aSPRA Asociación Peruana de Reproducción Animal

www.spermova.pe

SPERMOVA

Spermova 2016; 6(1): 36-42

Artículo de Revisión

DOI. 10.18548/aspe/0003.06

STRATEGIES TO IMPROVE FERTILITY IN CATTLE: ARTIFICIAL INSEMINATION FOLLOWING ESTRUS VERSUS TIMED ARTIFICIAL INSEMINATION

Estrategias para mejorar la fertilidad en bovinos: Inseminación artificial después del estro versus inseminación artificial a tiempo fijo

P.S. Baruselli[1]*, M.F. Sá Filho[1], A.A. Ambrósio[1], R.M. Ferreira[1]

[1] Department of Animal Reproduction, FMVZ, University of São Paulo, Brazil.

E-mail: barusell@usp.br

RESUMEN

Actualmente la inseminación artificial (AI) es la técnica más usada en el mundo para diseminar la genética superior y para mejorar la eficiencia reproductiva en hatos bovinos. No obstante, los reportes de diferentes partes del mundo indican una performance de baja tasa de preñez post inseminación, debido a errores en la detección de celo o una alta incidencia de anestros. En ganado lechero, el uso de AI seguido de una detección visual de celo es relativamente simple para su aplicación en un programa de manejo rutinario e intensivo (ordeños 2 a 3 veces por día), permitiendo un frecuente contacto con vacas en celo. Sin embargo, en ganado de carne, la implementación de programas de AI basados en detección de celo es difícil por el sistema de manejos de estos animales. Las vacas de carne son frecuentemente criadas en condiciones extensivas, con grandes distancias entre las zonas de pastoreo y el lugar de inseminación artificial, asimismo el número de operarios para el manejo es el mínimo y con funciones adicionales al manejo reproductivo. El programa de IA con celo natural requiere mínimo el manejo de dos peridos de observación de celo por día y la conducción de la vaca al lugar de inseminación dentro de las 12h siguientes a la detección de celo. El desarrollo de la inseminación a tiempo fijo en vacas a escala comercial permite programar un nuero grande de inseminaciones en pocos días, sin la necesidad de detección de estro. Asimismo, el uso de TAI en los días post parto temprano en ganado chero y carne reduce el intervalo parto concepción y consecuentemente el intervalo entre partos, lo cual causa un efecto dramático en el retorno económico. En ganado de carne la inseminación a tiempo fijo, tiene la ventaja de concentrar a las hembras en su mejor momento de fertilidad y estimulando la ciclicidad y sincronización de estros en vacas vacías. Otra de las ventajas, es que los partos son concentrados en el mejor periodo del año para generar un nacimiento exitoso con una potencialidad de desarrollo. La inseminación a tiempo fijo es una herramienta muy importante para mejorar la performance reproductiva en ganado lechero. Una adecuada incorporación de los programas de AI tienen el potencial de mejorar la fertilidad y consecuente incrementar la productividad.

Palabras clave: IATF estro, sincronización, bovino

ABSTRACT

Artificial insemination (AI) is currently the major biotechnique used worldwide to disseminate superior genetics and to improve reproductive efficiency in bovine herds. Conversely, reports from different parts of the world indicate low pregnancy rates in cattle submitted to AI, due to both mistakes in heat detection or a high incidence of anestrous. In dairy cattle, the use of AI following visual detection of estrus is relatively easier to be used because their routine of management is intense (milking two to three times a day), allowing a frequent contact with cows for estrus observation. However, for beef cattle, the implementation of AI programs based on estrus detection is harder to be used because of several management conditions. Beef cows are frequently raised extensively, with great walking distances between their pasture to the corral where the AI is performed, the number of employers designated for cattle management is reduced and they have several activities besides reproduction. Because of the necessity of at least two periods of estrus observation per day and the conduction of cattle to the corral around 12 h following estrus detection to be inseminated, the AI is somehow unfeasible in beef farms. The development of timed AI (TAI) enabled insemination of cows in commercial scale, because it allows the programmed AI of large number of cows in the same day without the need for estrus detection. Besides, the use of TAI in early postpartum dairy and beef females reduces the interval partum-conception and, consequently the interval between parturitions, which has a dramatic effect on farm economic return. For beef cattle, TAI also brings the advantages of concentrating around half of the conceptions at the first days of the breeding season and stimulating cyclicity and a synchronous estrus return in cows that did not become pregnant at TAI. Thus, the calving season is also concentrate in the best periods of the year to generate offspring with greater weight and potential of development. TAI programs are currently important tools of reproductive management to improve reproductive performance of cattle. The adequate incorporation of these programs has the potential to enhance reproductive efficiency of livestock and consequently increase overall productivity of the farm.

Keywords: TAI, estrus, bovino, synchronization

INTRODUCCION

Artificial insemination (AI) is one of the most effective instruments available to cattle producers to improve productivity and profitability of cattle operation. The main advantages of using AI is the possibility to use sires of superior genetic merit, the capacity to mate specific sires to individual cows, the aggregation of increased genetics for replacement heifers, and the improvement of production traits in cattle operation. In beef cattle, the implementation of AI programs based on estrus detection is hampered by the frequent occurrence of postpartum anestrus and estrus detection failures (Williams *et al.*, 1996; Baruselli *et al.*, 2004). The estrus detection is impaired by technical and physiological problems, such as the large size of farms, the large number of animals per lot, the labor costs (Bó *et al.*, 2007), the short period of estrus manifestation (around 10h) of Bos indicus cows (Randel, 1976; Galina and Arthur, 1990; Galina *et al.*, 1996; Membrive, 2000; Rocha, 2000) and the high incidence of estrus at night (Pinheiro *et al.*, 1998; Landaeta-Hernandez *et al.*, 2002). The low estrus detection has been also reported for lactating dairy cows (Cordoba & Frieck, 2001; Cordoba & Frieck, 2002; Cavestany *et al.*, 2007; Gutiérrez *et al.*, 2009), Milk production is inversely proportional to estrus duration and reproductive performance of high producing dairy cows. Thus, estrus detection failure is a critical cause for poor reproductive efficiency of estrus detection-based reproductive programs (Senger, 1994).

Timed AI (TAI) programs allow insemination of cows regardless of cyclic status and eliminate the need for estrus detection, by exogenously controlling follicular and luteal function. These programs also afford an organized method to the use of AI, facilitating its use in beef and dairy herds (Baruselli, *et al.*, 2004; Bó *et al.*, 2007; Teixeira, 2010; Sá Filho *et al.*, 2013). TAI programs for allow insemination of all cows at the beginning of the breeding season, increasing the proportion of pregnant cows early in the breeding season and increased overall proportion of cows pregnant the end of the breeding season (Cavestany *et al.*, 2007; Gutiérrez et al., 2009; Teixeira, 2010; Herlihy *et al.*, 2011; Sá Filho *et al.*, 2013). However some questioning regarding the fertility of cows following TAI compared to estrus detection was raised and will be discussed above.

AI following estrus detection versus TAI in beef cattle

In pasture-based system, high pregnancy rates in the beginning of the breeding season are critical for herd profitability. Cows that conceive earlier in the breeding season calf earlier in the next calving season and consequently, have additional time for uterine regression before the next breeding season starts. This improves their chances to conceive again and reduces the risk of involuntary culling (Rhodes *et al.*, 2003). Moreover, calves born early in the calving season have greater live weight at weaning than those born later in the calving

season, yielding additional income to the producer (Cutaia *et al.*, 2003; Bó *et al.*, 2005).

The high incidence of anestrus post-partum together with the difficulties for estrus detection in pasture-based systems make the use of TAI programs essential to concentrate conception early after post partum and guarantee satisfactory pregnancy rates at the end of the breeding season (reviewed by Baruselli *et al.* 2004; Sá Filho *et al* 2013). Aiming to compare fertility after natural breeding and TAI programs and assure TAI is not prejudicial for conception outcomes, our research group designed two recent experiments (Sá Filho *et al.*, 2013).

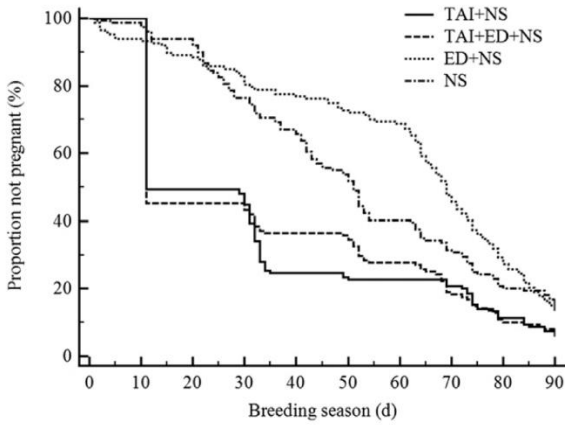

Figure 1. Survival curves for proportion of non-pregnant cows by days of breeding season (BS) for different breeding strategies during a 90-d breeding season. TAI+NS (n=150): timed AI on Day 11 of the BS, followed by natural service (NS) until the end of the BS; TAI+ED+NS (n=148): TAI on Day 11, then estrus detection (ED) twice daily, with AI 12h after ED until Day 45 of the BS, followed by NS until the end of BS; ED+NS (n=147): AI 12h after ED during the first 45 d of the BS, followed by NS until the end of BS; NS (n=149): cows were bred by NS throughout the BS. Adapted from Sá Filho *et al.*, 2013.

In the first study, we compared reproductive performance of Nelore cows subjected to four different reproductive programs in a 90-d breeding season: 1) only natural service (NS, n = 149), 2) AI after estrus detection for the first 45-d of the breeding season followed by NS (ED+NS, n = 147), 3) TAI followed by estrus detection + AI until 45-d of the breeding season and then NS (TAI+ED+NS, n = 148), and 4) TAI followed by NS (TAI+NS, n = 150). Time to pregnancy was reduced (P < 0.001) for TAI+NS and TAI+ED+NS (median days to pregnancy = 11 days) compared with ED+NS and NS cows (Figure 1). Moreover, greater (P = 0.001) proportion of cows was pregnant at 45 days of the BS when they were subjected to TAI [TAI+NS = 75.3%a, and TAI+ED+NS = 63.5%b] compared to cows from NS [(23.3%c] or ED+NS [44.3%d]. Breeding by TAI (TAI+NS = 92.7%a; TAI+EDþ+NS = 91.9% a) also resulted greater (P < 0.01) proportion of cows pregnant at the end of the BS than cows not bred by TAI (ED+NS = 85.0% b; NS = 83.2% b).

In a subsequent study (Sá Filhp *et al.*, 2013), we compared the use of natural service (NS) alone during the entire breeding season with the used of TAI at onset of the breeding season followed by natural service (TAI+NS). A total of 507 postpartum beef cows Nelore and crossbred Nelore x Angus) were used. The use of TAI resulted in 52.4% P/AI. Similarly to the previous study, TAI cows had higher pregnancy rate at the first 45 d of the breeding season than those only exposed to natural bull mating (63.5% vs 46.3%, P = 0.001; Table 1 and Figure 2). However, similar pregnancy rates between groups were found at the end of the breeding season (Figure 2).

In this same study, when parity was evaluated, primiparous cows had lower P/AI following TAI and lower cumulative pregnancy rate during and at the end of the breeding season (Table 1). Indeed primiparous beef cows raised in pasture-based systems usually show prolonged periods of postpartum anestrus (Wiltbank, 1970) and reduced P/AI to TAI programs compared with multiparous cows (Sá Filho *et al.*, 2009).

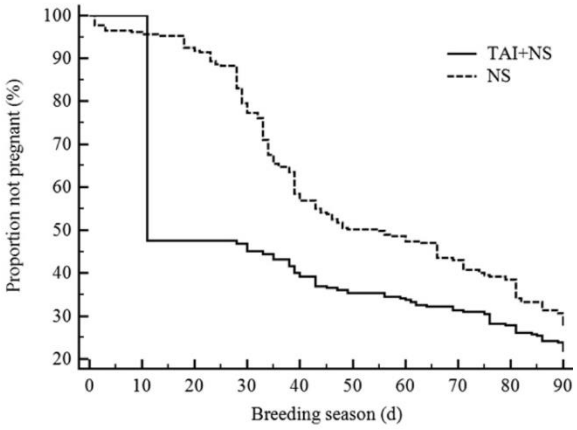

Figure 2. Survival curves for proportion of non-pregnant cows by days of breeding season (BS) for postpartum beef cows bred by natural service (NS; dashed line; n=255) during a 90-d breeding season or by timed AI (TAI) at beginning of the BS followed by NS (TAI+NS; solid line; n=252). Median interval to pregnancy for NS and TAI groups was 55 d and 11 d (adjusted hazard ratio, 1.64; 95% confidence interval, 1.34–2.01), respectively. Adapted from Sá Filho *et al.*, 2013.

Table 1. Reproductive performance of postpartum beef cows bred by natural service (NS) or timed artificial insemination (TAI) followed NS. Adapted from Sá Filho *et al.*, 2013.

Item	N	P/AI, % (N)	45 days, % (N)	End, % (N)
Breeding strategy				
NS	255	–	46.3 (118)	71.0 (181)
TAI+NS	252	52.4 (132)	63.5 (160)	77.0 (194)
P		–	0.001	0.31
Parity				
Primiparous	250	41.3 (121)	36.8 (92)	58.0 (145)
Multiparous	257	61.8 (131)	72.4 (186)	87.6 (225)
P		0.002	<0.001	<0.001
Breed				
Nelore	302	45.0 (151)	46.4 (140)	62.5 (197)
Crossbred	205	62.4 (101)	67.3 (138)	84.4 (173)
P		0.007	0.03	0.05
BCS				
Low (<3)	244	40.5 (121)	38.9 (95)	58.6 (143)
Medium (≥3)	263	62.6 (131)	69.6 (183)	86.3 (227)
P		<0.001	0.005	0.005

As for body condition score (BCS), it was also shown that assuring a good nutritional status at parturition (BCS ≥ 3.0; scale 1 to 5) is an important strategy to optimize the postpartum conception rate of beef cows, regardless of reproductive management (natural mating or TAI followed by natural mating; Table 1). Similar results were observed for postpartum Zebu cows previously by Ayres *et al.* (2014). Finally, it was also observed (Sá Filho *et al.*, 2013) differences in conception for Bos indicus pure breed and crossbred Bos indicus x Bos taurus cows, regardless of reproductive program (Table 1).

Therefore, it is important to be aware of several particularities inherent to breed, parity, and nutritional status strategies that can affect the efficiency of reproductive programs. However, despite of these differences, TAI seems to be a strategic tool to anticipate conception early postpartum and to improve pregnancy outcomes at the end of the breeding season, without any lack of fertility compared to estrus detection programs.

AI following estrus detection versus TAI in dairy cattle

Although dairy cows are managed daily, allowing frequent observation of estrus, the main limiting factors for the massive use of AI are still the failures and difficulties to perform efficient estrus detection. Even in well-organized farms the rate of estrus detection barely achieves 50% (Van Eerdenburg *et al.*, 2002), which in turn result in few number of AI (50% service rate). However, when TAI is used the service rate achieves 100%, ending up with a larger number of cows inseminated, increasing the percentage of pregnancy per AI (P/AI; reviewed by Rodrigues *et al.*, 2011).

Several studies were already performed aiming to evaluate the efficacy of the TAI protocols as a tool to improve reproductive management of dairy cows (Cordoba & Fricke, 2002; Cavestany *et al.*, 2007; Gutiérrez *et al.*, 2009; Lima *et al.*, 2009; Bisinotto & Santos, 2010; Teixeira *et al.*, 2010; Herlihy *et al.*, 2011; Ribeiro *et al.*, 2011; Rodrigues *et al.*, 2011). Also, the concern of how TAI may affect fertility was investigated. In this context, similar P/AI has been found for cows breed after estrus detection or following TAI (Santos *et al.*, 2009; Teixeira *et al.*, 2010; Wiltbank *et al.*, 2011). Furthermore, TAI protocols have the great advantage of anticipating the first service and conception postpartum, increasing the proportion of cows establishing pregnancy sooner after the voluntary waiting period (Cavestany *et al.*, 2007; Gutiérrez *et al.*, 2009; Teixeira, 2010; Herlihy *et al.*, 2011).

In Brazil, the impact of TAI on the first day after the voluntary waiting period on reproductive performance of high-producing Holstein cows was compared to the use of AI after estrus detection (Teixeira, 2010; Table 1). For that, cows were subjected to AI following estrus detection during 150 days in milk (DIM) or first service with TAI followed by estrus detection and AI. Similar (P = 0.55) P/AI was obtained for cows receiving the first service following TAI or after estrus detection (Table 2). The second service was related to AI after the detection of estrus return from TAI cows vs estrus detection + AI cows. The second service P/AI was also similar (P = 0.92) between groups (Table 2).

Table 2. Pregnancy per AI (P/AI) 30 and 60 days after artificial insemination (AI) after estrus detection or timed AI (TAI) and pregnancy loss between 30 and 60 days after AI for the first and second services of Holstein cows; intervals calving – insemination, first – second AI, and calving – conception; service rate, and cumulative pregnancy rate at 150 days in milk (DIM). Adapted from Teixeira *et al.*, 2010.

	Estrus detection + AI	TAI	P value
1st AI			
P/AI 30 d (%)	26.8 (125/467)	25.5 (126/495)	0.55
P/AI 60 d (%)	21.2 (99/467)	17.8 (88/495)	0.13
Pregnancy loss (%)	20.8 (26/125)	30.2 (38/126)	0.09
Interval calving - 1st AI (d)	78.3 ± 0.9	60.6 ± 0.1	0.0001
2nd AI			
P/AI 30 d (%)	26.2 (74/283)	26.2 (90/344)	0.92
P/AI 60 d (%)	21.6 (61/283)	20.9 (72/344)	0.89
Pregnancy loss (%)	17.6 (13/74)	20.0 (18/90)	0.73
Interval calving - 2nd AI (d)	105.1 ± 1.2	96.2 ± 0.9	0.001
Service rate (57-78 DIM; %)	41.4 (203/490)	100.0 (203/490)	0.001
Interval 1st - 2nd AI (d)	31.9 ± 0.85	37.6 ± 1.0	0.001
Interval calving - conception	94.6 ± 1.8	87.4 ± 1.8	0.005
Pregnancy rate 150 DIM (%)	41.8 (205/490)	41.8 (207/495)	0.99

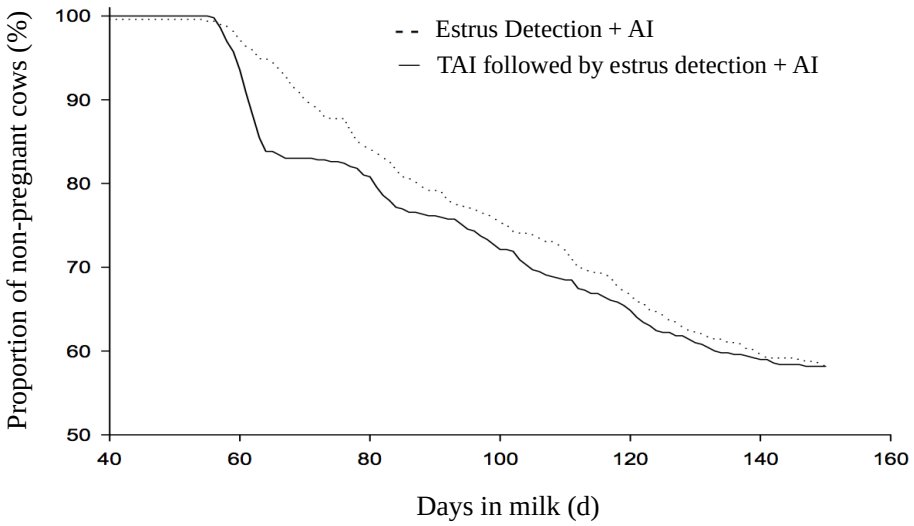

Figure 2. Survival curves for proportion of non-pregnant cows by Days in milk for high-producing Holstein cows bred by artificial insemination after estrus detection (Estrus detection + AI; dashed line; n = 467) or by timed AI followed by AI after estrus detection (TAI followed by estrus detection + AI; solid line; n = 495) during 150 days post partum. Adapted from Teixeira *et al.*, 2010.

However, shorter intervals from calving to first AI (P = 0,001), from calving to second AI (P = 0,001), from first and second AI (P = 0,001) and from calving to conception (P = 0.005) were observed in cows receiving one TAI after the voluntary waiting period followed by observation of estrus return and AI compared to AI after estrus detection during 150 days post partum (Table 2). The cumulative pregnancy rate after 150 DIM was similar among TAI cows and those inseminated only after visual estrus detection (Table 1).

Thus, TAI allowed the premature conception after the voluntary waiting period of high-producing Holstein cows, without reducing the conception rate after AI. Is also brings the advantage of increasing the first service rate post-partum from less than 50% to 100%, concentrating a greater number of pregnancies after the first post-partum insemination (Figure 2).

CONCLUSIONES

The TAI emerged as a crucial reproductive tool to improve beef and dairy herds' reproduction efficiency and to accelerate herds' genetic gain. It allows the anticipation of conception early after postpartum, diminishing the interval partum – conception and, consequently, the interval between two subsequent parturitions for close to 12 months for beef cattle and 13 months for dairy. The main results for beef herds are the production of more calves (one calve per cow per year), the improvement of the quality of calves (massive use of programmed AI), the reduction of involuntary culling at the end of the breeding season, and the availability of more genetically superior heifers for replacement of culled females. For dairy farms, TAI brings as advantage, the increase of milk production by shortening the interval between parturition (closer subsequent peak lactations) with high production of genetically superior heifers to start the reproductive programs. Moreover, TAI is secure for fertility, resulting in similar P/AI than females that underwent AI after estrus observation. However, TAI potentially increases service rates to 100%, and thus pregnancy rates, improving farms` profitability.

REFERENCIAS

- Ayres H, Ferreira RM, Torres-Júnior JR, Demétrio CG, Sá Filho MF, Gimenes LU, Penteado L, D'Occhio MJ, Baruselli PS. Inferences of body energy reserves on conception rate of suckled Zebu beef cows subjected to timed artificial insemination followed by natural mating. Theriogenology 2014. 82(4):529-536.
- Baruselli PS, Reis EL, Marques MO, Nasser LF, Bó GA. The use of hormonal treatments to improve reproductive performance of anestrous beef cattle in tropical climates. Animal Reproduction Science. 2004; 82-83:479–86.
- Bisinotto RS, Chebel RC, Santos JEP. Follicular wave of the ovulatory follicle and not cyclic status influences fertility of dairy cows. Journal of Dairy Science 2010. 93(8):3578-3587.
- Bó GA, Cutaia L, Chesta BE, Picinato D, Peres L, Maraña D, Avilés M, Menchaca A, Veneranda G, Baruselli PS. Implementacion de programas de inseminación artificial en rodeos de cría de argentina. , June 2005, Córdoba, Argentina, pp . Pages 97-128 in Proc VI Simposio Internacional de Reproducción Animal. 2005. Vol. 24-26. IRAC, Córdoba AR.
- Bó GA, Cutaia L, Peres LC, Pincinato D, Maraña D, Baruselli PS. Technologies for fixed-time artificial insemination and their influence on reproductive performance of Bos indicus cattle. Soc Reprod Fertil Suppl 2007; 64:223–36.
- Cavestany D, Betancour H, Blanc JE, Lemaire C, Slavica J, Moreira F, Piaggio J, Risco C. Reproductive efficiency in grazing lactating dairy cows under a programmed reproductive management system. Aust Vet J 2007; 85:141–7.
- Cordoba MC, Fricke PM. Evaluation of two hormonal protocols for synchronization of ovulation and timed artificial insemination in dairy cows managed in grazing-based dairies. J Dairy Sci 2001; 84: 2700–8.
- Cordoba MC, Fricke PM. Initiation of the breeding season in a grazing-based dairy by synchronization of ovulation. J Dairy Sci 2002; 85:1752–63.
- Cutaia L, Veneranda G, Tribulo R, Baruselli P., Bó, G.A. 2003. Programas de Inseminación Artificial a Tiempo Fijo en Rodeos de Cría: Factores que lo Afectan y Resultados Productivos. Pages 119-132 in V Simposio Internacional de Reproducción Animal. . Vol. 25-27 Argentina.
- Galina, C.S., Arthur, G.H., 1990. Review on cattle reproduction in the tropics. Part 4. Oestrus cycles. Anim. Breed. Abstr. 58, 697–707.
- GalinaGS, Orihuela A, Bubio I. Behavioral trends affecting estrous detection in Zebu cattle. Anim. Reprod. Sci. 1996. 42, 465–470.
- Gutiérrez JC, Palomares R, González R, Portillo G, Montero- Urdaneta M, Rubio-Guillén J, *et al.* Shortening the postpartum anoestrous interval in suckled crossbred dual purpose cows using progestagen intravaginal sponges plus eCG and PGF2a. Reprod Domest Anim 2009; 44:48–54.
- Herlihy MM, Berry DP, Crowe MA, Diskin MG, Butler ST. Evalu- ation of protocols to synchronize

estrus and ovulation in seasonal calving pasture-based dairy production systems. J Dairy Sci 2011; 94:4488–501.

- Landaeta-Hernández AJ, Yelich JV, Lemaster JW, Fields MJ, Tran T, Chase CC Jr, Rae DO, Chenoweth PJ. Environmental, genetic and social factors affecting the expression of estrus in beef cows. Theriogenology 2002. 57, 1357–1370.
- Lima FS, Risco CA, Thatcher MJ, Benzaquen ME, Archbald LF, Santos JE, Thatcher WW. Comparison of reproductive performance in lactating dairy cows bred by natural service or timed artificial insemination. Journal of Dairy Science 92(11):5456-5466.
- Membrive CMB Estudo da sincronização das ondas foliculares e das caracter´ ısticas de estro, por radiotelemetria, em novilhas cruzadas (Bos taurus indicus × Bos taurus taurus) tratadas com acetato de melengestrol e prostaglandina F2a associados a hCG, GnRH ou 17? estradiol+progesterona, Master Thesis. Universidade de São Paulo, São Paulo, SP. 2000.
- Pinheiro OL, Barros CM, Figueredo RA, Valle ER, Encarnação RO, Padovani CR. Estrous behavior and the estrus-to-ovulation interval in Nelore cattle (Bos indicus) with natural estrus or estrus induced with prostaglandin F2alpha or norgestomet and estradiol valerate. Theriogenology 1998. 49, 667–681.
- Randel RD. LH and ovulation in Brahman, Brahman × Hereford and Hereford heifers. J. Anim. Sci. 1976. 43, 300.
- Rhodes F M, McDougall S, Burke CR, Verkerk GA, Macmillan KL. Invited review: treatment of cows with an extended postpartum anestrous interval. Journal of Dairy Science 2003. 86(6):1876-1894.
- Ribeiro ES, Cerri RLA, Bisinotto RS, Lima FS, Silvestre FT, Greco LF, Thatcher WW, Santos JEP. Reproductive performance of grazing dairy cows following presynchronization and resynchronization protocols. Journal of Dairy Science 2011. 94(10):4984-4996.
- Rocha JL. Sincronização hormonal da onda folicular e do estro em novilhas de corte mestiças monitoradas por radiotelemetria, PhD Thesis. Universidade de São Paulo, São Paulo, SP. 2000.
- Rodrigues CA, Ferreira RM, Vieira LM, Ranieri AL, Silva PRL, Baruselli PS. How FTAI and FTET impact reproductive efficiency of Brazilian dairy herds. Acta Scientiae Veterinariae, 2011. 39(Suppl 1): s3 - s13.
- Sá Filho OG, Meneghetti M, Lamb R. C., and J. L. Vasconcelos. Fixed-time artificial insemination with estradiol and progesterone for Bos indicus cows II: strategies and factors affecting fertility. Theriogenology 2009. 72(2):210-218.
- Sá Filho MF, Penteado L, Reis EL, Reis TA, Galvão KN, Baruselli PS.Timed artificial insemination early in the breeding season improves the reproductive performance of suckled beef cows. Theriogenology 2013, 79:625-632.
- Santos JEP, Rutigliano HM, Filho MFS. Risk factors for resumption of postpartum estrous cycles and embryonic survival in lactating dairy cows. Anim. Reprod. Sci. 2009. 110(3-4):207-221
- Santos JEP, Rutigliano HM, Filho MS. Risk factors for resumption of postpartum estrous cycles and embryonic survival in lactating dairy cows. Anim. Reprod. Sci. 2009. 110(3-4):207-221.
- Senger PL. The estrus detection problem: new concepts, technologies, and possibilities. J Dairy Sci 1994; 77:2745–53.
- Teixeira AA. Impacto da inseminação artificial em tempo fixo na eficiência reprodutiva de vacas de leite de alta produção. In: Departament of Animal Reproduction. Vol. Master. University of São Paulo, São Paulo. 2010.
- Van Eerdenburg FJ, Karthaus D, Taverne MA, Merics I, Szenci O. The relationship between estrous behavioral score and time of ovulation in dairy cattle. Journal of Dairy Science. 2002. 85(5): 1150-1156.
- Williams GL, Gazal OS, Guzmán Vega GA, Stanko RL. Mechanisms regulating suckling-mediated anovulation in the cow. Anim. Reprod. Sci. 1996. 42, 289–297.
- Wiltbank JN. Research Needs in Beef Cattle Reproduction. Journal of Animal Science 1970, 31(4):755-762.
- Wiltbank MC, Sartori R, Herlihy MM, Vasconcelos JL, Nascimento AB, Souza AH, Ayres H, Cunha AP, Keskin A, Guenther JN, Gumen A.. Managing the dominant follicle in lactating dairy cows. Theriogenology 2011, 76(9):1568-1582.