https://doi.org/10.22319/rmcp.v15i1.5998

Article

Relationship between body development and reproductive response of heifers to estrus synchronization protocols in the small-scale dairy system

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Abstract:

The objectives were to determine the reproductive response of Holstein heifers in small-scale dairy herds to estrus synchronization protocols based on prostaglandins (PG), estradiol benzoate (EB), and progesterone (P4). Heifers at least 13 mo old (n= 138) were randomly included in one of two synchronization protocols: PG) administration of 500 μg cloprostenol i.m. at d 0 and d 14; and PGPE) similar to PG but with an additional application of 100 mg

P4 + 2 mg EB on d 7. The estrus rate of the PG group was similar to that of the PGPE group (84.3 *vs* 79.4 %; $P>0.1$). Heifers in PGPE had a higher percentage of estrus between 37-84 h post-treatment *vs* the PG group (94.2 *vs* 82.5 %; $P=0.05$). The conception rate of the PGPE group was higher than that of the PG group (94.4 *vs* 83.1 %; $P=0.05$). In the PG group, body development at weaning was lower in heifers that did not show estrus *vs* those that did ($P<0.05$). Nonetheless, in the PGPE group, birth weight was lower in heifers that showed estrus than those that did not ($P<0.05$). In conclusion, heifers in the small-scale dairy system have a good reproductive response to prostaglandin-based estrus synchronization (cloprostenol). The inclusion of EB + P4 into the hormonal synchronization protocol with PG improves conception rate but has a minimal effect on the distribution of the beginning of estrus expression after treatment.

Keywords: Estrus synchronization, Heifers, Small-scale dairy herds.

Received: 30/05/2022

Accepted: 07/12/2023

Introduction

Artificial insemination (AI) is one of the most effective reproductive technologies for accelerating genetic progress in cattle herds. First-service conception rates in heifers using AI fluctuate between 45 and 75 %(1,2,3). To obtain the best results, it is necessary to have an efficient detection of estrus or schemes of synchronization of estrus or ovulation that allow insemination in periods of greater fertility. However, failures to detect estrus are one of the most recurrent problems, even with the use of technologies for its detection(4,5,6). Evidence suggests that about 30 % of estrus recorded in dairy herds are not actually estrus(7), and accuracy can only reach 50 %(5). Therefore, AI in the intensive system is commonly performed in conjunction with hormonal presynchronization and synchronization programs and fixed-time artificial insemination(8,9).

In the small-scale dairy system, problems of reproductive inefficiency and suboptimal body development of heifers during their rearing period have been identified, increasing the age at first calving(10,11). The inadequate reproductive management and, in particular, the problem of estrus detection in this system, is exacerbated by the fact that the producers themselves are responsible for carrying out all herd management activities, in addition to agricultural tasks(12), which complicates the incorporation of intensive protocols for reproductive management similar to those implemented in specialized herds[8,9]. In addition, producers in the small-scale dairy system prefer to inseminate only animals in standing estrus because they associate it with higher fertility.

The prostaglandin (PG)-based estrus synchronization protocol is an alternative for heifers in the small-scale dairy system because it is easy to implement. Nevertheless, the manifestation of estrus is distributed between 2 and 5 d after the end of the treatments due to the variable age or size of the dominant follicle at the time of PG application[13,14,15]. The hormonal induction of the restart of a new wave of follicular development during synchronization protocols allows animals to have follicles with a few days of dominance at the time of service[16,17], which has been associated with a higher conception rate at service[18]. In addition, the use of estradiol benzoate (EB) + progesterone (P4) to induce a new wave of follicular development has been associated with better synchrony in the occurrence of estrus after synchronization with PG in beef cattle[19]. Reducing the dispersion of estrus manifestation could decrease the time spent performing estrus detection and AI when scheduling groups of animals for service.

On the other hand, the suboptimal body development of calves during rearing not only contributes to the increase in ages at first calving but can also affect the future productive performance of replacements. For example, an increase of 100 g per day in daily weight gain between one and fourteen months of age can translate into an increase in milk, fat, and protein (345 L, 6.1 kg, and 7.5 kg, respectively) at 250 d in milk from their first lactation[20]. Recent studies support that different events (including body development) that occur in the pre- and postnatal life of animals can influence the health and future productive performance of mammals[21-25], which is known as developmental programming. Animals at early ages in the small-scale system are commonly exposed to events that can influence their productivity; however, their effects on reproductive performance have not been explored in this system.

The objectives of the present study were to determine the reproductive response of Holstein heifers in small-scale dairy herds to prostaglandin-based estrus synchronization protocols and to determine whether the inclusion of estradiol benzoate and progesterone in the protocol improves synchrony in estrus manifestation and conception rate. Additionally, it was evaluated whether there is an association between the early body development of heifers and their reproductive response to synchronization.

Material and methods

The study was conducted in Los Altos de Jalisco region, Mexico. This region maintains a subhumid temperate climate, with an average annual temperature of 17.8 ºC and an average annual rainfall of 817 mm[26]. It was included 138 Holstein heifers kept in milk production units (n= 11), with an average of 70 cows in production, characteristic of the family or small-scale system of the Los Altos de Jalisco region[27]. The criteria considered for heifers to start their estrus synchronization protocols were to have a minimum body weight of 290 kg and be at least 13 mo old, considering the minimum necessary values recommended in the family system[28]. Although it was not determined whether the heifers were cycling at the time of service, it was assumed that they already had this condition since it has been described that puberty in Holstein heifers can begin as early as 6 mo of age, with an average of 8.2 months[29], an age considerably lower than the minimum age established in this study to receive the service (13 mo).

Body weight was estimated by measuring the thoracic perimeter with the help of a specialized tape measure for female Holstein cattle (Coburn; Whitewater, WI, USA), while the height at the withers was obtained using a tape measure (Teletape, Ketchum, Ontario, Canada). When the heifers were inseminated, their body condition was recorded on a scale of 1 to 5, where 1 corresponds to an animal in a state of wasting and a value of 5 corresponds to an obese animal[30].

Groups of at least 6 heifers were included per production unit and randomly selected for incorporation into one of two estrus synchronization protocols. In the protocol called PG (n= 70), a dose of prostaglandins (500 μg of Cloprostenol, Inducel®) was applied intramuscularly on d 0 and a second dose on d 14. In the protocol called PGPE (n= 68), a dose of prostaglandins (500 μg of Cloprostenol) was applied on d 0, a dose of 2 mg of estradiol benzoate (Syntex, Zoetis, Kalamazoo, MI, USA) plus 100 mg of progesterone (Horproges, Guadalajara, Jalisco, Mexico) on d 7, and a second dose of prostaglandins on d 14. The doses of EB + P4 were chosen according to those used in previous studies in beef heifers[31,32]. None of the heifers in the study had any prior hormone treatment.

A visual estrus detection system was implemented. This system consisted of observation for periods of 60 min in the morning and 60 min in the afternoon, for five consecutive days from the second application of cloprostenol. The beginning of estrus was defined when the heifers allowed the mounting for the first time and remained immobile. Artificial insemination was performed 12 h after the onset of estrus and by a single technician in all cases. The semen used came from the same bull to reduce the variation in fertility due to the bull effect. When estrus was not observed in the heifers, they were inseminated five days after the second application of cloprostenol, which was implemented at the request of the cooperating producers.

The size of the potentially ovulatory follicle was evaluated by transrectal ultrasonography (UMS900 Universal Imaging, New York, USA) on the day of heifer insemination. At 45 d after insemination, the diagnosis of gestation was made through the rectal palpation technique and with the help of ultrasound.

In heifers that had information on their growth indicators, it was retrospectively determined whether there were differences between those that showed estrus and those that did not within each synchronization protocol. The indicators considered were weight and height at birth, weaning, and at 2 mo, weight gain at weaning and from birth to the service. In addition, body condition at service was considered.

The analyses were performed using the SAS statistical program[33], and all analyses with a value of $P \leq 0.05$ were considered statistically significant. The variables estrus detection rate, conception rate, and the percentage of heifers that showed estrus between 37 and 84 h after the second application of cloprostenol were analyzed by logistic regression adjusted to a binomial distribution using the GLIMMIX procedure.

The variables age, body weight, and body condition at service, as well as the diameter of the ovulatory follicle and the onset of estrus (time elapsed between the last application of Cloprostenol and the onset of standing estrus), were analyzed by ANOVA using the GLM procedure, considering the production unit as a block, within the statistical model. The variables age at service and body condition at service were transformed through their natural logarithm before their analysis. The retrospective analysis within each synchronization group (PG and PGPE) for the different growth indicators (weight, height, and weight gain) was performed by ANOVA and the GLM procedure, also considering the production unit as a block in the statistical model.

Results

Table 1 shows the results on age, body development, and reproductive response of heifers to the first service according to the synchronization protocol. No significant differences were observed between heifer groups for age, weight, and body condition at the time of the first service ($P > 0.05$). No significant differences were observed between heifer groups in estrus rate, total conception rate, and ovulatory follicle diameter ($P > 0.05$). Nonetheless, a statistically significant effect on conception rate was found in heifers that showed estrus

(*P*=0.05). The heifer group of the PGPE treatment had a higher conception rate (94.44 %; 51/54) compared to the group of the PG treatment (83.05 %; 49/59).

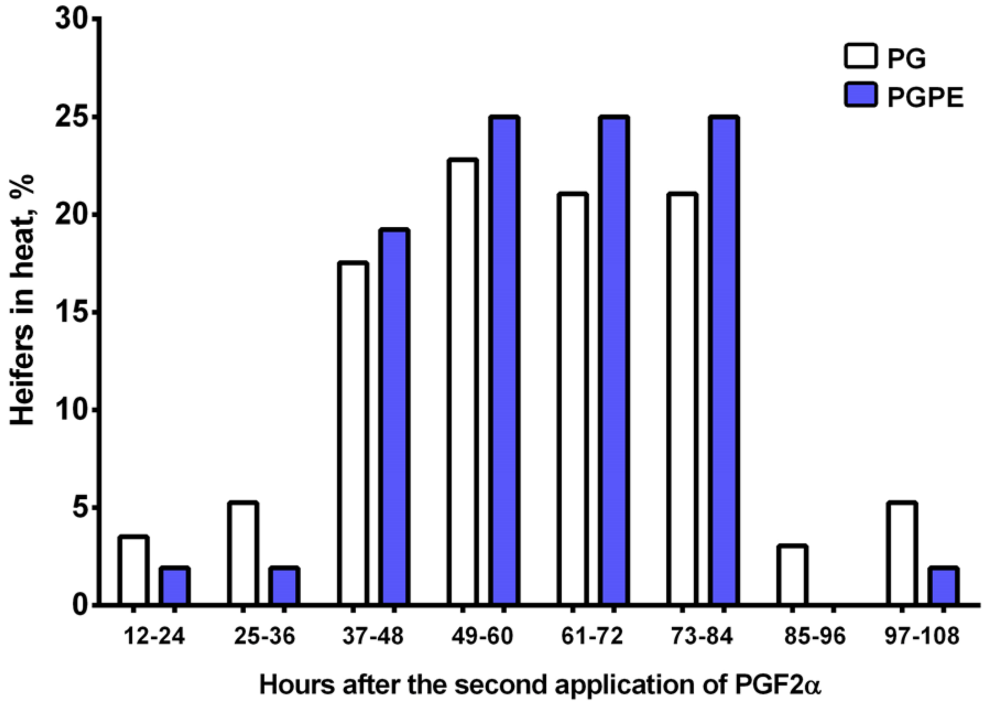
Table 1: Reproductive response of heifers to the first service according to the estrus synchronization protocol

Variable	Synchronization protocol		
	PG	**PGPE**	***P***
N	70	68	-
Age at first service, days	462.97±5.3	459.8±6.0	NS
Weight at service, kg	359.4±4.2	355.2±4.3	NS
Body condition at service	3.31±0.05	3.32±0.05	NS
Estrus rate, %	84.29 (59/70)	79.41 (54/68)	NS
Total conception rate, %	82.61 (57/69)	85.29 (58/68)	NS
Conception (only cows in estrus), %	83.05 (49/59)	94.44 (51/54)	0.05
Preovulatory follicle diameter, mm	11.09±0.30	11.00±0.29	NS

Continuous variables are shown as the average ± standard error. PG= administration of one dose of PGF2∝ on day 0 and another on day 14; PGPE= administration of one dose of PGF2∝, progesterone plus estradiol benzoate, and PGF2∝ on days 0, 7, and 14, respectively.
NS=Not significant (*P*>0.05).

Figure 1 shows the distribution of time in which heifers manifested estrus after the synchronization protocols were completed. As can be seen, the period in which a higher percentage of estrus manifestation was recorded was between 37 and 84 h, regardless of the synchronization protocol. Based on this information, a statistical analysis was performed to identify which treatment group showed a higher percentage of heifers in estrus between 37 and 84 h. A significant difference (*P*=0.05) was observed, in which the group of heifers of the PGPE treatment had a higher percentage of animals showing estrus (94.2 %; 49/52) compared to the group of PG treatment (82.5 %; 47/57).

Figure 1: Distribution of standing estrus manifestation over the next 5 days (shown in 12-h periods) after estrus synchronization protocols were completed



PG= administration of one dose of PGF2∝ on day 0 and another on day 14; PGPE= administration of one dose of PGF2∝, progesterone plus estradiol benzoate, and PGF2∝ on days 0, 7, and 14, respectively. (*P*=0.05).

Table 2 shows the growth indicators between birth and the time of first service of the heifer groups according to the estrus synchronization protocol and estrous response to it. As can be seen, heifers that did not show estrus in the PG group had a lower weight and height at 2 mo of age ($P<0.05$) and tended to have a lower weight ($P<0.1$) and daily weight gain at weaning ($P<0.1$) compared to the group that showed estrus. On the other hand, heifers that showed estrus in the PGPE group had lower birth weight ($P<0.05$) than the group that did not show estrus, but no differences were observed in the development at weaning.

Table 2: Indicators of heifer growth according to estrus synchronization protocol and estrous response to treatment

	Synchronization protocol			
	PG		PGPE	
Indicator	They did not show estrus	They showed estrus	They did not show estrus	They showed estrus
N	4	22	3	22
Birth weight, kg	39.67±1.18	40.76±0.44	43.78±1.51[a]	40.35±0.51[b]
Birth height, cm	82.12±1.65	81.66±0.64	82.69±3.62	80.69±1.23
Weight 2 months, kg	62.06±4.44[a]	76.70±1.64[b]	81.74±8.12	70.43±2.77
Height 2 months, cm	89.51±1.79[c]	93.69±0.66[d]	96.00±3.23	91.00±1.10
Weaning weight, kg	75.13±5.46[c]	87.13±2.02[d]	93.79±9.66	78.93±3.29
Weaning height, cm	92.55±2.63	95.00±0.97	97.40±3.24	92.54±1.10
DWG weaning, kg/d	0.503±0.07[c]	0.663±0.03[d]	0.652±0.10	0.550±0.03
DWG birth-service, kg/d	0.707±0.04	0.718±0.02	0.717±0.03	0.709±0.01

Values shown as average ± standard error. PG= administration of one dose of PGF2∝ on day 0 and another on day 14; PGPE= administration of one dose of PGF2∝, progesterone plus estradiol benzoate, and PGF2∝ on days 0, 7, and 14, respectively. DWG= daily weight gain.

[abc] Different literal between groups for each synchronization protocol indicates statistical difference ($^{ab}P \leq 0.05$) or trend ($^{cd}P \leq 0.10$).

Discussion

The present study was focused on determining whether, in small-scale dairy herds, heifers respond favorably to prostaglandin-based estrus synchronization protocols and determining whether the inclusion of estradiol benzoate and progesterone in the protocol improves synchrony in estrus manifestation and conception rate. The results indicated that heifers in this production system show a good response to synchronization with prostaglandins. On the other hand, adding these hormones to the conventional protocol improved the conception rate, but the distribution of estrus manifestation once the synchronization protocol ended was only slightly reduced.

In addition, the present study evaluated whether there was an association between body development from birth to the service of heifers and their reproductive response to synchronization. The observed results suggest the existence of a relationship between heifer body development and estrus manifestation after synchronization; however, these did not show a clear trend.

Regardless of the protocol variant used, the estrus and conception rates observed in the present study were outstanding (by 14 and 20 %, respectively) compared to the results observed in Holstein heifers synchronized with prostaglandins of the specialized system[34,35]. In specialized production units, the high density of animals limits estrus detection efficiency[4]. Nevertheless, in the cooperating dairy herds there were small groups of heifers in which an external work team helped detect estrus during the study. Although the metabolism of heifers is not as high as in lactating cows, it has been suggested that animals with greater potential for milk production, such as those present in the specialized system, show a reduced intensity and duration of estrus, which makes it difficult to detect[36]. The combination of these factors could explain why the estrus rate was outstanding in the present study.

On the other hand, a reduction in fertility at service has been observed as the age of heifers increases (> 16 mo) at the time of insemination[37] or a wide variability in fertility due to the bull used[38]. In the present study, the heifers were between 13 and 15 mo old at the time of service, semen from a bull with proven fertility in the area was used, and there was a good estrus detection rate, which is associated with better fertility at service[4]. These factors could explain why the conception rate observed was outstanding in the present study compared to the specialized production system.

This study also evaluated the response obtained by adding estradiol benzoate and progesterone to the conventional prostaglandin-based estrus synchronization protocol. The above with the purpose of reducing the dispersion in the expression of estrus and improving the conception rate. Regardless of the treatment used, most heifers initiated standing estrus between 37 and 84 h after the end of the synchronization protocol. On the other hand, the inclusion of estradiol benzoate and progesterone in the hormonal synchronization protocol improved the conception rate at service and increased, albeit slightly, the percentage of estrus manifestation between 37 and 84 h after the end of synchronization (Figure 1). Previous studies have described that the induction of a new wave of follicular development during hormonal synchronization protocols improves fertility at service[16,17,18] and reduces the distribution of estrus occurrence after synchronization[19].

The conception and estrus rates observed in the PGPE treatment are probably associated with the fact that the application of estradiol benzoate and progesterone induced a new wave of follicular development and, consequently, the development of ovarian follicles in closer stages and in full dominance at the time of ovulation. It is known that the combination of estrogen and progesterone reduces serum gonadotropin concentrations, which causes regression of the dominant follicle in turn (with maximum size, but in some cases already aged) and induces a new wave of follicular development during hormonal synchronization[16,17]. The presence of dominant follicles in fullness favors the expression of genes, as well as cellular signals that confer greater competence to the follicles so that the released oocytes are successfully fertilized and continue their embryonic development process[39,40]. It is important to note that the results regarding conception and estrus presentation rates were not associated with age, weight, body condition at service, or the size of the ovulatory follicle since they were similar between treatments (Table 1).

This study also evaluated whether early body development of replacements could affect the reproductive response of heifers to estrus synchronization. The results support an association between body development at an early age in heifers and the manifestation of estrus in response to synchronization. Heifers that did not show estrus in the PG group had lower body development until two months of age. In previous studies, it has been observed that low weight gain in the preweaning stage impacts age at first service or conception[41,42]. On the other hand, heifers that showed estrus in the PGPE group had lower birth weight; however, their body development until service was similar between animals that showed estrus or not. It has been indicated that postnatal compensatory growth in low birth weight calves allows them to cope with adverse events such as weaning and probably compensate for their future productive performance[43,44].

It should be noted that weight, body condition (Table 1), and daily weight gain from birth to service (Table 2) were similar among the heifers in each treatment studied. It is possible that the estrous response observed in the present study and associated with early body development is due to effects known as developmental programming. This phenomenon refers to the fact that the productive performance of animals can be programmed during the pre- and early postnatal life due to environmental effects that modulate gene expression through epigenetic marks in chromatin[22,23,25]. Negative effects of suboptimal body development during early life on the reproductive performance of heifers have been previously described[41,42]. Nonetheless, the number of observations and the lack of consistency in the results of the present study limit their interpretation. Further studies are required to explore these possible effects on heifers in the small-scale dairy system.

Conclusions and implications

In conclusion, heifers in the small-scale dairy system have a good reproductive response to prostaglandin-based estrus synchronization (cloprostenol). The inclusion of estradiol and progesterone in the prostaglandin hormone synchronization protocol improves the conception rate but has a minimal effect on the distribution of the onset of estrus expression after treatment. Although an association was detected between the early body development of heifers and their estrous response, no conclusive effects were observed.

Acknowledgments

The study was financed with fiscal funds allocated to the project SIGI 23335132549 entitled "Nutritional supplementation in critical periods of calf rearing, to improve their productive performance in family/semitechnified milk production systems" of the National Institute of Forestry, Agricultural, and Livestock Research.

Conflict of interest

The authors declare that they have no financial or personal conflict of interest associated with this study.

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