requirement.

MANUFACTURERS

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Ethical approval. The study was with approval from the Federal University of Pelotas Ethics and Animal Experimentation under the number 6905, in accordance with Brazilian laws and ethical principles published by the Brazilian College of Animal Experimentation.

Declaration of interest. The authors report no conflicts of interest. The authors alone are responsible for the content and writing of paper.

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