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Genetic Prediction of Holstein Breed Cows in The Semi-Arid Region

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Abstract. Molecular genetic assessments are modern selection tools that provide accurate information to producers seeking to improve the health, well-being, and profitability of their herd. The aim of the present study was to elaborate the genomic profile of Holstein cows from the semiarid region of Pernambuco through the Genomic Predicted Transmission Ability values, to correlate milk production characteristics with conformation and reproduction characteristics, and to evaluate information on carriers for genetic diseases. Thirty-nine Holstein cows were used to obtain the Genomic Predicted Transmission Ability-GPTA, a 12k chip (12 thousand genetic markers – CLARIFIDE®) by Zoetis. The averages of GPTA in this study were higher than those of American average, namely 384 pounds of milk production, 17.9 pounds of fat, and 12.9 pounds of protein. For CCS, females showed moderate susceptibility to mastitis. The volume and fat content were considered the most indicated selection criteria to improve the gains in quantity and concentration of solids in milk. Carriers for VMC and CHD were identified. It appeared that the Holstein herd from the semiarid region presented a genetic profile with the potential to improve the productive characteristics, allowing the identification of animals with genetic anomalies before entering the reproductive phase.

Keywords: Genetic Correlation, GPTA, Haplotypes, Milk production.

Introduction

The Holstein breed is universally known as one with the greatest potential for milk production, so it is the preferred herd in several Brazilian regions, even in places considered inhospitable for a specialized European breed. Currently, Pernambuco has one of the largest herds of the Holstein breed in the North/Northeast of Brazil (Oliveira et al. 2020) which has a unique genetic constitution – the cows are adaptable to the edaphoclimatic conditions of the Agreste Semiarid Region (Araújo et al. 2020).

In addition to reproductive efficiency, milk production is the crucial consideration in dairy breeding programs to give economic return. Although different studies demonstrate antagonistic relationships between production and reproduction characteristics (Jamrozid et al. 2005; Penev et al. 2017) and between production characteristics and milk constituents (Rennó et al. 2003; Sneddon et al. 2015).

Types and conformation characteristics have always been incorporated in the development of genetic evaluations, considering that the strong selection for milk production has harmed some physical aspects of the animals (Degroot et al. 2002), and linear characteristics may directly link to the productive parameters of the herd (Madrid, Echeverri 2014).

The incorporations of genomic evaluations are available on the market and used in various parts of the world; they seek to make predictions related to milk quality, health, and well-being through reliable genetic predictions, which allows the improvement of breeding programs based on herd trends (Miglior et al. 2005).

García-Ruiz et al. (2016) reported that genomic selection (GS) has been the most important and adopted method in the US and reported the impact of this selection in 7 years for dairy cattle, thus demonstrating an increase in the rate of improvement for traits with moderate to low heritability. In the US and Canada, young bulls have been evaluated using genomic information since 2009 (Li et al., 2020).

Genomic tests are a reality in the improvement of dairy herds, with an early evaluation of traits in both females and males, as well as diagnosis of genetic diseases. According to Meydan et al. (2010), genetic diseases affect dairy farming and are associated with decreased reproductive performance, being indirectly linked to reduced productivity of animals. Many countries already include animal health characteristics in their programs to minimize their effects on milk production and cow conformation (Mackey et al., 2007; Berry et al., 2016).

The objective of this work was to elaborate the genomic profile of Holstein cows from the Brazilian semiarid region for a breeding program

Materials and Methods

Experimental Design and Treatment

This study used 39 Holstein cows born between 2009 and 2018 from the herd of the Experimental Station of the Instituto Agronômico de Pernambuco-IPA, municipality of São Bento do Una. The feed consisted mainly of corn silage and sorghum, supplemented with various concentrates according to the cows' average production. The cows were milked twice a day (5:00 am; 2:00 pm) with teat cleaning and pre-and post-dipping application. On the property, since the 1960s, Artificial Insemination has been used as a reproductive biotechnics, importing genetic material from dairy bulls.

Hair samples from the tail of each animal were collected for DNA extraction. GPTAs (Genomic Predicted Transmission Ability) were obtained using a 12k chip (12 thousand genetic markers – CLARIFIDE®) and the genotyping was carried out by Zoetis company. As a basis for phenotypic information was the American standard for genetic evaluations by the United States Department of Agriculture (USDA) in partnership with the Council on Dairy Cattle Breeding (CDCB).

The estimated productive characteristics were Milk Production (MP), Amount of Fat in Milk (AFM), Concentration of Fat in Milk (CFM), Amount of Protein in Milk (APM), Concentration of Protein in Milk (CPM), and Somatic Cells (SC).

The conformation characteristics were Body Compound (BC), Height (H), Body Depth (BD), Croup Angle (CG), Croup Width (CW), Posterior Udder Height (PUH), Udder Width (UW), Middle Ligament (ML), Udder Depth (UD), Anterior Ceiling Placement (ACP), Posterior Ceiling Placement (PCP), Ceiling Length (CompTet), Legs Lateral View (LLV), Legs Posterior View (LPV), Angle of hooves (AF) and Scoring of legs and feet (SLF). Finally, the evaluated breeding characteristics were the Daughter Pregnancy Rate (DPR), Cow Conception Rate (CCR), Heifer Conception Rate (HCR), Calving Ease (CE), and Fertility Index (FI).

The profile of genetic diseases that most affect Holstein cattle is Chondrodysplasia, Citrulinemia, Uridine Monophosphate Synthase Deficiency (UMSD), Factor XI, Vertebral Malformation Complex (VMC), Brachyspina, Cholesterol Deficiency Haplotype (CDH), Bovine Leukocyte Adhesion Deficiency (BLAD), HH1, HH2, HH3, HH4, and HH5. The results of GPTAs and haplotypes for genetic diseases were obtained through the Genomic Test (CLARIFIDE®-PLUS).

Data evaluations of milk production genotyping were verified by descriptive statistics, Pearson correlation, and verification of frequencies for diseases. All analyses were performed using SAS statistical analysis software (SAS Institute, 2018).

Results and Discussion

The animals evaluated by the low-density SNP presented when compared with the averages of GPTA (CDCB, 2020), values above the American average, with cows weighing 384 pounds for milk production, 17.9 pounds for fat, and 12.9 pounds for protein.

Table 1. Descriptive Statistics of GPTAs of milk and solids production characteristics, Somatic Cell Concentration, of Holstein cows from the semiarid region.

Variable	Initials	Minimum	Maximum	Average	Standard deviation
Milk Production (lb)	ML	-1458	838	-278,17	477,67
Amount of fat	AF	-50	32	-12,46	20,88
Fat concentration	FC	-0,16	0,24	-0,005	0,09
Amount of Protein	APP	-43	15	-11,69	13,47
Protein Concentration	PC	-0,09	0,07	-0,010	0,03
Somatic cells	SC	2,80	3,25	3,04	0,10

Table 1 shows the averages of predicted abilities of genomic transmission (GPTA) which, even with some negative values, indicate that these characteristics have low transmission of genetic values to the progeny. Pilonetto et al. (2019) found a negative value for females of the Holstein breed, in the southern region of Brazil. However, 2.5% of the animals evaluated in our study had higher means for milk production, 5.2% fat, and 7.8% protein, revealing the existence of females in the herd with the potential for transmitting excellent breeding values for MP, AFM, APM.

The results of SC analysis in Table 1 demonstrate that the females evaluated have the more genetic capacity, as they presented high values of SC and moderate susceptibility to mastitis. Brazil (2012) highlighted that different factors can influence the rate of new infections and, consequently, the somatic cell count, but the use of adequate milking management techniques is able to abruptly reduce SC levels in milk.

In Table 2, correlations between milk and solids production GPTA are shown. The correlations between milk production and the amount of fat and protein showed a low to high magnitude (0.09 and 0.81), respectively. A -0.61 (p<005) was found for milk production and fat concentration, and protein concentration (-0.43 p<0.05). These results corroborate by Boligon et al. (2005) who found low magnitude genetic correlation values between fat content and milk production, demonstrating that the higher the milk production, the more negative the fat percentages.

The characteristics of volume and solids concentration ranged from low to high magnitude. Fat volume was moderately correlated with protein volume (0.50 p<0.05), but highly correlated with fat percentage (0.72 p<0.01) and protein percentage (0.60 p <0.01). For protein volume, there was a low association with the concentration protein, namely 0.16, and negative association with fat content (-0.15) but not significant.

Table 2. Correlations between GPTAs of semi-arid Holstein cows for milk and solids production characteristics.

	Milk Production	Amount of Fat in Milk	Concentration of Fat in Milk	Amount of Protein in Milk	Concentration of Protein in Milk
Milk Production	1000	0.09 (0.5693)	-0.61 (<.0001)	0.81 (<.0001)	-0.43 (0.0052)
Amount of Fat in Milk	0.09 (0.5693)	1000	0.72 (<.0001)	0.50 (0.0010)	0.60 (<.0001)
Concentration of Fat in Milk	-0.61 (<.0001)	0.72 (<.0001)	1000	-0.15 (0.3423)	0.78 (<.0001)
Amount of Protein in Milk	0.81 (<.0001)	0.50 (0.0010)	-0.15 (0.3423)	1000	0.16 (0.3064)
Concentration of Protein in Milk	-0.43 (0.0052)	0.60 (<.0001)	0.78 (<.0001)	0.16 (0.3064)	1000

Table 3. Correlations between GPTAs of semi-arid Holstein cows for milk and solids production characteristics, body composition, udder composition, and leg and foot composition.

Milk Production and Body Composition					
	Milk Production	Amount of Fat in Milk	Concentration of Fat in Milk	Amount of Protein in Milk	Concentration of Protein in Milk
Body Compound	-0.22 (0.1609)	0.06 (0.7173)	0.20 (0.2187)	-0.05 (0.7400)	0.31 (0.0517)
Heigh	0.03 (0.8411)	0.13 (0.4110)	0.07 (0.6331)	0.11 (0.4776)	0.13 (0.4039)
Body Depht	-0.07 (0.6367)	0.27 (0.0928)	0.26 (0.0999)	0.12 (0.4471)	0.33 (0.0383)
Croup Angle	0.08 (0.6078)	-0.13 (0.4102)	-0.17 (0.2900)	-0.12 (0.4307)	-0.32 (0.0412)
Croup Widht	0.13 (0.4013)	0.21 (0.1994)	0.06 (0.6845)	0.26 (0.1047)	0.18 (0.2612)
Milk Production and Udder Composition					
	Milk Production	Amount of Fat in Milk	Concentration of Fat in Milk	Amount of Protein in Milk	Concentration of Protein in Milk
Posterior Udder Height	0.18 (0.2562)	0.28 (0.0773)	0.09 (0.5684)	0.32 (0.0432)	0.18 (0.2562)
Udder Widht	0.18 (0.2589)	0.28 (0.0772)	0.09 (0.5655)	0.32 (0.0436)	0.18 (0.2542)
Middle Ligament	0.22 (0.1679)	0.21 (0.1847)	0.01 (0.9684)	0.34 (0.0291)	0.14 (0.3704)
Udder depth	0.06 (0.6846)	0.04 (0.8035)	-0.02 (0.9018)	0.17 (0.2928)	0.15 (0.3514)
Anterior Ceiling Placement	0.27 (0.0831)	0.31 (0.0507)	0.04 (0.7921)	0.49 (0.0014)	0.26 (0.1005)
Posterior Ceiling Placement	0.32 (0.0407)	0.30 (0.0594)	0.01 (0.9898)	0.48 (0.0017)	0.17 (0.2949)
Ceiling Lenght	-0.14 (0.3856)	-0.42 (0.0074)	-0.23 (0.1553)	-0.30 (0.0610)	-0.23 (0.1540)
Milk Production and Composition Of Legs And Feet					
	Milk Production	Amount of Fat in Milk	Concentration of Fat in Milk	Amount of Protein in Milk	Concentration of Protein in Milk
Legs Lateral View	0.09 (0.5816)	0.07 (0.6619)	-0.01 (0.9915)	0.11 (0.4705)	0.01 (0.9323)
Legs posterior View	0.24 (0.1349)	0.16 (0.3217)	-0.04 (0.8015)	0.36 (0.0224)	0.14 (0.3742)
Anglo of Hoovs	0.13 (0.3986)	0.09 (0.5740)	-0.02 (0.8763)	0.19 (0.2335)	0.07 (0.6675)
Scoring of Legs and Feet	0.17 (0.2733)	0.20 (0.2197)	0.02 (0.8578)	0.27 (0.0904)	0.12 (0.4531)

According to these results, it is possible that there is a small reduction in the fat concentration when selecting for the protein volume. The fat content was highly correlated with the percentage of protein (0.78 $p<0.01$) and, given the positive association, it can be expected that the selection for the fat content contributes to the increase in the percentage of milk protein. The results indicate that in this population, the volume and fat content are the most indicated selection criteria to improve the gains in quantity and concentration of solids in milk. Madalena (2000) demonstrated the importance of the value paid to the equivalent of milk, defined as the price of 1 kg of milk with 3.5% fat and 3.1% protein. Improvements in the quality of milk produced in the dairy have gained attention in Brazil.

The correlation values between milk production characteristics and solids with conformation characteristics are shown in Table 3. There are positive results, although they are of low magnitude, with no significant correlations (p >0.05). The rump width was the characteristic that obtained the highest correlation coefficient between the characteristics of milk production and body composition (0.13), while the lowest value was found for the Body Compound (-0.22). Different results were reported by Cucco et al. (2017) as little or no influence of the correlation (0.03), suggesting that animals of medium height may have the greater dairy ability.

Correlation values were found for body depth in relation to fat volume and protein concentration (0.27 and 0.33, respectively), whereas for rump width the best results were observed in fat and protein volume (0, 21, and 0.26, respectively). The GPTAs for height and body length were positive and low for the amount of fat, for the amount of protein the body length had a negative value of -0.05, while for height the value was positive (0.11), although low. The rump angle showed negative correlations for the amount of fat and protein (-0.13 and -0.12, respectively).

For GPTAs with udder characteristics, correlations were observed higher than those found for body composition in relation to milk production. However, they were mostly low and not significant, with the exception of the placement of the posterior teats (0.32 P<0.05). Hind udder height and udder width had a magnitude of 0.18 and the lowest values were found in relation to udder depth and teat length

These results indicate that production capacity is associated with larger udders, but with high support capacity and better teat conformation, while low magnitude correlations between udder depth and milk volume indicate that shallower udders have better milk production, in addition to appearing as the best option for preserving the health and physical integrity of the breast system, facilitating milking and reducing risks such as teat injuries & occurrence of mastitis (Penev et al. 2017).

According to Berry et al. (2004) in a study with genetic correlations between traits of type and yield, most genetic correlations between udder composition such as udder height and udder attachment showed negative values of low magnitude in relation to milk production. Also, Cucco et al. (2017) demonstrated that leg and foot composition and body composition do not have a significant relationship with production characteristics, suggesting that the selection of animals for leg and foot compost and body composition does not affect milk production. The same authors demonstrated that udder height and width had a negative association with protein percentage.

Table 4. Correlations between GPTAs of semi-arid Holstein cows for milk and solids production and reproduction characteristics

Milk and Solid Production and Reproduction Characteristics					
	Milk Production	Amount of Fat in Milk	Concentration of Fat in Milk	Amount of Protein in Milk	Concentration of Protein in Milk
Daughter Pregnancy Rate	-0.33 (0.0349)	-0.34 (0.0321)	-0.03 (0.8164)	-0.44 (0.0042)	-0.11 (0.4851)
Cow Conception Rate	-0.21 (0.1992)	-0.01 (0.9623)	0.13 (0.4087)	-0.31 (0.0481)	-0.12 (0.4324)
Heifer Conception Rate	-0.31 (0.0532)	-0.31 (0.0532)	-0.07 (0.6505)	-0.43 (0.0051)	-0.25 (0.1190)
Calving Ease	0.06 (0.6902)	-0.17 (0.2821)	-0.17 (0.2748)	-0.04 (0.7813)	-0.17 (0.2961)
Fertility Index	-0.29 (0.0668)	-0.27 (0.0844)	-0.01 (0.9122)	-0.41 (0.0091)	-0.13 (0.4292)

Compositional characteristics of udder & solids is the most of the correlations were positive. Teat length showed negative correlations for all traits, highlighting the correlation with fat volume (-0.42 p< 0.05) indicating that cows had better milk fat production showed smaller teats. For protein quantity GPTAs, median correlations (p<0.05) were observed for udder width (0.32), medial ligaments (0.34), anterior and posterior teat placement (0.49 and 0.48, respectively), negative for teat lengths (-0.30) indicating cows with better udder conformation, better amounts of protein in milk.

Correlations observed between production and reproduction traits were of low magnitude (Table 4) and show that animals with high milk production potential may have lower reproductive efficiency. Only the correlations between Cow Conception Rate and Fat Percentage; Calving Ease and Milk Production had positive values, 0.13 and 0.06, respectively. The correlations between the amount of protein and pregnancy rate, conception rate in heifers, and infertility had moderate values and significant magnitude (P<0.05), but negative.

For the GPTAs of the conformation characteristics between legs, feet, and milk production, the values again showed low magnitude, with the highest values being for hind legs and legs and feet score (0.24 and 0.27). However, a correlation of 0.36 (p<0.05) for hind legs in the amount of protein was observed. The locomotor characteristics have little influence on milk production, but the fact that they are positive indicates that females with better production capacity tend to have better locomotion, which indirectly influences due to the better ability to fetch water and food, in addition to reducing the involuntary disposal of animals due to problems with uprightness, ligaments and poor body conformation (Esteves et al. 2004, Kern et al. 2015).

Historically, the systems of selection and choice of traits to be improved did not consider the genetic antagonism between production and reproduction, which, consequently, increased the negative effects on fertility. According to Collard et al. (2000), the focus on milk production traits tends to decrease the fertility and productive efficiency of cows, increasing the involuntary culling rate, so the choice of traits to be improved must be carefully planned to prevent reproductive problems in herds.

Table 5 shows the genotype frequencies for the main diseases that affect dairy herds. Females with Chondrodysplasia, Citrulinemia, UMSD, Factor XI, and Brachyspina were not found, as well as animals carrying BLAD, HH1, HH2, HH3, HH4, and HH5 were not identified. The herd had 7.7% of animals carriers for VMC, followed by 2.6% carriers for CDH.

Table 5 - Frequency of **haplotypes** for diseases in Holstein females from semi-arid region herds

Diseases	No. of observations	Nº of carriers	Freq. of carriers*
Chondrodysplasia	39	0	0
Citrullinemia	39	0	0
UMSD	39	0	0
Factor XI	39	0	0
VMC	39	3	7,7
Brachyspina	39	0	0
CDH	39	1	2,6
BLAD	39	0	0
HH1	39	0	0
HH2	39	0	0
HH3	39	0	0
HH4	39	0	0
HH5	39	0	0

Notes: (%); UMSD -Monophosphate Synthase Deficiency; VMC-Malformation Complex; Brachyspina, CDH- Cholesterol Deficiency Haplotype; BLAD, HH1, HH2, HH3, HH4, & HH5 - Bovine Leukocyte Adhesion Deficiency

Vertebral malformation complex (VMC) is a point genetic mutation and heterozygous animals tend to have low fertility, developing vertebral anomalies that lead to abortion or perinatal death (Kanae et al. 2005). Cholesterol deficiency is a genetically heritable disease responsible for lowering cholesterol levels. Carrier animals show reduced appetite, weight loss, frequent diarrhea, which can lead to death (Schutz et al. 2016).

The presence of carriers of VMC (6.14%) and CDH (1.28%) was recently identified in Holstein cows raised in Brazil (Pilonetto 2019), in other countries higher frequencies are commonly observed (Paiva et al. 2013; Kipp et al. 2016).

The results of this study reaffirm the importance of using genomic evaluations that, through genetic predictions, enables the targeting of crosses in order to contribute to animal improvement based on herd trends.

Conclusions

The use of low-density SNPs is an economical option for the process of choosing the animals to be used in the herd. It appears that the Holstein cow herd from the semiarid region analyzed has presented a genetic profile with the potential to improve the productive characteristics, allowing the identification of animals with genetic anomalies before entering the reproductive phase.

Genomic evaluations play an important role in animal genetic improvement, strongly contributing to the genetic progress of dairy herds.

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