Use of artificial insemination in dairy herds in Northwestern Rio-grandense, Brazil

Uso de inseminación artificial en rebaños lecheros en el Noroeste Rio-grandense, Brasil

Uso de inseminação artificial em rebanhos leiteiros no Noroeste Rio-grandense, Brasil

Heitor-José Cervo[1,2]; Júlio-Otávio Jardim-Barcellos[1]; Vanessa Peripolli[3]*; Concepta McManus[4].

[1]*Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Brazil.*

[2]*Instituto Federal do Rio Grande do Sul - Campus Sertão, Rio Grande do Sul, Brazil.*

[3]*Instituto Federal Catarinense - Campus Araquari, Santa Catarina, Brazil.*

[4]*Instituto de Biologia, Universidade de Brasília, Distrito Federal, Brazil.*

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Abstract

Background: The use of artificial insemination (AI) in dairy cattle has a direct impact on productivity through genetic improvement and, indirectly, by other technologies that allow for better expression of the genetic potential. **Objective:** To determine the association between the use of AI and other factors on productive performance of dairy cows. **Methods:** The study assessed AI impact on 195 dairy farms through the application of structured questionnaires to farmers. Analysis of variance (GLM) was used to evaluate herd milk production and farm size. Multivariate analysis was performed to observe the degree of association between AI and production. Four clusters were formed according to production traits and farm size. **Results:** Clusters showed high discrimination (90%). Principal factors explained 70% of the variance between clusters. The variables that best explained the variation between clusters were Lactating cows per year, Monthly milk production, Farm area and Total cows. The correspondence analyzes showed that AI use is associated with higher production levels and investment in nutrition, management, genetics, and technology. **Conclusion:** The use of AI enhances production by increasing productivity and enables greater gains per liter of milk marketed.

Keywords: *artificial insemination; cattle farms; cow; dairy cow; dairy farm; dairy cattle; dairy herd; dairy business; farm productivity; farm size; genetic improvement; herd size; insemination; milk; milk price; milk production; multivariate analysis; reproduction; reproductive biotechnologies.*

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***Corresponding author.** Instituto Federal Catarinense - Campus Araquari. Zip Code: 89245-000, Araquari, Santa Catarina, Brazil. Tel.: (47) 3803-7200. E-mail: vanessa.peripolli@hotmail.com

Resumen

Antecedentes: El uso de la inseminación artificial (IA) en ganado lechero impacta directamente sus niveles de producción a través del mejoramiento genético e, indirectamente, a través del uso de otras tecnologías que permiten una mejor expresión del potencial genético. **Objetivo:** Determinar la asociación entre el uso de IA y otros factores en el desempeño productivo de las vacas lecheras. **Métodos:** El estudio se realizó en 195 granjas lecheras para observar el impacto del uso de IA en la productividad mediante la aplicación de cuestionarios estructurados a los granjeros. Se utilizo un análisis de varianza (GLM) para evaluar la producción de leche del rebaño y el tamaño de la granja. Se realizaron análisis multivariados para observar el grado de asociación entre la inseminación artificial y la productividad. Se evaluaron cuatro grupos debido a las características de producción y el tamaño de la granja. **Resultados:** Los grupos mostraron una alta discriminación (90%). Los factores principales explicaron el 70% de la varianza entre grupos. Las variables que mejor explicaron la variación entre grupos fueron: Vacas lactantes por año, Producción mensual de leche, Área de la granja, y Vacas totales. Los análisis de correspondencia mostraron que el uso de IA está asociado con mayores niveles de producción e inversiones en nutrición, gestión, genética y tecnología. **Conclusiones:** El uso de la IA mejora la producción al aumentar la productividad y permite mayores ganancias por litro de leche comercializado.

Palabras clave: *análisis multivariable; biotecnologías reproductivas; granjas de ganado; granja lechera; inseminación; inseminación artificial; leche; mejora genética; negocio lácteo; precio de la leche; producción de leche; productividad agrícola; rebaño lechero; reproducción; tamaño de la granja; tamaño de la manada; vaca; vaca lechera.*

Resumo

Antecedentes: O uso de inseminação artificial (IA) em bovinos leiteiros afeta diretamente os níveis de produção por meio do melhoramento genético e indiretamente pelo uso de outras tecnologias que permitem a melhor expressão do potencial genético. **Objetivo:** Determinar a associação entre o uso de inseminação artificial e outros fatores no desempenho produtivo de vacas leiteiras. **Métodos:** Este estudo foi realizado em 195 fazendas para observar o impacto do uso da IA na produção de gado leiteiro, através da aplicação de questionários estruturados aos produtores de leite. A análise de variância (GLM) foi usada para avaliar a produção de leite do rebanho e o tamanho da fazenda. Análises multivariadas foram realizadas para observar o grau de associação da inseminação artificial com a produção. **Resultados:** Quatro grupos foram formados devido às características de produção e o tamanho da fazenda e apresentaram alta discriminação (90%). Os fatores principais explicaram 70% da variação entre os grupos. As variáveis que melhor explicaram a variação entre os grupos formados foram Vacas em lactação por ano, Produção mensal de leite, Área de criação e Total de vacas. As análises de correspondência mostraram que o uso da IA estar associado a maiores níveis de produção e investimentos em nutrição, manejo, genética e tecnologia. **Conclusões:** O uso da IA melhora a produção, aumentando a produtividade e permite maiores ganhos por litro de leite comercializado.

Palavras-chave: *análise multivariável; biotecnologias reprodutivas; fazendas de gado; fazenda de gado leiteiro; inseminação; inseminação artificial; leite; melhoramento genético; negócio de laticínios; preço do leite; produção de leite; produtividade agrícola; rebanho leiteiro; reprodução; tamanho da fazenda; tamanho do rebanho; vaca; vaca leiteira.*

Introduction

Artificial insemination (AI) is the most successful technology in cattle breeding for improving quality, productivity, and reproductive health of dairy cows (Patel *et al.*, 2017). The two main factors involved are improved reproductive health —especially through control of venereal diseases and genetic improvement in productivity- and reduction in the proportion of lethal genes (Patel *et al.*, 2017). To use this technology the farmer needs adequate structure in terms of nutrition, animal health and record keeping, in addition to properly trained employees who indirectly impact the production level of the herd to adequately express its genetic potential.

The evolution of AI in developed countries led to increased productivity and improved milk quality. The increased use of technologies enhanced global production of cow milk, reaching 659 billion L in 2018 (EMBRAPA, 2018).

Brazil, with 18.6 million of milked dairy cows, is the 4th world largest producer of milk with 34.23 billion L in 2018. Nevertheless, only 6.23% of Brazil's total dairy cattle are inseminated (ASBIA, 2017). This is relatively low compared to developed countries, that largely use more than 60% of AI in their herds (ASBIA, 2017). While the USA average yield is 10,457 L per cow milked/year with 65% of dairy cattle inseminated, Brazil production is 1,600 L per cow milked/year (EMBRAPA, 2018).

The State of Rio Grande do Sul has the highest productivity in Brazil, with 3,240 L per cow/year, is the second largest producer with about 4.6 billion L of milk/year and has the highest use of AI with 13,7% of dairy cattle inseminated. Within states, the Northwestern Rio-grandense mesoregion had the highest milk production in Brazil in 2016, with 3.0 billion L (IBGE, 2012).

Milk production has high socioeconomic impact in the Northwestern Rio-grandense mesoregion. Several studies have shown the benefits of using AI on production (Galvão *et al.*, 2013). Nevertheless, little is known about the relationship between AI use and production in this region. Therefore, the objective of this study was to determine the association between AI use and other factors on the productive performance of dairy cows in the Northwestern Rio-grandense mesoregion of Brazil.

Materials and Methods

This study was approved by the ethics committee of Rio Grande do Sul Federal University under the number 244.299.

Data collection

Data from structured questionnaires to Northwestern Rio-grandense mesoregion milk farmers and information on the number of people trained in AI (NPT) according to the Federal Institute of Rio Grande do Sul (IFRS) were used. Farmers (195) from the 216 municipalities that make up this mesoregion were randomly drawn for analysis and classified according to production activities, capital investment, technology, and use of AI.

Data analysis

All analyzes were performed with the computer program Statistical Analysis System v. 9.3(SAS, Cary, North Carolina, USA). Variables were standardized through the STANDARD procedure, assuming mean zero (0) and variance one (1). Analysis of variance (GLM) was used to evaluate herd size milk production and the size of the farm. The variables used in the analysis were the number of dairy cows (LC), dry cows (DC), calves up to 1 year (C1), males, bulls, working animals (WA), total number of animals (TNA), amount of milk produced per lactating cow (MPC), monthly milk production (MMP), price received per L of milk (PLM), and area for pasture production (area). Means were adjusted by the least squares (LSMEANS) method.

Multivariate analyzes were performed to determine factors that could influence the sources of variation. The FASTCLUS procedure was used to form clusters from production and area for pasture production. A factor analysis was performed to better understand the correlation structure

and sources of variation. In this analysis, the assumption was tested by the KMO orthogonality criterion (Kaiser, 1970). The SMC (squared multiple correlations) option was used to improve the explanation of each factor on the total variance. A scree test was used to establish the minimum number of variables to consider. Canonical variable analysis (CANCORR, CANDISC) was used for testing scenarios to discriminate groups in the dataset. Discriminant analysis (DISCRIM, STEPDISC) was used to see which variables separated the clusters (Lachenbruch, 1997).

For analysis of qualitative variables (nutrition of dairy cattle, management of animals and pastures, capital investment, and reproductive technologies) the results were categorized and used in the CORRESP procedure to show the degree of association with the use of AI and the sources of variation. The area of the farm was set to 1 (up to 40 Ha), 2 (between 40 and 100 Ha) or 3 (over 100 Ha) and the time in the dairy business as 1 (under 5 years), 2 (between 5 and 10 years) or 3 (over 10 years).

Results

Four clusters were formed with production traits and farm size (Table 1). The difference in farms with high production and large area to low production and small size is that they have, on average, 11 times more total animals (total) and lactating cows per year (LC). They also produce 20 times more milk (MMP) and have assigned 44 times higher area devoted to food production for the dairy herd.

Two factors explained 69.76% of the variance between clusters (Figure 1). A positive relationship was observed between production variables and farm size that explains 54.76% of the variation among clusters (Autovector 1). Within this general group there were farms with high productivity (Prod) associated with a greater number of people trained for AI (NPT) and the high price received per L of milk (PLM). These farms were efficient and profitable.

On average, farms were correctly allocated to their clusters at 89.55% average. Clusters 3, 2 and 1 (the second, third and fourth most productive) were discriminated at higher levels (100, 94.44, and 97.12%, respectively). The variables that best explained the variation between clusters were LC, MMP, farm area and total cows, explaining 86.74, 7.66, 6.68, and 5.34% of this variation, respectively. Production best explained the difference among clusters. Cluster 4, the most productive farms, showed some confounding with Cluster 3. Other factors could distinguish them, which are not only associated with production or farm size.

Correspondence analyses showed that higher AI use was associated with higher milk production and factors related to production (Figures 2 to 6). Use of AI was linked to higher productivity (Prod), farm size (area), length of time the farmer is in the dairy business (TDB), and higher price received per L of milk sold (MGI) (Figure 1 and 2). Figure 1 shows that farms in municipalities with the highest number of people trained for AI (NPT) and greatest use of AI receive more per L of milk and have higher productivity (Figure 2).

Table 1. Clusters formed by production traits and farm size.

Cluster	Production and farm SIZE	Frequency	Cows in lactation	Total animals	Production/ year (in L)	Area (in Ha)
1	Low and small	139	11.35	23.85	5,176.35	10.28
2	Low to average and small to medium	36	25.92	48.00	13,337.58	18.33
3	Average and medium to large	11	46.64	80.82	30,145.45	66.36
4	High and large	9	125.56	270.56	102,477.78	450.56

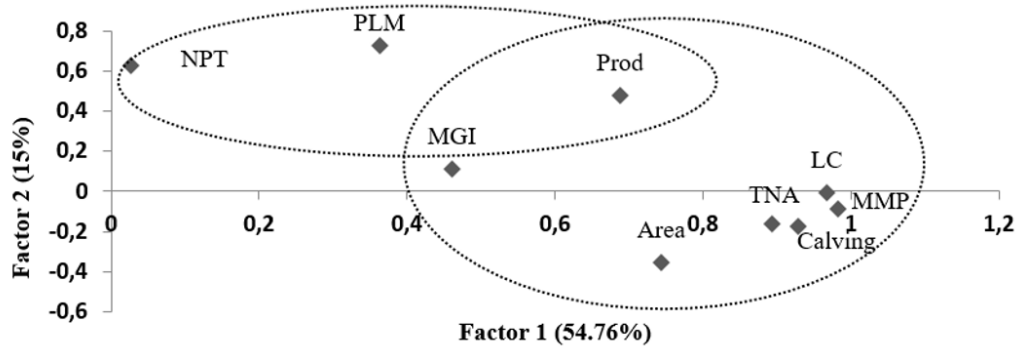

Figure 1. Graphical representation of first two main factors of relationships between herd characteristics in dairy farms in Northwestern Rio-grandense, Brazil.

LC: lactating cows; TNA: total: total number of animals; MMP: monthly milk produced; area: area used for producing food for the cows (Ha); Prod: amount of milk produced per year per lactating cow; PLM: price received per L of milk; MGI: monthly gross income of the farm from milk sales; calving: calving during the year; People trained: support training; NPT: number of people trained in the technique of artificial insemination by the Federal Institute of Rio Grande do Sul (IFRS) during the years 1998-2012.

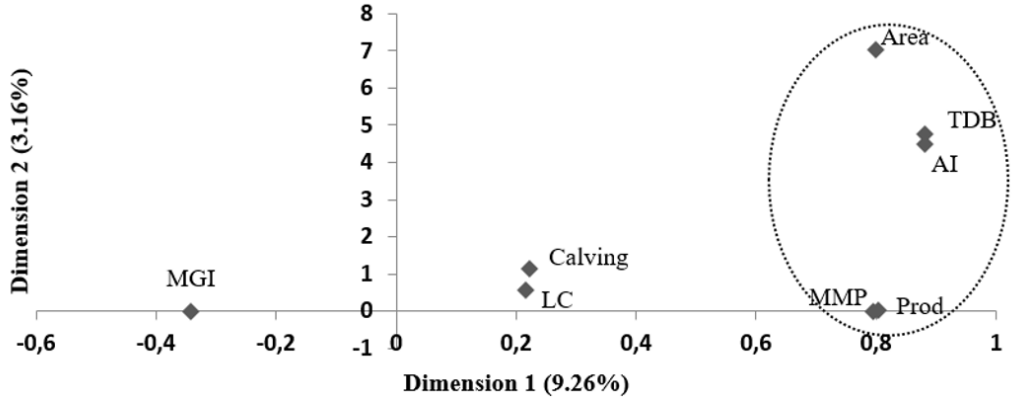

Figure 2. Association between use of artificial insemination, productive factors, and farm size in Northwestern Rio-grandense, Brazil.

AI: use of artificial insemination; Area: farm size (own + land lease); TDB: time in the dairy business; Calving: calving in the year; LC: lactating cows; MMP: price received per L of milk; MGI: monthly gross income received from milk sale; Prod: milk produced per lactating cow/year.

A negative association was observed among AI use and grazing native pasture (Native), use of common salt (Salt) and crop residues (Crop), and positive association with the use of conserved forage (Hay and Silage), concentrates and mineral salt (Mineral) for feeding livestock (Figure 3).

Figure 4 shows outsourcing rearing of replacement animals (Replacement) is associated with selection of animals for higher production (SPI), and a second use of AI.

Figure 5 shows the importance of training farmers in AI technology. Farms from municipalities with the highest number of people trained (NPT) were associated with increased production (LC and Calving), larger investment in area and land, physical (Participates in events and Equipment), institutional (People trained and participates in events) and human (F1, F2, E1, E2, and E3) resources. Secondly, larger farms (area), with better facilities (Buildings), higher number

of equipment, but with lower production (LC and Calving) were associated with the greatest number of people trained in AI. These results show that farms with both high and low production seek AI as an alternative to improve production efficiency.

The association between AI use (Figure 6) with other reproductive biotechnologies (embryo transfer, fixed-time AI, pregnancy diagnosis, and sexed semen) was positive. New biotechnologies may eventually lead to a decrease in the use of AI.

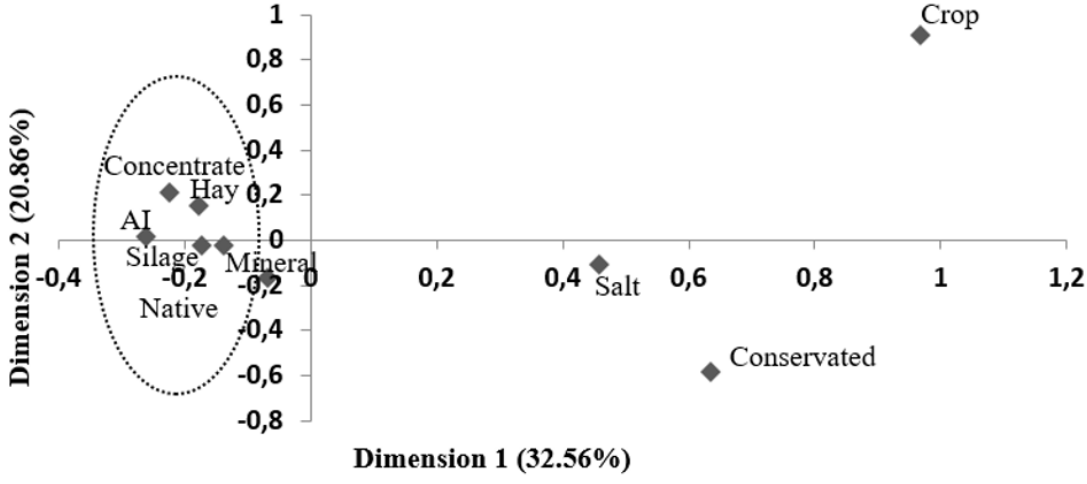

Figure 3. Association of artificial insemination with dairy cattle nutrition in Northwestern Rio-grandense, Brazil.
AI: artificial insemination; Native: grazing native pasture; Cultivated: cultivated pasture; Crop: residue crops; Salt: common salt; Mineral: mineral salt.

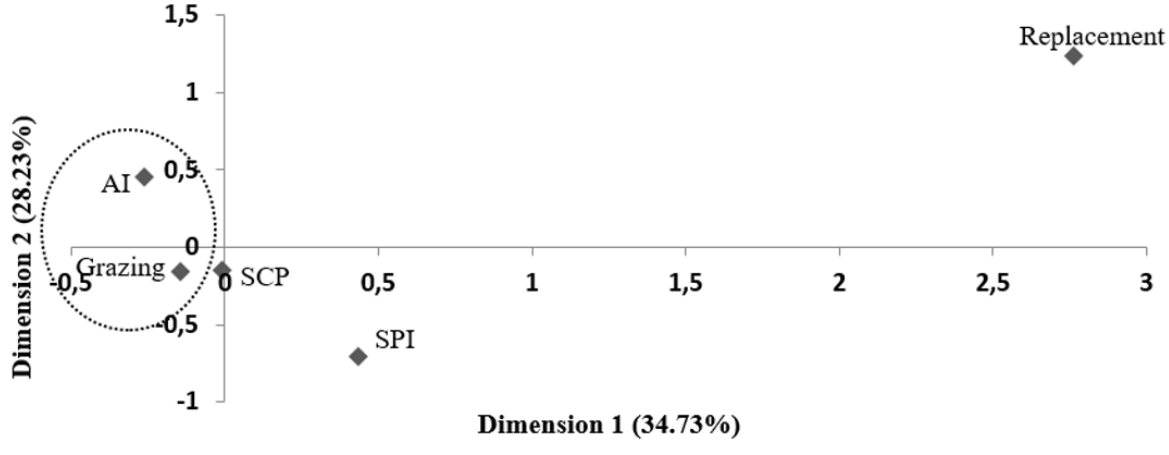

Figure 4. Association between use of artificial insemination and management of animals and pastures in dairy farms in Northwestern Rio-grandense, Brazil.
Replacement: animal replacement; Grazing: rotational grazing; SCP: selection against cows with problems; SPI: selection for production indices; AI: artificial insemination.

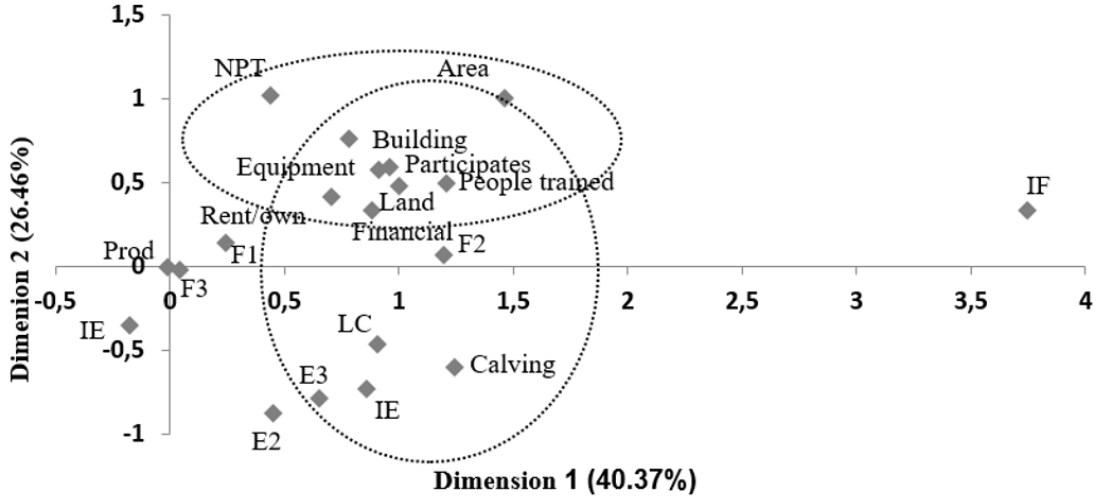

Figure 5. Association between production factors and capital investment in dairy farms in Northwestern Rio-grandense, Brazil.

Calving: calving per year; LC: lactating cows; Prod: milk produced per lactating cow/year; Area: farm size; Ren to/own: either rent or own farm; Land: land value; IE: illiterate employees; E1: employees with 1st degree; E2: employees with 2nd degree; E3: employees with 3rd degree; IF: illiterate family members; F1:family members with 1st degree; F2: family members with 2nd degree; F3: family members with 3rd degree; Financial: financial support; Equipment: type of equipment used on the farm; Building: type of buildings on the farm; Participates: participates in events; People trained: support training; NPT: number of people trained in the technique of artificial insemination by the Federal Institute of Rio Grande do Sul (IFRS) during the years 1998-2012.

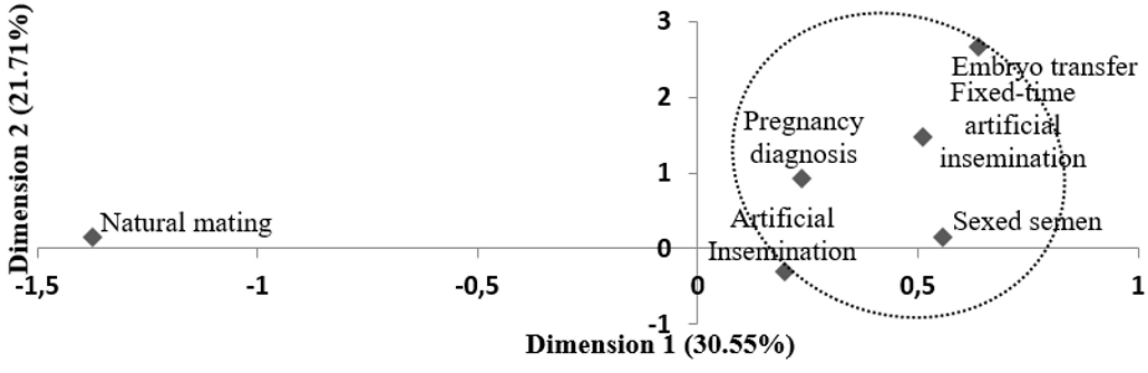

Figure 6. Association of artificial insemination use with other reproductive technologies in dairy herds in Northwestern Rio-grandense, Brazil.

Discussion

Farm efficiency depends on intensification of production processes. Farmers who invest more in technology tend to have large-scale production, receive more per volume produced and achieve higher quality (Cabrera *et al.*, 2010). Farms that invest more in training and knowledge are more likely to use technology, thereby achieving higher production and economic returns (Davis, 2010). Not only access to new technologies, but also to extension services are crucial for productive and economic efficiency.

Similarity in production variables and farm size allowed for high differentiation between clusters. On average, farms were correctly allocated to their clusters at an average of 90%, determining the farms and productions of different size that can be influenced by factors related to the use of technology and process management.

The number of dairy cows is a determining factor for the classification of production systems and use of technologies (Khanal *et al.*, 2010). These results, although discriminate well among clusters for production and farm size, show that there may be other factors such as environmental and socioeconomic differentiation (Liang *et al.*, 2013) which also influence dairy herd production. Other factors may also be important, not only those associated with production levels or farm size. Technologies that minimize the effect of heat stress (Lucy *et al.*, 2011), disease-prevention (Bruijnis *et al.*, 2013), that provide greater efficiency in food utilization (Auldist *et al.*, 2013), and other related management factors and process management (Cabrera *et al.*, 2010) are positively associated with milk production. Reproductive technologies linked to semen (Hansen and Fuquay, 2011) and embryo use (Hasler, 2014) influence production. Farms using AI more intensely tend to have higher technology use, which generate productive and economic impacts (Davis *et al.*, 2010).

As much as 90% of farms use AI in Northwestern Rio-grandense mesoregion, with 49% using it exclusively and 41% using AI and natural breeding in cows returning to estrus. This average is higher than the 14% national estimate (ASBIA, 2017). It is assumed that the use of AI has a positive effect on milk productivity in the Northwestern Rio-grandense mesoregion.

The effect of AI is related to genetic merit of proven parents and passed on to offspring. Genetics to increase productivity, fertility, resistance against diseases that cause involuntary culling (Cummins *et al.*, 2012), or selection to increase milk solids and milk quality increase production efficiency and profitability of dairy farms (Coleman *et al.*, 2010), which agrees with the present study.

Time spent in the dairy business (TDB) leads to improvement of practices related to animal production and management (Costa *et al.*, 2013), constituting a significant factor for productive efficiency. As an example, knowledge about disease transmission and accidents caused by bulls, acquired over the years, determine better results (Patel *et al.*, 2017). Experience with AI brings improvement in handling of equipment and materials, identification of estrus, choice of the ideal moment for insemination, greater ability to perform the technique and better choice of location for semen deposition. This experience can lead to pregnancy levels close to those obtained with natural mating (López-Gatius, 2012).

The importance of nutrition for growth, maintenance, health, reproduction, and gene expression is reflected in productive efficiency (Schütz *et al.*, 2013). Forage stored (hay and silage), concentrates and minerals have great potential to meet animal requirements (Thomas *et al.*, 2013).

Several studies show lower rate of return to estrus and increased fertility, decreased embryonic mortality (Cardoso *et al.*, 2013) and its association with better nutrition so the animals can increase reproductive and productive efficiency.

Increased production efficiency in dairy farming requires investment in technology innovations that allow intensification of milk production (Suplicy

et al., 2012). Hiring expert services or service integration practices is often used by farmers. Outsourcing calf rearing to puberty is a common practice in some dairy farms. The decision of using outsourcing is related to management processes that enhance this activity (Khanal *et al.*, 2010). These services reduce the age at first calving through intensive animal nutrition and improve herd genetics through AI with semen from superior sires (Cummins *et al.*, 2012).

Educational centers have an important role in training people in AI. The IFRS is the only institution in Rio Grande do Sul State approved for ASBIA. Also, greater use of AI is also associated with the participation of farmers in educational events. Dissemination of technologies and their consequences for production can be seen through participation in fairs, field days, seminars, and short courses, and are important to determine the extent that new technologies can be used to obtain the best results. Farmer involvement in the use of instruments that enable them to become efficient ensures greater profitability and quality of life (Davis *et al.*, 2010).

The use of AI in dairy herds determines increased production and higher income (Davis *et al.*, 2010) serving as a basis for developing other biotechnologies. Fixed-time AI has, as main objective, the reduction of calving interval and increased production (Wiltbank and Pursley, 2014). Problems related to silent heats, deficiencies in estrus and anestrous detection -which decrease production- are minimized using this technology (Piccardi *et al.*, 2013). Male calves do not have economic value in dairy herds, so the genetic potential of the dam is reduced. The use of AI with sexed semen allows for greater gene expression by decreasing the time between generations (DeJarnette *et al.*, 2010) as well as increasing production and profitability of dairy farming. The use of early diagnosis of pregnancy brings a quick perception by the farmer of problems that increase the calving interval, such as embryonic mortality, improper time of AI, or insemination technique, as well as metritis and endometritis, endocrine changes, and anatomical defects (Roelofs *et al.*, 2010) allowing farmers to make decisions earlier.

Environmental and productive stress are also causes of embryonic mortality (Berg *et al.*, 2010). The use of embryo transfer (Embryo), while optimizing the use of the female, also becomes a solution for embryonic losses that lead to increased calving interval and decreased production (Thompson *et al.*, 2012). In general, the use of AI in Northwestern Rio-grandense mesoregion is associated not only with increased productivity, but also with the use of other technologies necessary to meet the needs of modern milk production systems.

It can be concluded that the use of artificial insemination is a determinant factor for increased production and milk quality and for greater profitability of production systems in the Northwestern Rio-grandense region, Brazil.

Declarations

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Conflicts of interest

The authors declare they have no conflicts of interest regarding the work presented in this report.

Author contributions

HJC, JOJB, and CM were responsible for the design or conception of the study. HJC administered the project. HJC and CM collected the data. HJC, VP, JOJB, and CM wrote, reviewed, and did a critical reading and editing of the paper.

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