

Reproductive losses in beef cattle rearing on extensive system production: Effects of genotype and parity

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ABSTRACT - We evaluated the reproductive losses in three periods: period I - starting from the time the cows were exposed to the bulls to pregnancy diagnoses (PD, number of cows diagnosed as non-pregnant/total exposed cows $\times$ 100); period II - from the time of PD to calving (number of calving cows/number of cows diagnosed as pregnant $\times$ 100); and period III - from calving to weaning (number of weaned calves/number of calving cows $\times$ 100) in purebred Hereford (HH) and Angus (AA) cows and their crosses in beef cows under extensive production systems. Likewise, the effect of parity (nulliparous, primiparous, and multiparous) and the interaction between both factors were studied. A thirteen-year data set (2505 record) of an experimental breeding herd, maintained in an extensive production system based on natural grassland, was used. The dataset was under a complete diallel design between HH and AA breeds. Both the genetic group and parity of the cow affected the reproductive losses, but only in period I. No interaction was found. Purebred cows had higher reproductive losses than the crossbred cows, without differences between the purebred (HH and AA) or between the crossbred (AH and HA). The greatest losses were observed rather in primiparous than in nulliparous and multiparous cows without difference between the latter two. The use of crossbred cows in extensive production systems is an alternative to reduce reproductive losses and to increase calf harvest.

Keywords: beef cows, cow genotype, native grassland, pregnancy losses

1. Introduction

Cow-calf systems need to increase productivity and efficiency to be sustainable and reduce the environmental impact, taking special account of animal welfare. Reproductive losses are a major cause of failure in cattle, resulting in delayed pregnancy and fewer calves born, with a concomitant financial loss to the beef industry (Shorten et al., 2015). Most of the beef cattle breeding herds are raised on pasture-based systems (Greenwood, 2021). The Campos natural grassland encompasses roughly 450,000 km² over Uruguay, south Brazil, and eastern Argentina, and is one of the largest meat-producing and exporting regions in the world (USDA, 2016). Cow nutrition depends on the grasslands, which present high variability within and between years, being highly weather-dependent (Modernel et al., 2018), and may compromise the nutritional status and the reproductive performance of cows (Do Carmo et al., 2016).

Reproductive losses occur at any point of the process that begins when a cow is exposed to a bull or is inseminated and ends when the calf is weaned. One of the main problems faced by the extensive rearing system in grasslands is the long anestrus postpartum associated mainly with the low availability of forage during winter (Claramunt et al., 2018) when the demand of the fetus is increasing (Quintans et al., 2010; Do Carmo et al., 2016). Thus, cows mobilize body reserves before calving, determining a period of negative energy balance (Bell, 1995) that delays the return to cycling after calving (Yavas and Walton, 2000; Burns et al., 2010). This situation is even more critical in primiparous cows that must face the stress of the first lactation and are still growing (Carroll and Hoerlin, 1966). After the cyclicity restarts, the challenge is that the cow conceives, maintains pregnancy through calving, and for the calf, it is to survive until weaning. However, while fertility rate in beef cattle is generally high (Diskin and Morris, 2008; Pohler et al., 2020), embryonic losses of up to 40% within the first three weeks of gestation have been reported in beef cattle (Diskin and Sreenan, 1980; Maurer and Chenault, 1983). These losses occur mainly during the pre-implantation stage due to interference in signaling between the embryo and the mother (15–17 days after fertilization; Goff, 2002), leading to pregnancy loss (Garrett et al., 1988). In turn, these losses are not easy to detect in the extensive production systems, where pregnancy is diagnosed by ultrasonography or manual palpation from 28 to 60 days after fertilization (Romano et al., 2017). After pregnancy diagnoses, the reproductive losses are low in healthy and well-managed herd. Indeed, late embryo loss or early fetal mortality in beef cows is approximately 5–8%; however, it could increase due to sanitary or management issues (Pohler et al., 2020).

Calf mortality (from birth to weaning) can cause large economic losses to the farmers. In a tropical extensive system in Australia, Bunter et al. (2014) reported an average of 9.5% calf-born mortality, while Sanderson and Dargatz (2000) reported 5.8% in the United States. On the other hand, Singh et al. (2009) reported a calf mortality rate of around 12.5 to 30% in India. The percentage of calf mortality before weaning is influenced by many factors, such as dystocia, infectious diseases, level of nutrition of the cows, colostrum production, and management practices during calving periods (i.e., Singh et al., 2009; Murray et al., 2016). However, the main cause of losses from calving to weaning is related to dystocia problems (Matto Romero, 2008). The influence of the sire breed used in crossbreeding has a pronounced effect on the birth weight of the calf and, therefore, on the presence of dystocia (Price and Wiltbank, 1978). The service with low-birth-weight bulls, with body size similar to the females, and the use of genetic values improving easy calving sires are decisive to achieve adequate reproductive efficiency and minimize dystocia problems (Campero et al., 2017).

The heterosis produced by crossbreeding could be an alternative to improve reproductive characteristics (Martin et al., 1992). In this sense, the advancement of puberty (Martin et al., 1992), the increase in the pregnancy rate (Winder et al., 1992; Olson et al., 1993), the increase in weight at birth and at weaning (Olson et al., 1993), and the decrease in the calving interval (Wall et al., 2005) of crossbred animals can be attributed to the effects of heterosis. However, the literature fears the effect of crossbreeding on reproductive losses in beef cows under extensive systems. Hence, it was hypothesized that in extensive beef breeding cows, crossbred cows have lower reproductive losses between mating and weaning periods than purebred cows, regardless of parity. A second hypothesis is that primiparous cows have the highest reproductive losses regardless of genotype (GG). The objective of this work was to compare the reproductive losses of purebred [Hereford (HH) and Angus (AA)] and crossbred (HA and AH) cows and the effect of parity (nulliparous, primiparous, and multiparous).

2. Material and Methods

2.1. Management of animals and experimental data

All procedures used in the present work were conducted according to Udelar protocols for experimental animals.

This work is a retrospective study of the reproductive losses of breeding cows of two different purebred HH, AA, and their F1 crossbred (AH and HA). The dataset used in this work contained 2505 records

of pregnancy diagnosis, calving and weaning of multiparous (cows with more than two calving), primiparous (first calving cows), and nulliparous (heifers without calving) cows collected over a 13-year period (1994 – 2006; Table 1). The cows belonged to the experimental flock from the Estación Experimental Bernardo Rosengurtt, Facultad de Agronomía, Udelar (32°S, 54°W), Uruguay. The dataset was under a complete diallelic design between HH and AA breeds. The general management of the herd was previously reported by Pereyra et al. (2015). Briefly, the cows grazed on 256 ha of natural grassland (Campos) in an extensive system production typical of the region. The forage production of the Campos grassland presents a spring-summer seasonality (accumulating in this period 60% of the total annual production; Do Carmo et al., 2018). Campos grassland was dominated by *Andropogon lateralis*, *Paspalum notatum* and *P. dilatatum*, *Axonopus affinis*, *Bothriochloa laguroides*, *Schizachyrium* sp., and *Coelorhachis selloana* pastures in the summer, and *Piptochaetium montevidense*, *Piptochaetium stipoides*, and *Stipa setigera* pastures in the winter. The average forage allowance during the studied period was 1.14 UG/ha.

Table 1 - Number of mated cows by genotype and parity

Parity	Genotype			
	AA	HH	AH	HA
Multiparous	506	578	167	156
Primiparous	197	226	85	90
Nulliparous	322	410	117	116
Total	1025	1214	369	362

AA - purebred Angus cows; HH - purebred Hereford cows; AH - Angus × Hereford crossbred cows; HA - Hereford × Angus crossbred cows.

The rainfall regime in the region presents variability between months and years, but with rains present throughout the year. The average annual rainfall for the studied period was approximately 1,800 mm. The climate is classified as Cfa type (subtropical, humid, without dry season), and the temperature range in the coldest months is between –3 and 18 °C and above 22°C in the warmest months according to Köppen (Panario and Bidegain, 1997).

Multiparous and primiparous cows were mated with andrologically evaluated bulls during 80 days beginning on December 1st (summer, SH) following the most frequent mating period in the region. Each bull was placed with different genotypes of cows assigned to mate with it (paternity identification). Three bulls of each breed were used per year, repeating one of them the following year to connect the information between years. Nulliparous cows were bred when they were 24 months of age and at least 280 kg of body weight (BW). The mating period lasted 45 days (late November to mid-January, late spring – summer; SH). Estrus was synchronized five days after estrus detection (twice a day) with a dose of prostaglandins, and estrus detection continued for the next five days. The heifers that showed estrus were inseminated 12 h after detection with semen collected from the corresponding assigned bulls. Thereafter, bulls were introduced in the corresponding heifers' groups during the rest of the mating period. During the first winter of the heifers, they were supplemented with 1 kg/animal/day of whole rice bran (88% dry matter [DM]; 14.1 g/100 g of crude protein in DM; 9.2 g/100 g of acid detergent fiber in DM; 24.1 g/100 g of neutral detergent fiber in DM; 15.0 g/100 g ethereal extract in DM). The diagnosis of gestation was conducted 45 days after the mated period ended.

2.1.1. Variables studied

The total reproductive losses (number of weaned calves/total exposed cows × 100) were studied in three periods: I - from the mating period to pregnancy diagnoses (PD, number of cows diagnosed as non-pregnant/total exposed cows × 100); II - from PD to calving (number of calving cows/number of cows diagnosed as pregnant × 100); and III - from calving to weaning (number of weaned calves/numbers of calving cows × 100).

2.1.2. Statistical analysis

Data were analyzed using SAS Academic Edition (Statistical Analysis System, OnDemand for Academics). Reproductive losses presented binomial distribution and were analyzed using the GLIMMIX procedure; the model included the effects of the GG (HH, AA, AH, HA), parity (multiparous, primiparous, and nulliparous), and their interactions as fixed effects, and the year and the bull as random effects. The effect of the bull was removed from the models because the covariance parameter was zero or close to zero. Least squares mean tests were conducted to analyze differences between groups. The means were compared with Tukey's test ($P \leq 0.05$). Results were presented as least square means $\pm$ pooled standard error according to the following model:

Model: Reproductive losses according to genotype and parity

$$Y_{ijkl} = \mu_0 + GG_i + P_j + (GG*P)_{ij} + C_k + Y_l + \varepsilon_{ijkl}$$

in which μ_0 = general average, GG_i = fixed effect of cow genotype, P_j = fixed effect of cow parity, $(GG*P)_{ij}$ = fixed effect of interaction between cow genotype and parity, C_k = random effect of each cow, Y_l = random effect of year, and ε_{ijkl} = experimental error associated with each observation.

3. Results

3.1. Reproductive losses

The total reproductive losses (from mating to weaning) were affected by the GG of the cows ($P < 0.01$). On average, purebreds presented higher losses than their crossbreds (0.45 ± 0.03 vs. 0.28 ± 0.02 ; $P < 0.01$; Table 2). Parity also affected total reproductive losses ($P < 0.01$). Primiparous cows presented greater losses ($P \leq 0.02$) than nulliparous and multiparous cows with no difference between the last two parities: primiparous (0.46 ± 0.03) vs. nulliparous (0.30 ± 0.02) vs. multiparous (0.33 ± 0.02) (Table 2). No GG and parity interaction was found in any period studied.

Cow GG and parity affected the reproductive losses in period I ($P < 0.01$; Table 3). Purebred cows had greater reproductive losses ($P < 0.01$) than the crossbred, with no differences between the purebreds

Table 2 - Total reproductive losses (from mating to weaning), standard error of the mean (SEM) in purebred Hereford (HH) and Angus (AA) cows and their crossbred (AH and HA) according to parity

Parity	Genotype				P-value
	HH	AA	AH	HA	
Nulliparous	0.38a $\pm$ 0.03	0.32a $\pm$ 0.03	0.25a $\pm$ 0.05	0.26a $\pm$ 0.05	0.10
Primiparous	0.56b $\pm$ 0.04	0.62b $\pm$ 0.04	0.35a $\pm$ 0.07	0.31a $\pm$ 0.07	≤ 0.03
Multiparous	0.42b $\pm$ 0.02	0.40b $\pm$ 0.02	0.25a $\pm$ 0.03	0.24a $\pm$ 0.03	≤ 0.01

a,b - Means with different lowercase letters differed with P-value < 0.05 .

Table 3 - Reproductive losses and standard error of the mean (SEM) from mating to pregnancy diagnoses (period I), from pregnancy diagnoses to calving (period II), and from calving to weaning (period III), in cows of different genotypes (GG) [purebred Hereford (HH) and Angus (AA) cows and their crossbred (AH and HA)] and different parities [nulliparous (NP), primiparous (PP), and multiparous (MP) cows]

Period	GG				Parity			SEM	P-value ¹		
	HH	AA	AH	HA	NP	PP	MP		GG	Parity	GG $\times$ Parity
I	0.21b	0.24b	0.15a	0.15a	0.11a	0.35b	0.15a	0.01	0.01	< 0.001	0.35
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.26	0.11	0.86
III	0.04	0.04	0.03	0.03	0.04	0.04	0.03	0.01	0.51	0.34	0.62

¹ The interaction between GG $\times$ Parity did not affect the variables studied ($P > 0.20$).

a,b - Means with different lowercase letters differed with P-value < 0.05 .

(HH and AA) or between the crossbreds (AH and HA). On the other hand, the greatest losses were observed in primiparous rather than in nulliparous and multiparous cows, with no difference between the latter two ($P \leq 0.01$; Table 3). No interaction between GG and parity was detected.

4. Discussion

Crossbred cows showed lower reproductive losses than the purebred animals regardless of parity; however, the advantage of the first was only observed during period I, that is, since the cows were exposed to the bulls or AI to pregnancy diagnosis. The mating period began without knowledge if the cows had resumed their cyclicity after calving; so, in this period cows were included that did not show estrus during the mating period, or showed it late, and since then, they had few opportunities or a single chance to get pregnant. It should be noted that after a single insemination, only half of the cows get pregnant (Reese et al., 2020) and less than 65% of cows become pregnant after a single or multiple natural service (Lunstra and Laster, 1982).

The length of postpartum anestrus in breeding herds is considered a major limitation in the reproductive performance of the breeding cow (Yavas and Walton, 2000; Vasconcelos et al., 2009; Burns et al., 2010; Quintans et al., 2010). It is possible that purebred cows had a longer anestrus postpartum than crossbred cows. There is evidence that purebred Angus had longer postpartum anestrus than Angus $\times$ Jersey or Angus $\times$ Kiwi crosses; however, when pregnancy rate was compared at mid-mating period, this advantage was only observed in the latter crossbred cows, and at 42 days (end of mating period), the difference disappeared (Hickson et al., 2012). In addition, there is evidence that Hereford purebred cows have a longer interval to the first luteal phase than beef $\times$ dairy crossbred cows (King and Macleod, 1984). Cundiff et al. (1974) and Morris et al. (1987) worked on reciprocal crossbreeding experiments between Hereford and Angus and found a shorter interval to the first estrus and a higher pregnancy rate for crossbred compared with purebred cows.

The lower losses shown by crossbred cows in period I in the present study could be associated with an earlier resumption of ovarian activity, at least partially, associated with a better metabolic status. Indeed, Laporta et al. (2014) reported that crossbred cows had greater body condition scores, blood insulin, and IGF-I concentrations and hepatic GHR mRNA abundance. These cows had more body reserves and estimated energy intake and were able to better adapt to the environmental changes (i.e., nutrient and energy supply) during the gestation-lactation cycle without decreasing calf weight, milk yield, or commencement of luteal activity than the purebred cows. It is unlikely that the difference observed in this study was due to differences in fertilization rate, since it is usually high in cows (Diskin and Morris, 2008). However, it is not possible to rule out differences between genetic groups in the proportion of early embryonic losses, as they are high in cows (Pohler et al., 2020), and pregnancy diagnoses were conducted after the period of maximum early embryo losses.

The establishment of pregnancy in cows depends on the maintenance of the corpus luteum and the consequent secretion of progesterone, one of the main hormones responsible for maintaining pregnancy (Binelli et al., 2001). Estradiol also has been shown to have a positive effect in this period (Starbuck et al., 2004). It is possible that the effect of heterosis induces a higher concentration of ovarian steroids, and thus at a higher rate of conception in crossbred than in purebred cows. He et al. (2007) compared the blood concentrations of estradiol and progesterone and the potential to produce embryos in pure Brahman and crossbreed-BMY and reported that the concentration of both hormones, estrogen and progesterone, the average number of corpora lutea, and embryos recovered was higher in crossbred than in purebred cows, suggesting a certain degree of heterosis in blood steroid reproductive hormones that could explain the larger embryo recovered.

It is well known that fertilization and blastocyst formation are the initial processes for any pregnancy to occur. Reese et al. (2020) reported that higher embryo losses occur during the first few days after fertilization. Embryos from crossbred cows may have better preimplantation development than those from purebred cows. In fact, embryos from crossbred cows show greater development than those produced by purebreds (Residiwati et al., 2020). Lazzari et al. (2011) produced purebred (Holstein)

and crossbred (Brown Swiss × Holstein) embryos *in vitro* and reported that purebred embryos had a lower blastocyst rate on days 7 and 8 and a lower elongation rate on day 12, indicating a reduced and delayed development compared with crossbred embryos. There are evidences that elongation is a crucial step for bovine embryo development, since most embryonic losses occur between blastulation and elongation (Diskin and Sreenan, 1980), and most advanced embryos at day 12 show a significantly higher rate of pregnancy than the smaller ones (Lazzari et al., 2002). It is possible that embryos of the crossbred cows had a greater capacity to establish pregnancy, but the present experiment was not designed to study the analytic variables, but rather the related economic ones (variables end point).

The differences in reproductive losses due to parity were also found in period I. As expected, the higher percentage of losses was shown by primiparous cows. These females have to face the stress of the first lactation and need to continue growing (Carroll and Hoerlin, 1966), being a survival strategy at the expense of reproduction. These results are consistent with previous reports (Reese et al., 2020); the combination of growth, lactation, and reproductive stressors induce a greater pregnancy loss in primiparous than in nulliparous or multiparous cows (Werth et al., 1996; Freetly et al., 2006). On the other hand, contrary to what was reported by other authors, no differences were found between the reproductive losses since the cows were exposed to the bulls or inseminated until the pregnancy diagnoses that the nulliparous and multiparous cows showed. Greater losses in multiparous cows than in primiparous cows were associated with failures in sperm transport or maternal recognition (Baez et al., 2016; Young et al., 2017), or the larger reproductive tract the first present (Madureira et al., 2020).

Nulliparous cows had fewer losses, probably due to the better condition they had at the beginning of the mating season, as they were not producing milk and did not have the influence of a calf (Batista et al., 2012). However, Shorten et al. (2015) reported a negative relationship between cow age and pregnancy rate, in which cows less than two years (nulliparous) and older than six years (multiparous) have limited capacity to get pregnant. In this work, the age of the heifers did not appear to be a problem, but their estrous were synchronized and they were subjected to AI, a different treatment than the multiparous cows. One way or another, our data did not allow us to find differences in reproductive losses between nulliparous and multiparous during period I.

Losses during period II were not affected by either GG nor parity, since there were no detected losses during this period, and the results indicated absence of diseases related to reproduction, nutritional, or genetic problems in the herd (Andrews, 2004). Furthermore, losses during period III were not affected by GG or parity. The main cause of losses from calving to weaning is due to dystocia problems (Matto Romero, 2008). According to Campero et al. (2017) the losses during this period due to dystopic calving were 11.1% for the British breed (Angus, Hereford) or with their respective crosses (Nellore, Brahman). In this work, dystocia was not a major problem, probably because calving ease was a criterion considered when selecting bulls. The calf losses from calving to weaning coincide with those reported by Radostits (1994), who found a percentage between 3 to 4%.

5. Conclusions

This study sheds some light on how crossbred cows (HA, AH) in an extensive production system showed fewer reproductive losses than the purebred cows (HH, AA), thus increasing calf harvest.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: Vivián Paradizo, R.; Pérez-Clariget, R. and Espasandin, A. C. **Data curation:** Vivián Paradizo, R.; Pérez-Clariget, R. and Espasandin, A. C. **Formal analysis:** Vivián Paradizo, R.; Pérez-Clariget, R. and Espasandin, A. C. **Funding acquisition:** Espasandin, A. C. **Investigation:**

Vivián Paradizo, R. **Methodology:** Vivián Paradizo, R. and Pérez-Clariget, R. **Project administration:** Espasandin, A. C. **Software:** Vivián Paradizo, R. and Espasandin, A. C. **Supervision:** Pérez-Clariget, R. and Espasandin, A. C. **Validation:** Vivián Paradizo, R. **Visualization:** Vivián Paradizo, R. and Espasandin, A. C. **Writing – original draft:** Vivián Paradizo, R. and Espasandin, A. C. **Writing – review & editing:** Pérez-Clariget, R.

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