VOL 3 No 2 de 2019, Revista Ecuatoriana de Ciencia Animal, ISSN 2602-8220

Precision reproduction on dairy cattle (Reproducción de precisión en ganado lechero)[+].

Jéssica Nora Drum[1]; Roberto Sartori[1;] Leonardo de França e Melo[2*]

[1]**Department of Animal Science, ESALQ, University of São Paulo (USP), Piracicaba, SP, 13418-900, Brazil**

[2]**GENEAL – Animal genetics and biotechnology – Uberaba, MG, 38038-050, Brazil**

***Corresponding author:** leonardofmelo@hotmail.com

[+]**Nota del Editor:** Se respetó la versión original de la conferencia en idioma inglés.

Abstract

The technology is now an days an important tool for many fields. A good use of technology is capable of helping dairy farmers to produce more and better, hence increase the incomes. This good use is described as precision dairy farming. Reproduction is one of the most important areas in the farm. Dairy farmers need to have the cows becoming pregnant and calving in order to keep producing and selling milk. A smart use of monitoring indexes on reproductive management can lead to the greater rates. One of the most important rates is pregnancy rate (PR). There are many factors that can influence PR in dairy cows. Some of this factors are body condition score (BCS) at calving, loss of BCS after calving, infections and uterine involution, anovular condition, heat stress, estrous detection efficiency and use of manipulation of estrous cycle using hormones, as in fixed-time artificial insemination (FTAI). Currently there are many studies in this topics with alternatives to improve the herd reproductive management and work around these problems that will be suggested in this review. Some of this alternatives are: the intensification of reproductive management to increase number of animals inseminated (service rate - SR); use of FTAI protocols to synchronize cows and increase pregnancy per artificial insemination (P/AI), prevent health problems and a good management of nutrition especially during transition period. Furthermore, all of this options are affordable, when the incomes that they provided are taking in consideration.

Keywords: precision dairy farming, pregnant cows, reproductive management, body condition score, anovulation condition, heat stress, estrous detection efficiency.

Resumen

La tecnología es hoy en día una herramienta importante para muchos campos. Un buen uso de la tecnología es capaz de ayudar a los productores de leche a producir más y mejor, por lo tanto, aumentar los ingresos. Este buen uso es descrito como lechería de precisión. La reproducción es una de las áreas más importantes de la finca. Los productores de leche necesitan que las vacas se queden embarazadas y paren para poder seguir produciendo y vendiendo leche. Un uso inteligente de los índices de monitoreo en la gestión reproductiva puede llevar a tasas más altas. Una de las tasas más importantes es la tasa de embarazo (RP). Hay muchos factores que pueden influir en las relaciones públicas en las vacas lecheras. Algunos de estos factores son la puntuación de la condición corporal (BCS) al momento del parto, la pérdida de BCS después del parto, las infecciones y la involución uterina, la condición anovular, el estrés por calor, la eficiencia de detección de estro y el uso de la manipulación del ciclo estral utilizando hormonas, como en el tiempo fijo. Inseminación (ALCA). Actualmente hay muchos estudios en este tema con alternativas para mejorar el manejo reproductivo del hato y solucionar estos problemas que se sugerirán en esta revisión. Algunas de estas alternativas son: la intensificación del manejo reproductivo para aumentar el número de animales inseminados (tasa de servicio - SR); el uso de los protocolos FTAI para sincronizar las vacas y aumentar el embarazo por inseminación artificial (P / AI), prevenir problemas de salud y un buen manejo de la nutrición, especialmente durante el período de transición. Además, todas estas opciones son asequibles, cuando los ingresos que proporcionaron se toman en consideración.

Palabras claves: ganadería lechera de precisión, vacas preñadas, manejo reproductivo, puntaje de condición corporal, condición de anovulación, estrés por calor, eficiencia de detección de estro.

Introduction

Precision Dairy Farming is the use of technologies to measure physiological, behavioral, and production indicators on individual animals to improve management strategies and farm performance. The main objectives of Precision Dairy Farming are maximizing individual animal potential, early detection of diseases, and minimizing the use of medication through preventive health measures. Perceived benefits of Precision Dairy Farming technologies include increased efficiency, reduced costs, improved product quality, minimized adverse environmental impacts, and improved animal health and well-being (Bewley, 2010). Ward (1990) listed three benefits to investment in technology: 1) substitutive, replacing human power with machine power, 2) complementary, improving productivity and employee effectiveness through new ways of accomplishing tasks, and 3) innovative, obtaining a competitive edge. In addition to impacts on production, many technologies may also change milk composition, reproductive efficiency, and disease incidences (Galligan and Groenendaal, 2001).

Reproduction can have a multiple impacts on a farm, from altering culling policies, increasing retention of better replacements, moving primiparous cows into a more productive 2nd lactation, and improving milk production (Ribeiro et al., 2012). Culling and replacement policies also have a tremendous impact on profitability of the herd, and both are associated with reproductive efficiency. Improvements in reproduction result in greater flexibility in these policies and allow managers to take programmed decisions based on economic aspects rather than biological considerations (Groenendaal et al., 2004). Reproductive inefficiency increases cost per pregnancy, increases retention of low-producing cows because of their pregnancy status, and reduces the number of replacements, which diminishes the gain in genetic merit of the herd. Maintaining the same replacement pressure when reproduction is poor becomes, in many cases, costly and risky as it requires purchase of heifers that may be of lower genetic merit and results in breaks of biosecurity (Ribeiro et al., 2012).

This review aims to bring up most recent concepts and studies that can be a guide for producers to have better management of reproduction in their farms, keeping in mind the economic impact of new techniques on farm budget. In addition, describe what was already done and what still need to be studied regarding the most important barriers in reproduction of dairy cows.

Overview of reproductive performance in dairy cattle

In order to have a good productive and reproductive performance is necessary to reduce especially the calving interval (CI). The CI can be improved by intensive reproductive management with the cows, through the use of biotechnologies such as artificial insemination (AI). It leads to more cows becoming pregnant sooner after the voluntary waiting period (VWP) and an increase in service rate (SR). Service rate is defined as the percentage of the non-pregnant cows in the farm that are inseminated. When SR is multiplied by conception rate (CR) results in a most complete indexes for evaluating the reproductive efficiency in a dairy farm, the pregnancy rate (PR).

Pregnancy rate is defined as the percentage of non-pregnant cows that become pregnant during each 21-d period. The PR allows herd managers to know how soon cows become pregnant after having a calf. Many reproductive specialists prefer use PR as an indicator of reproductive success because PR is easily defined and available sooner and because non-pregnant cows and SR are factored into its calculation (VanRaden et al., 2004, Norman et al., 2009)

It is been noted that high producing dairy cows have presented a progressive increase in reproductive problems, apparently due to multifactorial causes (Lucy, 2001). The most suitable reason, in which was believed for a long time is the increase in milk production by itself, associated with the increase in feed intake. Multiple studies have demonstrated negative effect of the increase in milk production and reproductive efficiency in dairy cows (Royal et al., 2000, Lucy, 2001, Washburn et al., 2002). The CR during the forties and fifties was over 50% (Barrett and Casida, 1946, Casida, 1961, Mares et al., 1961), approximately 50% in the seventies (Macmillan and Watson, 1975, Spalding et al., 1975, Washburn et al., 2002) and 40% in the nineties (Schmitt et al., 1996, Pursley et al., 1997b, Washburn et al., 2002). Nowadays the CR reported have being under 40% (Negrao et al., 2002, López-Gatius, 2003, Sartori et al., 2006, Vasconcelos et al., 2006). However, this affirmation has been demystified for new data in well-managed large farms.

A personal communication kindly provided by Prof. Dr. Paul Fricke and Milo Wiltbank, related to the Dairy Cattle Research Center of University of Wisconsin, reported great data in reproductive efficiency even in high producing dairy cows. They used data from 538 lactating dairy cows with milk production of 99 lb/day/cow on average (2 times milking) during the year of 2015. The average of P/AI were 47% with SR of 66% and PR 31%, having the first three inseminations from 76 to 176 DIM. This data indicates that is possible have higher production and nevertheless, present great indexes for reproductive performance.

Regarding Brazilian overview of dairy farms, data generated by the GERAR group (Specialized Group in Applied Reproduction to the Herd; created by a partnership between the School of Veterinary Medicine and Animal Science, São Paulo State University in Botucatu, and Zoetis, São Paulo), evaluated data from Brazilian farms. A total of 71,738 cows (42,894 multiparous and 28,844 primiparous), have shown an average of 30% P/AI for multiparous and 35% for primiparous. The same group evaluated PR in dairy farms in all different regions of Brazil. For important regions of milk producers, the PR ranged from 9 to 34%. On the other hand, data from US herds, considering Holstein dairy cows, reported as having 30% P/AI average on first breeding, stable in this value since 1996, being 34% in 2006. Furthermore, in the same year, the PR reported was 24.9% on average (Norman et al., 2009). Since PR depends upon the SR and P/AI, they showed that the factor that can more easily help to improve the PR is SR. In other words, achieve a PR greater than 15%in the farm, is necessary to have at least 50% in SR, even considering the P/AI on average of 30%. The most suitable alternative that have being used to intensify the reproductive management, increasing service rate after partum is the fixed time artificial insemination (FTAI) (Pursley et al., 1995).

Estrous detection in dairy cattle

Duration of the estrous cycle in dairy cattle is directly related to the category (heifers, primiparous and lactating cows) and to the level of milk production. Studies using HeatWatch, which allows continuous estrous detection 24h a day, compared heifers and lactating cows. The authors demonstrated that heifers present more time of estrous behavior than cows (11 vs 7 hours), and looking at the whole picture, 60% of the cows presented less than 8 hours (Nebel et al., 1997). Other studies also showed this same results for cows housed in free stalls (Dransfield et al., 1998, At-Taras and Spahr, 2001) and pasture (Dransfield et al., 1998, Xu et al., 1998).

Later, in a well-designed study, Lopez et al.(2004) evaluated different milk production levels and estrous behavior. Their analyses included simple ovulations (n=350), except first ovulation postpartum and for milk production, was used data from 10 days before estrous. Cows with >39.5 kg/milk/day (high production) presented less time (6.2 vs 10.9 hours) and intensity of estrous (6.3 vs 8.8 mounts) than low production cows (<39.5 kg/milk/day). In addition, low production cows had greater circulating estradiol than high production (8.6 vs 6.5 pg/mL) but smaller ovulatory follicle (17.4 ± 0.2 vs 18.6 ± 0.3 mm). For all this reasons, a reproductive management based on only estrous detection on the first service postpartum can lead to lower SR, not because of human failure in detect the estrous behavior, but because the physiology of high production dairy cows. However, the use of FTAI can help to diminish the effect of the physiology on reproduction efficiency:

The FTAI have been reported as having high ovulation rate at the end of the protocol (78%), and from that group, 49% became pregnant. Furthermore, cows that properly synchronized to the protocol, emerging new follicular wave, regressing the CL before AI and ovulating at the end, had even greater P/AI (56%) (Monteiro Jr et al., 2015a). The P/AI, as one of the factors composing the PR, can impact directly improving this rate. In addition, since the cows are synchronized, not pregnant, they will show estrous before the diagnoses (21 to 23 days after AI) which can be detected and the cow re-inseminated, increasing the SR and decreasing days open.

Anovulatory condition

One major problem in dairy herds is the incidence of cows that have not resumed ovulation by the end of the voluntary waiting period, termed anovular cows. Incidence of anovular cows averages ~24% in US high-producing dairy herds (Bamber et al., 2009, Santos et al., 2009b). Anovular cows have impaired reproductive performance because of reduced insemination risk in herds breeding to estrus and reductions in P/AI and increased pregnancy loss compared with cows in diestrus regardless of the reproductive program used (Santos et al., 2009b). A portion of reduced fertility in anovular cows is attributed to development of the ovulatory follicle under low concentrations of progesterone (Gumen and Wiltbank, 2005).

There are different phenotypes of anovular dairy cattle. The no dominant follicle anovular phenotype, is rarely observed (~1 in 1,000 cows) and is characterized by maximal growth of the largest follicle to a size that is less than deviation (< 8 mm) (Wiltbank et al., 2002, Gumen et al., 2003, Lopez et al., 2005). The small dominant follicle anovular phenotype, is characterized by growth of dominant follicles (>8 mm) but not to ovular size. This resembles prepubertal anovulation (Adams et al., 1994, Evans et al., 1994) and postpartum anovulation in suckled beef cows or undernourished dairy cows (Beam and Butler, 1997, Crowe et al., 1998, Beam and Butler, 1999, Salfen et al., 2001, Evans, 2003). Follicles do not grow to preovulatory size or have insufficient circulating E2 to initiate estrus, GnRH/LH surge, and ovulation. The large anovular follicle phenotype can be classified into two different phenotypes, based on maximal size of the anovular follicles (Wiltbank et al., 2002). Cows with follicular cysts have been discussed for many years and are obvious due to the large diameter of the anovular follicles (>25 mm). The ovaries are not static in cows with follicular cysts and new follicular waves are observed in the presence of these large follicular structures (Cook et al., 1990, Cook et al., 1991, Gumen et al., 2002, Gumen and Wiltbank, 2002). The other type of large anovular follicle phenotype is characterized by growth of an ovulatory size follicle (generally 18-22 mm), high circulating E2, but lack of ovulation (Gumen and Wiltbank, 2002, Wiltbank et al., 2002, Gumen et al., 2003)

A study that evaluated prevalence and heritability of anovulation using data from 13 different studies with a total of 5,818 lactating dairy cows (Bamber et al., 2009), found that incidence of anovulation at ~65 days after calving was 23.3% using transrectal ultrasound of ovaries and measurements of circulating P4. Heritability was moderate (0.160 to 0.192, according to model) consistent with another large (3,282 records) study (0.16; (Royal et al., 2002)). Although body condition score (BCS) was not found to be a good diagnostic for anovulation, there was a modest phenotypic correlation (-0.192) between BCS and anovulation (Bamber et al., 2009). In most studies, the relationship between milk production and anovulation was small or insignificant (Wiltbank et al., 2002, Lopez et al., 2005, Bamber et al., 2009, Santos et al., 2009b).

Fertility is much lower in lactating cows (P/AI of 25-40%) than heifers (P/AI of 60-65%) or non-lactating cows (60-65%)(Lucy, 2001, Sartori et al., 2002, Wiltbank et al., 2011). Programs that synchronize ovulation and allow timed AI have been developed to improve insemination rates. In the early studies of Ovsynch it was observed that it increased service rate but did not alter P/AI (Pursley et al., 1995, Pursley et al., 1997a, Pursley et al., 1997b). A recent systematic review of the literature with 71 comparisons in 53 research papers (Rabiee et al., 2005) concluded the P/AI obtained following synchronized estrus with prostaglandin or a combination of GnRH and prostaglandin were comparable to those using timed AI following Ovsynch. These findings show that FTAI can benefit dairy operations by allowing more cows to be inseminated using timed AI without compromising P/AI.

A study performed in a large farm in Brazil evaluated incidence and risk factors associated with anovulation in lactating dairy cows (Monteiro Jr et al., 2017). Holstein cows (Primiparous = 357 and multiparous = 585), producing 43.6 ± 11.0 kg/d of milk, had 28.5% (268/942) reported as incidence of anovulation. The distribution of phenotypes was 4.1% (11/268), 27.6% (74/268), 59.7% (160/268), and 8.6% (23/268) for 4 to 8 mm, 9 to 14 mm, 15 to 24 mm, and 25 mm, respectively. An interesting thing, is that there was no difference in pregnancy per AI (P/AI) on d 60 of cows inseminated after estrus detection between anovular and cyclic cows (16.7% [8/48] vs. 18.1% [62/342], respectively), but a lower proportion of anovular cows was inseminated by estrus detection (27.1% [49/181] vs. 63.5% [344/542]). Nevertheless, when inseminated by FTAI, anovular cows had lower P/AI on d 60 than cyclic cows (16.3% [22/135] vs. 25.6 [50/195]) and, regardless of AI type, anovular cows were inseminated later (73.0 vs. 62.0 DIM) than cyclic cows. This results agreed with the importance of the intensification in reproductive management, which can help to reestablish the ciclicity in cows that would not be able to show estrous by itself.

Body condition effect on conception rate

One of the factors that can influence PR in dairy cattle is the body condition score (BCS) at calving, the loss of BCS on postpartum. It is known that a small number of crossbred cows with lower BCS at calving returned to estrous and had lower fertility after calving (Ruas et al., 2004). Similarly, Holstein cows that lose more BCS on first weeks after partum presented lower reproductive efficiency (Butler and Smith, 1989).

An important evidence that BCS influences P/AI was evidenced by some authors that classified the loss of -0.75 in a one to five-point scale as excessive loss, -0.5 moderate loss, no change and gained BCS as +0.25 (Chebel et al., 2018). They compared from day of dry-off to parturition and described that loss of BCS during the dry period was associated with reduced likelihood of pregnancy after the first and second postpartum inseminations. In addition, loss of BCS during the dry period was a predisposing factor associated with health disorder, while cows that gained had greater yield of milk, fat and protein, but reduced somatic cells in subsequent lactation.

A recent study performed in Brazil confirmed this evidences (Barletta et al., 2017). Using 232 lactating Holstein cows in a retrospective cohort study. Cows were assessed for BCS at specific days in relation to calving (-21, -7, 7 and 21) and were grouped according to changes in BCS (lost, maintained and gained). They reported that changes in BCS affected ($P<0.01$) P/AI, days to first ovulation, and percentage of cyclic cows at 50 DIM. At 30 after TAI, P/AI was lower for cows that lost BCS (d30 = 18%, 21/115) and maintained (33%, 26/80) comparing to cows that gained (47%, 32/68). The percentage of cows cycling at 50 DIM also differed among experimental groups, and was greatest for cows that gained BCS (100%; 69/69), intermediate for cows that maintained BCS (94.4%; 51/54), and least for cows that lost BCS (81.1%;99/122). Nevertheless, days in milk at first postpartum ovulation was lower for cows that gained BCS, intermediate for cows that maintained BCS, and greater for cows that lost BCS (Barletta et al., 2017).

Other previous studies in United States agreed with this data. Carvalho et al. (2014) retrospectively analyzed the relationship between energy status and fertility in dairy cattle was compared near AI, early post-partum changes in BCS and postpartum changes in body weight (BW). Regarding near AI, most cows (93%) were cycling at initiation of the breeding Ovsynch protocol (first GnRH injection) at 53 ± 3 DIM. A lower P/AI was found in cows with lower (≤2.50) versus higher (≥2.75) BCS (40.4 vs. 49.2%).

The second experiment from the same study used lactating cows from 2 commercial dairies. The BCS change was evaluated from calving until the third week postpartum. Overall, P/AI at 70-d pregnancy diagnosis differed dramatically by BCS change and was least for cows that lost BCS (22.8%, 180/789), intermediate for cows that maintained (36.0%, 243/675), and greatest for cows that gained (78.3%, 331/423). Interestingly, in the third experiment, evaluating BW from first to ninth, cows that most lose weight presented more degenerated embryos.

Thus the nutrition management of cows on dry period and immediately post-partum should have an extra care, in order to have cows calving with adequate BCS in order to maintain as much as possible on post-partum.

Diseases influencing the conception rate

Another strategy of management during peri-partum should focused on reduce the cows stress. The increase in stress levels during this period is positive correlated with the incidence of post-partum diseases such as retained fetal membranes.

A sharp increase in nutrient requirements generally occurs at the onset of lactation, when feed intake is usually depressed, which causes extensive mobilization of body tissues, particularly body fat, but also AA, minerals, and vitamins (Santos et al., 2011). Despite orchestrated homeostatic controls and homeorhetic adjustments to handle with the changes in metabolism caused by milk production, 40 to 70% of dairy cows across different levels of milk production, breeds, and management systems develop metabolic or infectious diseases in the first months of lactation (Santos et al., 2011, Ribeiro et al., 2013).

Ribeiro et al (2013) demonstrated that clinical and subclinical diseases had additive negative effects on reproduction, delaying resumption of estrous cyclicity and reducing pregnancy per AI (P/AI). Occurrence of multiple diseases further reduced reproductive efficiency compared with a single disease. Individually, subclinical hypocalcemia, elevated NEFA concentration, metritis, and respiratory and digestive problems reduced estrous cyclicity by d 49 postpartum. A Brazilian study corroborate this data, showing that healthy cows where less reported as developing anovular condition, while one disease had intermediate incidence and multiple diseases had much greater number of anovular cows (Monteiro Jr et al., 2017).

Many other studies have reported that health problems are directly associated to BCS changes before and after calving (Barletta et al., 2017, Chebel et al., 2018). Recently in an experiment designed to evaluate BCS during transition period in lactating dairy cows, besides having low P/AI, authors demonstrated that cows which lost BCS during this period had more health events, than cows that gained or maintained BCS (Chebel et al., 2018). Additionally, the same authors show that loss of BCS during the dry period is associated with greater likelihood of treatment with antimicrobials, anti-inflammatories, and supportive therapy.

Altogether, these studies demonstrated that inflammatory disease before breeding reduced fertilization of oocytes and development to morula, and impaired early conceptus development to elongation stages and secretion of IFN-τ in the uterine lumen. Diseases caused inflammation-like changes in transcriptome of conceptus cells, increased risk of pregnancy loss, and reduced pregnancy or calving per breeding. Moreover, the effects on reproduction were independent of cyclic status before synchronization of the estrous cycle and body condition score at breeding, which all had additive negative effects on fertility of dairy cows. Occurrence of disease at preantral or at antral stages of ovulatory follicle development had similar detrimental effects on pregnancy results. The carryover effects of diseases on developmental biology might last longer than 4 mo. Reduced oocyte competence is a likely reason for carryover effects of diseases on developmental biology, but impaired uterine environment was also shown to be involved. (Santos et al., 2011)

Heat stress and fertility

Another factor that may influence the P/AI, hence the reproductive efficiency in dairy cattle is the heat stress. Lactating dairy cows have increased metabolism because of milk production that decreases the ability to dissipate heat (Kadzere et al., 2002). Oocytes and embryos at early stages are extremely sensitive to heat stress and the negative effects of high milk production on oocyte quality, fertilization, and early embryonic development are exacerbated by heat stress (Hansen and Arechiga, 1999).

High environmental temperatures reduce the rate at which embryos progress during the development period (Ealy et al., 1993). Embryos 3 d after conception and older are less sensitive to heat stress (Ealy et al., 1993, Hansen and Arechiga, 1999).

Sartori et al. (2002) reported that lactating cows are affected by environmental temperature more than heifers. The average maximum and minimum ambient temperatures were higher and lower, respectively, at the heifer facility than at the lactating cow stanchion barn. In spite of the higher maximum ambient temperature, heifers had lower ($P<0.05$) body temperature (38.7±0.01; ranging from 37.7 to 40.2°C), than lactating cows (39.3±0.03; ranging from 38.0 to 41.7°C). Lactating cows had a greater ($P<0.05$) increase in body temperature in response to increases in environmental temperature than was observed in heifers. During winter, a sample of cows (15 dry cows and 23 lactating cows) was used to assess rectal temperature at the time of embryo collection. Dry cows had a slightly lower ($P<0.05$) body temperature (38.6±0.07; ranging from 38.2 to 39.2°C) than lactating cows (38.8±0.04; ranging from 38.5to 39.1°C). They also recovered embryos and oocytes from Holstein cows and heifers during the summer, 6 days after observation of estrus, and verified that the fertilization rate was greater in heifers than in lactating cows. The percentage of good quality embryos was also greater in heifers than in lactating cows. Differences in fertilization rate between lactating and non-lactating cows in winter were not found but the percentage of good quality embryos was greater in non-lactating cows than in lactating cows. Another group studied the effect of body temperature on day 7 after AI on the probability of conception, determined on d28 and corroborate previous data. High body temperature on d7 decreased the probability of conception determined on d 28. The BT on d 14 tough, did not influence conception determined on d28 (Demetrio et al., 2007).

American studies indicated this effect during the whole year, when for all dairy breeds, fertility is best following fall calvings and poorest following spring calvings in United States (VanRaden et al., 2004). Other studies in US have also reported that fewer cows express estrus or conceive during hot summer months (De Rensis and Scaramuzzi, 2003). In addition, season effects were largest for Holsteins and for the Southeast region of United States (VanRaden et al., 2004). Other data in Holstein cows also showed that spring calvings in the southeastern United States result in many more days open (Oseni et al., 2003).

Besides the importance of intensification in reproductive management, higher efficiency is not possible without looking at the big picture. This data reinforced the importance of a good environment focused in thermal control especially during hot season.

Benefits and expenses of reproductive management intensification

Few studies evaluated the economic benefits of different AI programs in lactating dairy herds (Tenhagen et al., 2004, Giordano et al., 2011). Tenhagen et al. (2004) demonstrated that incorporation of timed AI programs such as Ovsynch improved reproductive performance and resulted in economic advantage over only estrous detection when the efficiency of detection of estrus was low. Giordano et al. (2011) evaluated three reproductive programs for lactating dairy cows: AI based on detection of estrus, the double Ovsynch program for first AI followed by resynchronization of nonpregnant cows with Ovsynch starting on day 32 after the previous AI, and the double Ovsynch program for first and subsequent AI. Although the timed AI programs were $17 and $21, respectively, more expensive/cow/yr to implement than the estrous detection program, they resulted in $45 and $69 more income per cow/yr, respectively.

However, fertility and reproductive performance in timed AI programs are not always superior to that of cows inseminated at detected estrus (Santos et al., 2004, Tenhagen et al., 2004, Santos et al., 2009a, Chebel and Santos, 2010). Therefore, it is important to consider which timed AI program to use and select the one that offers the highest fertility when detection of estrus is completely eliminated (Giordano et al., 2011).

Ribeiro et al (2012), compared many types of reproductive management in United States farms, varying in accuracy and intensification of the management. They were: 1) detection of estrus at 40% with 85% accuracy; 2) detection of estrus at 40% with 95% accuracy; 3) detection of estrus at 60% with 85% accuracy; 4) detection of estrus at 60% with 95% accuracy; 5) timed AI for all AI with 85% compliance of treatments; 6) timed AI for all AI with 95% compliance of treatments; 7) timed AI for first AI with 85% compliance of treatments followed by detection of estrus at 40% with 85% accuracy; 8) timed AI for first AI with 95% compliance of treatments followed by detection of estrus at 40% with 85% accuracy; 9) timed AI for first AI with 85% compliance of treatments followed by detection of estrus at 60% with 85% accuracy; and 10) timed AI for first AI with 95% compliance of treatments followed by detection of estrus at 60% with 95% accuracy. Under the assumptions of Galvão et al. (2013), the highest 21-day cycle pregnancy rate was obtained when cows were subjected to program 10 timed AI for first AI with 95% compliance of treatments followed by detection of estrus at 60% with 95% accuracy. This same program resulted in the shortest median days (113) to pregnancy and the greatest profit per cow/yr with both milk price scenarios, $0.33/kg of milk (profit of $375/cow) or $0.44/kg of milk (profit of $1,616/cow).

In order to evaluate the impact of the intensive use of fixed time artificial insemination (FTAI) on reproductive efficiency in a dairy herd in São Paulo State, Brazil, Monteiro Jr (2015b) analyzed 4512 artificial inseminations (AI; 1688 in primiparous and 2824 in multiparous cows) performed between 2009 and 2014. These data were from lactating dairy cows, managed in a free stall system with average production of 35.4±9.4 kg of milk/d. For analysis, two groups were established based on the reproductive management strategy: Non-Intensive (2009-2011), where cows were treated with two applications of PGF2α at 40±7 and 54±7 days in milk (DIM), and on 73±7 DIM cows were subjected to FTAI; and Intensive (2012-2013), in which cows received PGF2α (at 40±3 DIM), and after 14 d (54±3 DIM) were subjected to the FTAI. In both groups, after the VWP (40 DIM), cows observed in estrus were inseminated. For the N-INT group pregnancy diagnosis was conducted every 14 d, and for the INT, it was done every 7 d. The main FTAI protocol used during the period of the study was the following. D-10: Progesterone insert + 2 mg estradiol benzoate (EB) or 100 µg GnRH, D-3: 500 µg cloprostenol sodium, D-2: P4 insert removal + 500 µg cloprostenol sodium + 1.0 mg estradiol cypionate (ECP), D0: FTAI (Melo et al., 2016). When reproductive management was intensified, the proportion of cows inseminated by FTAI increased ($P < 0.01$) from 29.1% (559/1920) to 56.9% (1474/2592), and cows were inseminated earlier. Data from a survival analysis showed that after intensifying the use of FTAI, cows were inseminated for the first time earlier ($P < 0.01$) and became pregnant sooner ($P < 0.01$) (Monteiro Jr et al., 2015b, Sartori et al., 2016).

Conclusion

In conclusion, there are many problems impairing reproductive performance in dairy farms and some of them are inherent of the high producing cows physiology. Although, many of this problems have been extensively studied and can be prevented and bypassed by constant monitoring and accuracy of performing the reproductive management. Besides all the technology developed for FTAI protocols, the estrous detection should not be discarded, because when it is well performed, can decrease costs and increase service rate. However, a good management of nutrition and monitoring of the health of the animals is crucial to achieve high pregnancy rates. The ability of solve problems in the farm is the real management using dairy precision technology.

REFERENCES

Abeygunawardena, H. and C. M. B. Dematawewa. 2004. Pre-pubertal and postpartum anestrus in tropical Zebu cattle. Animal Reproduction Science 82:373-387.

Adams, G. P., A. C. O. Evans, and N. C. Rawlings. 1994. Follicular waves and circulating gonadotropins in 8-month-old prepubertal heifers. J Reprod Fert 100:27-33.

At-Taras, E. and S. Spahr. 2001. Detection and characterization of estrus in dairy cattle with an electronic heatmount detector and an electronic activity tag. Journal of Dairy Science 84(4):792-798.

Bamber, R. L., G. E. Shook, M. C. Wiltbank, J. E. P. Santos, and P. M. Fricke. 2009. Genetic parameters for anovulation and pregnancy loss in dairy cattle. J. Dairy Sci. 92(11):5739- 5753.

Barletta, R., M. Maturana Filho, P. Carvalho, T. Del Valle, A. Netto, F. Rennó, R. Mingoti, J. Gandra, G. Mourão, and P. Fricke. 2017. Association of changes among body condition score during the transition period with NEFA and BHBA concentrations, milk production, fertility, and health of Holstein cows. Theriogenology 104:30-36.

Barrett, G. and L. Casida. 1946. Time of insemination and conception rate in artificial breeding. Pages 556-557 in Proc. Journal of Dairy Science. Amer Dairy Science Assoc 1111 N Dunlap Ave, Savoy, Il 61874.

Beam, S. W. and W. R. Butler. 1997. Energy balance and ovarian follicle development prior to the first ovulation postpartum in dairy cows receiving three levels of dietary fat. Biol Reprod 56:133-142.

Beam, S. W. and W. R. Butler. 1999. Effects of energy balance on follicular development and first ovulation in postpartum dairy cows. J Reprod Fert 54:411-424.

Bewley, J. 2010. Precision dairy farming: advanced analysis solutions for future profitability. Pages 2-5 in Proc. Proceedings of the first North American conference on precision dairy management, Toronto, Canada.

Butler, W. and R. Smith. 1989. Interrelationships between energy balance and postpartum reproductive function in dairy cattle. Journal of dairy science 72(3):767-783.

Carvalho, P. D., A. H. Souza, M. C. Amundson, K. S. Hackbart, M. J. Fuenzalida, M. M. Herlihy, H. Ayres, A. R. Dresch, L. M. Vieira, J. N. Guenther, R. R. Grummer, P. M. Fricke, R. D. Shaver, and M. C. Wiltbank. 2014. Relationships between fertility and postpartum changes in body condition and body weight in lactating dairy cows. Journal of Dairy Science 97(6):3666-3683.

Casida, L. 1961. Present status of the repeat-breeder cow problem. Journal of Dairy Science 44(12):2323-2329.

Chebel, R. C., L. G. Mendonça, and P. S. Baruselli. 2018. Association between body condition score change during the dry period and postpartum health and performance. Journal of dairy science 101(5):4595-4614.

Chebel, R. C. and J. E. P. Santos. 2010. Effect of inseminating cows in estrus following a presynchronization protocol on reproductive and lactation performances. Journal of Dairy Science 93(10):4632-4643.

Cook, D. L., J. R. Parfet, C. A. Smith, G. E. Moss, R. S. Youngquist, and H. A. Garverick. 1991. Secretory patterns of LH and FSH during development and hypothalamic and hypophyseal characteristics following development of steroid-induced ovarian follicular cysts in dairy cattle. J Reprod Fertil 91(1):19-28.

Cook, D. L., C. A. Smith, J. R. Parfet, R. S. Youngquist, E. M. Brown, and H. A. Garverick. 1990. Fate and turnover of ovarian follicular cysts in dairy cattle. J Reprod Fertil 90(1):37-46.

Crowe, M. A., V. Padmanabhan, M. Mihm, I. Z. Beitins, and J. F. Roche. 1998. Resumption of follicular waves in beef cows is not associated with periparturient changes in follicle- stimulating hormone heterogeneity despite major changes in steroid and luteinizing hormone concentrations. Biol Reprod 58:1445-1450.

De Rensis, F. and R. J. Scaramuzzi. 2003. Heat stress and seasonal effects on reproduction in the dairy cow—a review. Theriogenology 60(6):1139-1151.

Demetrio, D. G. B., R. M. Santos, C. G. B. Demetrio, and J. L. M. Vasconcelos. 2007. Factors affecting conception rates following artificial insemination or embryo transfer in lactating holstein cows. Journal of Dairy Science 90(11):5073-5082.

Dransfield, M., R. Nebel, R. Pearson, and L. Warnick. 1998. Timing of insemination for dairy cows identified in estrus by a radiotelemetric estrus detection system. Journal of dairy science 81(7):1874-1882.

Ealy, A. D., M. Drost, and P. J. Hansen. 1993. Developmental changes in embryonic resistance to adverse effects of maternal heat-stress in cows. Journal of Dairy Science 76(10):2899- 2905.

Evans, A. C. O. 2003. Characteristics of ovarian follicle development in domestic animals. Reprod. Domest. Anim. 38(4):240-246.

Evans, A. C. O., G. P. Adams, and N. C. Rawlings. 1994. Endocrine and ovarian follicular changes leading up to the first ovulation in prepubertal heifers. J Reprod Fert 100:187- 194.

Galligan, D. and H. Groenendaal. 2001. Economic concepts in the valuation of" products" used in dairy production including a real option's approach. Pages 233-245 in Proc. 36th Annual Pacific Northwest Animal Nutrition Conference, Boise, Idaho.

Galvão, K., P. Federico, A. De Vries, and G. M. Schuenemann. 2013. Economic comparison of reproductive programs for dairy herds using estrus detection, timed artificial insemination, or a combination. Journal of dairy science 96(4):2681-2693.

Giordano, J. O., P. M. Fricke, M. C. Wiltbank, and V. E. Cabrera. 2011. An economic decision- making support system for selection of reproductive management programs on dairy farms. Journal of Dairy Science 94(12):6216-6232.

Groenendaal, H., D. Galligan, and H. Mulder. 2004. An economic spreadsheet model to determine optimal breeding and replacement decisions for dairy cattle. Journal of dairy science 87(7):2146-2157.

Gumen, A., J. N. Guenther, and M. C. Wiltbank. 2003. Follicular size and response to Ovsynch versus detection of estrus in anovular and ovular lactating dairy cows. J. Dairy Sci. 86(10):3184-3194.

Gumen, A., R. Sartori, F. M. J. Costa, and M. C. Wiltbank. 2002. A GnRH/LH surge without subsequent progesterone exposure can induce development of follicular cysts. Journal of Dairy Science 85(1):43-50.

Gumen, A. and M. C. Wiltbank. 2002. An alteration in the hypothalamic action of estradiol due to lack of progesterone exposure can cause follicular cysts in cattle. Biol. Reprod. 66(6):1689-1695.

Gumen, A. and M. C. Wiltbank. 2005. Follicular cysts occur after a normal estradiol-induced GnRH/LH surge if the corpus hemorrhagicum is removed. Reproduction 129(6):737-745.

Hansen, P. J. and C. F. Arechiga. 1999. Strategies for managing reproduction in the heat-stressed dairy cow. Journal of Animal Science 77:36-50.

Kadzere, C., M. Murphy, N. Silanikove, and E. Maltz. 2002. Heat stress in lactating dairy cows: a review. Livestock production science 77(1):59-91.

López-Gatius, F. 2003. Is fertility declining in dairy cattle?: a retrospective study in northeastern Spain. Theriogenology 60(1):89-99.

Lopez, H., D. Z. Caraviello, L. D. Satter, P. M. Fricke, and M. C. Wiltbank. 2005. Relationship between level of milk production and multiple ovulations in lactating dairy cows. J. Dairy Sci. 88(8):2783-2793.

Lopez, H., L. D. Satter, and M. C. Wiltbank. 2004. Relationship between level of milk production and estrous behavior of lactating dairy cows. Animal Reproduction Science 81(3-4):209-223.

Lucy, M. C. 2001. ADSA Foundation Scholar Award - Reproductive loss in high-producing dairy cattle: Where will it end? Journal of Dairy Science 84(6):1277-1293.

Macmillan, K. and J. Watson. 1975. Fertility differences between groups of sires relative to the stage of oestrus at the time of insemination. Animal Science 21(3):243-249.

Mares, S., A. Menge, W. Tyler, and L. Casida. 1961. Genetic Factoes Affecting Conception Rate and Early Pregnancy Loss in Holstein Cattle. Journal of Dairy Science 44(1):96-103.

Melo, L. F., P. L. J. Monteiro Jr, R. S. Surjus, J. N. Drum, M. C. Wiltbank, and R. Sartori. 2016. Progesterone-based fixed-time artificial insemination protocols for dairy cows: GnRH vs. estradiol benzoate at initiation and estradiol cypionate vs. estradiol benzoate at the end. Journal of Dairy Science In Press.

Monteiro Jr, P. L. J., M. Borsato, F. L. M. Silva, A. B. Prata, M. C. Wiltbank, and R. Sartori. 2015a. Increasing estradiol benzoate, pretreatment with gonadotropin-releasing hormone, and impediments for successful estradiol-based fixed-time artificial insemination protocols in dairy cattle. Journal of Dairy Science 98(6):3826-3839.

Monteiro Jr, P. L. J., B. Gonzales, J. N. Drum, A. B. Prata, S. Soriano, J. E. P. Santos, M. C. Wiltbank, and R. Sartori. 2017. Incidence and risk factors related to anovulation in dairy cows. Journal of Dairy Science 99:505.

Monteiro Jr, P. L. J., J. A. H. Gonzales, B. Gonzales, and R. Sartori. 2015b. Intensification of reproductive management in a dairy herd Animal Reproduction 12(3):649.

Nebel, R. L., S. Jobst, M. Dransfield, S. Pandolfi, and T. Bailey. 1997. Use of radio frequency data communication system, HeatWatch®, to describe behavioral estrus in dairy cattle. J. Dairy Sci 80(Suppl 1):179.

Negrao, S., J. Chiari, D. Demetrio, and C. Rodrigues. 2002. Therapeutic embryo in high production dairy cows with more than three artificial inseminations. Theriogenology 57(1):555-555.

Norman, H. D., J. R. Wright, S. M. Hubbard, R. H. Miller, and J. L. Hutchison. 2009. Reproductive status of Holstein and Jersey cows in the United States. Journal of Dairy Science 92(7):3517-3528.

Oseni, S., I. Misztal, S. Tsuruta, and R. Rekaya. 2003. Seasonality of days open in US Holsteins. Journal of dairy science 86(11):3718-3725.

Pursley, J. R., M. R. Kosorok, and M. C. Wiltbank. 1997a. Reproductive management of lactating dairy cows using synchronization of ovulation. Journal of Dairy Science 80(2):301-306.

Pursley, J. R., M. O. Mee, and M. C. Wiltbank. 1995. Synchronization of ovulation in dairy cows using PGF2alpha and GnRH. Theriogenology 44(7):915-923.

Pursley, J. R., M. C. Wiltbank, J. S. Stevenson, J. S. Ottobre, H. A. Garverick, and L. L. Anderson. 1997b. Pregnancy rates per artificial insemination for cows and heifers inseminated at a synchronized ovulation or synchronized estrus. Journal of Dairy Science 80(2):295-300.

Rabiee, A. R., I. J. Lean, and M. A. Stevenson. 2005. Efficacy of Ovsynch program on reproductive performance in dairy cattle: A meta-analysis. Journal of Dairy Science 88(8):2754-2770.

Ribeiro, E. S., K. N. Galvão, W. W. Thatcher, and J. E. P. Santos. 2012. Economics aspects of applying reproductive technologies to dairy herds. Animal Reproduction 9:370-387.

Ribeiro, E. S., F. S. Lima, L. F. Greco, R. S. Bisinotto, A. P. A. Monteiro, M. Favoreto, H. Ayres, R. S. Marsola, N. Martinez, W. W. Thatcher, and J. E. P. Santos. 2013. Prevalence of periparturient diseases and effects on fertility of seasonally calving grazing dairy cows supplemented with concentrates. Journal of Dairy Science 96(9):5682-5697.

Royal, M., A. Darwash, A. Flint, R. Webb, J. Woolliams, and G. Lamming. 2000. Declining fertility in dairy cattle: changes in traditional and endocrine parameters of fertility. Animal science 70(3):487-501.

Royal, M. D., J. E. Pryce, J. A. Woolliams, and A. P. Flint. 2002. The genetic relationship between commencement of luteal activity and calving interval, body condition score, production, and linear type traits in Holstein-Friesian dairy cattle. J Dairy Sci 85(11):3071-3080.

Ruas, J. R. M., L. e. Borges, and A. M. Neto. 2004. Cria e recria de fêmeas F1: Holandês x Zebu para a produção de leite. Informe Agropecuário 25(221):40-46.

Salfen, B. E., F. N. Kojima, J. F. Bader, M. F. Smith, and H. A. Garverick. 2001. Effect of short-term calf removal at three stages of a follicular wave on fate of a dominant follicle in postpartum beef cows. J. Anim. Sci. 79(10):2688-2697.

Santos, J., R. Bisinotto, E. Ribeiro, F. Lima, L. Greco, C. Staples, W. Thatcher, M. Smith, M. Lucy, and J. Pate. 2011. Applying nutrition and physiology to improve reproduction in dairy cattle. Reproduction in Domestic Ruminants VII:387-403.

Santos, J., H. Rutigliano, and M. Sá Filho. 2009a. Risk factors for resumption of postpartum estrous cycles and embryonic survival in lactating dairy cows. Animal Reproduction Science 110(3):207-221.

Santos, J. E. P., S. O. Juchem, R. L. A. Cerri, K. N. Galvao, R. C. Chebel, W. W. Thatcher, C. S. Dei, and C. R. Bilby. 2004. Effect of bST and reproductive management on reproductive performance of Holstein dairy cows. Journal of Dairy Science 87(4):868-881.

Santos, J. E. P., H. M. Rutigliano, and M. F. S. Filho. 2009b. Risk factors for resumption of postpartum estrous cycles and embryonic survival in lactating dairy cows. Anim. Reprod. Sci. 110(3–4):207-221.

Sartori, R., A. Gumen, J. N. Guenther, A. H. Souza, D. Z. Caraviello, and M. C. Wiltbank. 2006. Comparison of artificial insemination versus embryo transfer in lactating dairy cows. Theriogenology 65(7):1311-1321.

Sartori, R., A. Prata, A. Figueiredo, B. Sanches, G. Pontes, J. Viana, J. Pontes, J. Vasconcelos, M. Pereira, and M. Dode. 2016. Update and overview on assisted reproductive technologies (ARTs) in Brazil. Animal Reproduction 13(3):300-312.

Sartori, R., R. Sartor-Bergfelt, S. A. Mertens, J. N. Guenther, J. J. Parrish, and M. C. Wiltbank. 2002. Fertilization and early embryonic development in heifers and lactating cows in summer and lactating and dry cows in winter. Journal of Dairy Science 85(11):2803- 2812.

Schmitt, E.-P., T. Diaz, M. Drost, and W. Thatcher. 1996. Use of a gonadotropin-releasing hormone agonist or human chorionic gonadotropin for timed insemination in cattle. Journal of Animal Science 74(5):1084-1091.

Spalding, R., R. Everett, and R. Foote. 1975. Fertility in New York artificially inseminated Holstein herds in dairy herd improvement. Journal of Dairy Science 58(5):718-723.

Tenhagen, B.-A., M. Drillich, R. Surholt, and W. Heuwieser. 2004. Comparison of timed AI after synchronized ovulation to AI at estrus: Reproductive and economic considerations. Journal of dairy science 87(1):85-94.

VanRaden, P. M., A. H. Sanders, M. E. Tooker, R. H. Miller, H. D. Norman, M. T. Kuhn, and G. R. Wiggans. 2004. Development of a National Genetic Evaluation for Cow Fertility. Journal of Dairy Science 87(7):2285-2292.

Vasconcelos, J. L. M., D. Demétrio, R. Santos, J. Chiari, C. A. Rodrigues, and O. Sa Filho. 2006. Factors potentially affecting fertility of lactating dairy cow recipients. Theriogenology 65(1):192-200.

Ward, J. M. 1990. A portfolio approach to evaluating information systems investments and setting priorities. Journal of Information Technology 5(4):222-231.

Washburn, S., W. Silvia, C. Brown, B. McDaniel, and A. McAllister. 2002. Trends in reproductive performance in southeastern Holstein and Jersey DHI herds. Journal of Dairy Science 85(1):244-251.

Wiltbank, M. C., A. Gumen, and R. Sartori. 2002. Physiological classification of anovulatory conditions in cattle. Theriogenology 57(1):21-52.

Wiltbank, M. C., R. Sartori, M. M. Herlihy, J. L. M. Vasconcelos, A. B. Nascimento, A. H. Souza, H. Ayres, A. P. Cunha, A. Keskin, J. N. Guenther, and A. Gumen. 2011. Managing the dominant follicle in lactating dairy cows. Theriogenology 76(9):1568-1582.

Xu, Z., D. McKnight, R. Vishwanath, C. Pitt, and L. Burton. 1998. Estrus detection using radiotelemetry or visual observation and tail painting for dairy cows on pasture. Journal of Dairy Science 81(11):2890-2896.