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USE OF REPRODUCTIVE BIOTECHNOLOGIES TO IMPROVE THE FERTILITY OF REPEAT-BREEDER AND HEAT-STRESSED DAIRY COWS

Uso de biotecnologías reproductivas para mejorar la fertilidad de vacas lecheras repetidoras y con estrés por calor

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ABSTRACT

Cows that do not become pregnant during early lactation after successive inseminations are usually classified as repeat-breeder cows. Furthermore, heat stress has a pronounced deleterious effect on fertility in dairy herds throughout the world, especially in hot and humid summer months in tropical and subtropical areas. Studies describes the detrimental effect of heat stress on reproduction, with emphasis on carry over effects of heat stress on oocyte quality, embryo development and P/AI. Additionally, lower fertilization rate is also an important characteristic associated with repeat-breeder cows. In repeat-breeder cows, decreased fertility has been related to a deleterious effect on oocyte quality. Thus, the fertility problems observed in repeat-breeder and heat stress cows may be related to poor oocyte quality associated with a metabolic status. Studies support thar embryo transfer can be a practical and effective solution to achieve pregnancy in repeat-breeder and heat-stressed dairy cows (with reduced oocyte quality and fertility to insemination).

Keywords: repeat-breeder, heat-stressed, fertility, reproductive biotechnologies

RESUMEN

Las vacas que no quedan preñadas durante la lactancia temprana después de sucesivas inseminaciones generalmente se clasifican como vacas repetidoras. Además, el estrés por calor tiene un efecto nocivo pronunciado sobre la fertilidad en los rebaños lecheros en todo el mundo, especialmente en los meses cálidos y húmedos de verano en áreas tropicales y subtropicales. Los estudios describen el efecto perjudicial del estrés por calor en la reproducción, con énfasis en los efectos de arrastre del estrés por calor en la calidad de los ovocitos, el desarrollo del embrión y la P/IA. Además, una baja tasa de fecundación es una característica importante asociada con las vacas repetidoras. En vacas repetidoras, la disminución de la fertilidad se ha relacionado con un efecto nocivo sobre la calidad de los ovocitos. Por lo tanto, los problemas de fertilidad observados en vacas repetidoras y en estrés por calor pueden estar relacionados con una mala calidad de los ovocitos asociada con un estado metabólico. Los estudios respaldan que la transferencia de embriones puede ser una solución práctica y efectiva para lograr la preñez en vacas lecheras repetidoras y estresadas por calor (con calidad de ovocitos y fertilidad reducidas para la inseminación).

Palabras clave: vacas repetidoras, estres por calor, fertilidad, biotecnologías reproductivas

INTRODUCTION

Bos taurus dairy cows have been intensively selected for milk production over the years. The intensity of genetic selection, modernization and consolidation of dairy industry is accompanied by several challenges, including fertility disorders in dairy cows (Lucy, 2001). Also, high producing taurine cows do not have adequate adaptability to tropical climates. Tropical and subtropical climates mainly affect food consumption, milk production and reproductive efficiency of Bos taurus dairy cows (Walsh et al., 2011).

The climate adaptation and production obstacles frequently observed in dairy cows in tropical countries reveal the importance of developing and improving technologies to support productivity and, consequently, profitability of dairy herds. Among the existing technologies, reproductive biotechnologies are highlighted in optimization of production process.

Artificial insemination (AI) is the most used reproductive biotechnology in the world and its application generates great benefits for herds when compared to use of natural service (Lima et al., 2010; Lamb and Mercadante, 2016; Baruselli et al., 2018). This technique allows use of semen from genetically superior bulls, accelerating genetic gain, generating greater economic returns. However, cows selected for high milk production generally have low reproductive efficiency after artificial insemination (Chebel et al., 2004; Baruselli et al., 2017; Cardoso Constantini et al., 2021).

Fertility is multifactorial and can be impaired by several factors, including environment, management, genetics and their interactions (Walsh et al., 2011). Considering fertility of dairy cows in tropical and subtropical climates, we face two main problems: repeat breeder cows and heat-stressed cows. The fertility of dairy cows has been studied for many years in search of strategies that can improve the reproductive efficiency in these animals. These strategies were discussed throughout this review.

FERTILITY OF REPEAT BREEDER COWS

Repeat breeder cows are usually defined as cows that did not become pregnant during early lactation (after 3 or 4 services) without identifying anatomic or infectious anomalies (Ferreira et al., 2011). The causes related to low fertility and service repetitions are still controversial.

Ferreira (2012) carried out a study to compare the fertility to FTAI of Holstein cows in early (n=206) and late lactation (n=230). The animals received the same synchronization protocol and the same batch of proven fertility semen. Cows in early lactation had 100.5 days in milk, 0.8 previous AI services and produced 39.3 Kg of milk/day. Late lactation cows, on the other hand, had more days in milk (339.2 days; $P<0.0001$), more previous AI services (5.8; $P<0.0001$) and lower milk production (27.6 liters/day; $P<0.0001$). The pregnancy rate at 30 days after AI was higher in cows inseminated in early lactation than in late lactation cows (26% vs. 17%; $P=0.03$).

The low fertility of repeat-breeder cows can be associated with high gain in body condition score and establishment of peripheral insulin resistance. Peripheral insulin resistance can be established by reducing tissue sensitivity to respond to physiological insulin concentration (De Azevedo and Coelho, 2016; Baruselli et al., 2016) in cows fed diets with high energy concentration (Sales et al., 2011). Insulin regulates transport of glucose to oocyte and embryo and, in case of alterations in metabolism, cellular apoptosis can be verified (Santos et al., 2008). Several studies induced the establishment of peripheral insulin resistance in dry cows (Rezende et al., 2018), in pregnant cows and in repeat-breeder cows at the end of lactation (Bayeux et al., 2018; Mingoti, 2018; Oliveira et al., 2016). These studies confirmed the establishment of the peripheral insulin resistance after analysis of glucose tolerance test.

Other studies have associated peripheral insulin resistance with poor oocyte quality and impaired early embryonic development (Ferreira, 2012). Lactating cows may be consuming energy beyond requirements. However, cows in late lactation with excessive energy intake showed increased insulin resistance and reduced blastocyst rate compared to cows consuming only adequate amounts of energy (Sales et al., 2015).

Studies have shown that relative and absolute number of mitochondrial DNA (mtDNA) copies were reduced in oocytes recovered from cows at the end of lactation (repeat-breeders cows), suggesting a reduction in oocyte quality (Ferreira, 2012). Furthermore, the expression of mitochondrial-related genes (MTCO1, POLG, POLG2, PPARg, TFAM) were increased in late-lactation cows, suggesting the activation of compensatory mechanisms in response to mitochondrial dysfunction (reduced mtDNA copy number) with the aim of improving generation of energy (ATP) required during early embryonic development. Furthermore, there was a higher proportion of BAX/BCL2 in cows at the end of lactation, indicating apoptosis of oocytes.

Overall, based on the available data, it can be inferred that there is a possible association between reduced oocyte quality and insulin resistance, which is mainly manifested in late lactation repeat-breeder cows.

As an alternative for reproductive management, embryo transfer in repeat-breeder cows was found to have higher pregnancy rates when compared to AI (Rodrigues et al., 2007a; Ferreira et al., 2011). These data support the fact that fertility problems may be associated with oocyte quality and/or failure in early embryonic development. Several studies support the improvement of pregnancy rates in dairy cows when receiving embryo transfer produced in vivo (Rodrigues et al., 2004; Rodrigues et al., 2007a) or in vitro (Scheis et al., 2019; Baruselli et al., 2020) compared to cows receiving AI.

FERTILITY OF DAIRY COWS UNDER HEAT STRESS

Reduced fertility in heat-stressed cows is a multifactorial problem, which hyperthermia affects the cellular function of various tissues of female reproductive tract (Wolfenson et al., 2000; Hansen et al., 2001). Heat stress induces follicular codominance, decreased estrus duration and reduced oocyte competence to develop into a blastocyst (Sartori et al., 2004; de S. Torres-Junior et al., 2008). Furthermore, heat stress compromises follicular dynamics (Badinga et al., 1993) and ability of dominant follicle to exert its dominance (Wolfenson et al., 1995). Oocytes obtained from Holstein cows during the summer have a lower capacity to develop into a blastocyst after in vitro fertilization when compared to oocytes obtained during the winter (Rocha et al., 1998; Al-Katanani et al., 2002; Baruselli et al., 2020).

In a study conducted by our research group, it was shown that number of viable embryos produced in vivo (SOV) was lower during hot season when compared to cold season of the year (Vieira et al., 2014). Furthermore, Ferreira et al. (2011) found that during the warmest season of the year, repeat-breeder cows have low oocyte competence to develop into a blastocyst, decreasing the blastocyst rate compared to cows in peak lactation under the same conditions. However, the heat stress effect was not observed in heifers, demonstrating a possible association between reduced fertility and heat stress according to category.

Ferreira et al. (2016) found that poor oocyte quality during the summer of repeat-breeder cows was associated with lower mitochondrial DNA copy number and higher expression of genes that cause apoptosis.

According to these studies, the hot season of the year can affect folliculogenesis, compromising oocyte quality by direct actions related to temperature elevation (increased respiration rate, skin and rectal temperature) or by changes in follicular function. These studies highlight the negative effects of heat stress on oocyte quality, indicating the importance to establish management strategies to increase the reproductive efficiency of dairy cows under these conditions.

EMBRYO TRANSFER AS A STRATEGY TO IMPROVE FERTILITY OF REPEAT-BREEDER AND HEAT-STRESSED DAIRY COWS

Embryo transfer (ET) is an important reproductive biotechnology used around the world to multiply animals with high merit, accelerating genetic gain of herds (Bo et al., 2006). In recent decades, ET has shown considerable growth, mainly due to scientific and technological advances in development of innovative processes in production of embryos. Currently, in vitro embryo production (IVP) represents 92.1% of embryos produced in Brazil and 66% of embryos produced in the world (Viana et al., 2018; IETS, 2018). Furthermore, the development of technologies for synchronization of follicular growth wave for fixed-time embryo transfer (FTET) has increased the number of recipients able to receive an embryo and has eliminated need for estrus detection (Baruselli et al., 2000; Bo et al., 2002; Baruselli et al., 2010).

Heat stress has a deleterious effect on the fertility of dairy cows worldwide. This fact is particularly important in tropical areas, where summers are hot and humid. Studies prove that ET is an important tool to increase fertility during heat stress by circumventing the damage caused to oocyte and early embryonic development caused by hyperthermia. In a retrospective study by Baruselli et al. (2011), a comparison was made between lactating Holstein cows submitted to AI or ET during summer and winter (Figure 1). It was reported that during HS (spring/summer), the overall conception rate decreased for Holstein cows submitted to either AI or ET (effect of season; P=0.001). However, conception rates were always higher following ET compared with AI (effect of breeding technique; P=0.001), especially during HS (interaction of season and breeding technique; P= 0.003). There was a significant reduction in conception rate of cows inseminated in spring/summer when compared to cows inseminated in autumn/winter. However, this reduction was not significant when ET was used.

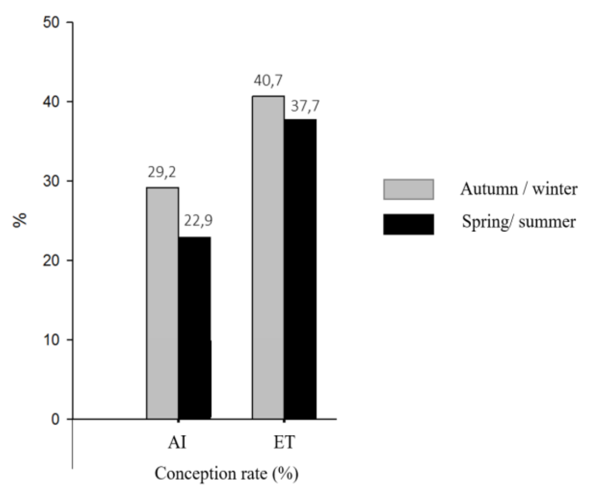

Figure 1. Conception rate of high producing Holstein cows submitted to AI (n=19,112) or ET (n=5,364) during hot (grey bars) and cold (black bars) seasons; adapted from Baruselli et al., 2011.

Therefore, ET is a management tool to maintain high pregnancy rates throughout the year. One reproductive strategy would be to produce embryos in cooler months and use them during periods of heat stress. Many studies have shown and support that ET can improve fertility of dairy cows compared to AI, especially during warm months (Rodrigues et al. 2007b; Chebel et al. 2008; Vasconcelos et al. 2011; Hansen et al. 1999; Rodrigues et al. 2008; Vasconcelos et al. 2011; Hansen et al. 1999; Rodrigues et al. 2008; et al. 2004; Baruselli et al. 2011; Ambrose et al. 1999; Drost et al. 1999).

The TE technique when used in repeat-breeder cows as recipients also resulted in an increase in pregnancy rates when compared to AI, supporting the hypothesis that fertility problems in repeat service cows may be associated with poor oocyte quality and/or failure to early embryonic development. Studies show that cows diagnosed as repeat-breeders have a satisfactory pregnancy rate after embryo transfer (Rodrigues et al. 2004; Baruselli et al. 2011; Ambrose et al. 1999; Drost et al. 1999).

A retrospective analysis of data from a large commercial herd in Brazil carried out by Rodrigues et al. (2007a) was performed using repeat breeder (≥ four services without getting pregnant; Figure 2, B) and non-repeat breeder (Figure 2, A) lactating Holstein cows that were submitted to ET or AI throughout the year. For both categories, pregnancy per ET (P/ET) was higher along the year than P/AI, but the differences were more pronounced in the warmer months (November through April in the southern hemisphere) than in the cooler months of the year.

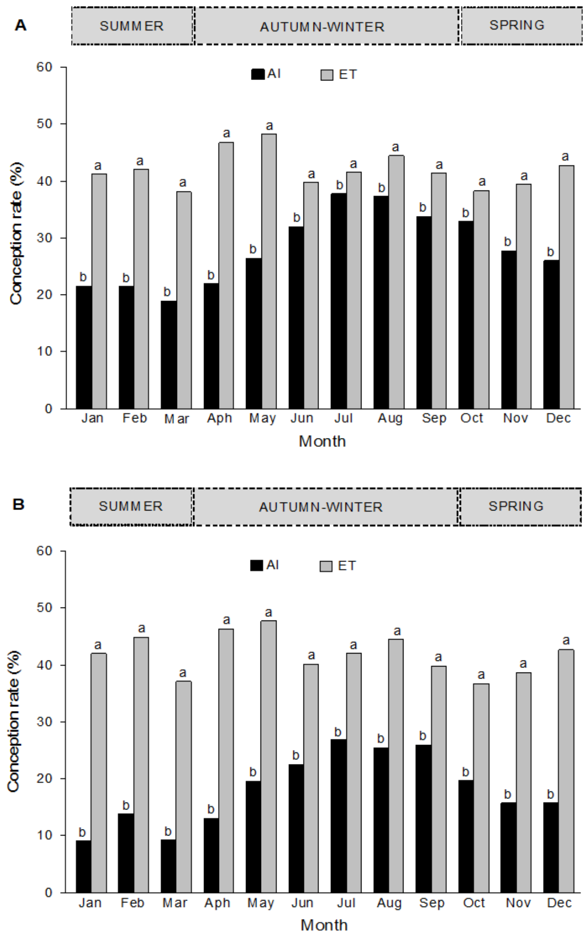

Figure 2. Conception rates (P/AI and P/ET) of lactating Holstein cows submitted to AI (black bars) or embryo transfer (ET; gray bars) throughout the year: (A) non-repeat breeders (AI = 18,568 and ET = 4,871) and (B) repeat breeders (≥4 services; AI = 5,693 and ET = 3,858; adapted from Rodrigues et al. (2007a).

CONCLUSION

In conclusion, although embryo transfer technique is primarily used to multiply animals of high genetic merit, this biotechnology can be used to overcome reproductive problems encountered during heat stress and in s repeat-breeder cows.

Conflicto de intereses

Los autores declaran no tener conflicto de intereses.

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